

SP 30:2023

भारत की राष्ट्रीय विद्युत संहिता
National Electrical Code of India 2023



भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
The National Standards Body of India
Ministry of Consumer Affairs, Food & Public Distribution
Government of India

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भारतीय मानक
Indian Standard

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(दूसरा पुनरीक्षण)

National Electrical Code of India 2023

(Second Revision)

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INTRODUCTION

India is on the path of sustainable development and its infrastructure sector has grown progressively. The buildings and services so constructed depend on power for their construction and effective utilization. Building and Industry sectors are fastest growing segments of economy in past decade and are expected to remain so for running decade. It would also see adoption of various technological innovation both for quality of life and sustainable economic growth. In fact, power is one of the prime movers of development and electricity is the predominant form of energy being used on account of ease of generation/conversion, transmission, distribution, and utilization.

Specific statutory provisions to be adhered to in the supply and use of electricity had been laid down by the erstwhile *Indian Electricity Act,* 1910 and the *Indian Electricity Rules,* 1956 framed, thereunder. After the enactment of *The Electricity Act,* 2003, repealing the previous *Indian Electricity Act* of 1910, the *Indian Electricity Rules* of 1956 were replaced by regulations in 2010. A need was felt to elaborate upon these regulations since the agencies involved have varied practices, in view of their diverse interests, and different accessibility levels to technological developments. Earlier, in order to rationalize these practices, India's first National Electrical Code, formulated in 1985, was a compendium of several well-established codes of practice which provided assistance on economic selection, installation and maintenance of electrical equipment employed in the usage of electrical energy. This edition was revised in 2011, to include special aspects like solar PV power supply systems. The code complemented and elaborated on the *statutory provisions,* for the ease of application by the system engineers, by recommending the best practices for electrical installations in a consolidated form in order to provide for unified practices and procedures along with consideration for safety and economic usage of energy in the design, execution, inspection and maintenance of electrical installations of various locations.

During the formulation of the National Electrical Code in 1985 and its subsequent revision in 2011, it was realized that the various referred codes on wiring practice, earthing, lightning protection etc., were revised and updated in line with the practices and technology available at that time. Over the years, there have been more updates in the technology and new practices are being followed. Also, there have been tremendous socio-economic changes, leading to change in the pattern of the usage of electricity. With technological advances and India's focus on renewable energy, an urgent need was felt to revise the NEC at the earliest to maintain its relevance in the present context.

The task for revision of NEC of India was taken up by the Electrical Installations Sectional Committee, ETD 20 considering the above factors. This revision follows the earlier structure of NEC, with modifications and additions being incorporated in line with IEC 60364 series of standards on 'Low-Voltage Electrical Installations' as well as the changes and developments that took place since the publication of NEC 2011. It is visualized that in future, further harmonization with international codes may be take place.

It is obligatory that the Electrical installation shall be carried out in accordance with the *Central Electricity Authority (Measures related to Safety and Electric Supply) Regulations 2010* (*amended in 2015, 2018, 2019*) and relevant regulations as amended or brought into force from time to time. It may be noted that Regulation 12 specifies to follow National Electrical Code for electrical installations. Further, it also states that all material, accessories, appliances etc., used in an electrical installation shall conform to Indian Standards or International Electrotechnical Standards (IEC) wherever they exist. Section 146 of Electricity Act states any contravention with the provisions of the Act or rules, regulations made thereunder is punishable. Under the various sections, reference of related regulations are given, which will prove helpful in interpretation. In the event of any inconsistency between CEA regulations and National Electrical Code, the provisions of CEA regulations shall prevail.

In this version, attention is drawn towards good workmanship and proper coordination and collaboration between the architect, civil work counterpart, agencies involved in the installation work of other building services and the agency executing the job of electrical installation, from the planning stage itself. The design of electrical installation is required to take into account the characteristics of available supply, nature of demand, environmental conditions, type of wiring and methods of installations, protective equipment, emergency control, disconnecting devices, prevention of mutual influence between electrical and non-electrical installations, accessibility and also, the user considering his ergonomic requirements (*well informed or ignorant*) etc.

The Code is divided into eight parts, which are further divided into multiple sections. Part 1 covers the General and common aspects, which applies to all types of electrical installations. Wiring installations are an important aspect of any electrical installation. The revision of Part 1 is being carried out to align with international practices and the latest provisions of IS 732 which is the relevant code of practice for wiring installations. The sections related to Power quality, earthing and lightning protection have been modified to align with the provisions of their respective codes. In view of increased concerns on safety aspects, sections on protection for safety such

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as protection against electric shock, protection against thermal effect and protection against fire due to arcing, protection against overcurrent and fault current, and protection against voltage disturbance and measures against electromagnetic influences have also been included.

Part 2 of the code covers the requirements related to standby or emergency generating stations and captive substations intended for serving an individual occupancy and/or intended to serve a building or a group of buildings, normally, housed in and around it. It provides guidance on layout and building construction aspects, selection of equipment, transformer installations, switching stations, station auxiliaries, testing and commissioning. It excludes the requirements under the purview of utilities, namely, the large generating stations, distribution substations and associated transmission system, or captive generator sets of large capacity. Reference to Central Pollution Control Board (CPCB) guidelines and Petroleum and Safety Explosives Guidelines have also been included.

Part 3 defines requirements for special installations or locations and includes specific sections on locations containing a bath or shower, swimming pools and fountains, rooms and cabins containing sauna heaters, construction and demolition site installations, conducting location with restricted movement, caravan parks camps and similar locations, marinas and similar locations, exhibitions, shows and stands, furniture, ELV lighting installations, community facilities and work places, installations in caravans and motor caravans, supplies for electric vehicles, operating or maintenance gangways, temporary electrical installations for structures, amusement devices and booths at amusement parks and circuses, heating cables and embedded heating systems, and office buildings, shopping and commercial centers and institutions. Optimum benefits from the use of electricity can be obtained only if the installation is of sufficient capacity and has enough flexibility. Safety, economy, efficiency, reliability, convenience as well as provision for future expansion are major considerations in planning the electrical layout. Guidelines are provided based on general characteristics of installations, supply characteristics and parameters. Switchgear for control and protection, service lines, metering, earthing, building services, fire protection and miscellaneous provisions have been covered. Miscellaneous provisions include telephone wiring, call bell system, clock system, group control, audio visual systems, closed circuit TV where applicable, emergency lights for critical areas of the dwelling. Provision for increased number of power supply points for residential units to accommodate the increasing number of gadgets along with provision to avoid overloading of supply points by consumer through reference to miniature circuit breakers and fuses under requirement of switchgear for control and protection has been made. New sections have been added considering growing extent of utilization and safety concerns.

Electrical networks in industrial buildings serve the purpose of distributing the required power to the consuming points where it is used for a multitude of purposes in the industry. The design of electrical installation in industrial premises is, therefore, more complicated than those in non-industrial buildings and is covered under Part 4 of the code. Industrial installation shall take care of load requirements and supply limitations in a simple and economic manner, ensuring protection to human life and loss of property by fire. The network layout shall also facilitate easy maintenance and fault localization. A particular feature of electrical installations in industrial buildings is the reliability of supply to essential operations for which standby and emergency supply sources/networks are available. The needs of such systems depends on the type and nature of the industrial works.

Locations in industrial buildings which are hazardous in nature, require special attention with respect to design of electrical installations, therein. In order to help identify the specific nature of each industry and the probable hazardous locations, industrial installations are classified for assisting the design engineer in the choice of equipment and methods.

Outdoor electrical installations are designed and erected for short term use ranging from a few hours to few months. In some cases, they can also be used for long periods of time. Such installations are, generally, unprotected from environmental hazards as compared to installations in buildings. Outdoor installations are, hence, classified into public lighting installations, temporary outdoor installations and permanent outdoor installations to address specific concerns in an optimal way. Major risks power in such installations arise from short circuits, resulting in fire accidents, and exposure to live wires, resulting in shock. Outdoor installations are required to comply not only with the general requirements, but also additional requirements regarding supply intake arrangements, control of circuits, earthing, and protection against overload, short circuit and earth leakage. Part 5 of the code covers the aspects for outdoor installations.

With the increasing mechanization for enhancing the farm output of the country, there is increased use of electricity for essential purposes in agriculture and Part 6 of the code covers the electrical installations requirements associated with the agricultural sector. Installations in agricultural premises are different outdoor installations as the external influences completely different. The overall power requirements for such installations may be small, the presence of livestock and other extraneous factors necessitate laying down specific requirements to ensure safety. Specific

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requirements of electrical installations in agricultural premises which include premises where livestock are present and farm produce are handled or stored are covered. Agricultural processing at the farm premises are also covered.

In areas where hazardous atmosphere during normal operations are likely to occur, special emphasis from the view of design of electrical installations shall be laid. Liquids, gases and vapours and dust generated, processed, handled and stored by industry are combustible. On ignition, these may burn readily and with considerable explosive force when mixed with air in the appropriate proportions. With regard to electrical installations, such ignition sources include arcs, sparks or hot surfaces produced either in normal operation or under specified fault conditions. NEC provides guidelines for electrical installations and equipment in locations where hazardous atmosphere is likely to be present with a view to maximize electrical safety. When electrical equipment is to be installed in or near a hazardous area, effort shall be made to locate the equipment in less hazardous or non-hazardous areas and thereby, reducing the effort for additional requirements. Ventilation or use of protective gas also reduces the probability of the presence of explosive gas atmosphere so that areas of greater hazard can be transformed to areas of lesser hazard or to non-hazardous areas. Regulatory requirements are to be adhered to for such installations. Part 7 of NEC covers the special requirements for electrical installations in hazardous area.

Excessive reliance on fossil fuel resources to meet the energy requirement of the country is considered unsustainable in the long-run and has an adverse impact on the environment and ecology. This has resulted in the quest of renewable sources of energy as a viable option to achieve the goal of sustainable development. India has been committed to increase share of energy from renewable sources and has been making calculated efforts in this direction.

We are aiming for 24 x 7 power for all, with 450 GW of renewable power generation capacity by 2030 (further, extended to 500 GW non-fossil based capacity by 2030). Many of the government's major initiatives, such as Make in India (MII) initiative or Aatma Nirbhar Bharat Abhiyan (ANBA: Self-reliant India), require access to reasonably priced, high quality and reliable power to take off. Social conditions, also, demands for adequate and quality supply of electricity.

In case of Variable Renewable Energy (VRE) generation, there will be likely instances of generation being more than the demand during certain periods of the day and seasons. Thus, such avenues are to be explored which could absorb the excess power generated successfully and thereby, rendering the system operation stable and economical.

Harnessing of solar energy is one such area which is expected to supplement energy supply efforts. Part 8 on solar photovoltaic installations provides guidelines on general safety procedures and practices in solar PV installations, general characteristics of solar PV components and installations, requirements and recommendations in wiring and earthing of PV installations on buildings or industrial structures and requirements and recommendations in electrical safety protection of solar PV systems.

The Code excludes guidance on tariff. After revision of NEC, there will be instances of revisions of individual referred codes with time. It is, therefore, recommended to follow the provisions of the latest standards/codes of practice. In order to avoid such instances where the Indian Standards and provisions of this code may differ, attention is drawn to the relevant standard. In order to keep pace with such changes and to incorporate the additional knowledge that will be gained through the implementation of the Code, a continuous review is envisaged. Thus, the users of this Code are encouraged to bring to the notice of Bureau of Indian Standards, need of modifications that may be required in the light of changing technology or other factors, as this is a continuous process.

The National Electrical Code of India (hereafter, referred to as the Code) contains guidelines, for adoption by various concerned stakeholders. Its provisions are expected to serve as a model for adoption in the interest of safety and economy and with the intent to keep our electrical installation practices at par with the best practices in the world.

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NEC AND SUSTAINABLE DEVELOPMENT GOALS (SDGs)



The United Nations defines 17 Sustainable Development Goals (SDGs) at the core of its blueprint for building a better world by 2030. The SDGs serve as a universal plan for all countries to end poverty and stimulate economic growth, preserve the environment and ensure prosperity for all. The SDGs set the global development agenda until 2030 with clear objectives and measurable targets to determine progress for each goal. Given the link between economic development, social inclusion and environmental sustainability, these goals must be addressed as a group and will require global cooperation.

The United Nations has recognized electricity as the cornerstone for economic development and calls for access to affordable, reliable and clean energy in SDG 7.

Electricity is essential for economic development, serving as a gateway to opportunities for education, well-being, and connectivity. Various Standards referred in National Electrical Code of India is addressing the need to bring safe, affordable and clean electricity to the many people. Indian Standards in the document enable the safe and efficient use of renewable energy, whether integrated into the grid or installed off-grid to help remote communities access electricity.

Providing safe Electricity Access to communities and households has a huge transformational impact. As a result, mere provision for an electric bulb begins the transformation and then has multiple cascading benefits; eradication of poverty and hunger (SDGs 1 and 2), enabling rural and distance education (SDG4), empowering women and triggering gender equality (SDG5), reducing disease by easier access to clean drinking water (SDG6), affordable and clean energy for purposes of productive and domestic work enabling better lifestyle (SDG7), and eventually bringing innovation to entire industry and the future of electric grid (SDG9) and enabling an egalitarian global community (SDG10 and 11).

Referred Indian Standards in this document, can also help to increase prosperity and wellbeing. They remove barriers to trade while also providing regulators and consumers with the knowledge that products adhere to globally recognized requirements for safety, interoperability and performance.

While electricity is relevant to all SDGs, some of them are directly influenced in developing this document are :

- SDG 3: Good health and well-being
- SDG 6: Clean water and sanitation
- SDG 7: Affordable and clean energy
- SDG 9: Industry, innovation, and infrastructure
- SDG 11: Sustainable cities and communities
- SDG 12: Responsible consumption and production
- SDG 13: Climate action

The provisions given in this document is essential for safety, quality and risk management. It helps make cities smarter, supports universal energy access and improves energy efficiency of devices and systems. It allows industry to consistently build better products, helps government ensure long-term viability of infrastructure investments and reassures investors and insurers.

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COMMITTEE COMPOSITION

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NATIONAL ELECTRICAL CODE OF INDIA

PART 1 GENERAL AND COMMON ASPECTS

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PART 1 GENERAL AND COMMON ASPECTS

FOREWORD

Electricity has become an integral and inevitable part of everyone's life. The progress and technological advancement of modern society depends on electricity. However it is important to remember that, if electrical installations are not handled according to relevant guidelines, it could be harmful. Therefore, electrical installations require adequate planning right from concept stage to layout and designing, selection of proper equipment, their installation and their maintenance. Fundamental aspects of installation practice are common for most of the types of electrical installations. Part 1 of the National Electrical Code of India covers these aspects under its various Sections.

There are several Indian Standards existing on different aspects of electrical installation practice. An attempt has been made through this Code to refer to the present good practices and guidelines. A reference has also been made to product standards in order to inform the user of the Code about the availability and desirability to use them.

Aspects concerning specific occupancies are covered in other Parts and Sections of this Code. The fundamental principles of installation practice covered under Part 1 of this Code generally apply, unless modified or supplemented by subsequent Parts. This Part 1 would also be a useful reference for occupancies not explicitly covered by the scope of subsequent Parts of the Code.

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SECTION 1 SCOPE OF THE NATIONAL ELECTRICAL CODE OF INDIA

FOREWORD

Each Part/Section of the National Electrical Code of India covers the requirements related to electrical installations in specific occupancies. The fundamental and general principles governing electrical installation practice together with common aspects applicable to all types of installations has been brought out in a separate Part in order to serve as a reference document.

Effort has been made to make this part self-contained, so that users of the Code can derive utmost advantage in using it for application in the field even for occupancies not explicitly covered by the scope of subsequent Parts of the Code. Efforts have also been made to ensure that all the relevant details required for the understanding of the Code are available to the extent possible within Part 1 and effort has been made to keep the references of individual standards to the minimum.

The details enumerated in this Part are generally applicable to all types of occupancies and are to be read as modified or supplemented with the information provided in the relevant Parts of the Code.

1 SCOPE

This section of the code (Part 1/Sec 1) describes the scope of the National Electrical Code of India.

2 REFERENCES

The National Electrical Code of India takes into account the stipulations in several Indian Standards dealing with the various aspects related to electrical installation practices. Several product standards also exist, and compliance with relevant Indian Standards is desirable. It is therefore recommended that individual Parts/Sections of the Code should be read in conjunction with the relevant Indian Standards. List of such Indian Standards is given at relevant Part/Section of the Code.

At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 SCOPE OF THE NATIONAL ELECTRICAL CODE OF INDIA

3.1 The National Electrical Code of India covers the following:

a) Standard good practices for selection of various items of electrical equipment forming part of electrical installation;

b) Recommendations concerning safety and quality of the wiring in electrical installations of buildings or industrial structures, promoting compatibility between such recommendations and those concerning the equipment installed;

c) General safety procedures and practices in electrical work; and

d) Additional precautions to be taken for use of electrical equipment for special environmental conditions like explosive and active atmosphere.

3.2 The Code applies to electrical installations, such as those in:

a) Standby/emergency generating plants and building substations;

b) Domestic dwellings;

c) Office buildings, shopping and commercial centres and institutions;

d) Recreation and other public premises;

e) Medical locations;

f) Hotels;

g) Swimming pools;

h) Rooms containing sauna heaters;

j) Multi-storied buildings;

k) Supplies for electrical vehicles;

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m) Sports buildings;

n) Industrial and non-industrial premises;

p) Temporary and permanent outdoor installations;

q) Agricultural premises;

r) Installations in hazardous areas; and

s) Solar photovoltaic installations.

NOTES

1 Any type of installation not covered by the above shall be classified in the group which most nearly resemble its existing or proposed use.

2 Where change in the occupancy places it under the scope of a different Section of the Code, the same installation shall be made to comply with the requirements of the Code for the new occupancy.

3 While numbering above items, 'i' and 'o' are avoided to avoid confusion with numerals '1' and '0'.

3.3 The Code applies to circuits other than the internal wiring of apparatus.

3.4 The Code does not apply to traction, motor vehicles and installations in rolling-stock, on board-ships, aircraft or installations in underground mines.

3.5 The Code covers only electrical aspects of lightning protection of buildings.

3.6 The Code is also not intended to apply to:

a) Systems of distribution of energy to public; and

b) Power generation and transmission for such systems.

3.7 The Code also does not cover guidelines on the payment for electrical work done in installations.

4 Central Electricity Authority Regulations under regulation 12 (2) of Central electricity authority (Measures relating to safety and electric supply) Regulations, 2010 recommends the National Electrical code of India as a code to be followed.

NOTE — In the event of any inconsistency, the provisions of the regulations shall prevail.

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SECTION 2 DEFINITIONS

FOREWORD

Each Part and section of the Code gives, where necessary, definitions of terms and phrases relevant for the comprehension of the requirements stipulated therein. Users may find it convenient to refer to a detailed list of terms and their definitions contained in this section that are relevant to electrical installation practices. It may, however, be noted that for further guidance, recourse should be made to IS 1885 (series of standards) and IEC 60050 on electrotechnical vocabulary containing a compendium of terms in the field.

The definitions contained in the Code are based on the current international terminology as far as possible. Some definitions are based on the terminology drawn up by the relevant expert groups under the Electrotechnical Division Council with the objective of striking a correct balance between absolute precision and simplicity. The principal objective of this exercise is to provide definitions which are sufficiently clear so that each term is understood with the same meaning by all concerned. It may, sometimes, be felt that the definitions are not identical with those which may be found in other publications designed with different objectives and for other readers. Such differences are inevitable and should be accepted in the interest of clarity.

1 SCOPE

This section of the code (Part 1/Sec 2) covers definitions of terms.

2 REFERENCES

The standards listed in Annex A contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 TERMINOLOGY

For the purpose of the National Electrical Code of India, the following definitions shall apply, in addition to those contained in individual Parts/Sections and relevant Indian Standards.

3.1 Fundamental Definitions

3.1.1 *Arc* — Luminous discharge of electricity across an insulating medium, usually, accompanied by the partial volatilization of the electrodes.

NOTE — A complete sinusoidal current half cycle is not considered to be an arcing half cycle.

3.1.2 *Capacitor* — Two terminal devices characterized, essentially, by its capacitance.

3.1.3 *Conductor* — Conductive part intendent to carry electric current.

3.1.4 *Connection of Circuits*

3.1.4.1 *Series* — Connections of two terminal networks so that they form a single path for current.

NOTE — An example of a series connection is series resonant circuit.

NOTE — All two terminal networks in a series connection carry the same current.

3.1.4.2 *Parallel* — Connections of two terminal networks so that they are connected to a common terminal pair.

NOTES

1 An example of a parallel connection is parallel resonant circuit.

2 Same voltage is applied to all two terminal networks in a parallel connection.

3.1.5 *Series Parallel* — Series parallel connection (related to cells or batteries): Arrangement of cells or batteries wherein in series connected cells or batteries are connected in parallel.

3.1.6 *Dielectric* — A material medium in which an electric field can exist in a stationary state.

3.1.7 *Earth Fault*— Occurrence of an accidental conductive path between a live conductor and the earth or exposed conductive part of a protective conductor.

NOTES

1 The conductive path can pass through a faulty insulation, through structures (for example, poles scaffoldings, cranes, ladders) or through vegetation (for example, Tree, bushes) and can have a significant impedance.

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2 Earth fault with negligible fault impedance in solidly earthed neutral system or in a low impedance earthed neutral system are also named line - to - earth short – circuits.

3.1.8 *Earth Leakage Current* — Current which flows to earth or to extraneous conductive parts in a circuit which is electrically sound.

3.1.9 *Electric Circuit (or Circuit)* **—** An assembly of electrical equipment supplied from the same origin and protected against over current by the same protective devices. Certain types of circuits are categorized as follows:

NOTE — Electric circuit is also defined as circuit consisting of electric circuit elements only.

a) *Category 1 Circuit* — Circuit (other than a fire alarm or emergency lighting circuit) operating at low voltage and supplied directly from a mains supply system.

b) *Category 2 Circuit* — With the exception of fire alarm and emergency lighting circuits, any circuit for telecommunication (for example, radio, telephone, sound distribution, intruder alarm, bell, call and data transmission circuits) which is supplied from a safety source.

c) *Category 3 Circuit* — A fire alarm circuit or an emergency lighting circuit.

3.1.10 *Electric Current* — Scalar quantity equal to the flux of the electric current density ***J*** through a given directed surface

$$S:I=\int SJ\cdot endA$$

where $\boldsymbol{e}_n \mathrm{d}A$ is the vector surface element

NOTES

1 The electric current through a surface is equal to the limit of the quotient of the electric charge transferred through that surface during a time interval by the duration of this interval when this duration tends to zero.

2 For charge carriers confined to a surface, the electric current is defined through a curve of this surface (see the note to term “lineic electric current”).

3.1.11 *Electrode* — Conductive part in electric contact with a medium of lower conductivity and intended to perform one or more of the functions of emitting charge carriers to or receiving charge carriers from that medium or to establish an electric field in that medium.

3.1.12 *Functional Extra-low Voltage (FELV)* — extra-low voltage system in which not all of the protective measures required for SELV or PELV have been applied.

3.1.13 *Flashover* — Electrical breakdown between conductors in air, a gas or a liquid or in vacuum, at-least partly, along the surface of a solid insulation.

3.1.14 *Insulation Fault* — in the insulation of an equipment, wire or cable which can result either in an abnormal electric current through this insulation or in a disruptive discharge.

3.1.15 *Overload* — Operating conditions in an electrically undamaged circuit which causes an overcurrent.

3.1.16 *PELV (Protective Extra-low Voltage)* **—** extra-low voltage system which is not electrically separated from earth, but which otherwise satisfies all the requirements for SELV.

3.1.17 *SELV (Separated Extra Low-Voltage)* — An extra low-voltage system which is electrically separated from earth and from other system in such a way that a single fault cannot give rise to the risk of electric shock.

3.1.18 *Short-circuit* — Accidental or intentional conductive path between two or more conductive parts forcing the electric potential differences between these conductive parts to be equal to or close to zero.

3.1.19 *Spark* — Small luminous electric arc of short duration.

3.1.20 *Voltage, Potential Difference* — The line of integral from one point to another of an electric field, taken along a given path.

3.1.21 *Voltage Classifications* — Nomenclature of commonly used short names of voltages

3.1.23.1 *ELV (extra low voltage)* — A system with a nominal voltage $U_n \leq 50$ V a.c. or ≤ 120 V d.c. ;

3.1.23.2 *LV (low voltage)* — A system with a nominal voltage $U_n \leq 1\,000$ V a.c. and $\leq 1\,500$ V d.c.

3.1.23.3 *MV (medium voltage)* — A system with a nominal rms voltage is 1 kV $< U_n \leq 33$ kV

3.1.23.4 *HV (high voltage)* — A system with a nominal rms voltage is $33 < U_n \leq 150$ kV.

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3.1.23.5 *EHV (extra high voltage*) — A system with a nominal rms voltage is > 150 kV.

NOTES

1 The above nomenclatures are adopted from IS 17036 and IS 732 for the purpose of this code.

2 Regulatory commissions of state governments use different definitions, which are not considered in this code

3.2 Equipment

3.2.1 *Apparatus* **—** Device or assembly of devices which can be used as an independent unit for specific functions.

3.2.2 *Appliance* — apparatus intended for household or similar use.

3.2.3 *Auto-transformer* — A transformer in which at least two windings have a common part.

3.2.4 *Bimetallic-Connector* — Connector formed by two different metals metallurgically bonded, used to connect conducting parts consisting of these same metals.

3.2.5 *Circuit-Breaker (Mechanical)* — A mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions, and breaking currents under specified abnormal circuit conditions such as those of short circuit.

NOTE — A circuit breaker is usually intended to operate infrequently, although some types are suitable for frequent operation.

3.2.6 *Circuit Breaker Linked* — A circuit breaker, the contacts of which are so arranged as to make or break all poles simultaneously or in a definite sequence.

3.2.7 *Class-I-Equipment* — Equipment in which protection against electric shock does not rely on basic insulation only, but which includes an additional safety precaution in such a way that means are provided for the connection of exposed conductive parts to a protective conductor in the fixed wiring of installation in such a way that accessible conductive parts may not become live in the event of a failure of basic insulation.

NOTE — For information on classification of equipment with regard to means provided for protection against electric shock, *see* IEC 61140.

3.2.8 *Class-II-Equipment* — Equipment in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions, such as double or reinforced insulation are provided, there being no provision for the connection of exposed metal work of the equipment to a protective conductor, and no reliance upon precautions to be taken in the fixed wiring of the installation.

3.2.9 *Class-III-Equipment* — Equipment in which protection against electric shock relies on supply at SELV and in which voltages higher than those of SELV are not generated.

3.2.10 *Current using Equipment* — Equipment which converts electrical energy into another form of energy, such as light, heat, or motive power.

3.2.11 *Disconnector* — A mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements.

NOTES

1 A disconnector is also known as isolator.

2 A disconnector is capable of opening and closing a circuit when either a negligible current is broken or made, or when no significant change in the voltage across the terminals of each pole of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and current under abnormal conditions such as those of short-circuit for a specified time.

3.2.12 *Electrical Equipment (Equipment)* — Any item used for such purposes as generation, conversion, transmission, distribution or utilization of electric energy, such as electric machines, transformers, switchgear and control gear, measuring instruments, protective devices, wiring systems, current-using equipment.

3.2.13 *Electric Motor* — A machine which converts electrical energy into mechanical energy.

3.2.14 *Electrode Boiler (or Electrode Water Heater)* — Electric boiler used for heating water due to flow of alternating electric current through water between electrodes.

3.2.15 *Enclosed Fuse-link* — Fuse-link in which the fuse-element(s) is (are) totally enclosed, so that during operation within its rating it cannot produce any harmful external effects, for example, due to development of an arc, the release of gas or the ejection of flame or metallic particles.

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3.2.16 *Fixed Equipment* — Electric equipment fastened to a support or otherwise secured in a specific location

3.2.17 *Fuse* — A device which, by fusing of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device.

3.2.18 *Fuse-base (Fuse-mount)* — The fixed part of a fuse provided with contacts and terminals for connection to the system. The fuse-base comprises all the parts necessary for insulation.

3.2.19 *Fuse-carrier* — The movable part of a fuse designed to carry a fuse link.

3.2.20 *Fuse-element* — A part of the fuse-link designed to melt under the action of current exceeding some definite value for a definite period of time.

3.2.21 *Fuse-link* — A part of fuse, including the fuse element(s), which requires replacement by a new or renewable fuse link after the fuse has operated.

3.2.22 *Fuse-switch* — A switch in which a fuse-link or a fuse-carrier with fuse-link forms the moving contact.

3.2.23 *Generator* — A machine for converting mechanical energy into electrical energy.

3.2.24 *Hand-held Equipment* — Electric equipment intended to be held in the hand during normal use.

3.2.25 *Induction Motor* — An alternating current motor without a commutator in which one part only, the rotor or a stator, is connected to the supply network, the other working by induction.

3.2.26 *Interconnecting Bus-bar* — A conductor other than cable, used for external connection between terminals of equipment.

3.2.27 *Lightning Arrester (Surge Diverter)* — A device which has the property of diverting to earth any electrical surges of excessively high amplitude applied to its terminals and is capable of interrupting flow of current if present and restoring itself thereafter to its original operating condition.

3.2.28 *Low-voltage Switchgear and Control gear Assembly* — A combination of one or more low voltage switching devices together with associated control, measuring, signaling, protective, regulating equipment etc., completely assembled under the responsibility of the manufacturer with all the internal electrical and mechanical inter-connections and structural parts. The components of the assembly may be electromechanical or electronic

3.2.29 *Luminaire* — Apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all the parts necessary for fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electric supply.

NOTE — The term lighting fitting is deprecated.

3.2.30 *Luminaire Supporting Coupler (LSC)* — A means comprises of LSC outlet and an LSC connector, providing mechanical support for a luminaire and the electrical connection to and disconnection from a fixed wiring installation.

3.2.31 *Miniature Circuit-breaker* — A compact mechanical device for making, carrying and breaking a circuit both in normal conditions and also making, carrying for a specified duration and breaking currents under specified abnormal circuit conditions such as those of short circuit.

3.2.32 *Mobile Equipment* — Electrical equipment which is moved while in operation or which can be easily moved from one place to another while connected to the supply.

3.2.33 *Motor Generator Set* — Set which consists of one or more motors mechanically coupled to one or more generators.

3.2.34 *Plug* — Accessory having pins designed to engage with the contacts of a socket-outlet, also incorporating means for the electrical connection and mechanical retention of flexible cables or cords.

3.2.34.1.1 *Portable Equipment* — Equipment intended to be carried by a person during its operation.

NOTE — Portable equipment carried by a person during its operation is sometimes referred to as hand-held equipment.

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3.2.35 *Relay (Electric Relay)* — Device designed to produce sudden predetermined changes in one or more electric output circuits, when certain conditions are fulfilled in the electric input circuits controlling the device.

3.2.36 *Residual Current Device (RCD)* — Mechanical switching device or association of devices designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions.

3.2.37 *Residual Current Operated Circuit-Breaker with Integral Overcurrent Protection (RCBO)* — Residual current operated circuit-breaker designed to perform the functions of protection against overloads and/or short circuits.

3.2.38 *Residual Current Operated Circuit-breaker without Integral Overcurrent Protection (RCCB)* — Residual current operated circuit-breaker not designed to perform the functions of protection against overloads and/or short circuits.

3.2.39 *Stationary Equipment* — Fixed equipment or equipment not provided with a carrying handle and having such a mass that it cannot easily be moved.

NOTE — The value of this mass is 18 kg in IEC standards relating to household appliances

3.2.40 *Switch* — A mechanical switching device capable of making, carrying and breaking current under normal circuit conditions, which may include specified operating overload conditions, and also of carrying for a specified time currents under specified abnormal circuit conditions such as those of short circuit.

NOTE — A switch may also be capable of making, but not breaking, short-circuit currents

3.2.41 *Switch, Linked* — A switch, the contacts of which are so arranged as to make or break all poles simultaneously or in a definite sequence.

3.2.42 *Switch-disconnector* — A switch which, in the open position, satisfies the isolating requirements specified for a disconnector.

NOTE — A switch-disconnector is otherwise known as an isolating switch.

3.2.43 *Switch-fuse* — A switch in which one or more poles have a fuse in series in a composite unit.

3.2.44 *Switchboard* — An assembly of switchgear with or without instruments, but the term does not apply to a group of local switches in a final circuit.

NOTE — The term 'switchboard' includes a distribution board.

3.2.45 *Switchgear* — An assembly of main and auxiliary switching apparatus for operation, regulation, protection or other control of electrical installations.

3.2.46 *Switchgear and Controlgear* — A general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures.

3.2.47 *Surge Protective Devices (SPD)* — A device that is intended to limit transient over voltages and divert surge currents. It contains at least one non-linear component.

3.2.48 *Transformer* — A static piece of apparatus with two or more windings which, by electromagnetic induction, transform a system of alternating voltage and current into another system of voltage and current usually of different value and at the same frequency for the purpose of transmitting electrical power.

3.3 Wiring Practice

3.3.1 *Accessory* — A device, other than current-using equipment, associated with such equipment or with the wiring of an installation.

3.3.2 *Aerial Conductor* — Any conductor which is supported by or suspended on insulators above the ground and is directly exposed to the weather.

NOTE — The following four classes of aerial conductors are recognized:

a) Bare aerial conductors;
b) Covered aerial conductors;
c) Insulated aerial conductors;

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d) Weatherproof neutral-screened cable; and

e) Aerial bunched cable.

3.3.3 *Back-up Protection* — Protection which is intended to operate when a system fault is not cleared or abnormal condition not detected in the required time, because of failure or inability of other protection to operate or failure of appropriate circuit-breaker(s) to trip.

3.3.4 *Barrier* — A part providing a defined degree of protection against contact with live parts, from any usual direction of access.

3.3.5 *Basic Insulation* — Insulation of hazardous-live-parts which provides basic protection.

NOTE — This concept does not apply to insulation used exclusively for functional purposes.

3.3.6 *Basic Protection* — Protection against electric shock under fault-free condition.

3.3.7 *Bonding Conductor* — A protective conductor providing equipotential bonding.

3.3.8 *Bonding Network (BN)* — A set of interconnected conductive parts that provide a path for current at frequencies from direct current (d.c.) to radio frequency (RF) intended to divert, block or impede the passage of electromagnetic energy.

3.3.9 *Bonding Ring Conductor (BRC)* — A bus earthing conductor in the form of a closed ring.

NOTE — Normally the bonding ring conductor, as part of the bonding network, has multiple connections to the common bonding network (CBN) that improves its performance.

3.3.10 *Bunched* — Cables are said to be 'bunched' when two or more are contained within a single conduit, duct or groove or, if not enclosed, are not separated from each other.

3.3.11 *Buried Direct* — A cable laid in the ground in intimate contact with the soil.

3.3.12 *Busbar Trunking System* — A type-tested assembly, in the form of an enclosed conductor system comprising solid conductors separated by insulating materials. The assembly may consist of units such as:

a) Busbar trunking units, with or without tap-off facilities;

b) Tap-off units where applicable; and

c) Phase-transposition, expansion, building- movement, flexible, end-feeder and adaptor units.

3.3.13 *Bypass Equipotential Bonding Conductor* — Bonding conductor connected in parallel with the screens of cables.

3.3.14 *Wire* — Flexible cylindrical conductor, with or without an insulating covering, the length of which is large with respect to its cross-sectional dimensions.

NOTE — The cross-section of a wire may have any shape, but the term "wire" is not generally used for ribbons or tapes.

3.3.15 *Cable* — A length of single-insulated conductor (solid or stranded), or two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering.

3.3.16 *Cable, Armoured* — A cable provided with a wrapping of metal (usually in the form of tape or wire) serving as a mechanical protection.

3.3.17 *Cable, Flexible* — A cable containing one or more cores, each formed of a group of wires, the diameters of the cores and of the wires being sufficiently small to afford flexibility.

3.3.18 *Cable Bracket* — A cable support consisting of single devices fixed to elements of building or plant construction.

3.3.19 *Cable Channel* — An enclosure situated above or in the ground, open or ventilated or closed, and having dimensions which do not permit the access of persons but allow access to the conductor and/or cables throughout their length during and after installation.

NOTE — A cable channel may or may not form part of the building construction.

3.3.20 *Cable Cleat* — A component of a support system which consists of elements spread at intervals along the length of the cable or conduits and which mechanically retains the cable or conduit.

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3.3.21 *Cable Coupler* — A means enabling the connection, at will, of two flexible cables. It consists of a connector and a plug.

3.3.22 *Cable Ducting* — A manufactured enclosure of metal or insulating material, other than conduit or cable trunking, intended for the protection of cables which are drawn-in after erection of the ducting, but which is not specifically intended to form part of a building structure.

3.3.23 *Cable Ladder* — Cable support consisting of a series of transverse supporting elements rigidly fixed to main longitudinal supporting members.

3.3.24 *Cable Tray* — Cable support consisting of a continuous base with raised edges but no covering.

NOTE — A cable tray may be perforated or mesh.

3.3.25 *Cable Trunking* — System of closed enclosures comprising a base with a removable cover, intended for the complete surrounding of insulated conductors, cables, cords and/or for the accommodation of other electric equipment including information technology equipment.

3.3.26 *Cable Tunnel* — Corridor whose dimensions allow persons to pass freely throughout the entire length, containing supporting structures for cables and joints and/or other elements of wiring systems.

3.3.27 *Cartridge Fuse Link* — A device comprising a fuse element or several fuse elements connected in parallel enclosed in a cartridge usually filled with an arc-extinguishing medium and connected to terminations. The fuse link is the part of a fuse which requires replacing after the fuse has operated.

3.3.28 *Circuit, Final, Sub* — An outgoing circuit connected to one-way distribution fuse-board and intended to supply electrical energy at one or more points to current-using appliances, without the intervention of a further distribution fuse-board other than a one-way board. It includes all branches and extensions derived from that particular way in the board.

3.3.29 *Cold Tail* — Part for connecting the heating resistor and the wire from power supply and conceiving no obvious heating.

3.3.30 *Combustible* — Capable of burning.

3.3.31 *Common Equipotential Bonding System, Common Bonding Network* — Equipotential bonding system providing both protective equipotential bonding and functional equipotential bonding

3.3.32 *Conductor, Bare* — A conductor not covered with insulating material.

3.3.33 *Conductor, Earthed* — A conductor with no provision for its insulation from earth.

NOTE — A protective conductor in a TN-S system.

3.3.34 *Conductor, Insulated* — A conductor adequately covered with insulating material of such voltage grade and thickness as to prevent danger.

3.3.35 *Conductor for Portable Appliances* — A combination of a plug and socket arranged for attachment to a portable electrical appliance or to a flexible cord.

3.3.36 *Confined Conductive Location* — A location having surfaces which are mainly composed of extraneous conductive parts and which are of such dimensions that movement is restricted to such an extent that contact with surfaces is difficult to avoid (for example in a boiler).

3.3.37 *Connector* — The part of a cable coupler or of an appliance coupler which is provided with female or male contact and is intended to be attached for a temporary duration to the other part of the flexible cable connected to the supply.

3.3.38 *Connector Box or Joint Box* — A box forming a part of wiring installation provided to contain joints in the conductors of cables of the installation.

3.3.39 *Consumer Unit (may also be known as a Consumer Control Unit or Electricity Control Unit)* — A particular type of distribution board comprising a type-tested coordinated assembly for the control and distribution of electrical energy, principally in domestic premises, incorporating manual means of double-pole isolation on the incoming circuit(s) and an assembly of one or more fuses, circuit-breakers, residual current

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operated devices or signaling and other devices proven during the type-test of the assembly as suitable for such use.

3.3.40 *Consumer's Terminals* — The ends of the electrical conductors situated upon any consumer's premises and belonging to him at which the supply of energy is delivered from the service line.

3.3.41 *Cord, Flexible* — A flexible cable having conductor of small cross-sectional area. Two flexible cords twisted together are known as 'Twin Flexible Cord'.

NOTE — For the maximum diameter and minimum number of wires for flexible cord, *see* IS 8130.

3.3.42 *Cut-out* — Any appliance for automatically interrupting the transmission of electricity through the conductor when the current rises above a pre-determined amount and shall also include fusible cut-out.

3.3.43 *Dead* — At or about earth potential and/or disconnected from any live system.

3.3.44 *Direct Contact* — Electric contact of persons or animals with live parts.

3.3.45 *Discrimination* — Ability of a protective device to operate in preference to another protective device in series.

3.3.46 *Distribution Circuit (of Buildings)* — Electric circuit supplying distribution boards.

3.3.47 *Distribution Fuse-board* — An assemblage of parts including one or more fuses arranged for the distribution of electrical energy to final sub-circuits.

3.3.48 *Double Insulation* — Insulation comprising both basic insulation and supplementary insulation.

3.3.49 *Duct* — A closed passage way formed under ground or in a structure and intended to receive one or more cables which may be drawn in.

3.3.50 *Ducting* (*see* **3.3.49**)

3.3.51 *Earth* — The conductive mass of the earth, whose electric potential at any point is conventionally taken as zero.

3.3.52 Earth (local) — Part of the Earth which is in electric contact with an earth electrode and the electric potential of which is not necessarily equal to zero.

3.3.53 *Earthing Arrangement* — All the electric connections and devices involved in the earthing of a system, an installation and equipment.

3.3.54 *Earth Electrode* — Conductor or group of conductors in intimate contact with and providing an electrical connection to earth.

3.3.55 *Earthing* — Connection of the exposed conductive parts of an installation to the main earthing terminal of that installation.

3.3.56 *Earthed Concentric Wiring* — A wiring system in which one or more insulated conductors are completely surrounded throughout their length by a conductor, for example a sheath, which acts as a PE or PEN conductor.

3.3.57 *Earthing Conductor* — A protective conductor connecting the main earth terminal (or equipotential bonding conductor of an installation when there is no earth bus) to an earth electrode or to other means of earthing.

3.3.58 *Earth Electrode Network* — Part of an earthing arrangement comprising only the earth electrodes and their interconnections.

3.3.59 *Electric Shock* — Physiological effect resulting from an electric current passing through a human or animal body.

3.3.60 *Electrical Installation (of a Building)* — Assembly of associated electric equipment having co-ordinated characteristics to fulfil specific purposes.

3.3.61 *Electrically Independent Earth Electrodes* — Earth electrodes located at such a distance from one another that the maximum current likely to flow through one of them does not significantly affect the potential of the other(s).

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3.3.62 *Electrical Source for Safety Services* — Electrical source intended to be used as part of an electrical supply system for safety services.

3.3.63 *Electrical Supply System for Safety Services* — A supply system intended to maintain the operation of essential parts of an electrical installation and equipment:

a) For health and safety of persons and livestock; and

b) To avoid damage to the environment and to other equipment.

NOTE — The supply system includes the source and the circuit(s) up to the terminals of the electrical equipment.

3.3.64 *Emergency Switching* — Opening operation of a switching device intended to remove electric power from an electrical installation to avert or alleviate a hazardous situation.

3.3.65 *Equipotential Bonding* — Electrical connection putting various exposed conductive parts and extraneous conductive parts at a substantially equal potential.

NOTE — In a building installation equipotential bonding conductors shall interconnect the following conductive parts:

a) Protective conductor;

b) Earth continuity conductor; and

c) Risers of air-conditioning system and heating systems (if any).

3.3.66 *Exposed Conductive Part* — A conductive part of electrical equipment, which can be touched and which is not normally live, but which may become live under fault conditions.

NOTE —Typical exposed conductive parts are walls of enclosures, operating handles, etc.

3.3.67 *External Influence* — Any influence external to an electrical installation which affects the design and safe operation of that installation

3.3.68 *Flammable* — A material capable of being easily ignited.

3.3.69 *Extraneous Conductive Part* — A conductive part not forming part of the electrical installation and liable to introduce an electric potential, generally the electric potential of a local earth.

3.3.70 *Factory Built Assembly (of LV Switchgear and Controlgear) — See* IS/IEC 61439-2.

3.3.71 *Earth Fault* — Occurrence of an accidental conductive path between a live conductor and the exposed conductive part or a protective conductor or earthing arrangement.

NOTE — The conductive path can pass through a faulty insulation, through structures (for example, poles, scaffoldings, cranes, ladders), or through vegetation (for example trees, bushes) and can have a significant impedance.

3.3.72 *Flammability* — Ability of a material or product to burn with a flame under specified test condition.

3.3.73 *Fitting, Lighting* — A device for supporting or containing a lamp or lamps (for example, fluorescent or incandescent) together with any holder, shade, or reflector, for example, a bracket, a pendant with ceiling rose, or a portable unit.

3.3.74 *Functional Bonding Conductor* — Conductor provided for functional equipotential bonding.

3.3.75 *Functional Earthing* — Earthing a point or points in a system or in an installation or in equipment for purposes other than electrical safety.

3.3.76 *Gas Installation Pipe* — Any pipe, not being a service pipe or pipe comprised in a gas appliance, for conveying gas for a particular consumer and including any associated valve or other gas fitting.

3.3.77 *Indirect Contact* — Electric contact of persons or animals with exposed-conductive-parts which have become live under fault conditions.

NOTE — Extraneous conductive parts are generally at earth potential.

3.3.78 *Insulation* — All the materials and parts used to insulate conductive elements of a device.

NOTE — See also the definitions for basic insulation, double insulation, reinforced insulation and supplementary insulation.

3.3.79 *Insulation Co-ordination* — Selection of the dielectric strength of equipment in relation to the operating voltages which can appear on the electric power system for which the equipment is intended, and taking into account the service environment and the characteristics of the available preventing and protective devices.

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3.3.80 *Ignitability* — Measure of the ease with which a specimen can be ignited due to the influence of an external source, under specified test condition.

3.3.81 *Ignition* — Initiation of combustion.

3.3.82 *Installations* — Assembly of associated electric equipment having coordinated characteristics to fulfil specific purposes.

3.3.83 *Isolation* — Function intended to make dead for reasons of safety all or a discrete section of the electrical installation by separating the electrical installation or section from every source of electric energy

3.3.84 *Live or Alive* — Electrically charged so as to have a potential difference from that of earth.

3.3.85 *Local Earthing* — Part of the Earth which is in electric contact with an earth electrode and the electric potential of which is not necessarily equal to zero.

3.3.86 *Line Conductor* — Conductor which is energized in normal operation and capable of contributing to the transmission or distribution of electric energy but which is not a neutral or mid-point conductor.

NOTE — Also, called as Phase conductor (in a.c. systems) which is a deprecated term now a days.

3.3.87 *Main Earthing Terminal* — Terminal or bus bar which is part of the earthing arrangement of an installation and enabling the electric connection of a number of conductors to achieve equipotential bonding.

3.3.88 *Meshed Bonding Network (MESH-BN)* — Bonding network in which all associated equipment frames, racks and cabinets and usually the d.c. power return conductor are bonded together as well as at multiple points to the CBN and may have the form of a mesh.

3.3.89 *Minimum Illumination* — Illumination for emergency lighting at the end of rated operating time.

3.3.90 *Minor Works* — Additions and alterations to an installation that do not extend to the provision of a new circuit

3.3.91 *Mechanical Maintenance* — The replacement, refurbishment or cleaning of lamps and non-electrical parts of equipment, plant and machinery.

3.3.92 *Multiple Earthed Neutral System* — A system of earthing in which the parts of an installation, specified to be earthed are connected to the general mass of earth and, in addition, are connected within the installation to the neutral conductor of the supply system.

NOTE — This definition is applicable only for voltages up to 1000 Va.c.

3.3.93 *Neutral or Neutral Conductor (Symbol N)* — A conductor connected to the neutral point of a system and capable of contributing to the transmission of electrical energy.

The term also means the equivalent conductor of an IT or d.c. system unless otherwise specified in the regulations and also identifies either the mid-wire of a three-wire d.c. circuit or the earthed conductor of a two- wire earthed d.c. circuit.

3.3.94 *Non-flame Propagating Component* — Component which is liable to ignite, as a result of an applied flame, but in which the flame does not propagate and which extinguishes itself within a limited time after the flame is removed.

3.3.95 *Origin of an Electrical Installation* — The point at which electrical energy is delivered to an electrical installation.

NOTE — An electrical installation may have more than one origin.

3.3.96 *Overcurrent* — A current exceeding the rated value. For conductors, the rated value is the current carrying capacity.

3.3.97 *Overcurrent Detection* — A method of establishing that the value of current in a circuit exceeds a predetermined value for a specified time

3.3.98 *PEL Conductor* — A conductor combining the function of both a protective earthing and a line conductor.

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3.3.99 *PEM Conductor* — A conductor combining the function of both a protective earthing conductor and a midpoint conductor.

3.3.100 *PEN Conductor* — A conductor combining the functions of both protective earthing conductor and neutral conductor.

3.3.101 *Parallel Earth Continuity Conductor* — Conductor usually laid along the cable route to provide a continuous low impedance metallic earth connection between the earthing systems at the ends of the cable route.

3.3.102 *Phase Conductor* — Phase conductor (in a.c. systems) is replaced with Line conductor.

3.3.103 *Point (in Wiring)* — A termination of the fixed wiring intended for the connection of current using equipment.

3.3.104 *Powertrack* — A system component, which is generally a linear assembly of spaced and supported busbars, providing electrical connection of accessories.

3.3.105 *Powertrack System (PT System)* — An assembly of system components including a powertrack by which accessories may be connected to an electrical supply at one or more points (predetermined or otherwise) along the power track.

NOTE — The maximum current rating of a power track system is 63 A.

3.3.106 *Protective Conductor* — A conductor used for some measures of protection against electric shock and intended for connecting together any of the following parts:

a) Exposed conductive parts;
b) Extraneous conductive parts;
c) The main earthing terminal; and
d) The earthed point of the source, or an artificial neutral.

3.3.107 *Protective Earthing* — Earthing a point or points in a system or in an installation or in equipment, for purposes of electrical safety.

3.3.108 *Protective Euqipotential Bonding* — Equipotential bonding for the purpose of safety.

3.3.109 *Protective Multiple Earthing (PME)* — An earthing arrangement, found in TN systems, in which the earthing conductor (either PEN or PE) is connected to local earthing for the purpose of reducing fault loop impedance and in case of PEN conductor, to limit potential of line conductor to earth during neutral disconnection.

3.3.110 *Protective Separation* — Separation of one electric circuit from another by means of:

a) Double insulation;
b) Basic insulation and electrically protective screening; or
c) Reinforced insulation.

3.3.111 *Service* — The conductors and equipment required for delivering energy from the electric supply system to the wiring system of the premises served.

3.3.112 *Socket-outlet and Plug* — Socket-outlet is an accessory having socket-contacts designed to engage with the pins of a plug and having terminals for the connection of cables or cords. Plug is connector attached to a cable.

3.3.113 *Reinforced Insulation* — Insulation of hazardous-live-parts which provides a degree of protection against electric shock equivalent to double insulation.

NOTE — Reinforced insulation may comprise several layers which cannot be tested singly as basic insulation or supplementary insulation.

3.3.114 *Resistance Area (for an Earth Electrode only)* — The surface area of ground (around an earth electrode) on which a significant voltage gradient may exist.

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3.3.115 *Response Time* — the time from a sudden change of a control quantity until the corresponding change of an output quantity has reached a specified fraction of its final value.

3.3.116 *Ring Final Circuit* — A final circuit arranged in the form of a ring and connected to a single point of supply.

3.3.117 *Safety Service* — An electrical system for electrical equipment provided to protect or warn persons in the event of a hazard, or essential to their evacuation from a location.

3.3.118 *Simple Separation* — Separation between electric circuits or between an electric circuit and local earth by means of basic insulation.

3.3.119 *Space Factor* — The ratio (expressed as a percentage) of the sum of the overall cross-sectional areas of cables (including insulation and sheath) to the internal cross-sectional area of the conduit or other cable enclosure in which they are installed. The effective overall cross-sectional area of a non-circular cable is taken as that of a circle of diameter equal to the major axis of the cable.

3.3.120 *Spur* — A branch cable connected to a main line at a point on its route.

3.3.121 *Standby Supply System* — A system intended to maintain supply to the installation or part thereof, in case of interruption of the normal supply, for reasons other than safety of persons.

NOTE — Standby supplies are necessary, for example, to avoid interruption of continuous industrial processes or data processing.

3.3.122 *Supplementary Insulation* — Independent insulation applied in addition to basic insulation for fault protection.

3.3.123 *System* — An electrical system consisting of a single source or multiple sources running in parallel of electrical energy and an installation. Types of system are identified as follows, depending upon the relationship of the source, and of exposed-conductive parts of the installation, to Earth:

a) *TN system* — A system having one or more points of the source of energy directly earthed, the exposed conductive-parts of the installation being connected to that point by protective conductors.

b) *TN-C system* — A system in which neutral and protective conductor functions are combined in a single conductor throughout the system.

c) *TN-S system* — A system having separate protective conductor throughout the system.

d) *TN-C-S system* — A system in which neutral and protective conductor functions are combined in a single conductor in part of the system.

e) *TT system* — A system having one point of the source of energy directly earthed, the exposed-conductive-parts of the installation being connected to the earth electrodes electrically independent of the earth electrodes of the source.

f) *IT system* — A system in which all live parts are isolated from earth or one point connected to earth through an impedance. The exposed-conductive-parts of the electrical installation are earthed independently or collectively or to the earthing of the system.

NOTE — The types of systems depending upon the relationship to the source and of the exposed conductive parts of the installation to earth are defined in IS 3043.

3.4 Miscellaneous Terms

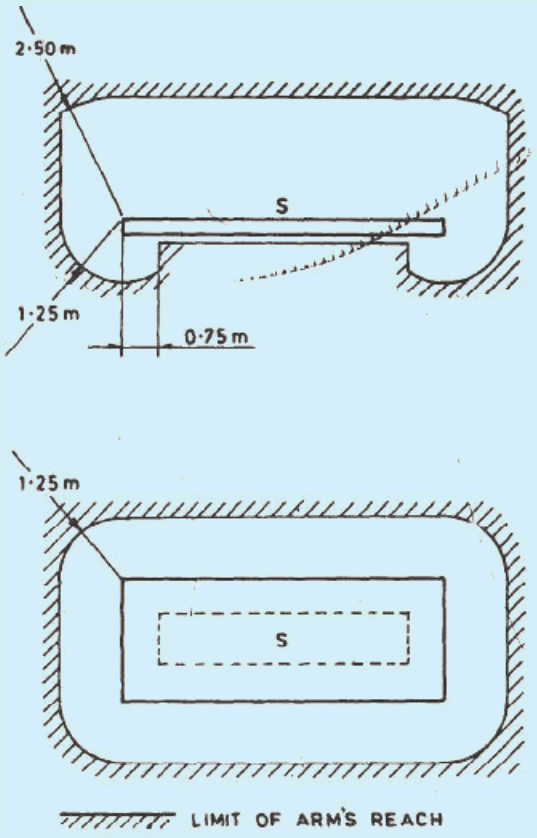
3.4.1 *Agricultural and Horticultural Premises* — Rooms, location or areas where live stocks are kept and feed, fertilizers, vegetable and animal products are produced, stored, prepared or processed and plants are grown such as greenhouse.

3.4.2 *Ambient Temperature* — Average temperature of air or another medium in the vicinity of the equipment

NOTE — During the measurement of the ambient temperature the measuring instrument/probe should be shielded from draughts and radiant heating.

3.4.3 *Arm's Reach* — Either the distance measured from the floor to the fingertips of a person fully extended in the vertical direction or for any other direction at one-third of that distance.

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NOTE — This space is by convention, limited as shown in Fig. 1.

FIG. 1 LIMIT OF ARM'S REACH

3.4.4 *Barrier* — A part providing protection against direct contact from any usual direction of access

3.4.5 *Basin of Fountain* — A basin not intended to be occupied by persons and which cannot be accessed (reached by persons) without the use of ladders or similar means. For basins of fountains which may be occupied by persons, the requirement of swimming pools applies.

3.4.6 *Booth* — Non-stationary unit intended to accommodate equipment generally for pleasure or demonstration purpose.

3.4.7 *Building* — Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, verandah, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents, shamianahs, tarpaulin shelters, etc, erected for temporary of the Authority shall not be considered as building.

3.4.8 *Building Voids, Accessible* — Space within the structure or the components of a building accessible only at certain points.

NOTE — Examples are space within partitions, suspended floors, ceilings and certain types of window frames, door frames and architraves A specially formed building void in an element of building is also known as a duct.

3.4.9 *Building Void, Non-accessible* — A space within the structure or the components of building which has no ready means of access.

3.4.10 *Clearance* — The distance between two conducting parts along a string stretched the shortest way between these conducting parts.

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3.4.11 *Competent Person* — A person who can judge the work assigned and recognize possible hazards on the basis of professional training, knowledge, experience and knowledge of the relevant equipment.

3.4.12 *Connected Load* — That part of the installed load of the consumer that may be supplied by the supply undertaking.

3.4.13 *Consumer or Customer* — The party who receives electricity from the supply or distribution undertaking.

3.4.14 *Continuous Operating Voltage (Uc)* — Maximum rms voltage which may be continuously applied to an SPD's mode of protection. This is equal to rated voltage.

3.4.15 *Conventional Impulse Withstand Voltage* — The peak value of an impulse test voltage at which insulation does not show any disruptive discharge, when subjected to a specified number of applications of impulses of this value, under specified condition.

NOTE — Standard impulse wave of 1.2/50 µs shall be used.

3.4.16 *Conventional Touch Voltage Limit* — Maximum value of the prospective touch voltage which is permitted to be maintained indefinitely in specified conditions of external influences.

3.4.17 *Conventional Operating Current (of a Protective Device)* — Specified value of the electric current intended to cause the protective device to operate within a specified duration.

NOTES

1 For fuses this current is called the conventional fusing current. For circuit breakers this current is called the conventional operating current.

2 The conventional operating current is greater than the rated current or current setting of the device and the conventional time varies according to the type and rated current of the protective device.

3.4.18 *Creepage Distance* — Shortest distance or the sum of the shortest distances along the surface on an insulator between two conductive parts which normally have the operating voltage between them.

NOTES

1 The surface of cement or of any other non-insulating jointing material is not considered as forming part of the creepage distance.

2 If a high resistance coating is applied to parts of the insulating part of an insulator, such parts are considered to be effective insulating surfaces and the distance over them is included in the creepage distance.

3.4.19 *Impulse* — Usually an aperiodic transient voltage or current which rises rapidly to a peak value and then falls, generally more slowly, to zero. Ideally, it approximates a double exponential form. Other forms are sometimes used for special purposes

3.4.20 *Current Carrying Capacity of a Conductor* — The maximum current which can be carried by a conductor under specified conditions without its steady state temperature exceeding a specified value.

3.4.21 *Danger* — Risk of electrical injury when electrical energy is present in an electrical installation

3.4.22 *Demand* — The magnitude of electricity supply, expressed in kW or kVA

3.4.23 *Design Current (of a Circuit)* — The magnitude of the current intended to be carried by the circuit in normal service.

3.4.24 Distribution Undertaking — The party supplying electricity to consumers entirely from external sources of power via a distribution network.

3.4.25 *Domestic Tariff* — A tariff applicable particularly or exclusively to domestic consumers.

3.4.26 *Earth Fault Current* — Current flowing to earth due to an insulation fault.

3.4.27 *Earth Electrode Resistance* — The resistance of an earth electrode to earth.

3.4.28 *Earth Fault Loop Impedance* — The impedance of the earth fault current loop (phase to earth loop) starting and ending at the point of earth fault. This impedance is denoted by the symbol Z. The earth fault loop comprises the following, starting at the point of fault:

a) the circuit protective conductor;

b) the consumer's earthing terminal and earthing conductor, and for TN systems, the metallic return path;

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c) for TT and IT systems, the earth return path;
d) the path through the earth neutral point of the transformer;
e) the transformer winding; and
f) the line conductor from the transformer to the point of fault.

3.4.29 *Earth Leakage Current* — Current flowing from the live parts of the installation to earth, in the absence of an insulation fault.

3.4.30 *Earthing Resistance, Total* — The resistance between the main earthing terminal and the conductive mass of earth.

3.4.31 *Enclosure* — Housing affording the type and degree of protection suitable for the intended application.

3.4.32 *Fault Current* — Current which flows across a given point of fault resulting from an insulation failure.

3.4.33 *Fault Protection* — Protection against electric shock under single fault conditions.

NOTE — For low voltage installation, systems and equipment, fault protection generally corresponds to protection against in direct contact, mainly with regards to failure of basic insulation. Indirect contact is "contact of persons or livestock with exposed- conductive parts which have become live under fault conditions."

3.4.34 *Final Circuit* — Electric circuit intended to supply directly electric current to current using equipment or socket-outlets.

3.4.35 *Hazardous-Live Part* — Live part which, under certain conditions, can give a harmful electric shock

3.4.36 *Heating Tariff* — A tariff applicable to electricity supplies taken for space heating or for other heating applications.

3.4.37 *Impulse Current* — A parameter used for the classification test for SPDs; it is defined by three elements, a current peak value, a charge Q and a specific energy W/R.

3.4.38 *Impulse Withstand Voltage* — The highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified condition.

3.4.39 *Installed Load* — The sum of the nameplate ratings of the electrical apparatus installed on the consumer's premises.

3.4.40 *Kilo watthour Rate (kWh Rate)* — The amount to be paid per unit of energy (kWh) consumed.

3.4.41 *Industrial Tariff* — A tariff applicable particularly or exclusively to industrial consumers.

3.4.42 *Leakage Current* — electric current in an unwanted conductive path under normal operating conditions.

NOTE — This current may have a capacitive component including that resulting from the deliberate use of capacitors.

3.4.43 *Lighting Protection Zone* — Zone where the lightning electromagnetic environment is defined.

3.4.44 *Lighting Tariff* — A tariff applicable to electricity supplies taken mainly for lighting.

3.4.45 *Line Conductor* — Conductor which is energized in normal operation and capable of contributing to the transmission or distribution of electric energy but which is not a neutral or mid-point conductor.

3.4.46 *Live Part* — Conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

NOTE — This concept does not necessarily imply a risk of electric shock.

3.4.47 *Load Factor* — The ratio, expressed as a numerical value or as a percentage, of the consumption within a specified period (year, month, day, etc.), to the consumption that would result from continuous use of the maximum or other specified demand occurring within the same period.

NOTES

1 This term should not be used without specifying the demand and the period to which it relates.

2 The load factor for a given demand is also equal to the ratio of the utilization time to the time in hours within the same period.

3.4.48 *Meter Rent* — An amount to be paid for a specified period for metering, and allied equipment installed.

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3.4.49 *Monitoring* — Observation of the operation of a system or part of a system to verify correct functioning or detect incorrect functioning by measuring system variables and comparing the measured value with the specified value.

3.4.50 *Nominal Voltage (of an Installation)* — Value of the voltage by which the electrical installation or part of the electrical installation is designated and identified.

NOTE — The actual voltage may differ from the nominal voltage by a quantity within permitted tolerances.

3.4.51 *Obstacle* — Part preventing unintentional direct contact, but not preventing direct contact by deliberate action.

3.4.52 *Occupancy or Use Group* — The principal occupancy for which a building or a part of a building is used or intended to be used; for the purposes of classification of a building according to occupancy, an occupancy shall be deemed to include the subsidiary occupancies which are contingent upon it.

3.4.53 *Overcurrent* — A current exceeding the rated value. For conductors the rated value is the current carrying capacity.

3.4.54 *Overcurrent Detection* — A method of establishing that the value of current in a circuit exceeds a predetermined value for a specified length of time.

3.4.55 *Overload Current (of a Circuit)* — Overcurrent occurring in an electric circuit, which is not caused by a short-circuit or an earth fault.

3.4.56 *Power Factor Clause* — A price adjustment clause setting out the charges which apply according to the level of power factor or to the magnitude of reactive energy consumption.

NOTE — The power factor is generally measured by the ratio of kWh to kVAh consumed during the specified period.

3.4.57 *Prospective Fault Current (Ipf)* — The value of fault current at a given point in a circuit resulting from a fault of negligible impedance between live conductor having a difference of potential under normal operating conditions, or between a live conductor and an exposed conductive part.

3.4.58 *Prospective Touch Voltage* — Voltage between simultaneously accessible conductive parts when those conductive parts are not being touched by a person or an animal.

3.4.59 *Protective Conductor Current* — Electric current appearing in a protective conductor, such as leakage current or electric current resulting from an insulation fault.

3.4.60 *Rated Current* — Value of current in accordance with which the relevant performance of a transformer operated meter is fixed.

3.4.61 *Rated Impulse Withstand Voltage Level (Uw)* — Impulse withstand voltage: highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified conditions

3.4.62 *Residual Current* — Algebraic sum of the values of the electric currents in all live conductors, at the same time at a given point of an electric circuit in an electrical installation.

3.4.63 *Residual Operating Current* — Value of residual current which causes the residual current device to operate under specified conditions

3.4.64 *Room Height* — The vertical distance measured from the finished floor surface to the finished ceiling surface. The underside of the joints or beams or tie beams shall determine the upper point of measurement for determining the head room.

3.4.65 *Service Line, Service* — A line for connecting a current consuming installation to the distribution network.

3.4.66 *Shock Current* — A current passing through the body of a person or an animal and having characteristics likely to cause dangerous patho-physiological effects.

3.4.67 *Short-Circuit Current* — An overcurrent resulting from a fault of negligible impedance between live conductors having a difference in potential under normal operating conditions.

3.4.68 *Simultaneously Accessible Parts* — Conductors or conductive parts which can be touched simultaneously by a person or by an animal.

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NOTE — Simultaneously accessible parts may be:

a) live parts;
b) exposed-conductive-parts;
c) extraneous-conductive-parts;
d) protective conductors; and
e) soil or conductive floor.

3.4.69 *Skilled Person* — A person who can judge the work assigned and recognize possible hazards on the basis of professional training, knowledge, experience and knowledge of the relevant equipment.

3.4.70 *Supply Terminals* — The point at which a consumer receives energy.

3.4.71 *Surge Current* — A transient wave appearing as an overcurrent caused by a lightning electromagnetic impulse.

3.4.72 *Tariff* — A statement setting out the components to be taken into account and the methods to be employed in calculating the amounts to be paid to the supply undertaking by the consumer, according to the characteristics of the supply.

3.4.73 *Temporary Overvoltage (U_{TOV})* — Power frequency overvoltage of relatively long duration.

NOTES

1 A temporary overvoltage is undamped or weakly damped. In some cases its frequency may be several times smaller or greater than power frequency.

2 TOVs may be caused by faults in the LV system or in the HV system.

3 Temporary overvoltages, typically, lasting up to several seconds, usually originate from switching operations or faults (*for example*, sudden load rejection, single-phase faults, etc.) and/or from non-linearity (ferro resonance effects, harmonics, etc).

3.4.74 *Touch Voltage* — Voltage between conductive parts when touched simultaneously by a person or an animal.

NOTE — The value of the effective touch voltage may be appreciably influenced by the impedance of the person or the animal in electric contact with these conductive parts.

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ANNEX A

(*Clause* 2)

LIST OF STANDARDS ON ELECTROTECHNICAL VOCABULARY

IS No./International Standard	*Title*
732 : 2019	Code of practice for electrical wiring installations
1885 (Part 1) : 1961	Electrotechnical vocabulary — Part 1 Fundamental definitions
1885 (Part 9) : 1992/ IEC 60050-446 : 1983	Electrotechnical vocabulary — Part 9 Electrical relays *(second revision)*
1885 (Part 10) : 2008/ IEC 60050 (448) : 1995	Electrotechnical vocabulary — Part 10 Power system protection (*second revision*)
1885 (Part 11) : 1966	Electrotechnical vocabulary — Part 11 Electrical measurements
1885 (Part 14) : 1967	Electrotechnical vocabulary — Part 14 nuclear power plants
1885 (Part 15) : 2008/ IEC 60050-482 : 2004	Electrotechnical vocabulary — Part 15 Primary and secondary cells and batteries (*second revision*)
1885 (Part 16/Sec 1) : 1968/ IEC 60050-45 : 1958	Electotechnical vocabulary — Part 16 Lighting — Section 1 General aspects
1885 (Part 16/Sec 2) : 1968/ IEC 60050-45 : 1958	Electrotechnical vocabulary — Part 16 Lighting — Section 2 General illumination, lighting fittings and lighting for traffic and signalling
1885 (Part 16/Sec 3) : 1967/ IEC 60050-54	Electrotechnical vocabulary — Part 16 Lighting — Section 3 Lamps and auxiliary apparatus
1885 (Part 17) : 1979/ IEC 60050-441 : 1974	Electrotechnical vocabulary — Part 17 Switchgear and control gear (*first revision*)
1885 (Part 27) : 2008/ IEC 60050-551 : 1998	Electrotechnical vocabulary — Part 27 Power electronics (*third revision)*
1885 (Part 28) : 1993/ IEC 60050-321 : 1986	Electrotechnical vocabulary — Part 28 Instrument transformers (*first revision*)
1885 (Part 29) : 1971	Electrotechnical vocabulary — Part 29 Mining terms
1885 (Part 30) : 1971	Electrotechnical vocabulary — Part 30 Overhead transmission and distribution of electrical energy
1885 (Part 32) : 2019/ IEC 60050-461 : 2008	Electrotechnical vocabulary — Part 32 Electric cables (*second revision)*
1885 (Part 34) : 1972	Electrotechnical vocabulary — Part 34 Cinematography
1885 (Part 35) : 2021/ IEC 60050-411 : 1996	Electrotechnical vocabulary — Part 35 Rotating machinery (*second revision*)
1885 (Part 37) : 1993/ IEC 60050-691 : 1973	Electrotechnical vocabulary — Part 37 Tariffs for electricity (*first revision)*
1885 (Part 38) : 1993/ IEC 60050-421 : 1990	Electrotechnical vocabulary — Part 38 Power transformers and reactors (*second revision*)
1885 (Part 43) : 1977	Electrotechnical vocabulary — Part 43 Electrical equipment used in medical practice
1885 (Part 51) : 2012/ IEC 60050-841 : 2004	Electrotechnical vocabulary — Part 51 Industrial electroheat (*second revision*)
1885 (Part 53) : 1980	Electrotechnical vocabulary — Part 53 Mica
1885 (Part 54) : 2021/ IEC 60050-471 : 2015	Electrotechnical vocabulary — Part 54 Insulators

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IS No./International Standard	*Title*
1885 (Part 55) : 1981	Electrotechnical vocabulary — Part 55 Electric fans
1885 (Part 57) : 2008/ IEC 60050-131 : 2002	Electrotechnical vocabulary — Part 57 Circuit theory (*second revision)*
1885 (Part 60) : 1993/ IEC 60050-426 : 1990	Electrotechnical vocabulary — Part 60 Electrical apparatus for explosive atmospheres (*first revision*)
1885 (Part 61) : 1985	Electrotechnical vocabulary — Part 61 Nuclear medical instruments
1885 (Part 62) : 2021/ IEC 60050-212 : 2010	Electrotechnical vocabulary — Part 62 Electrical insulating solids liquids and gases *(second revision*)
1885 (Part 69) : 1993/ IEC 60050-602 : 1993	Electrotechnical vocabulary — Part 69 Generation, transmission and distribution of electricity — Generation
1885 (Part 70) : 1993/ IEC 60050-604 : 1987	Electrotechnical vocabulary: Part 70 Generation, transmission and distribution of electricity — Operation
1885 (Part 71) : 1993/ IEC 60050-605 : 1983	Electrotechnical vocabulary — Part 71 Generation, transmission and distribution of electricity — Substations
1885 (Part 72) : 2008/ IEC 60050-101 : 1998	Electrotechnical vocabulary — Part 72 Mathematics (*first revision)*
1885 (Part 73) : 2012/ IEC 60050-111 : 1996	Electrotechnical vocabulary — Part 73 Physics and chemistry (*first revision)*
1885 (Part 74) : 2012/ IEC 60050-151 : 2001	Electrotechnical vocabulary — Part 74 Electrical and magnetic devices (*first revision*)
1885 (Part 75) : 2012/ IEC 60050-351 : 2006	Electrotechnical vocabulary — Part 75 Control technology (*first revision)*
1885 (Part 77) : 1993/ IEC 60050-466 : 1990	Electrotechnical vocabulary — Part 77 Overhead lines
1885 (Part 78) : 1993/ IEC 60050-601 : 1985	Electrotechnical vocabulary — Part 78 Generation, transmission and distribution of electricity — General
1885 (Part 79) : 1993/ IEC 60050-603 : 1986	Electrotechnical vocabulary — Part 79 Generation, transmission and distribution of electricity — Power system planning and management
1885 (Part 80) : 1994/ IEC 60050-301 : 1983	Electrotechnical vocabulary — Part 80 General terms on measurements in electricity
1885 (Part 81) : 1993/ IEC 60050-302 : 1983	Electrotechnical vocabulary — Part 81 Electrical measuring instruments
12360 : 1988	Voltage bands for electrical installations including preferred voltages and frequency
17036 : 2018	Distribution system supply voltage quality
IEC 60050	International electrotechnical vocabulary

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SECTION 3 GRAPHICAL SYMBOLS FOR DIAGRAMS, LETTER SYMBOLS AND SIGNS

FOREWORD

Several graphical symbols are used for installation diagrams. Considerable amount of standardization has been achieved in the field of symbols for electrotechnology. It is now possible to devise electrical network schematics using them so that these schematic diagrams could be uniformly understood by all concerned.

Assistance has also been derived from IS 12032 (all parts).

1 SCOPE

This section of the code (Part 1/Sec 3) covers graphical symbols for diagrams, letter symbols and signs.

2 REFERENCES

The standards listed in Annex A contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 GRAPHICAL SYMBOLS

For the purposes of the Code, the graphical symbols given below shall apply.

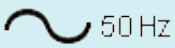
3.1 Fundamental Symbols

3.1.1 *Direct Current*

3.1.2 *Alternating Current, General Symbol*



a) *Alternating current, single-phase*, 50 Hz



b) *Alternating current, three-phase at* 415 V, 50 Hz



c) *Alternating current, three-phase with neutral at* 50 Hz



3.1.3 *Neutral*



3.1.4 *Positive Polarity*



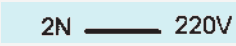
3.1.5 *Negative Polarity*

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3.1.6 *Direct Current, two Conductors at 110 V*



3.1.7 *Direct Current, three Conductors including Negative at 220 V*



3.1.8 *Underground Cable*



3.1.9 *Overhead Line*



3.1.10 *Winding, Delta*



3.1.11 *Winding, Star*



3.1.12 *Terminals*



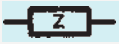
3.1.13 *Resistance/Resistor*



3.1.13.1 *Variable resistor*



3.1.14 *Impedance*



3.1.15 *Inductance/Inductor*



3.1.16 *Winding*



3.1.17 *Capacitance, Capacitor*



3.1.18 *Earth*



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3.1.19 *Fault*



3.2 Equipment

3.2.1 *Flexible Conductor*



3.2.2 *Generator*



3.2.2.1 *AC generator*



3.2.2.2 *DC generator*



3.2.3 *Motor*



3.2.4 *Synchronous Motor*

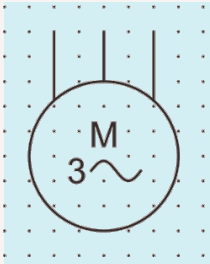


3.2.5 *Mechanically Coupled Machines*



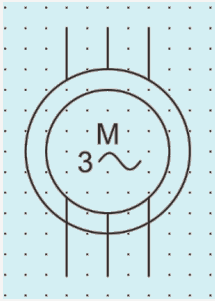
3.2.6 *Induction Motor*

3.2.6.1 *Induction Motor, Three-Phase, Squirrel Cage*

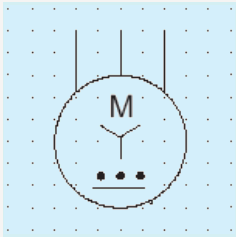


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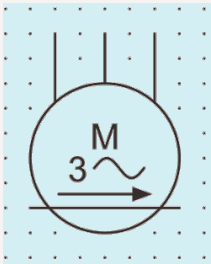
3.2.6.2 *Induction Motor with Wound Rotor, three Phase*



3.2.6.3 *Induction Motor, Three-Phase, Star-Connected*



3.2.6.4 *Linear Induction Motor, Three-Phase*



3.2.7 *Transformers with two Separate Windings*

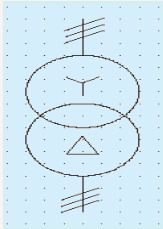


3.2.8 *Auto-Transformer*



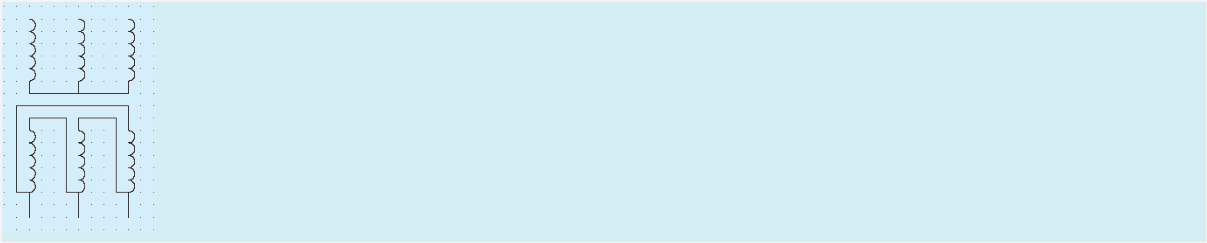
3.2.9 *Three-Phase Transformer*

3.2.9.1 *Three-Phase Transformer, Connection Star-Delta/Form 1*

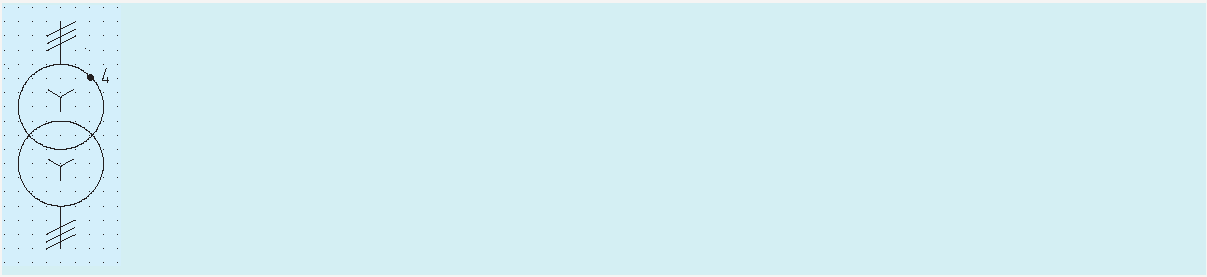


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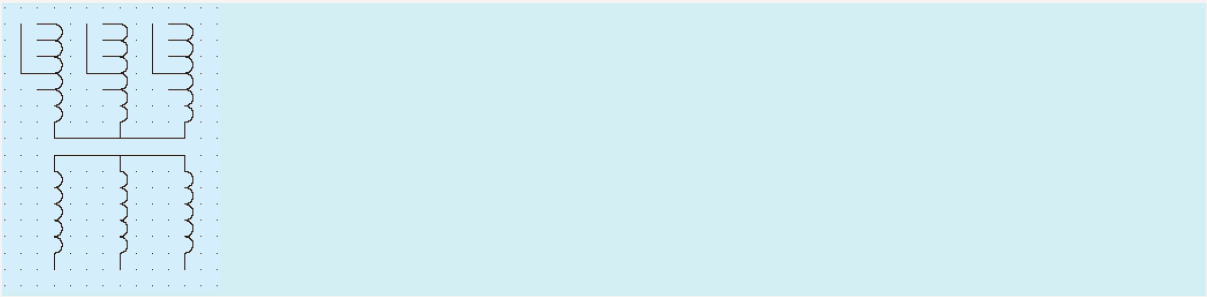
3.2.9.2 *Three-Phase Transformer, Connection Star-Delta/Form 2*



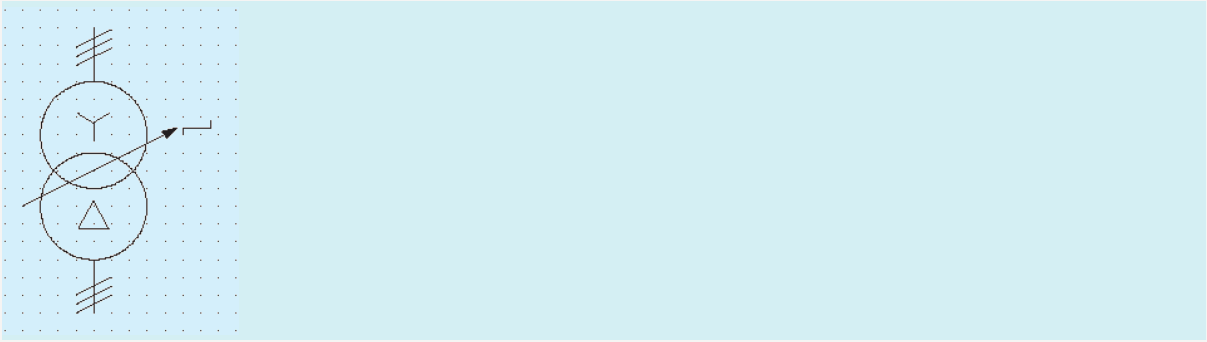
3.2.9.3 *Three-Phase Transformer with Four Taps, Connection: Star-Star/Form 1*



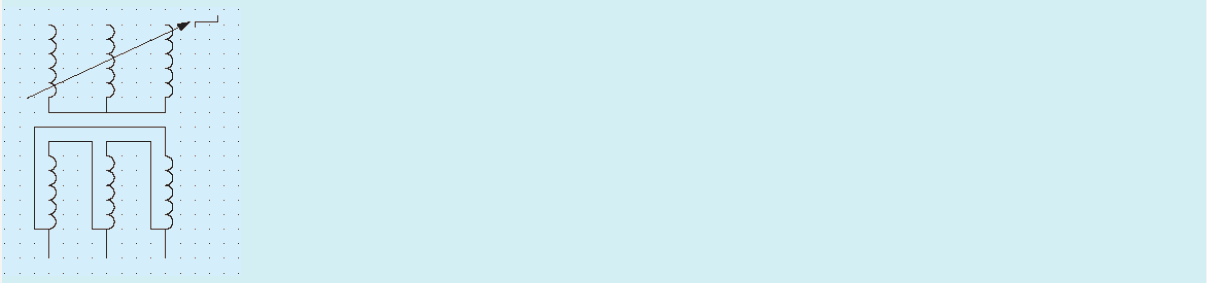
3.2.9.4 *Three-Phase Transformer with Four Taps, Connection: Star-Star/Form 2*



3.2.9.5 *Three-Phase Transformer with Tap Changer/Form 1*

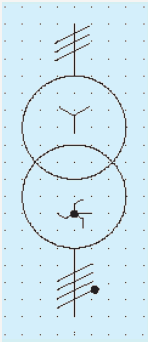


3.2.9.6 *Three-Phase Transformer with Tap Changer/Form 2*

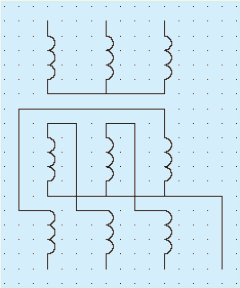


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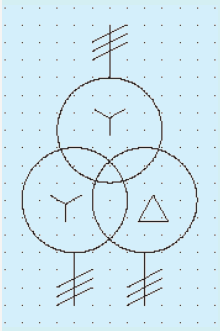
3.2.9.7 *Three-Phase Transformer, Connection Star – Zigzag with the Neutral brought out/Form 1*



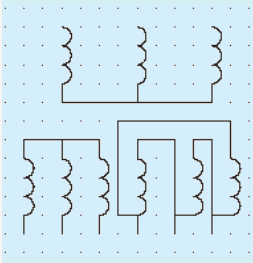
3.2.9.8 *Three-Phase Transformer, Connection Star – Zigzag with the Neutral brought out/Form 2*



3.2.9.9 *Three-Phase Transformer, Connection Star – Star-Delta/Form 1*



3.2.9.10 *Three-Phase Transformer, Connection Star – Star-Delta/Form 2*



3.2.10 *Starter*



3.2.11 *Direct-on-Line Starter for Reversing Motor*



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3.2.12 *Star-delta Starter*



3.2.13 *Auto-transformer Starter*



3.2.14 *Rheostatic Starter*



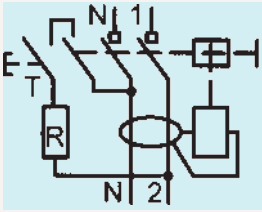
3.2.15 *Switch*



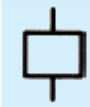
3.2.16 *Contactor*



3.2.17 *Relay*



3.2.18 *Circuit-breaker*



3.2.19 *Isolator*

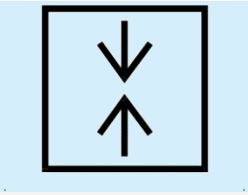


3.2.20 *Residual Current Circuit Breaker*



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3.2.21 *Overvoltage Protection Device*



3.2.22 *Fuse*



3.2.23 *Signal Lamp*



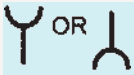
3.2.24 *Link*



3.2.25 *Distribution Board, Cubicle Box, Main Fuse Board with Switches*



3.2.26 *Socket Outlet, 6A*



3.2.27 *Socket Outlet, 16A*



3.2.28 *Plug*



3.2.29 *Voltmeter*



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3.2.30 *Ammeter*



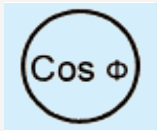
3.2.31 *Wattmeter*



3.2.32 *Varmeter*



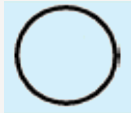
3.2.33 *Power Factor Meter*



3.2.34 *Ohmmeter*



3.2.35 *Indicating Instrument* (*General Symbol*)



3.2.36 *Recording Instrument* (*General Symbol*)



3.2.37 *Integrating Meter*



3.2.38 *Watthour Meter*



3.2.39 *Clock*



3.2.40 *Master Clock*



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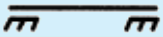
3.2.41 *Current Transformer*



3.2.42 *Voltage Transformer*



3.2.43 *Wiring on the Surface*



3.2.44 *Wiring in Conduit*



3.2.45 *Lamp*



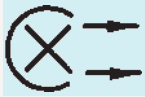
3.2.46 *Lamp Mounted on a Ceiling*



3.2.47 *Emergency Lamp*



3.2.48 *Spot Light*



3.2.49 *Flood Light*



3.2.50 *Heater*



3.2.51 *Storage Type Water Heaters*



3.2.52 *Bell*



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3.2.53 *Buzzer*



3.2.55 *Ceiling Fan*



3.2.55 *Exhaust Fan*



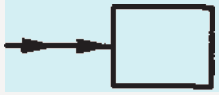
3.2.56 *Fan Regulator*



3.2.57 *Aerial*



3.2.58 *Radio Receiving Set*



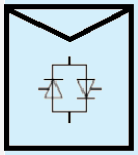
3.2.59 *Television Receiving Set*



3.2.60 *Manually Operated Fire Alarm*



3.2.61 *Soft Starter*



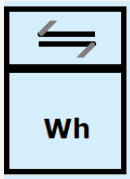
3.3 Solar PV and EV charging

3.3.1 *Grid tie Inverter*

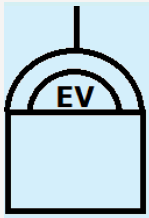


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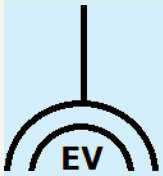
3.3.2 *Bidirectional Meter*



3.3.3 *Electric Charging Station*



3.3.4 *Electric Charging Point*



3.2.5 *Automatic Fire Detector Switch*



4 LETTER, SYMBOLS AND SIGNS

4.0 General

4.0.1 Quantities and units in electrotechnology, in addition to electricity and magnetism, covers other subjects, such as radiation and light, geometry, kinematics, dynamics and thermodynamics. Several disciplines interact with each other such that terminology used in one discipline becomes closely interrelated with that of the other. In order to enable uniform understanding and representation, the letter symbols and signs used in abbreviations for denoting quantities, their functions and units shall conform to those recommended in IS 3722 (Part 1) and IS 3722 (Part 2).

4.0.2 Guidance on the choice of alphabet and their type, representation of vector quantities, symbols of units, numerical values, and guidance on the use of subscripts are covered in IS 3722 (Part 1).

4.0.3 Table 1 of IS 3722 (Part 2) gives a reference list of symbols and subscripts used in electrotechnology.

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ANNEX A

(*Clause* 2)

LIST OF STANDARDS ON GRAPHICAL SYMBOLS

IS/Other Publications	*Title*
2032 (Part 19) : 1977	Graphical symbols used in electrotechnology: Part 19 Electrical equipment used in medical practice
3722 (Part 1) : 1983	Letter symbols and signs used in electrical technology: Part 1 General guidance on symbols and subscripts (*first revision*)
3722 (Part 2) : 1983	Letter symbols and signs used in electrical technology: Part 2 Reference tables for symbols and subscripts (*first revision*)
10381 : 1982	Terms (and their hindi equivalents) commonly used for name — Plates and similar data of electrical power equipment
11353 : 1985	Guide for uniform system of marking and identification of conductors and apparatus terminals
12032 (Part 1) : 1987/ IEC 60617-1 (1985)	Graphical symbols for diagrams in the field of electrotechnology: Part 1 General information
12032 (Part 2) : 1987/ IEC 60617-2 (1983)	Graphical symbols for diagrams in the field of electrotechnology: Part 2 Symbol elements, qualifying symbols and other symbols having general application
12032 (Part 3):1987/ IEC 60617-3 : 1983	Graphical symbols for diagrams in the field of electrotechnology: Part 3 conductors and connecting devices
12032 (Part 4) : 1987/ IEC 60617-4 (1984)	Graphical symbols for diagrams in the field of electrotechnology: Part 4 Passive components
12032 (Part 6) : 1987/ IEC 60617-6 (1983)	Graphical symbols for diagrams in the field of electrotechnology: Part 6 Production and conversion of electrical energy
12032 (Part 7) : 1987/ IEC 60617-7 (1983)	Graphical symbols for diagrams in the field of electrotechnology: Part 7 Switchgear, controlgear and protective devices
12032 (Part 8) : 1987/ IEC 60617-8 (1983)	Graphical symbols for diagrams in the field of electrotechnology: Part 8 Measuring instruments, lamps and signalling devices
12032 (Part 11) : 1987/ IEC 60617-11 (1983)	Graphical symbols for diagrams in the field of electrotechnology: Part 11 Architectural and topographical installation plan and diagrams

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SECTION 4 GUIDE FOR PREPARATION OF DIAGRAMS, CHARTS, TABLES AND MARKING

FOREWORD

Various types of diagrams and charts are required to be prepared during the planning and execution stages of an electrical installation work. It is therefore necessary to define the different types of diagrams, charts and tables, their purposes and format and the guiding principles for preparing them for maintaning uniformity.

This section of the Code covers general guidelines on the preparation of diagrams, charts, tables and marking.

The guidelines for marking of conductors is given in **3.6**. It provides a common basis for understanding and identifying conductors and apparatus terminals, but more importantly, ensure safety to operating and maintenance personnel.

1 SCOPE

This section of the code (Part 1/Sec 4) covers guidelines for preparation of diagrams, charts and tables in electrotechnology and for marking of conductors.

2 REFERENCES

The standards listed in Annex A contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 PREPARATION OF DIAGRAMS, CHARTS AND TABLES

3.0 General

3.0.1 *Diagram*

A diagram may show the manner in which the various parts of a network, installation, group of apparatus or items of an apparatus are interrelated and or interconnected.

3.0.2 *Chart*

A chart may show the interrelation between:

a) different operations,
b) operations and time,
c) operations and physical quantities, and
d) states of several items.

3.0.3 *Table*

A table replaces or supplements a diagram or a chart.

3.1 Classification according to Purpose

The main classifications are:

a) Explanatory diagrams,
b) Explanatory charts or tables,
c) Wiring diagrams or wiring tables, and
d) Location diagrams or tables.

3.1.1 *Explanatory Diagrams*

Explanatory diagrams are intended to facilitate the study and understanding of the functioning of an installation or equipment. Three types are defined as under:

a) *Block Diagram*

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Relatively simple diagram to facilitate the understanding of the principle of operation. It is a diagram in which an installation or equipment together with its functional interrelationships are represented by symbols, block symbols or pictures without necessarily showing all the connections.

b) *Circuit Diagram*

Explanatory diagram intended to facilitate the understanding of the functioning in detail. It shows by symbols an installation or part of an installation and the electrical connections and other links concerned with its operation.

c) *Equivalent Circuit Diagram*

Special type of circuit diagram for the analysis and calculation of circuit characteristics.

3.1.2 *Explanatory Charts or Tables*

Explanatory charts or tables are intended to facilitate the study of diagrams and to give additional information. Examples are given as under:

a) *Sequence Chart or Table*

Gives the successive operation in a specified order.

b) *Time Sequence Chart or Table*

Is one which in addition takes account of the time intervals between successive operations.

3.1.3 *Wiring Diagrams or Wiring Tables*

Wiring diagrams are intended to guide the making and checking of the connection of an installation or equipment. For an equipment, they show the internal or external connections or both. The diagrams may sometimes show the layout of the different parts and accessories, such as terminal blocks and the wiring between them.

3.1.3.1 *Unit wiring diagram*

Diagram represents all connections within a unit of an installation.

3.1.3.2 *Interconnection diagram*

Diagram represens the connections between the different units of an installation.

3.1.3.3 *Terminal diagram*

Diagram showing the terminals and the internal and/or external conductors connected to them.

NOTE — Any of the wiring diagram may be replaced or supplemented by a table.

3.1.4 *Location Diagrams or Tables*

A location diagram or table contains detailed information about the location of parts of the equipment (for example, terminal blocks, plug-in units, sub-assemblies, modules, etc.). It shows the item designations used in related diagrams and tables.

NOTES

1 A location diagram need not necessarilym be to the scale.

2 Several types of diagrams may be combined into a single diagram, forming a mixed diagram. The same drawing may form both an explanatory and wiring diagram.

3.2 Classification according to Method of Representation

3.2.1 The method of representation is distinguished by the:

a) number of conductors, devices or elements represented by a single symbol (*see* **3.2.1.1**);

b) arrangement of the symbols representing the elements or parts of an item of apparatus (*for example*, detached or assembled) (*see* **3.2.1.2**); and

c) placing of the symbols to correspond with the topographical layout of the devices (*see* **3.2.1.3**).

3.2.1.1 *Number of conductors*

According to the number of conductors, devices or elements represented by a single symbol, the two methods of representation as given below may be distinguished.

a) *Single-line Representation*

Two or more conductors are represented by a single line.

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In particular, a single line may represent:

1) circuits of a multi-phase system;
2) circuits which have a similar electrical function;
3) circuits or conductors which belong to the same signal path;
4) circuits which follow the same physical route; and
5) conductor symbols which would follow the same route on the diagram.

Several similar items of apparatus may accordingly, be represented by a single symbol.

b) *Multi-line Representation*

Each conductor is represented by an individual line.

3.2.1.2 *Arrangement of symbols*

According to the arrangement of the symbols representing the elements or parts of an item of apparatus on the diagram, the methods of representation are given below:

a) *Assembled Representation*

The symbols for the different parts of an item of apparatus or of an installation or equipment are drawn in close proximity on the diagram.

b) *Semi-assembled Representation*

The symbols for the different parts of an item of apparatus or of an installation are separated and arranged in such a way that the symbols for mechanical linkages between the parts which work together may be drawn easily.

c) *Detached Representation*

The symbols for the different parts of an item of apparatus or of an installation are separated and arranged in such a way that the circuits may easily be followed.

3.2.1.3 *Topographical representation*

The positions of the symbols on the diagram correspond wholly or partly to the topographical (physical) location of items represented.

The following are examples where topographical representation may be used.

a) Wiring diagrams;
b) Architectural diagrams; and
c) Network diagrams.

NOTE — Several of these methods of representation may be used on the same diagram.

3.3 Item Designation

3.3.1 Item is a term used for component equipment, plant, unit, etc, which is represented by a graphical symbol on a diagram. The item designation is shown at an appropriate place near the graphical symbol of the item. This designation correlates the item on different diagrams, parts list, circuit descriptions and components in the equipment.

3.3.2 An item designation may be used for general or special purposes depending on the kind of information required. Guidelines on assignment of item designation, groups together with standard letter codes for the same are covered in IS 8270 (Part 2), IEC 81346-1 and IEC 81346-2.

3.4 General Rules for Diagrams

3.4.1 Paper sizes for drawings shall preferably be according to the international A-series (*see* IS 1064). The choice of drawing sizes should be decided after taking into account the necessary factors enumerated in 2.2 of IS 8270 (Part 2).

3.4.2 In IS 2032 series of standards and IS 12032 series of standards, different kinds of symbols as well as symbols of different forms are specified to the extent possible. Any symbol may be composed using the guidance from IS 2032 and Part 1/Sec 3 of the Code, IEC 60417 and ISO 7000. The basic rules for the choice of symbols shall be:

a) to use the simplest form of symbol adequate for the particular purpose;

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b) to use a preferred form wherever possible; and

c) to use the chosen form consistently throughout the same set of documentation.

3.4.3 Specific guidelines on the application of IS 2032 series of standards, IS 12032 series of standards, IEC 60417 and ISO 7000 with the objective of selection of choice of alternative symbols, symbol sizes, line thickness, orientation of symbols and methods of indicating symbol location are covered in IS 8270 (Part 3).

3.5 Interconnection Diagrams and Tables

3.5.1 Interconnection diagrams and tables provide information on the external electrical connections between equipment in an installation. They are used as an aid in the fabrication of wiring and for maintenance purposes. Information on the internal connections of units are normally not provided but references to the appropriate circuit diagram [*see* IS 8270 (Part 4)] may be provided.

3.5.2 The diagrams may employ single or multiple representation and may be combined with or replaced by tables, provided clarity is maintained. Tables are recommended when the number of interconnections is large.

3.5.3 Guidance on layout, identification and types of interconnection diagrams and tables are given in IS 8270 (Part 5).

3.6 Marking and Arrangement of Conductors

3.6.0 *General*

3.6.0.1 The purpose of marking is to provide a means whereby conductors can be identified in a circuit and also, after they have been detached from the terminals to which they are connected. Main marking is a system of marking characterizing each conductor or group of conductors irrespective of their electrical function. Supplementary marking is used as supplement to a main marking based on the electrical function of each conductor or group of conductors.

3.6.0.2 The various methods of marking applicable to electrical installations and the equipment which form part of them are covered in IS 5578.

3.6.1 *Identification of Insulated and Bare Conductors*

For the purposes of this Code, the provisions of Table 1 of IS 11353 shall apply for the general application of marking conductors in installation. The rules also apply for marking conductors in assembles, equipment and apparatus. Reference is also drawn to the provision contained in relevant Indian Standard.

3.6.2 *Arrangement of Conductors*

Bus-bars and main connections which are substantially in one plane shall be arranged in the order given in **3.6.2.1** or **3.6.2.2** according to the system. The relative order remains applicable even if any poles of the system are omitted.

3.6.2.1 *a.c. systems*

The order of phase connection shall be red, yellow and blue:

a) When the run of the conductors is horizontal, the red shall be on the top or farthest away as viewed from the front.

b) When the run of the conductors is vertical, the red shall be on the left or farthest away as viewed from the front.

c) When the system has a neutral connection in the same place as the phase connections, the neutral shall occupy an outer position.

d) Unless the neutral connection can be readily distinguished from the phase connections, the order shall be red, yellow, blue and black.

3.6.2.2 *d.c. systems*

The order of arrangement shall be positive, mid-point (if available) and negative:

a) When the run of the conductors is horizontal, the positive shall be on the top or farthest away as viewed from the front.

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b) When the run of the conductors is vertical, the positive shall be on the left or farthest away as viewed from the front.

c) When the system is three-wire system with the conductors in the same place, the neutral (mid-wire) shall occupy the middle position.

ANNEX A

(*Clause* 2)

LIST OF REFERRED STANDARDS

IS/Other Publications	*Title*
1064 : 1980	Specification for paper (*second revision*)
2032 (Part 15) : 1976	Graphical symbols used in electrotechnology — Part 15 Aircraft electrical symbols
2032 (Part 19) : 1977	Graphical symbols used in electrotechnology — Part 19 Electrical equipment used in medical practice
2032 (Part 25) : 1980	Graphical symbols used in electrotechnology — Part 25 Electrical installations in ships
5578 : 1984	Guide for marking of insulated conductors (*first revision*)
8270 (Part 1) : 1976	Guide for preparation of diagrams, charts and tables for electrotechnology — Part 1 Definitions and classification
8270 (Part 2) : 1976	Guide — For preparation of diagrams, charts and tables for electrotechnology — Part 2 Item designation
8270 (Part 3) : 1977	Guide for preparation of diagrams, charts and tables for electrotechnology — Part 3 General requirements for diagrams
8270 (Part 4) : 1977	Guide for preparation of diagrams, charts and tables for electrotechnology — Part 4 Circuit diagrams
8270 (Part 5) : 1976	Guide for preparation of diagrams, charts and tables for electrotechnology — Part 5 Interconnection diagrams and tables
8270 (Part 6) : 1983	Guide for preparation of diagrams, charts and tables for electrotechnology — Part 6 Unit wiring diagrams and tables
11353 : 1985	Guide for uniform system of marking and identification of conductors and apparatus terminals
IEC 60417 DB	Graphical symbols for use on equipment
IEC 81346-1 : 2009	Industrial systems, installations and equipment and industrial products — Structuring principles and reference designations — Part 1 Basic rules
IEC 81346-2 : 2019	Industrial systems, installations and equipment and industrial products — Structuring principles and reference designations — Part 2 Classification of objects and codes for classes

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SECTION 5 UNITS AND SYSTEMS OF MEASUREMENT

FOREWORD

The International System of Units (SI) have received worldwide acceptance and is accepted in most of the countries. It had been introduced in India under the *Weights and Measures Act*, 1976. Use of SI Units in matters relating to electrical engineering practice has many advantages.

This Section of the Code is restricted to electrical units only.

1 SCOPE

This Section of the Code (Part 1/Sec 5) covers units and systems of measurement in electrotechnology.

2 REFERENCE

The standards contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the edition indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/Other Publications	*Title*
IS/ISO 80000-2 : 2009	Quantities and units — Mathematical signs and symbols to be used in the natural sciences and technology

3 UNITS AND SYSTEMS OF MEASUREMENT

3.1 Absolute Units

3.1.1 *Ampere (Unit of Electric Current)*

SI unit of electric current, equal to the electric current corresponding to the flow of $(1/1.602\,176\,634) \times 10^{19}$ *elementry electric charges per second.*

3.1.2 *Coulomb (Unit of Quantity of Electricity)*

The quantity of electricity conveyed in one second by a current of one ampere.

3.1.3 *Farad (Unit of Electric Capacitance)*

The capacitance of an electric capacitor having a difference of electric potential of one volt between the plates, when it is charged with a quantity of electricity of one coulomb.

3.1.4 *Henry (Unit of Electric Inductance)*

The inductance of a closed circuit in which an emf of one volt is produced when the current in the circuits varies at the uniform rate of one ampere per second.

3.1.5 *Ohm (Unit of Electrical Resistance)*

The electrical resistance between two points of a conductor when a constant potential difference of one volt, applied to these points, produces a current of one ampere in the conductor, provided no emf is generated in the conductor.

3.1.6 *Volt (Unit of Electric Potential Difference)*

The difference of electric potential which exists between two points of a conductor carrying a constant current of one ampere, when the power dissipated between these points is one watt.

3.1.7 *Weber (Unit of Magnetic Flux)*

The magnetic flux which, linked with a circuit composed of a single turn produces in it an emf of one volt if it is uniformly reduced to zero in one second.

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3.1.8 *Watt (Unit of Electric Power)*

The power which results in the production of energy at the rate of 1 J/s.

3.1.9 *Siemens (Unit of Electric Conductance)*

The conductance of a conductor of resistance 1 ohm and is numerically equal to 1 ohm^{-1}.

3.1.10 *Tesla*

The tesla is a magnetic flux density of 1 Wb/m^2.

3.2 The electrical units defined in **3.1**, together with their expression in terms of other units, recommendations on the selection of their multiples and submultiples and supplementary remarks (if any) are enumerated in Table 1.

Table 1 Electrical Units of Measurement

(*Clause* 3.2)

Sl No.	Quantity	Name	Symbol	Expression in Terms of Other Units	Expression in Terms of SI Base Units	Selection of Multiples
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Electric current	ampere	A	–	—	kA, mA, µ*A,* nA, pA
ii)	Power	watt	W	J/s	$m^2.kgs^{-3}$	GW, MW, kW, mW, µ W
iii)	Quantity of electricity, electric charge	coulomb	C	–	s.A	kC, µC, nC, pC
iv)	Electric potential, potential difference, electromotive force	volt	V	W/A	$m^2.kgs^{-3}.A^{-1}$	MV, kV, mV, µ V
v)	Capacitance	farad	F	C/V	$m^2.kg.s^{-1}.A^{-1}$	mF, µF, nF, pF
vi)	Electrical resistance	ohm	Ω	V/A	$m^2.kg.s^{-1}.A^{-2}$	G Ω, M Ω. K Ω, m Ω, ... µ Ω
vii)	Conductance	siemens	S	A/V	$m^{-2}.kg^{-1}.s^{-1}$	kS, mS, µS
viii)	Magnetic flux	weber	Wb	V.s	$m^2.kg.s^{-2}.A^{-1}$	mWb
ix)	magnetic flux density	tesla	T	Wb/m^2	$kg.s^{-1}.A^{-1}$	mT, µT. nT
x)	Inductance	henry	H	Wb/A	$m^2.kg.s^{-2}.A^{-2}$	mH, µH, nH, *p*H
xi)	Conductivity	siemens/ metre	S/m	–	$m^1.kg^{-1}.S^1, A^1$	MS/m, kS/m
xii)	Electric field strength	volt/metre	V/m	–	$m.kg.s^{-1}.A^{-1}$	MV/m, kV/m or V/mm, V/m, mV/m, µV/m
xiii)	Permeability	henry/metre	H/m	–	$m.kg.s^{-2}.A^{-2}$	µH/m, nH/m
xiv)	Permittivity	farad per metre	F/m	–	$m^{-1}.kg^{-1}.s^4.A^2$	µF/m, nF/m, pF/m
xv)	Reluctance	1 per henry	H^{-1}	–	$m^{-2}.kg^{-1}.s^2.A^2$	–
xvi)	Resistivity	Ohm metre	Ω.m	–	$m^1.kg.s^{-1}.A^{-2}$	G Ω m, M Ω m, k Ω m, Ω cm, m Ω m, *v* Ω m, n Ω m

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SECTION 6 STANDARD VALUES

FOREWORD

Standardization of basic parameters, such as voltage, currents and frequency is a pre-requisite to laying a sound foundation for further work relating to product or installation engineering. The values of basic parameters recommended in this section are based on IS 12360.

Reference to CEA (Safety) Regulations, 2010 may also be made.

1 SCOPE

This section of the Code (Part 1/Sec 6) covers standard values of a.c. and d.c. distribution voltages, preferred values of current ratings and standard system frequency.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No	*Title*
1076 (Part 1) : 1985/ ISO 3 : 1973	Preferred numbers: Part 1 Series of preferred numbers
12360 : 1988	Voltage bands for electrical installations including preferred voltages and frequency
16711 : 2017	48 V ELVDC Distribution System — Guidelines

3 STANDARD VALUES OF VOLTAGES

3.0 General

3.0.1 Standard values of voltages as mentioned in IS 12360 relating to a.c. transmission and distribution systems are reproduced in this section. However, it may be noted that for types of installations covered in subsequent parts of the Code, lower voltage values would be more relevant.

3.0.2 For medium and low voltage of distribution system, nominal voltages were 230 V for single-phase and 230/400 V for three-phase system were the recommended standard values. Later on, to align with IEC recommendations and in view of the economic advantages, nominal values of 240 V for single-phase and 240/415 V for three-phase were adopted with a tolerance of ± 6 percent. IS 12360 may be referred for the latest values.

3.0.3 In the case of voltages above 1 kV, product standards relate the voltage rating of equipment with respect to highest system voltages (generally, 10% above the nominal voltage).

3.1 Standard Declared Voltage

3.1.1 *Single-phase, Two-wire System*

The standard voltage shall be as per IS 12360.

3.1.2 *Three-phase System*

3.1.2.1 The standard voltages for three-phase system shall be as per IS 12360.

3.1.3 As per the international standards, the direct current (d.c.) of 60V is established as the upper limit for a Safety Extra Low Voltage circuit (SELV), that is, safe to touch directly under dry conditions. Considering both safety and distribution losses, 48V is chosen as the distribution voltage for d.c.

3.1.4 For ELVDC and LVDC, IS 16711 may be referred.

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3.2 Voltage Limits for a.c. Systems

3.2.1 The voltage at any point of the system under normal conditions shall not depart from the declared voltage by more than the values given below:

a) 6 percent in the case of low or medium voltage;

NOTE — IS 12360 may be referred for the latest provisions.

b) 6 percent on the higher side or 9 percent on the lower side in the case of high voltage; or

c) 12.5 percent in the case of extra high voltage.

NOTE — The permissible variations given above are in accordance with CEA (Safety) Regulations, 2010, and are applicable to the supply authorities.

3.2.2 For installation design purposes, the limits of voltage between which the system and the equipment used in the system shall be capable of operating continuously are as follows:

System Voltage (*U*n)	*Highest Voltage* (*U*m)	*Lowest Voltage*
(1)	(2)	(3)
240 V	264 V	216 V
415 V	457 V	374 V
3.3 kV	3.6 kV	3.0 kV
6.6 kV	7.2 kV	6.0 kV
11 kV	12 kV	10 kV
22 kV	24 kV	20 kV
33 kV	36 kV	30 kV
66 kV	72.5 kV	60 kV
132 kV	145 kV	120 kV
220 kV	245 kV	200 kV
400 kV	420 kV	380 kV

NOTES

1 This variation in voltage should not be confused with the permissible variation from the declared voltage as given in **3.2.1**.

2 IS 12360 may be referred for the latest provisions

4 PREFERRED CURRENT RATINGS

The preferred current ratings shall be selected from the R5 series. If intermediate values are required, the same shall be selected from R10 series [*see* IS 1076 (Part 1)].

5 STANDARD SYSTEM FREQUENCY

5.1 The standard system frequency shall be 50 Hz.

5.2 The limits within which the frequency shall be maintained are governed by the CEA (Safety) Regulations, 2010.

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SECTION 7 FUNDAMENTAL PRINCIPLES

FOREWORD

The basic criteria in the design of electrical installation are enumerated in this section which shall be adhered to during the planning stages. The specific nature of each occupancy calls for additional information, which are summarized in the respective sections of the Code.

Considerable assistance has been derived from IS 732. It may be noted that subsequent requirements of the Code would, however, provide adequate guidelines in respect of achieving the desired levels of specific planning, work execution, workmanship and safety.

1 SCOPE

This Section of the Code (Part 1/Sec 7) enumerates the fundamental principles of design and execution of electrical installations.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards:

IS/Other Publications	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
SP 7 : 2016	National Building Code of India
SP 72 : 2010	National Lighting Code
CEA Regulations	Central Electricity Authority (measures related to Safety and Electric Supply) Regulations, 2010
	Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010
	Central Electricity Authority (Safety Requirements for Construction, Operation and Maintenance of Electric Plants and Lines) Regulations, 2011

3 FUNDAMENTAL PRINCIPLES

3.1 General

For any electrical installation to be safe, functional, easy to use, augmentable, prone to minimal breakdowns requiring zero or minimum down time and conforming to all Statutory Provisions. Electrical Installation as part of Building Service, design shall be based on fundamental principles as given under this section. Consideration shall also be given to related recommendations under National Building Code.

3.2 Green Building Concept

Under environmental and energy conservation aspects, all related provisions shall be considered under fundamental principles, comprising of natural light, ventilation, thermal insulation, solar systems etc.

3.3 Design

3.3.1 *Planning*

It is an initial important step which helps the work to get completed smoothly and in time with minimum changes and reworking and without conflicts with the work of other utility services.

3.3.2 *Exchange of Information and Coordination*

Proper coordination and collaboration between the user, architect, civil and electrical engineer, suppliers of electricity, water, telephone, cable/internet etc. shall be ensured from the planning stage of the installation. Compiling requirements of such various building services providers, and establishing a common platform amongst the team leaders of various agencies working on these services, is an important part under planning.

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3.3.3 *Electrical Aspects of Building Services*

Depending on type of utility, various electrical aspects involved shall be considered and discussed at planning stage amongst stake holders. *For example*, air-conditioning system may require limited heat transmittance from walls, roof and fenestration; lifts have requirements such as size of lift shaft, pit, overhead, machine room etc. The requirements shall be complied with (for more details, refer Part 1/Sec 15).

3.3.4 *Architectural Plan*

It is necessary to consider following points during preparation of plans with consent of related agencies of building/utility service providers, for smooth and timely completion of work without conflicts between various service providers.

3.3.4.1 *Site plan/layout*

Following points shall be considered during preparation of site plan/layout:

a) In case of any overhead/underground line(s) on the proposed site, it is important to check/obtain mandatory clearances from any proposed structure, as per CEA Regulations and NOCs from the concerned authorities (*see* Annex A).

NOTE — Refer Reg(58), (60), (61), (63) and (65) of CEA (Measures Related to Safety and Electric Supply) Regulations, 2010.

b) Earthing stations/pits to have an access for testing, maintenance/watering and requirement of minimum clearance from other underground system.

c) Ducts/trenches/chambers, as per routes of UG systems with required depth/clearance from other underground utility service.

d) Type of system earthing and location of earth electrodes (for example, Foundation earth, ring earth, type A vertical/horizontal rods etc)

3.3.4.2 *Building plan*

a) *Provision of Spaces/Room*

Requirement of spaces such as length, width and height for system plant, sub-station, generator, panels, control rooms, shafts etc. to accommodate related equipment with mandated clearances shall be considered.

b) *Doors/Openings*

Doors/openings (width and height), of rooms shall be suitable to size of equipment for in/out movement during installation/maintenance.

c) *Location*

Locations of spaces/room shall be suitable to concerned building/utility service provider from the point of view of minimizing system losses, easy access and facility to repair and maintain.

d) *Routes*

Allocating space and providing civil work (*for example,* ducts, shafts, openings, space above false ceiling and below the beam soffit) along the routes of building/utility services shall also be considered at planning stage with required sizes.

e) *Ventilation*

Specific ventilation requirement of any particular equipment shall be taken care of (*for example*, battery rooms and equipment like transformers requiring adequate heat dissipation).

f) *External Influences*

External influences (*for example*, climatic factors such as rains, sunlight, air quality like humidity, corrosive environments, dusty environment etc. affecting safety, service life, continuity and functionality of electrical installation shall also be considered to adopt required preventive measures.

g) *Natural light/sunlight*

This requirement shall be considered from the point of view of energy conservation such as solar panels of water heating system and PV systems require shadowless and are usually placed on terrace.

NOTE — Use of renewable energy is counted under credit points while evaluating Green Building.

h) *Future Expansion*

Building/utility service provider shall envisage future requirement and make the required provisions.

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3.4 Electrical Safety

Electrical safety is prime importance considering hazards related to human life and fire. Part 1/Sec 22 of this code shall be referred for safety in electrical work.

4 ELECTRICAL INSTALLATION DESIGN

4.1 General

Appropriate design is a foundation of safe, trouble free and convenient to use installation throughout service life. It shall be based on following principles:

a) Compliance with statutory norms;
b) Safety as topmost priority;
c) Functionality;
d) Quality and continuity of supply;
e) User friendly; and
f) Anticipation of future requirements.

4.2 Electrical Load

4.2.1 *General Assessment*

Depending on type/use of building and premises assessment of load shall be done considering area in m^2 as a base. This decides the requirement of electrical supply LT or HT, and sub-station if needed and its capacity.

4.2.2 *Connected Load and Contract Demand*

Connected load shall be worked out and assessment of contract demand shall be done. This step is necessary for approaching electrical supply provider.

4.2.3 *Emergency and Critical Load*

Further electrical load of important services like lifts, water pumps, emergency services like fire pumps, fire lift, critical services requiring supply integrity during fire and evacuation shall be worked out.

4.3 Electrical Supply

4.3.1 Design shall comprise the following source(s) of electrical supply as per requirement:

a) Primary power — Electrical supply Company;
b) Back-up supply — Gen-set/battery based;
c) Solar PV system — Grid connected/non grid connected; and
d) Uninterrupted power supply – electronic/mechanical UPS based.

4.3.2 Required capacity in kW/kVA shall be assessed as per **4.2**.

4.3.3 *Conditions of Supply*

Compliance with the requirement of Electricity Supply Code published by the State Regulatory Commission shall be checked for availing supply from distribution licensee.

4.4 Electrical Drawings/Layouts

Detailed electrical drawings are important to plan and schedule execution of work in coordination with other agencies like electrical inspectorate, local bodies etc. Electrical drawings shall include:

a) Location of light, fans, 6A power outlets, generally categorized under lighting load;
b) Location of power outlets for electrical systems/load generally 16A and above;
c) Location of switchboards, distribution boxes, electrical panels;
d) Routes of cabling/busways;
e) Single line diagrams showing switchgears, DBs etc. with their capacities, connected load, cable sizes, protections, etc.;

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f) Layouts of panel rooms, meter rooms, sub-stations, Gen-sets with allied equipment; required clearances; and

g) Layout of embedded conduits, wires, grounding conductors etc.

NOTES

1 Where prior approval to drawings is necessary, the same shall be taken from concerned authority.

2 Where necessary supporting specifications and calculations sheets shall be attached to justify capacity of switchgear/cable etc.

3 Coordination with other the drawings of other utility services shall be checked and agreed mutually.

4.5 Lighting Design

4.5.1 *National Lighting Code*

Lighting design shall be as per recommended lux levels, CCT, Glare Index, and shall be in accordance with National Lighting Code (SP 72).

4.5.2 *Energy Conservation Building Code (ECBC)*

In lighting design guidelines/recommendations shall also be taken into consideration in respect of efficacy (Lumen/watt), lighting power density etc. mentioned under ECBC.

4.6 Wiring Installation Design

Wiring installation design shall be as per IS 732. Wiring sizes, class, types, method of installation shall be as per the situation, type of load etc.

4.7 Protections

Reference for protections to be provided shall be taken from following Sections of Part 1 under this code:

Section 10 Protection for safety — Protection against electric shock

Section 11 Protection for safety — Protection against thermal effect and Protection against fire due to arcing.

Section 12 Protection for safety — Protection against over current and fault current

Section 13 Protection for safety — Protection against voltage disturbances, electromagnetic disturbances and voltage surges

4.8 Materials

All materials, fittings, equipment and their accessories, appliances etc. used in an electrical installation shall conform to Indian Standards wherever they exist. In case an Indian Standard does not exist, the materials and other items shall conform to relevant International Standard.

5 ELECTRICAL INSTALLATION WORK

5.1 License, Certificate of Competency, Permit

Considering the risk and hazard to human life involved under electrical work, CEA (Measures Related to Safety and Electric Supply) Regulations, 2010 mandates persons to work on electrical installation having special knowledge, experience and skill. Electrical installations shall be carried out under the supervision of a person holding a certificate of competency issued by the appropriate government. The workmen shall also hold the appropriate certificate of competency.

NOTE — Helpers/trainees may assist licensed person on the installation work strictly under supervision of licensed person who shall allow him to work within the limited area, which has not been connected to source of electrical supply.

5.2 Planning and Coordination in execution of work

For quality, safe and time bound completion of work, works shall be planned in coordination with other concerned agency working on site. Modern tools, bar-chart, CPM, PERT in project planning may be used as per the scope and magnitude of project.

5.3 Layout

Proper layout and marking of work shall be given to workmen at proper stage of work by engineer/electrical supervisor. Locations where other services are also proposed, and coordination is necessary from the point of view of sequence of construction work, shall also be explained.

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5.4 Workmanship

Good workmanship is an essential requirement for compliance with this Code. With the best quality material in hand, if not used and constructed with proper method of construction requiring skilled workmanship, will not result into a good quality work.

5.5 Supervision

Strict supervision of work throughout execution of work is important. The work, especially hidden/concealed, shall be certified and record be maintained by work supervising authority. Observation of safety parameters with proper use is also an important task under supervision.

6 COMPLETION, TESTING AND HANDING OVER

The competent person authorized by the agency who executes the work shall treat following points as his responsibility.

6.1 After completion, installation shall be tested as per norms. Installation may be permitted for use subject to satisfactory test results and compliance with statutory requirements.

6.2 Test Results, Certifications, NOCs, electrical layouts, wiring diagrams shall be maintained as record.

6.3 Handing over of installation to the owner shall be with proper set of record documents, instruction manuals, service requirements with respect to equipment.

6.4 A composite document listing out the compliances to the essential requirements regarding safety parameters, operational limits and equipment capability (as per relevant international/national standards/norms) together with basic drawings and data sheets shall be provided and signed by the said competent person for verification by the statutory bodies (CEA/state electricity inspectorate/power supply company).

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ANNEX A

CENTRAL ELECTRICITY AUTHORITY (MEASURES RELATED TO SAFETY AND ELECTRIC SUPPLY) REGULATIONS 2010

Reference: Electricity Act 2003, Section 177 to be read in conjunction with section 53 Regulation 58 Clearance above ground of the lowest conductor of overhead lines.

1) No conductor of an overhead line, including service lines, erected across a street shall at any part thereof be at a height of less than-
   (i) for lines of voltage not exceeding 650 Volts - 5.8 m
   (ii) for lines of voltage exceeding 650 Volts but not exceeding 33 kV - 6.1 m
2) No conductor of an overhead line, including service lines, erected along any street shall at any part thereof be at a height less than-
   (i) for lines of voltage not exceeding 650 Volts - 5.5 m
   (ii) for lines of voltage exceeding 650 Volts but not exceeding 33 kV - 5.8 m
3) No conductor of an overhead line including service lines, erected elsewhere than along or across any street shall be at a height less than -
   (i) for lines of voltage up to and including - 4.6 m
   11 000 Volts if bare
   (ii) for lines of voltage up to and including - 4.0 m
   11 000 Volts, if insulated
   (iii) for lines of voltage exceeding 11 000 Volts - 5.2 m
   but not exceeding 33 kV
4) For lines of voltage exceeding 33 kV the clearance above ground shall not be less than 5.2 m plus 0.3 m for every 33 000 Volts or part thereof by which the voltage of the line exceeds 33 000 Volts;
5) For High Voltage Direct Current (HVDC) lines, the clearance above ground shall not be less than:

Sl No.	DC Voltage (kV)	Ground Clearance (m)
(1)	(2)	(3)
i)	100 kV	6.1
ii)	200 kV	7.3
iii)	300 kV	8.5
iv)	400 kV	9.4
v)	500 kV	10.6
vi)	600 kV	11.8
vii)	800 kV	13.9

Regulation 60

Clearance from buildings of lines of voltage and service lines not exceeding 650 Volts

1) An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

2) Where an overhead line of voltage not exceeding 650 V passes above or adjacent to or terminates on any building, the following minimum clearances from any accessible point, on the basis of maximum sag, shall be observed, namely:

a) for any flat roof, open balcony, varandah roof and lean-to-roof:
   i) when the line passes above the building a vertical clearance of 2.5 m from The highest point, and
   ii) when the line passes adjacent to the building a horizontal clearance of 1.2 m from the nearest point, and

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b) for pitched roof:

i) when the line passes above the -building a vertical clearance of 2.5 m immediately under the line, and

ii) when the line passes adjacent to the building a horizontal clearance of 1.2 m

c) Any conductor so situated as to have a clearance less than that specified above shall be adequately insulated and shall be attached at suitable intervals to a bare earthed bearer wire having a breaking strength of not less than 350 kg.

d) The horizontal clearance shall be measured when the line is at a maximum deflection from the vertical due to wind pressure.

e) Vertical and horizontal clearances shall be as specified in schedule-X.

NOTE — For the purpose of this regulation, the expression "building" includes any structure, whether permanent or temporary.

Regulation 61

Clearances from buildings of lines of voltage exceeding 650 V

a) An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

b) Where an overhead line of voltage, exceeding 650 V passes above or adjacent to any building or part of a building it shall have on the basis of maximum sag a vertical clearance above the highest part of the building immediately under such line, of not less than-

i) for lines of voltages exceeding 650 Volts up to and including 33,000 Volts - 3.7 m

ii) for lines of voltages exceeding 33 kV - 3.7 m plus 0.30 m for every additional 33,000 Volts or part thereof.

c) The horizontal clearance between the nearest conductor and any part of such building shall, on the basis of maximum deflection due to wind pressure, be not less than-

i) for lines of voltages exceeding 650 V up to and including 11,000 Volts - 1.2 m

ii) for lines of voltages exceeding 11,000 V and up to and including 33,000 V - 2.0 m

iii) for lines of voltages exceeding 33 kV - 2.0 m plus 0. 3 m for every additional 33 kV or part thereof

d) For High Voltage Direct Current (HVDC) systems, vertical clearance and horizontal clearance, on the basis of maximum deflection due to wind pressure, from buildings shall be maintained as below:

Sl No	DC Voltage (kV)	Vertical Clearance (m)	Horizontal Clearance (m)
(1)	(2)	(3)	(4)
i)	100 kV	4.6	2.9
ii)	200 kV	5.8	4.1
iii)	300 kV	7.0	5.3
iv)	400 kV	7.9	6.2
v)	500 kV	9.1	7.4
vi)	600 kV	10.3	8.6
vii)	800 kV	12.4	10.7

e) Vertical and horizontal clearances shall be as specified in schedule X.

NOTE — For the purpose of this regulation, the expression "building" includes any structure, whether permanent or temporary.

Regulation 63

Erection or alteration of buildings, structures, flood banks and elevation of roads -

a) If at any time subsequent to the erection of an overhead line, whether covered With insulating material or not, any person proposes to erect a new building or Structure or flood bank or to raise any road level or to carry out any other type of Work whether permanent or temporary or to make in or upon any building, or Structure or flood bank or road, any, permanent or temporary addition or alteration, he and the contractor whom he employs to carry out the erection, addition or alteration, shall give intimation in writing of his

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intention to do so, to the supplier or owner and to the Electrical Inspector and shall furnish therewith a scale drawing showing the proposed building, structure, flood bank, road or any addition or alteration and scaffolding thereof required during the construction.

b) On receipt of such intimation, the supplier or owner shall examine -
   i) whether the line under reference was laid in accordance with the provisions of these regulations and any other law;
   ii) whether it is technically feasible;
   iii) whether it meets the requirement of Right of Way (ROW);
   iv) whether such person was liable to pay the cost of alteration of the overhead line and if so, send a notice without undue delay, to such person together with an estimate of the cost of the expenditure likely to be incurred to so alter the overhead line and require him to deposit, within thirty days of the receipt of the notice, with the supplier or owner, the amount of the estimated cost.

c) If such person disputes the cost of alteration of the overhead line estimated by die supplier or owner or even the responsibility to pay such cost, the dispute may be referred to the Electrical Inspector whose decision thereof shall be final.

d) The Electrical Inspector shall estimate the cost of alteration of overhead line on the following basis, namely:
   i) the cost of material used on the alteration after crediting the depreciated" cost of the material which shall be available from the existing line;
   ii) the wages of labour employed in affecting the alteration;
   iii) supervision charges to the extent of-fifteen per cent of the wages mentioned in sub clause (ii); and charges incurred by the supplier or owner in complying with the provisions of section 67 of the Act, in respect of such alterations.

e) Any addition or alteration to the building or structure shall be allowed only after the deposit of such estimated cost to the supplier or owner.

f) No work upon such building, structure, flood bank, road and addition or alteration thereto shall be commenced or continued until the Electrical Inspector has certified that the provisions of regulation 58, 60 and 61 should not be contravened either during or after the aforesaid construction:

   Provided, that the Electrical Inspector may, if he is satisfied that the overhead line has been so guarded as to secure the protection of persons or property from injury, certify that the work may be executed prior to the alteration of the overhead line or in the case of temporary addition or alteration, without alteration of the overhead line.

g) The supplier or owner shall, on receipt of such deposit, alter the overhead line in such a way that it does not contravene the provisions regulation 58, 60 and 61 either during or after such construction within two months from the date of such deposit or within such longer period as the Electrical Inspector may allow.

Regulation 64

Transporting and storing of material near overhead lines -

a) No rods, pipes or similar materials shall be taken below, or in the vicinity of, any bare overhead conductors or lines if these contravene the provisions of regulations 60 and 61 unless such materials" are transported under the direct supervision of a person designated in this behalf by the owner of such overhead conductors or lines.

b) No rods, pipes or other similar materials shall be brought within the flash over distance of bare live conductors or lines.

c) No material or earth work or agricultural produce shall be dumped or stored, no trees grown below or in the vicinity of, bare overhead conductors, or lines to contravene the provision of regulations 60 and 61.

d) No flammable material shall be stored under the electric supply line.

e) No fire shall be allowed above underground cables.

f) Firing of any material below electric lines shall be prohibited.

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Regulation 65

General clearances -

a) For the purpose of computing the vertical clearance of an overhead line, the maximum sag of any conductor shall be calculated on the basis of the maximum sag in still air and the maximum temperature as specified under regulations 57, and computing any horizontal clearance of an overhead line the maximum deflection of any conductor shall be calculated on the basis of the wind pressure specified under regulations 57.

b) No blasting for any purpose shall be done within 300 m from the boundary of a sub-station or from the electric supply lines of voltage exceeding 650 V or tower structure thereof without the written permission of the owner of such sub-station or electric supply lines or tower structures and in case of mining lease hold area, without the written permission of the Inspector of Mines.

c) No cutting of soil within ten meters from the tower structure of 132 kV and above voltage level shall be permitted without the written permission of the owner of tower structure.

d) No person shall construct brick kiln or other polluting units near the installations or transmission lines of 220 kV and above within a distance of 500 m.

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SECTION 8 ASSESSMENT OF GENERAL CHARACTERISTICS OF BUILDINGS

FOREWORD

An assessment of the general characteristics of buildings is essential for designing electrical infrastructure, selecting type and method of electrical installation adhering to safety norms and required functionality listed under Part 1/Sec 15 of this code. This Part 1/Section 8 covers a checklist of various factors that require assessment. It follows the internationally recommended method of identification of the external influences on the electrical installation such as environment, utilization and method of construction of the building. Out of these influences, those which are specifically important for specific occupancies are listed in the relevant sections of the Code. However, it is aimed that this section enables understanding of installations not explicitly covered by the Code.

The contents of this (Part 1/Sec 8) are primarily intended for installations inside buildings and may be utilized for outdoor sites to the extent possible. However, severe conditions may prevail at outdoor sites may require special considerations.

1 SCOPE

This section of the Code (Part 1/Sec 8) covers guidelines for assessing the characteristics of buildings and the electrical installation therein.

2 ASSESSMENT OF GENERAL CHARACTERISTICS OF BUILDINGS

An assessment of the general characteristics of buildings as enumerated below is essential from the point of view of design and protection for safety of the electrical installation. These characteristics when assessed, shall also be taken into consideration in the selection and erection of equipment.

2.1 Identification of General Characteristics

The following points form characteristics of building required to be considered in electrical design:

a) *Geography*

It gives an idea about environmental aspects and climatic conditions which an electrical installation has to sustain (for further details, *see* Code A from Table 7 of IS 732). The condition of earth/soil is important factor for earthing design to serve its intended purpose/utilization.

b) Purpose of building from the point of view of utilization is also an important factor. Use of building as residential premises, commercial premises, hospital, public gathering, industrial etc. sets different parameters for electrical design. It also gives and idea about user using the electrical installation and the allied equipments. The design of electrical installation shall also consider the user whether ordinary, child, aged, handicap etc. or an instructed person with knowledge of risk and hazards of electricity (for further details, *see* Code B from Table 7 of IS 732).

c) Structure

To decide material specifications and method of electrical installation, height, area of building/civil structure and material method of its construction, concrete, brickwork, wooden, steel, sheet-metal permanent/temporary/hutments is an important consideration (for furhter details, *see* Code C from Table 7 of IS 732).

2.2 Identification of External Influences on the Electrical Installation in the Building

2.2.1 Consideration of following factors is important which externally influence the characteristics of building:

a) *Environments*

1) Ambient temperature;
2) Atmospheric humidity;
3) Altitude;
4) Presence of water;
5) Presence of foreign solid bodies;
6) Presence of corrosive or polluting substances;

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7) Mechanical stresses;
8) Presence of flora and/or mould growth;
9) Presence of fauna;
10) Electromagnetic; electrostatic or ionizing influences;
11) Solar radiation;
12) Seismic effects;
13) Lighting;
14) Wind; and
15) Maximum flood level.

b) *Utilization*
1) Capability of persons;
2) Electrical resistance of human body;
3) Contact of persons with earth potential;
4) Conditions of evacuation in an emergency; and
5) Nature of processed or stored material.

c) *Construction of Buildings*
1) Constructional materials; and
2) Building design.

2.2.2 Table 7 of IS 732 elaborates classification and codification of external influences which require assessment in the design and erection of electrical installation.

2.3 Maintainability

An assessment shall be made for easy accessibility to the portion of electrical installation for maintenance of the installation expected to be received during its intended life.

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SECTION 9 WIRING INSTALLATIONS

FOREWORD

In electrical project work major portion in buildings relates to wiring installation. This section of National Electrical Code is primarily intended to cover related guidelines for wiring installations in all type of buildings. These guidelines also cover reliability, maintenance and safety of installation.

The generic guidelines for wiring installation shall be carefully considered depending on type of occupancy, local conditions, material selection and other relevant points.

Assistance has been derived from IS 732 : 2019 for formulation of this section.

1 SCOPE

This section covers the essential design and constructional requirements, installation, material selection, safety and testing of Wiring Installations.

1.1 General

The guidelines of this section of code can be generally applied to wiring installation of all types of premises except those specifically excluded from its scope.

1.2 Design

1.2.1 The design scope covers wiring installations up to and including 1000 V a.c. and 1500 V d.c. with standard frequency.

1.2.2 Fixed wiring for information and communication technology signaling, control etc. It excludes internal wiring of equipment used in such systems.

1.2.3 Earthing/protective conductor provisions.

1.2.4 Compliance to the requirements related to design and installation where licensing or other government authorities have statutory controls.

1.2.5 Electrical provisions in relation with fire safety requirements.

1.2.6 Requirements in respect of architectural design and civil work from the point of view of wiring installation.

1.2.7 *Testing and Commissioning*

This section includes testing and commissioning of wiring installation as per Part 1/Sec 17 of this code. Individual equipment and cables wires shall be tested separately as per relevant sections and applicable Indian standards.

NOTE — For complete testing of the installation, refer 6 of IS 732 : 2019.

1.2.8 *Maintenance*

Maintenance and periodic inspections required for the installation are covered in this section

1.3 Exclusions from Scope

This standard does not cover electrical installations in:

a) Internal wiring of machinery/equipment;
b) Internal wiring/circuits for equipment operating at voltages exceeding 1 000 volts internally such as X-ray machines, discharge lamps, electrostatic precipitators, scanning apparatus etc.;
c) Special provisions required for Construction sites, exhibition area, fairgrounds etc. set up for temporary purpose;
d) Mobile and transportable units;
e) Railway traction equipment, rolling stock and signaling;
f) Ships and off shore installations;
g) Aircrafts;

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h) Lightning protection system of buildings; and

j) Control cabling, trailing cables, and all cabling in the scope of work of lift manufacturer after point of supply provided in machine room/near machine/controller.

2 REFERENCES

The Indian Standards given in Annex K contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 TERMINOLOGY

For the purpose of this section, the definition given in Part 1/Section 2 of this code Along with the following shall apply.

3.1 Busbar — Low impedance conductor to which several electric circuits can be separately connected.

3.2 Cable Ducting System — A system of closed enclosure of non-circular sections for insulated conductors, cable and cords in electrical installations, allowing them to be laid in and replaced.

3.3 Cable Trunking System — A system of closed enclosures comprising a base with a removable cover intended for the complete surrounding of insulated conductors, cables, cords and/or for the accommodation of other electrical equipment.

3.4 Conduit Fitting — A device designed to join or terminate one or more components of a conduit system, or change the direction.

3.5 Conduit Joint — An interface between two or more components of a conduit system, or between a conduit system and other equipment.

3.6 Conduit System — A closed wiring system consisting of conduits and conduit fittings for the protection and management of insulated conductors and/or cables in electrical or communication installations, allowing them to be drawn in and/or replaced, but not inserted laterally.

3.7 Distribution Board — A unit comprising isolation and one or more protective devices against over current, short circuit, earth leakage protection and ensuring the distribution of electrical energy to the circuits.

3.8 Luminaire — Apparatus which distributes, filters or transforms the light transmitted from one or more lamps/ light emitting device(s) and which includes all the parts necessary for supporting, fixing and protecting the lamps, but not the lamps themselves, and where necessary circuit auxiliaries together with the means for connecting them to the supply.

3.9 Wiring System — assembly made up of bare or insulated conductors or cables or busbars and the parts which secure and if necessary, enclose the cables or busbars

4 GENERAL AND COMMON ASPECTS OF ARCHITECTURAL DESIGN, PLANNING AND CIVIL CONSTRUCTION WORK FROM THE PERSPECTIVE OF WIRING INSTALLATIONS

4.1 Architectural design, planning and construction of civil work play an important role in compliance of safety norms, statutory requirements, convenience and ease of installation of electrical work. This helps maintaining quality parameters, ensure reliability, adequate functionality and trouble free working throughout the service life expectancy.

4.2 Starting from the initial stage, required provisions in architectural design, planning and construction of civil work from the perspective of electrical work shall be considered. Accordingly, electrical activities shall be planned during planning and bar-charts preparation.

4.3 Related requirements of design and planning can stage-wise be divided into:

a) Architectural design; and

b) Civil construction.

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NOTE — Though many guidelines are generic, the scope mentioned under **4.4** and **4.5** is mainly from the point of view of work of wiring installations and does not cover requirements related to transformer substation, generator room, etc.

4.4 Architectural Design Requirements

In consultation with Electrical agency such as Electrical Consultant/Contractor, supply points recommended by him or any authority shall be in line with the regulations. Approved method of construction, codes and standards shall be considered in architectural drawings as under:

4.4.1 *Routes and Service Entry Points*

Architectural drawings shall clearly mark electrical service entry points; cable routing underground and through the building structure so that detailing in drawings restricts the work at specified routes and no conflict shall occur with other building utility services. The drawings shall specify required horizontal and vertical clearances to be maintained from other utility services.

4.4.2 *Locations of Electrical Panels*

Locations and position for main and sub electrical panels shall be marked, and adequate space/room shall be allocated considering size of panel, required clearance in front, side and back. Consideration shall be given to space required for opening of the panel doors/racking out breakers, and approach boundaries (*see* Part 1/ Section 22), and accessibility. Floor mounting panels may be located in separate electrical panel rooms, having outward door opening, required fire rating and ventilation arrangement.

4.4.3 *Electrical Meter Rooms*

Electrical Meter Rooms shall be separate. The site shall be accessible to the consumer as well as service provider's personnel for meter reading, installation, inspection and maintenance. It shall be planned to have sufficient head room and a clear space of at least 1m in front of meters and control switches. Space on wall shall be sufficient to accommodate required number of meters at height suitable for taking readings can be taken without aid of any tackle. Also, the switchgears shall be at least 0.5 m above floor level and shall be placed at height to have an easy access for operation. The meter room shall be well ventilated, protected from external influences like direct sun, rain, water seepages, entry of rodents etc. Location of meter room shall be suitably adjacent or nearest to cable duct/shaft/vertical route of mains.

NOTE — Meter rooms shall not be located below stair cases where the mentioned requirements could not be complied with.

4.4.4 *Movement of Heavy/Bulky Electrical Equipment*

For installation/movement of heavy and/or bulky electrical equipment within building for maintenance, provision of adequate passages, stairways or any alternate mechanized provision for its shifting/vertical and horizontal movement shall be taken in to consideration.

4.4.5 *Shafts/Ducts*

There shall be provision of shafts for vertical electrical distribution, preferably, adjacent to electrical panels. Shafts shall be separate for electrical HT cables, LT power cables/bus-bar trunking and cabling for extra low voltage systems like telephones, security system, fire alarm, signaling, BMS or data networking etc. If independent shaft is not possible, there shall be segregation of required fire rating (not less than 2 hr). No other utility service shall run through these shafts. Shafts shall be accessible at all levels and shall not open in fire escape staircase. All shafts shall have fire prevention provision as per National Building Code and shall comply with fire safety requirements specified by local statutory authorities.

NOTE — The requirement is in line with the CEA Reg. 36(5) for all buildings above 15 m height.

4.4.6 *Interior Design*

Electrical points, locations of switch boards to suite the aesthetics, functionality as well as comfort and ease of operation shall be planned.

4.4.7 *Aesthetics and Electrical Safety*

There shall be mutual understanding between the architect and the person executing/supervising electrical works and these points shall be decided at planning stage. Aesthetics shall be maintained while taking care of safety requirements during electrical installation work such as convenience, ease of installation, further maintenance depending on type of wiring (concealed/surface/hybrid), location of distribution boxes,

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requirement of under-floor trunking/false flooring/false ceiling, wall partitions and openings to enter into/ work within as per the need.

4.4.8 *Illumination*

While designing interior work number, type, size, location of luminaries along with its type, size and design shall be decided and agreed by Architect and Electrical Agency, taking into account technical parameters such as lux level, CCT, heat dissipation, accessibility and maintenance.

4.4.9 *Ceiling Fans*

Ceiling fans shall be located so that there is required clearance between ceiling/false ceiling and fan blade, floor level and fan blade. Sweep of fan blades shall not obstruct light source. Location and size of fan shall be at suitable locations from utility point of view by users.

NOTE — In case of installation of false ceiling at a later stage, clearance of fan blades may be inadequate. Under such cases, suitable length fan rod may be used for replacing the existing rod at maintain required clearances. However, in case of limited height ceiling, it may not be possible.

4.4.10 *Exhaust Fans*

Cross ventilation shall be considered for allowing fresh air entry to particular envelope area where exhaust fans are installed (*for example*, toilets where exhaust fans are proposed for installation, door undercuts or louvres, preferably, at lower level for cross ventilation shall be provided)

NOTE — Non provision of entry for fresh air creates negative pressure within the envelope area. This increases the load on exhaust fan and results in heating and subsequent failure.

4.4.11 Location of earthing pits shall be shown on drawings so that they are accessible for testing and maintenance throughout the service period.

4.4.12 Areas requiring restricted access to designated person authorized to carry out electrical work shall be provided with necessary arrangements

4.5 Civil Planning and Constructional Requirements

It is important to plan activities of civil construction and electrical works in detail on bar chart or similar tools available for project planning. The bar chart shall be updated, and monitored to avoid conflicts, breakages and reworking. Following points provide general guidelines.

4.5.1 *Fire Rating*

The electrical panel rooms, doors, segregation arrangement within shaft shall have fire rating of minimum 2 h or as per requirements mentioned under NBC, Central Electricity Authority (measures related to Safety and Electric Supply) Regulations, 2010 and local fire prevention requirements.

4.5.2 *Shafts/Ducts/Chambers*

Design and location of cable ducts, shafts, chambers, their covers and entry points, shall be as per drawings provided by electrical agency, considering aspects of maintenance/repairs/replacement. Size of chambers shall be in consideration with bending radii of cables. At all flooring level, there shall be a provision to seal these shafts, so that in case of fire, it shall not spread or shall not cause smoke to move from one floor to other.

4.5.3 *Openings and Covers*

Manholes/opening of chambers shall not be less than 650 mm x 550 mm or 650 mm in diameter, where opening is intended for entry of person. Covers of manholes/chambers shall be of sufficient strength to withstand loads likely to be imposed on the structure. Covers shall be marked with the name of the service.

Openings/covers of junction boxes/draw-in boxes/accessories in conduit systems shall always be accessible.

4.5.4 *Enclosures for Underground Cables*

Cable enclosures shall be of required diameter so that cable can easily slide through. It shall have sufficient mechanical strength and shall be erected at required depth to meet requirements of IS 1255.

NOTE — Due to technological advancements, alternatives for cable enclosures other than pipes such as like precast ducts may be used provides that they comply with the relevant national or international standard.

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4.5.5 *Wall Thickness*

Walls shall be of sufficient thickness to accommodate concealed boxes/switch boards/distribution boxes so that installation of boxes do not affect strength of wall. Additional strengthening shall be considered, if necessary.

NOTE — *For example*, for 100 mm wall, it is not possible to accommodate boxes of depth 60 mm each back-to-back. Under such cases, staggering may solve problem to certain extent.

4.5.6 *Structural Strength*

In wiring installation where cable ladder/tray system is used for cable management, its structure along with the load of cables imposes load on the primary structure of building. Building structure shall have adequate capacity to bear the load.

At locations where there is crowding of conduits endanger may structural strength number of circuits from the particular DB/panel. Such situation may occur in beam, slab, and wall. Care shall be taken to avoid such situations, However, if such situation is unavoidable, necessary measures may be taken to retain structural strength.

4.5.7 *Sleeves/Core Cutting*

As far as possible, sleeves shall be erected for entry of wires/cables through wall, flooring and RCC structure during construction to avoid core cutting, damages and reworking at finishing stage. In case of requirement, consent of structural engineer shall be taken and shall be performed under supervision of civil engineer.

4.5.8 *Water Leakages/Seepages*

Design shall take into consideration the possibility of seepages, leakages, accumulation, and ground water in-surge etc. which is hazardous to electrical installation. Adequate provisions shall be made at locations for prevention and work shall be executed with care.

4.5.9 *Bathrooms/Washrooms*

In bathrooms/washrooms, splash of water from showers, faucets and wet areas may prove fatal. Guidance shall be taken from Part 3/Sec 2 of this code.

4.5.10 *Tandems in Flat Slab Post Tension Structures*

For flat slab post tension structure, locations of tandems marking shall be made to avoid puncture of/damage to tandems during electrical construction activity.

4.5.11 *Earthing*

Subsequent to construction of earthing electrodes, any construction work including excavation shall not damage any part of earthing system. Any civil work on construction site shall not cause cover-up/concealing of any portion of electrical earthing system without consent of person in-charge of electrical work.

5 ELECTRICAL DESIGN AND CONSTRUCTION OF WIRING INSTALLATIONS

Planning during initial design shall consider the estimated load, load pattern, type of occupancy, class of users and desired functionality with a provision of future enhancements helps achieve reliability, long term safe and trouble- free operation.

Prior to execution of work, preparation of detailed drawings showing electrical layouts and single line diagram is a primary step. It, also, forms an important part of documentation. Symbols used in the drawing shall conform to IS 12032 series of standards.

NOTE — It is important to observe norms, method of construction and appropriate material for use on site at various stages during the progress of work. Special checks shall be carried out for electrical works whicha re to be concealed. Supervisor or qualified and competent person may be assigned the responsibility for checking/certifying before concealing.

5.1 Statutory Requirements

5.1.1 *Regulation 12(1) of CEA Safety Regulations 2010*

All electric supply lines and apparatus shall be rated for power, insulation level and estimated fault current. They shall have sufficient mechanical strength and duty cycle for which they may be required to perform under the environmental conditions of installation. The design shall facilitate construction, installation, protection, working-on and maintenance in such a manner so as to ensure safety of human beings, animals and property.

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5.1.2 *Regulation 29(1) of CEA Safety Regulations 2010*

No electrical installation work, including additions, alterations, repairs and adjustments to existing installations, except such replacement of lamps fans, fuses, switches, domestic appliances of voltage not exceeding 250V and fittings as in no way alters its capacity or character, shall be carried out upon the premises of or on behalf of any consumer, supplier, owner or occupier for the purpose of supply to such consumer, supplier, owner or occupier except by an Electrical Contractor licensed in this behalf by the State Government and under the direct supervision of a person holding a certificate of competency and by a person holding a permit issued or recognized by the State Government.

NOTE – Reg (12) and (29) of CEA Safety Regulations, 2010 are specifically reproduced. However, all applicable regulations shall be adhered to.

5.2 Coordination with Architectural and Civil Agencies

5.2.1 According to proposed design and layout of wiring installation, requirement of spaces, clearances, accessibilities, approach ways, raceways, shafts, recommended wall thickness and required provisions for prevention from fire hazard under purview of architect/civil agency shall be intimated at planning stage.

5.2.2 Working drawings involving civil work and related electrical installation work shall be given to civil construction agency in a stage wise manner before footings, RCC structure, walls, doors and windows, plastering, flooring, interior design, painting, etc.

Table 1 Correlation and Dependability between Stages of Civil and Electrical Works

(*Clause* 5.2.2)

Sl No.	Stage of Civil Work	Electrical Work Involved
(1)	(2)	(3)
(i)	Footings	Erection of pipes for underground cables as per proposed routes and earth mat
(ii)	RCC structure	Laying and fixing conduits, concealed fan boxes, fixing sleeves after steel work, checking displacement during fixing of covers below steel work, supervising and confirming rigidity of conduits during casting.
		Where structural steel forms a part of earthing system, compliance shall be as per 14 of IS 3043 : 2018.
		Ferruling/welding/clamping between bars is important to maintain resistance within permissible limits.
(iii)	Walls	Chasing and fixing conduit drops, fixing boxes and drawing fish wires, if needed
(iv)	Door and windows	Drawing of wires
(v)	Plastering	Terminating wires/conductors, fixing switchboard accessories, cover plates over junction boxes etc.
(vi)	Flooring	Under floor raceways
(vii)	Interior, false ceiling	Related wiring, erecting fan down rods
		Fixing lighting fixtures, fans etc.
(viii)	Painting	Fixing switch board cover plates, light fixtures, fans electrical testing etc.

5.3 Types of Wiring Systems

Wiring systems are conventionally divided into surface wiring and concealed wiring. Under each of above, variation occurs on the basis of material and place of installation. For more details, refer IS 732. Accordingly, wiring systems have been categorized in to different types considering basic material, accessories necessary for installation taking into account the electrical and mechanical aspects as well as place of installation. Wiring system shall, therefore, be selected to suit and sustain in that particular location and maintain functionality, reliability and safety.

NOTE — Under surface wiring conventional wooden casing and capping and CTS wiring on hard wood batten are obsolete. For fixed wiring, use of cleat wiring is not recommended and hence, are not covered under scope of this section.

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5.3.1 *Wiring Systems*

Wiring systems excluding bus-bar trunking system and power track system can be categorized depending on following factors:

a) Method of installation in relation to type of conductor/cable (*for example*, bare conductor, insulated conductor, sheathed conductor, single core/multicore). It is based on accessories required for protection of conductor/cable and accessories required for fixing/installing. Categories are as under:

   1) Without fixing;
   2) Clipped direct;
   3) Conduit system;
   4) Trunking/raceways – skirting/flooring;
   5) Ducting;
   6) Ladder; tray; brackets;
   7) On insulators; and
   8) Support wire.

   These methods of installation shall be in accordance with Table A-1. Methods of installation with respect to conductors and cables are specified under Annex A (For more details, refer Annex R of IS 732 : 2019).

   NOTES

   1 Conduit system shall comply with IS 16205 series of standards (*see* **5.9**).

   2 Trunking system (for cables) shall comply IS 14927 series of standards (*see* **5.10**).

   3 Cable ducting/trunking system shall comply with IS 14927 series of standards.

   4 Cable ladder/tray system shall comply with IS/IEC 61537.

b) Method of installation with respect to place of installation as under:

   1) Building voids- accessible/non-accessible;
   2) Cable channel;
   3) Buried in ground;
   4) Embedded in structure;
   5) Surface mounted;
   6) Overhead/free in air;
   7) Window frames;
   8) Architraves; and
   9) Immersed.

   These methods shall be in accordance with Table A-2 (For more details, refer Annex R of IS 732 : 2019).

NOTES

1 Table A-3 indicates reference method to be used to obtain current carrying capacity (*see* **5.5**).

2 Reference methods are categorized into 10 parts: A1, A2, B1, B2, C, D1, D2, E, F, G; (*see* **5.5.2**).

5.3.2 *Bus-bar Trunking System (BTS)/(BBT)*

BTS shall comply with IS/IEC 61439-1 and IS/IEC 61439-6. Installation shall be as per the manufacturer's instructions starting from transformer LT side to primary distribution (main switchboard interconnecting sub-main DBs) and further, for secondary distribution to local DBs.

5.3.2.1 Selection may consider following limitations in conventional cable distribution:

a) Where ampacity is higher, conventional cable system requires number of parallel runs making it cumbersome.
b) Cables have restrictions of bending radii.
c) Erection of cables with clamps, trays, ladders is time consuming and laborious job activity requiring particular skill and good workmanship; and
d) Terminations and jointing of cables require skill and good workmanship.

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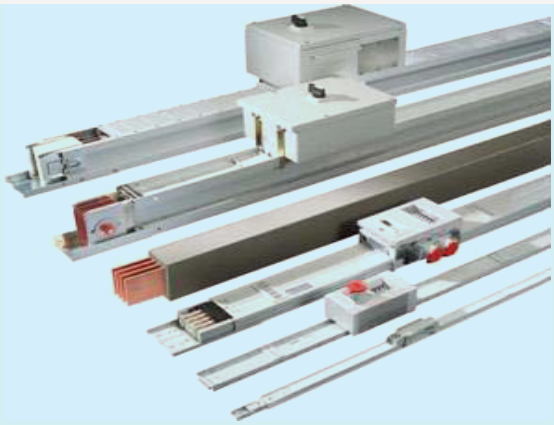


FIG. 1 BUS-BAR TRUNKING (BTS) AND TAP-OFF BOXES

5.3.2.2 BTS may be considered as an alternative with following attributes:

a) It is prefabricated in sections;
b) All accessories are factory made and precisely designed and is less prone to human error;
c) The installation including jointing, terminations, and tap-offs are convenient and do not require special skills and workmanship;
d) Additions/alteration are non-complex in nature;
e) Predefined electromagnetic induction values - lower electromagnetic interference;
f) Lesser voltage drops;
g) Better heat dissipation;
h) Good earth continuity;
j) Higher short-circuit withstand capacity;
k) Higher impulse voltage withstand capacity;
m) BTS may require reduced number of switchgears and hence, results in saving space and reduced sizing of panels;
n) Cable mess is eliminated. Also, it is halogen free and do not pose risk of toxic fumes generation in caseof fires and flame propagation; and
p) Ingress protection prevents possible damages due to rodents etc.

5.3.2.3 In high-rise buildings for vertical distribution and in large complexes, for horizontal distribution above mentioned attributes are desirable.

NOTE — Manufacturer's specifications may also be referred.

5.3.2.4 BTS are of two types – sandwich type or air insulated type. Generally, air insulated bus is manufactured for lower current ranges in comparison with sandwich bus. Air-insulated bus requires more space as compared to sandwich bus. It may cause chimney effect unless provision of fire barriers is provided. Considering the risks, use of air-Insulated BTS is not recommended in multistoreyed buildings above 15 m height, without provision of barriers.



FIG. 2 AIR-INSULATED BUS-BAR TRUNKING

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5.3.2.5 Sandwich bus is compact. It requires lesser space and there exist no risk of chimney effect.



FIG. 3 SANDWICH BUS TRUNKING

5.3.2.6 BTS of lower current range is also available for secondary distribution, *for example,* utility plug-in power outlets, lighting bus bar trunking etc. It may support dual circuits. Its applications is recommended in commercial establishments, shopping centers, IT parks, work benches in workshops/assembly lines in industries, hospitals, laboratories, warehouses/godowns etc. It enables easier maintenance. Lighting bus-bar trunking is convenient for high-bay illumination.



FIG. 4 LIGHTING BUS-BAR TRUNKING

5.3.3. *Power Track System (PT)*

PT system shall comply with IEC 61534 series of standards. Installation shall be carried out as per the manufacturer's instructions.

5.3.3.1 PT system technology is a convenient option for conventional fixed power/data/telephone sockets. It is prefabricated and hence, can be installed easily and quickly. It allows addition, repositioning, removal of power and data/telephone sockets safely as and when required. This system provides great flexibility and can be used at locations where detailed interior layouts are not finalized.



FIG. 5 POWER TRACK SYSTEM

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5.3.3.2 PT system is used for rated voltage not exceeding 240 V for single phase and 415 V for three-phase with rated current not exceeding 63A. These systems can be used for distributing electricity in household, commercial and industrial installations. Installation of this system shall be done as per the manufacturer's instructions.

5.3.3.3 It can be used on walls, skirting, and ceiling. Also, they can be of flush or semi-flush, surface mounted, suspended or spaced away from surface using fixing devices and shall comply with the norms specified in IEC 61534-21.

5.3.3.4 PT system may also be installed on floor/under floor complying with the requirements and tests specified in IEC 61534-22.

5.4 Selection and Erection in Relation to External Influences

In reference with Table 1 of Part 1/Section 8 of this code, following external influences depending on location/ environment shall be taken into account so that protection against the expected external influences is ensured during selection and erection of wiring system:

a) Ambient temperature (AA);
b) External heat sources;
c) Humidity (AB);
d) Water (AD);
e) Presence of solid foreign bodies (AE);
f) Presence of corrosive/polluting substances (AF);
g) Mechanical stresses – impact (AG);
h) Mechanical stresses – Vibration (AH);
j) Mechanical stresses – other (AJ);
k) Flora, mould (AK);
m) Fauna (AL);
n) Solar radiation (AN);
p) Seismic effects (AP);
q) Wind (AR);
r) Nature of processed or stored materials (BE); and
s) Building design (CB).

For further detailed classification, refer Annex L from IS 732 : 2019.

5.4.1 *Ambient Temperature (AA)*

Depending on geographical location, wiring system shall be suitable for the range limiting highest and lowest temperature in normal operation. In case of fault, limiting temperature which is maximum continuous operating temperature shall not exceeded (Refer Table 1 of Part 1/Section 8 of this code). Conventionally, AA4 (-5 to 40^0C), is regarded as normal limit.

5.4.2 *External Heat Sources*

Where wiring installation is likely to be exposed to external heat sources it shall be protected with heat shielding/ heat resisting insulated sleeving or segregating/placing sufficiently away from such heat source.

NOTE — Heat from external sources may be radiated or transferred through convection or conducted means. *For example*, from hot water system, appliances, manufacturing process, plant etc.

5.4.3 *Humidity (AB)*

Under humid environment, condensation shall not cause any damage. Insulation and sheath (in case of sheathed cable) shall not allow penetration of moisture. Under this category, AB4 (RH 5 percent to 95 percent and AH 1 Low Severity) is treated as normal.

5.4.4 *Water (AD)*

Wiring system shall comply relevant ingress protection class. And, if water accumulates, provision of draining shall be provided.

NOTE — In general, the sheaths and insulation of cables for fixed installations may be regarded, when intact, as proof against penetration by moisture. Special considerations apply to cables liable to frequent splashing, immersion or submersion.

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Table 2 Maximum Operating Temperature for Types of Insulation of Cables

(*Clause* 5.5.1)

Sl No.	Type of Insulation	Temperature Limit °C[1)]
(1)	(2)	(3)
(i)	Thermoplastic (PVC)	70 at conductor
(ii)	Thermosetting (XPLE/EPR rubber)	90 at conductor[2)]
(iii)	Mineral (thermoplastic PVC) covered or bare exposed to touch	70 at sheath
(iv)	Mineral (bare exposed to touch but not in contact with combustible material)	105 at sheath[2),3)]

[1)] Current carrying capacities are based on temperatures mentioned above or where certified conductor or cable may have maximum operating temperature limits in accordance with the manufacturer's specifications.

[2)] Where conductor operates exceeding 70°C, it shall be ascertained that the equipment connected to the conductor is suitable for the resulting temperature at the connection

[3)] For mineral insulated cables higher operating temperature may be possible depending upon the temperature rating of cable, its terminations, environmental conditions and external influences.

NOTES

1 Table does not include all types of cables.

2 This does not apply to bus-bar trunking system or power- track system or lighting track system for which current carrying capacity is provided by manufacturer.

3 For temperature limit of other types of cable please refer cable specifications or manufacturer.

5.4.5 *Presence of Solid Foreign Bodies (AE)*

Wiring system shall comply with relevant ingress protection class depending on its location. Where dust in significant quantities is present, additional measures may be taken so that heat dissipation is not affected, or cause creepage between conductors (*for example*, mining work, stone crushers etc.)

5.4.6 *Presence of Corrosive/Polluting Substances (AF)*

In presence of corrosive or polluting substance (*for example*, water, chemical zones, coastal areas etc.) all material and installation shall have additional provisions to resist such environment. Protective tapes, paint, grease, bimetallic accessories etc. as recommended by manufacturer shall be used.

5.4.7 *Impact (AG)*

Selection of wiring system shall take into consideration possible impact, penetration, compression etc. during installation, use or maintenance (*for example,* drilling a hole in wall where concealed wiring exists, digging where underground cable exists). Provisions such as be trunking ducting, conduit system may be used.

5.4.8 *Vibration (AH)*

Wiring system supported by or fixed to structures shall sustain possible vibrations. Such situation may occur during casting of RCC work where conduits are fixed to steel and vibrators are used for proper settlement of concrete. Vibrations may be of medium severity (AH2) or high severity (AH3). Precautionary measure may include making conduit system rigid, using flexible wires etc., at the locations susceptible to such situations.

5.4.9 *Mechanical Stresses (AJ)*

Sufficient care shall be taken to prevent mechanical stresses to affect reliability and safety of wiring installation (*for example*, unsupported heavy cable creates stress at terminals due to its own weight, pulling/threading of cables through conduit systems, bending of cables, underground/under floor cables, electro-dynamic forces resulting from short circuit currents, etc.)

5.4.10 *Flora, Mould (AK)*

Special protective measures such as regular cleaning shall be adopted at places where growth of vegetation and/or fungus can cause a potential hazard.

5.4.11 *Fauna (AL)*

At locations anticipated to constitute hazard (AL2) caused due to insects, birds, lizards, rodents etc. suitable measures shall be adopted by providing mechanical protection/suitable pest control which shall not cause adverse effect on installation.

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5.4.12 *Solar Radiation (AN)*

Adequate shielding shall be provided where solar radiation (AN2) or UV radiation is expected. Special precaution shall be taken for equipment subjected to ionizing radiation.

5.4.13 *Seismic Effects (AP)*

Wiring system shall sustain seismic hazard identified for respective geographical location.

5.4.14 *Wind (AR)*

Please refer 5.2.5.13 of IS 732:2019.

5.4.15 *Nature of Processed or Stored Materials (BE)*

Adequate fire prevention measures shall be taken for locations storing material having fire potential. for further information, refer 5.2.5.14 and 4.3.2 of IS 732 : 2019.

5.4.16 *Building Design (CB)*

Where structural movement is anticipated wiring system shall permit relative movement (CB3)/(CB4) so that conductors and cables are not subjected to excessive mechanical stress such as expansion joints in the building structure, bridges, etc.

5.5 Current Carrying Capacities

5.5.1 The current to be carried by any conductor for sustained periods during normal operation shall be such that the temperature limit depending on type of insulation is not exceeded as given under Table 2. Other than normal operation, consideration shall also be in regard with the ability to sustain effective operation of protection against electric shock, over-current, voltage drop (*see* **5.7**), thermal effect and limiting temperature of conductor and terminals. All these considerations form basis of cross-section of conductor.

5.5.2 *Reference Method of Installation*

5.5.2.1 To assess current carrying capacity of cable depending on various situations given under Table A-3, these methods of installation have been classified under 10 groups under following references:

a) *Reference Method A1*

Insulated conductors in conduit in thermally insulated wall/in mouldings/architraves/window frames.

b) *Reference Method A2*

Multi-core cable in conduit in thermally insulated wall.

NOTE — Insulated wall consisting of outer weatherproof skin, thermal insulation and inner skin of wood or similar material having thermal conductance at least 10 W/m^2. Conduit is fixed so as to be close to inner wall but not necessarily touching inner skin. Heat from cables is assumed to escape through the inner skin only. The conduit can be of metal or PVC.

c) *Reference Method B1*

Insulated conductors in conduit/trunking on wooden wall on/or concealed in masonry wall, suspended in trunking/in building void

d) *Reference Method B2*

Multi-core cable in conduit/trunking on wooden wall on/or concealed in masonry wall/flooring, suspended in trunking/building or ceiling void/duct in void/in masonry/open or closed cable channel

NOTE — Conduit is mounted on a wooden wall so that the gap between the conduit and the surface is less than 0.3 times the conduit diameter. The conduit can be of metal or plastic. Where the conduit is fixed to a masonry wall the current-carrying capacity of the cable or insulated conductors may be higher.

e) *Reference Method C*

Single-core or multi-core cable on a wooden wall imperforated tray/on or directly in masonry wall/ ceiling.

NOTE — Cable mounted on a wooden wall so that the gap between the cable and the surface is less than 0.3 times the cable diameter. Where the cable is fixed to or embedded in a masonry wall the current-carrying capacity may be higher.

f) *Reference Method D1*

Single core cable/multi-core cable in conduits/ducts in the ground.

NOTE — Cables drawn into 100 mm diameter of plastic, earthenware or metallic ducts laid in direct contact with soil having a thermal resistivity of 2.5 K·m/W and a depth of 0.75 m. For higher soil resistivity, apply correction factor as per Table B-16.

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g) *Reference Method D2*

Multi-core cables designed to be buried directly in the ground with or without added mechanical protection (*for example*, half round RCC pipe etc.)

NOTE — Cables laid in direct contact with soil having thermal resistivity of 2.5 K·m/W and a depth of 0.75 m. For higher soil resistivity, apply correction factor as per Table B-16.

h) *Reference Method E*

j) *Reference Method F*

k) *Reference Method G*

Reference method E, F, G is for single or multi-core cables in free air/spaced from surface/on perforated or wire-mesh tray/ladder/brackets/on insulators.

NOTE — A cable so supported that the total heat dissipation is not impeded. Heating due to solar radiation and other sources shall be taken into account. Care shall be taken that natural air convection is not impeded. In practice, a clearance between a cable and any adjacent surface of at least 0.3 times the cable external diameter for multi-core cables or one time the cable diameter for single-core cables is sufficient to permit the use of current-carrying capacities appropriate to free air conditions.

5.5.2.2 *Other methods*

a) *Cable on a Floor or Under a Ceiling*

This is similar to reference method C except that the current-carrying capacity for a cable on a ceiling is slightly reduced (*see* Table B-17 from Annex B) from the value for a wall or a floor because of the reduction in natural convection.

b) *Cable Tray System*

A perforated cable tray has a regular pattern of holes so as to facilitate the use of cable fixings. The current-carrying capacity for cables on perforated cable trays are derived from test work utilizing trays where the holes occupying 30 percent of the area of the base. If the holes occupy less than 30 percent of the area of the base, the cable tray is regarded as imperforated. This is similar to reference method C.

c) *Cable Ladder System*

This construction offers a minimum of impedance to the air flow around the cables, that is, supporting metal work under the cables occupies less than 10 percent of the plan area.

d) *Cable Cleats, Cable Ties:*

It is a device for fixing cables to cable tray or bundling cables together.

e) *Cable Hangers:*

Cable supports which hold the cable at intervals along its length and permit substantial free air flow around the cable.

f) *Cables in a Ceiling:*

This is similar to reference method A. It may be necessary to apply the correction factors due to higher ambient temperatures that may arise in the junction boxes, heat dissipating luminaries and similar items mounted in the ceiling. Correction factor as per Table B-14 of Annex B shall be applied.

5.5.3. Depending on reference method (*see* **5.5.2**) and insulation (*see* Table 2), Table B -1 refers Table B -2 to Table B-13 which provide current carrying capacity for respective cross section and type of conductor (Cu/Al) can be taken for design consideration. Table B-14, Table B-15 and Table B-16 state the further correction Factors and Tables B-17 to Table B-21 state reduction factors to be applied. These tables are given under Annex B. Particulars are tabulated as below:

Table 3 Reference Tables for Assessing Current Carrying Capacity

(*Clause* 5.5.3)

Table	Particulars	Use
B-1	Installation reference methods for forming basis of tabulated current carrying capacities	Provides reference for obtaining current carrying capacity for particular cross section and conductor Cu/Al
B-2	Current carrying capacities in amperes for PVC insulated, two loaded conductors copper (1.5 to 300 mm^2)/aluminium (>16 to 300 mm^2) conductor temperature 70°C with ambient temperature 30°C in air and 20°C in ground	Provides current carrying capacities under methods of installation A1, A2, B1, B2, C, D1, D2

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Table 3 (*Concluded*)

Table	Particulars	Use
B-3	Current carrying capacities in amperes for XLPE/EPR insulation two loaded conductors at temperature 90°C in air and 20°C in ground	Provides current carrying capacities under methods of installation A1, A2, B1, B2, C, D1, D2
B-4	Current carrying capacities in amperes for PVC insulation three loaded conductors at temperature 70°C in air and 20°C in ground	Provides current carrying capacities under methods of installation A1, A2, B1, B2, C, D1, D2
B-5	Current carrying capacities in amperes for XLPE/EPR insulation three loaded conductors at temperature 90°C in air and 20°C in ground	Provides current carrying capacities under methods of installation A1, A2, B1, B2, C, D1, D2
B-6	Current carrying capacities in amperes for mineral insulation copper conductor and sheath/PVC covered or bare, two/ three loaded conductors at metallic sheath exposed to touch temperature 70°C with ambient temperature 30°C	Provides current carrying capacities for copper conductor (1.5 to 4 mm^2 at 500 V and 1.5 to 240 mm^2 at 750 V) under C methods of installation.
B-7	Current carrying capacities in amperes at metallic sheath not exposed to touch at temperature 105°C with ambient temperature 30°C	Provides current carrying capacities for copper conductor (1.5 to 4 mm^2 at 500 V and 1.5 to 240 mm^2 at 750 V) under C methods of installation.
B-8	Current carrying capacities in amperes at metallic sheath exposed to touch temperature 70°C with ambient temperature 30°C	Provides current carrying capacities for copper conductor (1.5 to 4 mm^2 at 500 V and 1.5 to 240 mm^2 at 750 V) under E, F and G methods of installation.
B-9	Current carrying capacities in amperes at metallic sheath not exposed to touch at temperature 105°C with ambient temperature 30°C	Provides current carrying capacities for copper conductor (1.5 to 4 mm^2 at 500 V and 1.5 to 240 mm^2 at 750 V) under E, F and G methods of installation.
B-10	Current carrying capacities in amperes for PVC insulated, single/multi core cables copper (1.5 to 630 mm^2) conductor temperature 70°C with ambient temperature 30°C	Provides current carrying capacities under methods of installation E, F and G
B-11	Current carrying capacities in amperes for aluminium (>16 to 630 mm^2) conductor temperature 70°C with ambient temperature 30°C	Provides current carrying capacities under methods of installation E, F and G
B-12	Current carrying capacities in amperes for XLPE/EPR insulation copper conductor (1.5 to 630 mm^2), temperature 90°C at reference ambient temperature of 30°C	Provides current carrying capacities under methods of installation E, F and G
B-13	Current carrying capacities in amperes for aluminium conductor at reference ambient temperature of 30°C	Provides current carrying capacities under methods of installation E, F and G
B-14	Correction factor for ambient air temperature other than 30°C	Values given in Table B-2 to Table B-13 shall be used after applying correction factor in respect with the air ambient temperature
B-15	Correction factor for ambient ground temperature other than 200º C	Values given in Tables B-2 to Table B-5 shall be used after applying correction factor in respect with the ground ambient temperature
B-16	Correction factors for cables buried directly in ground/ducts for soil thermal resistivity other than 2.5 K-m/W	Values given in Table B-2 to Table B-5 for reference method D shall be used after applying correction factor
B-17	Reduction factor for one circuit/more than one circuit or one multi-core cable/more than one multi-core cable other than underground	Values mentioned in Tables B-2 to Table B-13 shall be used after applying the reduction factor
B-18	Reduction factor for one circuit/more than one circuit or one multi-core cable/more than one multi-core cable laid directly underground	Values mentioned in Table B-2 to Table B-5 shall be used after applying the reduction factor, for installation method D2
B-19	Reduction factor for one circuit/more than one circuit or one multi-core cable/more than one multi-core cable laid in duct in ground	Values mentioned in Table B-2 to Table B-5 shall be used after applying the reduction factor, for installation method D1
B-20	Reduction factor for group of more than one multi-core cable to be applied to reference current carrying capacities for multi-core cable in free air	Values given in Table B-8 to Table B-13 for reference method E shall be used after applying correction factor
B-21	Reduction factor for group of more than one circuit of single-core cables to be applied to reference current carrying capacities for one circuit of single-core cable in free air	Values given in Table B-8 to Table B-13 for reference method F shall be used after applying reduction factor

NOTE — Refer Tables B -1 to Table B-21 of Annex B

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5.5.4 *Guidelines to Use Tables to assess Required Current Carrying Capacity*

To assess the required current carrying capacity, multiple factors shall be taken into account for calculating the current carrying capacity of particular cross section of conductor. Following steps shall be taken for calculation:

Step 1

Check location

Decide type of wiring – surface/flush to the surface/concealed/underground/in air

Check situation – walls (masonry/wooden,/insulated), flooring (masonry/raised), ceiling, ducts, shafts, voids, ground where wiring is to be installed.

Step 2

Check for the reference method of installation (*see* **5.5.2.1**) or other methods (*see* **5.5.2.2**), for wiring decided (as per step 1) to fit in.

Step 3

Select/decide type of insulation of cable to be used from Table 2. Thermoplastic (PVC)/Thermosetting (XLPE – cross-linked polyethylene/EPR – ethylene propylene rubber)/mineral

NOTES

1 Table 2 gives temperature withstand capacity depending on type of insulation. Wiring system components including cables and wiring accessories shall only be installed or handled at temperatures within the limits stated in the relevant product standard or as given by the manufacturer.

2 In absence of specific instructions from manufacturer, insulation having FR/FRLSH grade shall be treated under thermoplastic category of PVC to consider temperature withstand capacity.

3 In respect of FS cables manufacturer's specifications shall be considered.

Step 4

Check/decide number of cores.

Step 5

Refer Table B-1 to refer current carrying capacities.

Step 6

To apply ambient temperature factor for reference methods A1, A2, B1, B2, C, E, F, G, use Table B-15 and for reference methods D1 and D2, use Table B-15.

Step 7

For reference method D1 and D2, apply correction factor if soil resistivity is other than 2.5 K-m/W (*see* Table B-16**)**.

Step 8

Apply reduction factor depending on the number of circuits from Table B-17 for above ground, Table B-18 for below ground and for duct in ground Table B-19.

Step 9

Apply group reduction factor from applicable table (Table B-20/Table B-21) for reference method of installation E and F as mentioned in Table B-1.

NOTE — If the same circuit (continuous conductor between terminations) passes through different locations requiring different methods of installation (*for example*, part of wiring is in void above false ceiling and part wiring embedded in walls, the lowest current carrying capacity shall be considered.)

5.5.5 *Simplified Method to Assess Current Carrying Capacity*

Alternatively, to assess current carrying capacity of cable, a simplified version is given in Table C-1, Table C-2 and Table C-3 of Annex C.

5.6 Effects of Harmonic Currents

5.6.1 *Neutral Current*

Where the neutral conductor carries current without a corresponding reduction in load of the line conductors, the current flowing in the neutral conductor shall be taken into account while ascertaining the current-carrying capacity of the circuit. The magnitude of neutral current due to third harmonic and further, triplen harmonics causes significant effect on current carrying capacity of the cables in the circuit.

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5.6.2 *Equipment Causing Harmonic Effect*

The equipment likely to cause harmonic current are fluorescent luminaries, LED luminaries, computers, VVVF drives and inverter technology based electrical gadgets.

5.6.3 *Effect of Harmonic Current on Size of Cable*

5.6.3.1 Where the neutral current is likely to be higher than the line current, then, cable size shall be selected on the basis of neutral current.

5.6.3.2 Where the cable size selection is based on a neutral current which is not significantly higher than the line current, it is necessary to reduce the tabulated current-carrying capacity for three loaded conductors.

5.6.3.3 If the neutral current is more than 135 percent of the line current and the cable size is selected on the basis of the neutral current, then the three-line conductors will not be fully loaded. The reduction in heat generated by the line conductors offsets the heat generated by the neutral conductor to the extent that it is not necessary to apply any reduction factor to the current-carrying capacity for three loaded conductors.

5.6.4 *Reduction Factors*

5.6.4.1 In balanced three-phase circuits, harmonic content of neutral currents due to the line currents is not cancelled. Under the circumstances, reduction factors shall be applied. If only two of the three phases are loaded, the neutral conductor carries the harmonic currents in addition to the unbalanced load current. Such a situation can lead to overloading of the neutral conductor.

5.6.4.2 If more than 15 percent of higher harmonics (*for example*, 9th, 15th, etc.) are expected, then, lower reduction factors are applicable. In case of more than 50% unbalance between phases, lower reduction factors may be applicable.

5.6.4.3 The tabulated reduction factors when applied to the current-carrying capacity of a cable with three loaded conductors give the current-carrying capacity of a cable with four loaded conductors where the current in the fourth conductor is due to harmonics. The reduction factors also takes into account the heating effect of the harmonic current in the line conductors.

Table 4 Reduction Factors for Harmonic Currents in Four-core and Five-Core Cables

(*Clause* 5.6.4.3)

Sl No.	Third Harmonic Content of Line Current %	Reduction Factor	
		Size Selection is Based on Line Current	Size Selection is Based on Neutral Current
(1)	(2)	(3)	(4)
1	0-15	1.0	--
2	15-33	0.86	--
3	33-45	--	0.86
4	45	--	1.0

NOTES

1 The triplen harmonic content of the line current is the ratio of the third harmonic and the fundamental (first harmonic), expressed in percent.

2 The reduction factors only apply to cables where the neutral conductor is within a four-core or five-core cable and is of the same material and cross-sectional area as that of line conductors. These reduction factors have been calculated based on triplen harmonic currents.

5.6.5 *Examples of applying Reduction Factors*

Consider a three-phase circuit with a design load of 39 A to be installed using four-core PVC insulated cable clipped to a wall, installation method C.

From Table B-4, a 6 mm^2 cable with copper conductors has a current-carrying capacity of 41A and hence is suitable if harmonics are not present in the circuit.

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Example 1 If 20 percent third harmonic is present, then a reduction factor of 0.86 is applied and the design load becomes:

$$\frac{39}{0.86} = 45A$$

For this load a 10 mm^2 cable is necessary.

Example 2 If 40 percent third harmonic is present; the cable size selection is based on the neutral current which is:

$$39 * 0.4 * 3 = 46.8\ A$$

and a reduction factor of 0.86 is applied, leading to a design load of:

$$\frac{46.8}{0.86} = 54.4A$$

For this load a 10 mm^2 cable is suitable.

Example 3 If 50 percent third harmonic is present; the cable size is again selected on the basis of neutral current which is*:*

$$39 * 0.5 * 3 = 58.5\ A$$

In this case, the reduction factor is 1 and hence, 16 mm^2 cable is required.

NOTES

1 All the above cable selections are based on the current-carrying capacity of the cable, voltage-drop and other aspects of design have not been considered.

2 Also *see* **5.8.4.1** and **5.8.4.2.**

5.7 Voltage Drop in Consumers Installation

The voltage drop between origin of an installation and any load point shall have limitations as given in the Table 5.

Table 5 Voltage Drop Limitation

(*Clause* 5.7)

Sl No.	Type of Installation	Lighting	Other
(1)	(2)	(3)	(4)
i)	A – low voltage installation supplied directly from public low voltage distribution system	3 percent	5 percent
ii)	B – low voltage installation supplied from private LV supply [a]	6 percent	8 percent

[a] It is recommended that voltage drop within final circuits does not exceed those indicated in installation type A.
When the main wiring system of installation is longer than 100 m these voltage drops may be increased by 0.005 percent per meter exceeding 100 m, without this supplement being greater than 0.5 percent.
Voltage drop is determined on the basis of demand by the current using equipment, applying diversity factor where applicable or from the values of the design current of circuits.

NOTES

1 Greater voltage drop may be accepted:

a) for motor during starting period; and

b) for other equipment having high inrush current.

2 Following temporary conditions are excluded:

a) voltage transients, and

b) voltage variation due to abnormal operation.

3 For extra low voltage circuits, it is not necessary to fulfill the voltage drop limits mentioned in this table for uses other than lighting (for example, bell, control, door opening, etc.) provided that it is ensured that the equipment is operating correctly.

5.8 Conductor and Cross-sectional Area

5.8.1 *Conductor*

While selecting conductor for size less than or equal to 16 mm^2, copper conductor of Class 1 or Class 2 is recommended. Over the period of time, loosening of contacts and oxide formation is prominent in Aluminum conductors which may lead to increased generation of heat and sparking.

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NOTE — Loose contacts are major cause heat generation leading to sparking and fire. Under routine maintenance, contacts of lighting circuits in switchboards may not be checked. Under these circumstances to mitigate the possibilities of fire hazard due to loose contacts, copper conductor is recommended.

5.8.2 *Cross-sectional Area*

Cross-sectional areas of conductor shall be selected considering following factors:

a) requirement of maximum current depending on designed/estimated load (including anticipated future requirement) under normal conditions;

b) fault level withstand capacity;

c) allowable voltage-drop[1] (*see* **5.7**);

d) harmonic disturbances (*see* **5.6**); and

(e) current carrying capacity[2] of the conductor under the respective situation and method of installation (*see* **5.5**).

5.8.3 Without prejudice to the above recommendations, the nominal cross section area of phase conductors in a.c. circuits and live conductor in d.c. circuit shall not be less than values specified in Table 6 due to mechanical reasons.

Table 6 Minimum Nominal Cross-Sectional Area of Conductors

(*Clause* 5.8.3)

Sl No.	Type of Wiring	Use of Circuit	Conductor and Cross Section
(1)	(2)	(3)	(4)
i)	Fixed installation cables and insulated conductors	Lighting circuits[1] power outlet[2] 6A	1.5 mm^2 Cu
ii)		Power circuits/,	2.5 mm^2 Cu
iii)		Power outlet[3] 6A	
		Power outlet[4] 16A	
		Appliance[5] < 2 kW	
iv)		Appliance[6] < 3 kW	4.0 mm^2 Cu
v)		Appliance[7] < 6 kW	6.0 mm^2 Cu
vi)		Signaling and controlling circuits	[8]0.5 mm^2 Cu
vii)	Flexible connections with insulated conductors and cables	For specific appliance	Cu (Class 5)
viii)		For any other application	[8]0.5 mm^2 Cu
xi)		Extra low voltage circuits	0.5 mm^2

[1] Maximum looping - 2 boards, subject to load < 1 kW/24 points

[2] Maximum 4 Nos., subject to total load < 1 kW

[3] Maximum 8 Nos., subject to total load < 2 kW

[4] Maximum 2 Nos., subject to total load < 2 kW

[5] 1 No, subject to total load < 2 kW/AC < 1TR

[6] 1 No, subject to total load < 3 kW/AC < 2 TR/3TR (3-PH)

[7] 1 No, subject to total load < 6 kW/AC < 3 TR (1-PH)

[8] In multi-core flexible cables containing 7 or more cores and in signaling control circuits intended for electronic equipment, a minimum nominal cross-sectional area of 0.1 mm^2 is permitted.

5.8.4 *Cross-sectional Area of Neutral Conductor*

5.8.4.1 In single phase circuits with two conductors and in three phase circuit with line conductor up to 16 mm^2 Cu or 25 mm^2 Al or where harmonic distortion is likely and THD is between 15 and 33 percent, cross sectional area of neutral conductor shall be at least equal to the area of line conductor.

---

1) Voltage drop directly correlates with the losses. Energy Conservation Building Code (ECBC) recommends limit for the total power losses, which ranges from 1 percent to 3 percent depending on Super ECBC, ECBC+, ECBC.

2) It shall be noted that for the same cross section of conductor, variation in current carrying capacity is quite large. Typically, it will be seen that under Table C-1, current carrying capacity of 1.5 mm^2 copper conductor varies from 13A to 26A, depending on situation and method of installation.

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5.8.4.2 If THD exceeds 33 percent, cross-sectional area of neutral conductor shall be increased (*see* **5.6**).

5.8.4.3 For poly phase circuits where cross sectional area of line conductor is greater than 16 mm^2 copper or 25 mm^2 aluminum, cross-sectional area of neutral conductor may be lower (but not less than 50 percent) than cross sectional area of the line conductors if following conditions are fulfilled simultaneously:

a) the load carried by the circuit in normal service is balanced between the phases;
b) third harmonics and the odd multiple of third harmonics current do not exceed 15 percent of the line conductor current;
c) the neutral conductor is protected against over currents; and
d) cross sectional area in not less than 16 mm^2 Cu or 25 mm^2 Al.

NOTE — For polyphase circuits, adequate provision shall be provided to operate switching device simultaneously on all phases and neutral to prevent single phasing.

5.8.5 *Cross Sectional Area of Protective Conductor*

Cross sectional area of protective conductor shall not be less than the appropriate value shown in Table 7.

Table 7 Cross Section Area of Protective Conductor

(*Clause* 5.8.5)

Sl No.	Cross section Area of Phase Conductor S mm^2 (Cu)	Minimum Cross Section Area of Protective Conductor mm^2
(1)	(2)	(3)
i)	S<16	S
ii)	16<S<35	16
iii)	S>35	refer 17.2.2.1 of IS 3043

NOTES

1 Applicable for same metal. If different metal is used, it shall have same ampacity. If exact size is not available, nearest next size is chosen.

2 The values shown above are generally applicable. For precise size, 12.2.2.1 of IS 3043 or 5.4.3.1.3 of IS 732 may be referred. It may be economical leading to small cross section compared to phase conductor. For IT and TT system of earthing, compatibility may be verified in consideration with earth fault loop impedance.

5.9 Conduits and Conduit Systems

5.9.1 Conduits shall comply with IS 9537 series of standards and conduit systems shall comply with IS 16205 series of standards. For underground conduits, IS 14930 (Part 2) shall be referred. (*see* **5.9.6**)

5.9.2 *Classification and Coding of Conduits*

The basic function of conduits is to provide mechanical, environmental and fire protection to cabling system. Depending on the characteristics, conduits are classified and coded as in Table 8.

NOTE — For conduits to be buried underground, also refer **5.9.5**.

a) material – metal/insulating/composite;
b) connecting – threadable/non-threadable
c) mechanical properties (stresses) – very light/light (LMS)/medium (MMS)/heavy (HMS)/very heavy;
d) bending – rigid/flexible/pliable/self-recovering;
e) flame propagation – propagating/non-propagating;
f) electrical – insulating/non-insulating;
g) external influences – temperature/ingress of water/corrosion; and
h) solar radiation – unprotected/protected.

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Table 8 Classification Coding for Conduit Systems

(*Clause* 5.9.2)

Sl No.	Digit	Code	Class
(1)	(2)	(3)	(4)
(i)	1st	1	Very light
	Resistance to compression	2	Light
		3	Medium
		4	Heavy
		5	Very heavy
(ii)	2nd	1	Very light
	Resistance to impact	2	Light
		3	Medium
		4	Heavy
		5	Very heavy
(iii)	3rd	1	+5°C
	Lower temperature range	2	-5°C
		3	-15°C
		4	-25°C
		5	-45°C
(iv)	4rd	1	+60°C
	Upper temperature range	2	+90°C
		3	+105°C
		4	+120°C
		5	+150°C
		6	+250°C
		7	+400°C
(v)	5th	1	Rigid
	Resistance to bending	2	Pliable
		3	Pliable/self-recovering
		4	Flexible
(vi)	6th	0	None
	Electrical characteristic	1	Electrically continuous
		2	Electrically insulating
		3	Electrically continuous and insulating
(vii)	7th	3	> 2.5 mm
	Ingress to solid objects	4	> 1.0 mm
		5	Dust protected
		6	Dust tight
(viii)	8th Resistance to ingress of water	0	None
		1	Vertical drops
		2	Drops on conduit @15°
		3	Spray
		4	Splash
		5	Jets
		6	Powerful jets
		7	Temporary immersion
(ix)	9th	1	Low - In and out
	Resistance against corrosion	2	Medium - In and out
		3	Medium-In, High-out
		4	High – In and out

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Table 8 *(Concluded)*

Sl No.	Digit	Code	Class
(1)	(2)	(3)	(4)
(x)	10th	0	None
	Tensile strength	1	Very light
		2	Light
		3	Medium
		4	Heavy
		5	Very heavy
(xi)	11th	1	Non flame propagating
	Resistance to flame propagation	2	Flame propagating
(xii)	12th	0	None
	Suspended load capacity	1	Very light
		2	Light
		3	Medium
		4	Heavy
		5	Very heavy

5.9.3 *Selection of Conduit*

5.9.3.1 Selection of conduit shall be on the basis of suitable characteristics required for protection and management of insulated conductors/cables and survival under respective site conditions, external influences and situation. However, broadly conduits can be divided in to metallic and non-metallic.

5.9.3.2 *Metallic conduits*

Metal conduits provide good mechanical protection. Usually, these conduits are available in Electric Resistance Welded (ERW), Electric Metal Tubing (EMT) and Galvanized. For ERW conduits are welded longitudinally and EMT is seamless. Metal conduits provide increased fire safety as it is does not catch fire and produce toxic smoke. However, metal conduits are susceptible to corrosion. Under moist and humid atmosphere where condensation is likely and also, under chemical zones, decision about its use shall be taken judiciously. Hot dipped Galvanised Conduits are more favourable under corrosive environment.

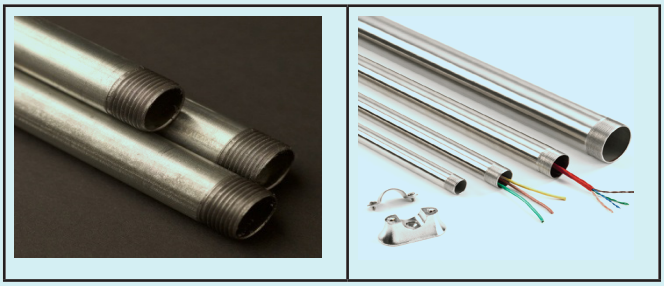


FIG. 6 HOT DIPPED GALVANIZED CONDUIT AND EMT

NOTES

1 For more information, refer Annex D (*see* Annex W of IS 732).

2 In case of requirement of conduit to provide mechanical protection to underground cable, it shall conform to relevant national/ international standards.

5.9.3.3 *PVC conduits*

PVC conduits provide adequate resistance, protection against mechanical impacts and provide additional insulation against corrosion. PVC conduits are cheaper and easier to install. Depending on situation, selection of conduits may be made.

NOTES

1 If quality of two or more options are available, criteria for selection shall include time required for installation, quality of workmanship, labour for required skill and estimated cost and material component. For example, installation of metal conduits requires cutting, bending, threading, requiring specialized skill, workmanship, labour and time.

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2 With advancement in technology, PVC conduits are increasingly replacing metal conduits. However, use of metal conduits is predominant where risk due to mechanical damages is high such as in industrial installation.

5.9.3.4 *Fire prevention, FR/FRLS properties*

Electrical conduit system shall be non-flame propagating. Depending on fire hazard, risks at public gathering places and other sensitive installations, use of PVC conduits with fire retardant/fire retardant with low smoke, halogen, and lead dissipating properties is recommended.

5.9.3.5 *uPVC conduits*

Un-plasticized PVC conduits provide high resistance to corrosion, UV effect and fire. These conduits have smooth surface which helps in drawing of wires. However, the flexibility is relatively less.

NOTE — Conduits shall be comply with the requirements mentioned with IS 9537 (Part 3).

5.9.3.6 *Size of conduit*

Size of conduit shall be decided on the basis of number of cables which can be easily and safely drawn within, without exceeding the limit of temperature rise (*see* Table 2) at full load under normal conditions and under that respective situation. For deciding the size of conduit, inside cross-sectional area of conduit, cross-sectional area of cable/s (calculated from the maximum overall diameter) and number of cables form basis of area to be occupied/ filled by cables. Fill factor shall not exceed values as given below:

a) One cable 53 percent
b) Two cables 31 percent
c) Three or more cables 40 percent

References may be taken from Table D-2 [Refer 7.1 of IS 9537 (Part 2)], Table D-3 [*see* 7.1 of IS 9537(Part 3)] and Table D-4 (*see* 16.1.2 and 16.1.3 of IS 694) given under Annex D.

NOTE — Between pull boxes, for every two deviations in direction of up to 90^0, area of conduit shall be considered less by 15 percent. There shall be no further deviation.

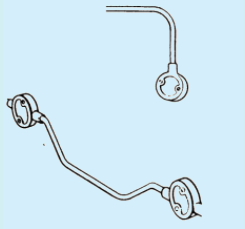


FIG. 7 BENDS IN CONDUITS

Upper part of figure shows 90° bend and lower part of figure shows four bends each of 45° aggregating to 180°.

Example:

To find suitable Heavy PVC conduit for:

Number of cables (stranded): *2*1.5 mm² (1 run)*
2 4.0 mm² (1 run)*
1 1.5 mm² (1 run)*

Number of bends 2 Nos. of 90°

To find Size of conduit:

Cross sectional area of cables from Table D-4 of Annex D

Class 2 - 1.5 mm² - 8.55 mm²

Class 2 - 4.0 mm² - 16.62 mm²

*Fill area = (5*8.55) + (2*16.62)*

= 75.99 mm²

Since number of cables are 7, Fill factor – 40 percent

75.99/0.4 = 189.98 ≈ 190

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Nearest and next cross sectional. area of conduit from Table D-3 of Annex D and since there are 2 bends of 90° area to be reduced by 15 percent

196 mm^2 20 mm conduit

333 mm^2 25 mm conduit

Less 15

196.85 = 166.6 mm^2 - It is less than 190 mm^2*

Next size

333.85 = 283.5 mm^2 - It is more than 190 mm^2.*

So suitable conduit size is 25 mm

5.9.4 *Installation of Conduits*

Installation of conduit systems can be primarily categorized into surface type and concealed type. The choice shall depend on level of planning, aesthetics, cost, maintenance and additions/alteration of installations.

Surface wiring facilitates ease of change. Concealed type wiring suites aesthetic requirements but requires pre-planning and comparatively, costs higher. Clearing fault and carrying out changes in concealed wiring is difficult as compared to surface type wiring. Whether surface type or concealed installation, safety shall be a priority.

NOTE — Installation of conduit systems shall be carried out as per the manufacturer's instructions. After assembling, the installation shall be safe and shall have resistance to external influences with minimum requirement of IP 67.

5.9.4.1 *Conduit layouts*

a) Layouts shall be precisely planned and marked in coordination with other utility services so as to not endanger safety. for example, at sufficient distance from gas pipeline.

b) Depending on layout, sequence of installation activity shall also be in coordination and shall not conflict works related to other utility services.

c) Conduits for wiring systems which are rigidly fixed and concealed in the walls shall run horizontally, vertically or parallel to the room edges. Wiring systems in ceilings or in floors may follow the shortest practical route. Sharp bends shall be avoided. In straight length between two pull-on/junction boxes maximum bends shall not be more than two.

d) When there are several conduits running in parallel, they must be arranged to avoid crossing at the point where they take different directions.

e) Layouts shall take in to consideration the bending radii of cables.

5.9.4.2 *Fixing of conduits*

Fixing of conduit on surface may be done with saddle/saddle with spacer/clips. For spacing between supports (refer Table D-5 of Annex D):

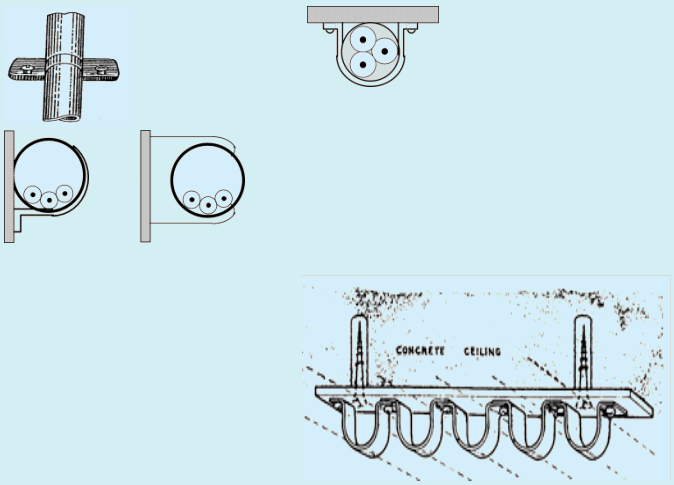


FIG. 8 METHODS OF FIXING CONDUIT WITH CLIP, SADDLE/S, SADDLE AND SPACER

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Screws, clamps/attaching component or joints to conduits shall not cause damage to the insulation of wire. The screws shall be fixed with plugs and shall have adequate length depending on the consistency of the base on which conduits are fixed. On stone walls, fixing may need additional wooden wedges/gutty to hold the screw firmly. In concealed type of wiring in walls, conduits may be fixed with 'U' nails.

5.9.4.3 *Conduit fittings and installation*

Conduit fittings shall comply with requirements of IS 3419. Provision of suitable fittings, junction and/or draw-in boxes shall be checked by inspection.

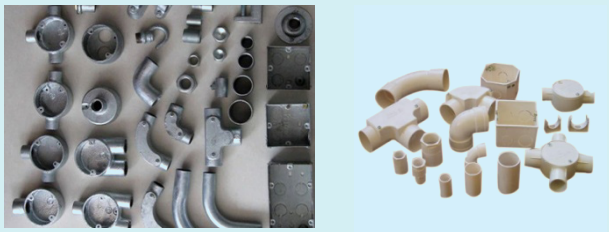


FIG. 9 CONDUIT FITTINGS

Elbows/tees (for use in surface wiring) shall be made at the locations where there are sharp changes in direction, to facilitate drawing of wires. Provision shall be made after every 3 m.

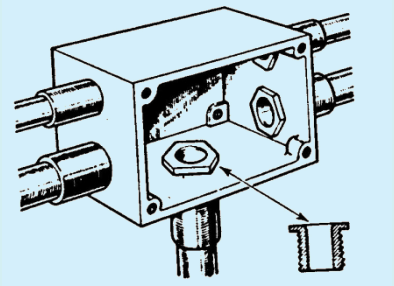


FIG. 10 DRAW IN BOX IN METAL CONDUIT SYSTEM

5.9.4.4 *General points to be observed in installation*

a) Within conduit system, there shall be no sharp edges, burrs or surface projections which may damage insulated conductor/cable or inflict injury to the installer or user.

NOTE — Often burr forms while cutting and threading the conduit and is more significant in case of metal conduits. It shall be carefully removed, and rubber bushes may be used at open ends of the conduits, before drawing of cables so that the insulation is not damaged.

b) *Expansion joints*

At expansion joints of buildings, necessary care shall be taken to use suitable flexible conduit/necessary fittings to sustain anticipated movement to not cause damage to the electrical equipment.

c) *Entry points*

All penetrations/entries through civil work like walls, slabs, floor, roofs etc. shall be sealed such that the planned fire resistance of all elements are not compromised.

d) *Earth continuity in metal conduit system*

To ensure safety in electrical installations, use of metal conduits as earth continuity conductor shall not be permitted in general.

NOTE — If circumstances require conduit system to be used as protective conductor, the system shall be tested after final installation and also, shall be periodically checked to confirm its suitability for purpose.

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e) *Joints in PVC conduit system*

All joints of conduits with fittings and accessories shall be made rigid with the resin/PVC solvent cement as recommended by the manufacturer. Such solvent shall be applied on the portions of conduit/fittings to be joined. Then, such portions shall be pushed in and held for 30 - 60 s as instructed by manufacturer. This part of installation procedure is important from the point of view of required degree of ingress protection (IP).

f) *Joints in Metal conduit system*

To make metal conduit system rigid, fittings with draw-in/inspection boxes shall be secured with check-nuts (*see* Fig. 10). Exposed portion of threading shall be coated with anti-corrosive paint. Sealants shall be applied at all joints as per desired Ingress Protection (IP).

g) *Bending of conduits*

Bending of metal conduits shall be done with proper pipe benders, a tool which allows bending of pipe at right angle/off-set at any required angle (*see* Fig. 11). Pipe bending of PVC conduits shall be done with spring as specified by the manufacturer. A person shall be acquainted with the technique to calculate required lengths of conduits considering expansions/shrinks occurring in conduits due to bending. Typical manual pipe benders for metal conduit and spring for PVC conduit is shown in Fig. 11.



FIG. 11 METAL PIPE BENDER



FIG. 12 PVC CONDUIT BENDING SPRINGS

Bending of conduits requires skill and shall be performed by competent person.

h) *Concealed conduit system in RCC work of slab or other - Conduits*

The conduits shall be fixed to steel with binding wire, especially, at the points of joints. Multiple crossings shall be avoided in the slabs to allow proper concreting thickness.

j) Concealed *conduit system in RCC work of slab or other - Deep junction/draw-in boxes*

Deep junction/draw-in boxes of 65mm depth or as required shall be used, depending on thickness of concreting. They shall be filled with dry sand or stuffed with suitable material and fixed with removable cover, so that the slurry does not enter and block/choke the routes of cabling and stuffed material may later be removed easily.

k) *Concealed conduit system in RCC work of slab or other - at the time of concreting*

Care shall be taken while installing concrete covers so that erected conduit system is not disturbed/ shifted, especially, at joints. Also, while pouring concrete in beams/columns, disturbance may be caused to installed conduit system due to use of vibrators. Hence, supervision and vigil while carrying out the task shall be ensured.

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m) *Concealed conduit system – in walls*

Proper care shall be taken while making chases so as to avoid weakening of walls. Conduits shall be fixed with clamps/U nails or by some other means if necessary. Care shall be taken for installation in internal walls to avoid back to back fixing of boxes and conduits, particularly, in 4 inches walls.

5.9.5 *Conduit System Buried Underground*

Conduit system to be buried in ground shall conform with the requirements specified in IS 16205 (Part 24). Changes with respect to IS 14930 (Part 1) for the conduits to be buried under ground are as under:

a) Multiwall conduit category included for underground use;
b) For Resistance to Impact, there are only two categories – normal duty (N) and light duty (L);
c) Under external influences, resistance to chemical attack is additional; and
d) Minimum inside diameter is nominal outside diameter divided by 1.33.

5.10 Trunking and Ducting System

5.10.1 Trunking/ducting system shall conform to IS 14927. Trunking is meant to provide mechanical, environmental and fire protection at different levels for insulated conductors/cables. These systems are used for surface type wiring.

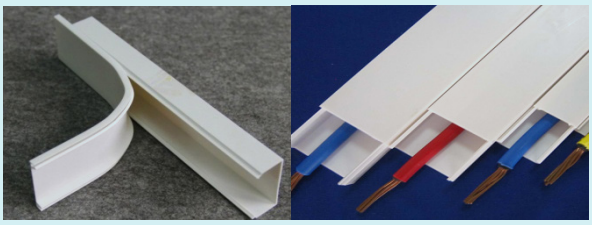


FIG. 13 PVC TRUNKING (CASING CAPPING)

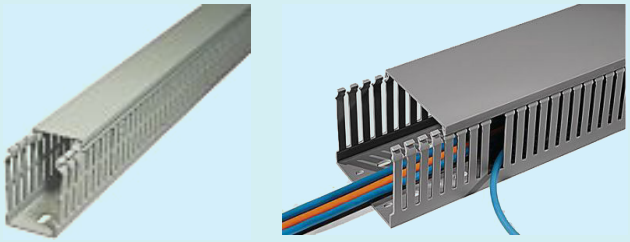


FIG. 14 SLOTTED TRUNKING/DUCTING

5.10.2 *Classification of Trunking/Ducting*

Depending on the characteristics Conduits are classified and coded as below:

a) material – metal/insulating/composite;
b) mechanical properties – very light/light/medium/heavy/very heavy;
c) temperature – states operative temperature range;
d) flame propagation – propagating/non-propagating;
e) electrical – without electrical continuity, with electrical continuity, insulating;
f) external influences – temperature/ingress of solid/water/corrosion;
g) solar radiation – unprotected/low, medium, high protection; and
h) cover retention – cover removable with tools/without tools.

5.10.3 *Fire Prevention*

Trunking and ducting system shall be flame retardant. Depending on fire hazard, risk at public gathering places and other sensitive installations, use of trunking/ducting having fire retardant/fire retardant with low smoke, halogen, and lead emmission properties is recommended.

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5.10.4 *Dimensions*

Table 9 Dimensions of Trunking/Ducting

Sl No.	Size (outer)	Wall Thickness	Approximate Internal Cross Section
	mm	mm	mm^2
(1)	(2)	(3)	(4)
1	12 × 12	1.2	119.5
2	16 × 12	1.2	153.0
3	16 × 16	1.2	196.0
4	25 × 12	1.2	239.1
5	25 × 16	1.2	307.4
6	25 × 25	1.2	510.8
7	38 × 16	1.3	474.4
8	38 × 25	1.3	793.0
9	50 × 16	1.5	611.0
10	50 × 50	1.5	2209
11	75 × 75	1.8	5098
12	100 × 50	1.8	4473
13	100 × 40	2.5	3333
14	200 × 30	2.5	5000
15	225 × 25	1.6	4687
16	225 × 38	1.6	7125
17	250 × 25	1.6	5103
18	250 × 38	1.6	7916
19	300 × 25	1.6	6250
20	300 × 30	2.5	7500
21	300 × 38	1.6	9500

NOTE — The sizes other than those specified in above table are also acceptable within width and height ranging from 12 to 300 mm provided that above width or height of 50 mm, wall thickness shall be at least 1.8 mm for trunking/ducting of insulating material and 1.6 mm for trunking/ducting of metal.

5.10.4 *Construction*

5.10.4.1 Construction shall be such that any surface, edge, screws, stud or other securing device does not damage to conductor or cables.

5.10.4.2 *Fixing*

Trunking/ducting system may be fixed with suitable contact adhesive or mounting device. Fixing screws and small spring clips of insulating trunking fitting need not be of insulating material provided that they do not come into contact with the conductors/In case of any such possibility, fixing may be done with screws, using PVC plugs and shall be so designed to withstand the mechanical stresses occurring during installing and normal use.

5.10.4.3 *Segregation*

If there is provision of segregation of circuits, the same shall be adequately secured.

5.10.4.4 *Accessible metal parts of system components which are liable to become alive in event of failure of insulation, shall have provision to connect with earth.*

5.11 Cable Tray/Ladder System

5.11.1 *Applicability/Use*

Cable tray/ladder system is an assembly of units or sections along with associated fittings forming a structural system used to securely fasten or support cables and may also include Raceways. It is one of the efficient cable

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management tools where routing of large quantum of cables are to be handled. This system can be used both for power and LV systems such as communication, data, control and signaling. It helps in ruling out possibility of disorganized mass of cables which may become difficult to trace at times. This system carries cables mostly in open state, hence, is advantageous for thermal management. In high-rise buildings, it can be one of the most suitable options suited for vertical distribution through shafts/ducts.

NOTE — Since cable ladder/Tray system is not fully enclosed, it does not offer complete mechanical and environmental protection. Therefore, this system is suitable for sheathed and armoured cables. Single insulated cables shall not be installed on system.

5.11.2 *Conformity with Standards*

It shall conform to IS/IEC 61537 series of standards.

5.11.3 *Structure*



FIG. 15 CABLE LADDER, TRAY SYSTEM

The ladder/cable tray has two side rails connected by cross members or rungs. The rungs provide convenient anchors for tying down the cables. A trough cable tray is a prefabricated structure consisting of a ventilated bottom with side rails. The ventilated trough cable tray supports cables better than the ladder type.

NOTE — Cable tray and ladder system is designed for use as support for cable. It is not an enclosure for providing mechanical protection. It is not intended to be used as support for a person working. Trying so may damage the system and cause injury to person.

5.11.4 *Material and Types*

These are available in wide variety of sizes, styles and material – metal/non-metal (*for example*, hot-dip galvanized, zinc electroplated, epoxy powder coated, fiber optic, GRP, FRP). Selection can be made on the basis of mechanical properties, effects of external influences. Fiber-optic cable installations are installed with solid-bottom cable trays as the drooping of fiber-optic cables may degrade system performance. Also, selection of solid-bottom trays reduces sensitivity to electromagnetic/radio-frequency interference and/or circuit sensitivity.

NOTE — Corrosion in metallic cable ladder/Tray system may occur due to climatic conditions, pollution or chemical environment. It is very difficult to repair such damages. Hence, it is most important that appropriate material is selected.

5.11.5 *Construction*

5.11.5.1 *Structural design aspects*

Construction of cable ladders/trays shall be done considering full load conditions. Distance between supports/ span may be decided depending on load pattern. Proper structural analysis shall be made considering horizontal beam structure, vertical column supports and brackets fixed on walls/vertical surfaces as eccentric load. Design may be approved by Structural Engineer. For supports, safe working load data may be called from the manufacturer.

NOTE — IS/IEC 61537 states that manufacturer shall declare SWL (safe working load) details of the product.

5.11.5.2 *Allowable deflection*

Allowable deflection of cable ladder/tray along the length and deflection of supports shall be restricted within limit as mentioned in IS/IEC 61537.

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5.11.5.3 *Bending radii*

There shall be correlation between bending radii of cable and radius of cable ladder/tray fittings and shall not be less than minimum bending radius of largest size of cable.

5.11.5.4 *Expansion joints*

Provision shall be made for the cable and the cable ladder/tray system to expand and contract by providing expansion joints and loops of cable at these points.

5.11.6 *Electrical Continuity*

Metallic/electrically conductive cable ladder/tray system shall retain adequate electrical continuity to ensure equi-potential bonding and connection to earth.

5.11.7 *Electromagnetic Compatibility*

Cable ladder/tray system do not support electromagnetic influences. However installation of current carrying cable may cause electromagnetic effects. This may cause disturbance in data networking cables. Necessary precautions may be taken as recommended in EN 50174-2.

5.11.8 *Fastening of Cables*

Cables shall be fastened to ladder/tray with correct size cable ties/cleats or suitable fixture so as to sustain electro mechanical effects.

5.11.9 *Segregation*

See **5.16** and **5.17**

5.12 Cable Duct/Channel System

5.12.1 *Application/Use*

This is enclosed system of metallic/non-metallic material to provide protection for cables against external influences. Depending on situation, selection of system – metallic or non- metallic and installation method – concealed type or surface type shall be made. Typical methods of installation can be seen under Table A-3 of Annex A.

5.13 Installation of Wires/Cables

While installing, following shall be checked:

a) where the wiring system is designed to be withdrawable, there shall be adequate means of access for drawing cable in or out;

b) if wiring system is designed to be buried in the structure, a conduit or cable ducting system for each circuit shall be completely erected before cable is drawn in;

c) radius of every bend in a wiring system shall be such that conductors and cables shall incur damage;

d) where a conductor or a cable is not continuously supported and is supported by suitable means at appropriate intervals, it shall be supported such that the conductor or cable does not suffer damage by its own weight;

e) cables or conductor used as fixed wiring shall be supported in such a way that they are not exposed to undue mechanical strain and there is no appreciable mechanical strain on the terminations of the conductors, taking into account the mechanical strain imposed by the weight of the cable or conductor on itself;

f) the conduits/trays, ladders, ducts, channels, raceways from where cables are to be pulled are cleared of burrs and sharp edges and shall be covered properly;

g) flexible wiring system shall be installed so that excessive tensile and torsion stresses to the conductors and connections are avoided; and

h) to facilitate pulling of heavy cables, provision of cable pulling equipment/tools shall be made.

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FIG. 16 CABLE PULLING TOOLS

j) data cables, OFCs and other LV system cables having similar mechanical properties shall be handled and installed with special care. Selection and fixing of Cable ties shall be such that it does not damage the cable (*for example*, thin ties or very tightly fastened tie may pierce through the shield of cable).

k) continuity of protective conductor shall not depend on its intermediate connections with enclosures/ system of wiring enclosures, equipment or armouring.

5.13.1 *Insulation of Wires/Cables*

During installation of wires/cables in any type of system/method, utmost care shall be taken to prevent damages to insulation. Bush shall be provided on open end of conduit at the time of drawing of wires. Twisting and bending is within permissible limits provided there is no risk at the time of installation and possibilities in future of External Influences which may affect insulation properties.

5.13.2 *Number of Wires/Cables*

Number of wires/cables shall be restricted within the allowable fill factor/space factor specified for the respective system.

5.13.3 *Spacing Between Cables*

Care shall be taken to install and maintain design conditions related to spacing on based current carrying capacity of cables.

5.13.4 *Colour Coding*

For identification of cables and conductors, IS 11353 gives guidance on uniform system of marking and identification of conductors and apparatus terminals (*see* Table E-1 under Annex E).

5.13.4.1 Every single core non-flexible cable and every core of twin or multicore non-flexible cable used as fixed wiring shall be identifiable throughout its length.

5.13.4.2 In case of Mineral insulated (MI) cables and bare conductors, colour sleeves may be used.

5.13.4.3 Colour coding of fixed wiring cables applies to all wiring up to the final distribution board and also, for circuit wiring, except red colored wire may be used for any phase.

5.13.4.4 For lighting, red wire shall be used from the switch to the lighting point.

5.13.4.5 For flexible cables and cords the distinctive colours are not same as those for fixed wiring. The colours for core identification are given in Table E-2 under Annex E.

5.13.5 *Electro Magnetic Effects*

Single-core cables armoured with steel wire or tape shall not be used for a.c. circuits. Conductors of a.c. circuits installed in ferromagnetic enclosure shall be arranged so that the conductors of all phases and the neutral conductor (if any) and the appropriate protective conductor of each circuit are contained in the same enclosure. Where such conductors enter ferrous enclosure, they shall be arranged so that the conductors are not individually surrounded by a ferrous material, or provision shall be made to prevent eddy (induced) currents (*also see* **5.11.7**).

5.13.6 *Electro Mechanical Effects*

Under fault conditions, excessive current flowing through cable can last fraction of seconds to few seconds. Such currents create high magnetic field which can interact to produce large mechanical forces, causing displacement

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and may lead to damaging of cable. Under such circumstances, proper type of fixtures help in transfer of these forces to the base. Such fixture shall also not cause damage to the cable.

5.13.7 *Connections and Termination of Wires*

It shall be ensured that the size of conductor and termination match properly. For all connections between conductors and connections between a conductor and terminal of electrical accessory, equipment shall provide:

a) durable electrical continuity by making connections sufficiently tight so that no charring or hot spot could be created;

b) all strands are properly inserted in terminal, where necessary use of appropriate type of lugs and metal (copper/aluminium/bimetal) is made;



FIG. 17 CABLE LUGS



FIG. 18 CABLE GLANDS

c) adequate mechanical strength so that weight of cable does not put strain on terminals. Where necessary, clamps shall be provided and appropriate type of glands shall be used;

d) temperature attained by terminal shall be within permissible range so that the effectiveness of the insulation of the conductors connected to them is not impaired; and

e) connections and terminations are done in suitable enclosures providing adequate mechanical protection and protection against external influences.

5.14 Fire Prevention – Lifesaving and Restricting Damages to the Property

5.14.1 *Selection of Wires (FR/FRLSH/HFFR)*

Selection of wires play an important role to address fire hazard risk. The degree of hazard depends upon the type of premises, its usage, occupancy etc. In order to prevent flame propagation during fire accident, wires/cables shall be of class FR/FRLSH/HFFR. Design of electrical installation shall recommend appropriate type and class of wire considering the following characteristics:

a) non propagation of flame – self-extinguishing;

b) low generation of smoke as it impairs visibility during fire; and

c) low or zero halogen as it causes toxic fumes/smoke which affects respiration system leading to suffocation and endangers life. Also, formation of acids leads to adverse effects on metal structures including steel embedded in concrete.

5.14.2 *Selection of Wires: FS – Circuit Integrity*

In addition to properties like low emission of smoke and corrosive gasses, FS cables are designed to withstand high temperatures. Use of FS cables shall, therefore, be made where integrity of electric supply is important especially to save human life and where electric supply is required for evacuation operation during the fire instances. These cables are designed to withstand temperatures from 650^0C to 950^0C and for period upto 180 min along with additional protection against mechanical shock and water splash. Categorized for Fire Survival is given in Table 10A.

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Table-10A Fire Survival Categories

(*Clause* 5.14.2)

NOTE — For more details, refer 3.5 of IS 17505 (Part 1) : 2020.

S. No.	Parameter	Functionality	Symbol
(1)	(2)	(3)	(4)
a)	Resistance to fire alone	950°C for 180 min	Symbol F
b)	Resistance to fire and water	650°C for 15 min followed by 5 bursts for water	Symbol W
c)	Resistance to fire and mechanical shock	950°C for 15 min along with 3 mechanical impacts	Symbol S
	Resistance to fire, water and shock	Category F3/F30/F60/F120 as below	Symbol FWS
Category F 3	Resistance to fire, resistance to fire with water, resistance to fire with mechanical shock, assessed separately when tested in accordance to **E-7.3**, **E-7.4** and **E-7.5** from Annex E of IS 17505 (Part 1) respectively.		
Category F 30	Resistance to fire with direct mechanical impact and water jet assessed in combination, when tested in accordance to Annex E for 30 min		
Category F 60	Resistance to fire with direct mechanical impact and water jet assessed in combination, when tested in accordance to Annex E for 60 min		
Category F 120	Resistance to fire with direct mechanical impact and water jet assessed in combination, when tested in accordance to Annex E for 120 min		

IS 17505 (Part 1) specifies its applicability for various purposes as given below:

Table-10B Application of FS cable

(*Clause* 5.14.2)

NOTE – For more details, refer Annex A of IS 17505(Part 1) : 2020.

Sl No.	System Description	Cable Fire Rating Required (°C)	Time for which System should Withstand (Minutes)
(1)	(2)	(3)	(4)
i)	Fire pumps	FS (950/FWS)	180
ii)	Pressurization	FS (950/FWS)	180
iii)	Smoke venting including its ancillary systems, such as dampers and actuators	950	60
iv)	Fire-fighting shaft (staircase, lift, lift lobby)	FS (950/FWS)	180
v)	Fireman's lifts (including all lifts)	FS (950/FWS)	180
vi)	Exit signage lighting	950	120
vii)	Emergency lighting	950	120
viii)	Fire alarm system		
	a) Conventional (zone-based system)	650	60
	b) Intelligent addressable system	650	60
ix)	Public address (PA)system (related to emergency voice evacuation and annunciation)	650	60
x)	Magnetic door hold-open devices	650	60
xi)	Lighting in fire command center and security room	FS (950/FWS)	180

NOTE — Above recommendations shall not be taken as limited to and may also include installations of high importance involving security of occupants and assets. Such wires are intended to withstand high temperature for the required time period and retain integrity of supply to serve emergencies/critical services.

5.14.3 *Spread of Fire*

Where a wiring system such as conduit, cable ducting, cable trunking, bus-bar trunking etc. penetrates through elements of building construction such as floors, walls, roofs, ceilings, partitions or cavity barriers, the voids/ openings left after installation of the wiring system shall be sealed according to the degree of fire resistance

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required for the element concerned. A part of a wiring system complying with the requirements of the relevant Indian Standard where testing for resistance to the propagation of flame is not mentioned such system shall be completely enclosed in non-combustible building material having the ignitability characteristic 'P'.

5.15 Underground Cable Work

5.15.1 *Depth of Cables*

Cables, conduits or ducts that are buried in the ground shall be laid with minimum depth of 750 mm or 1 000 mm for road crossing as per IS 1255 to assure protection against mechanical damage/impact.

NOTES

1 Depth shall be measured between finished ground level/surface and top edge of circumference of cable laid underground.

2 The depth mentioned is for LT and control cables

5.15.2 *Method of Construction*

Cable shall be laid on bedding of minimum 75 mm riddled soil or sand at bottom of trench and covered with additional riddled soil or sand of 75 mm and further, shall be covered with bricks/tiles/half round RCC pipes to provide mechanical protection. Cables across the roads/railway tracks shall be laid through ducts/conduits of sufficient mechanical strength.

NOTE — Based on environmental aspects, scarcity of sand and local restriction on use of sand, riddled soil shall be used.

5.15.3 *Identification and Route Marking*

Buried cables shall be marked by cable covers or a suitable marking tape along with an indicator above ground showing route and voltage level so that buried conduits/ducts are identifiable during excavation.

5.15.4 Cable supports and enclosures intended to provide mechanical protection shall not have sharp edges liable to damage the cable or insulation of conductor. Such enclosure shall have minimum 1.5 times internal diameter with respect to diameter of cable and shall be capable to sustain load exerted by external situation of the vehicular traffic when laid across the road.

5.15.5 *Clearances*

Clearances between cables (*for example*, power, telecommunication, data/IT related, internet etc.) shall be as mentioned in Table 11 or as per the respective service or standard, whichever is higher (*see* **5.16**, **5.17, 5.18**).

Table 11 Clearances for Underground Cables

(*Clause* 5.15.5)

Sl No.	Category of Cable/Service	Clearance
(1)	(2)	(3)
i)	Power cable to power cable	Not specific but shall suite de-rating factor
ii)	Power cable to control cable	200 mm
iii)	Power cable to communication cable	300 mm
iv)	Power cable to gas/water main	300 mm
NOTE — Inductive influence of power cable on sensitive control cable shall be checked		

5.16 Proximity to Other Services - Electrical

5.16.1 *Precaution in respect of Circuits of different Voltage Levels*

An extra-low voltage (Band I) SELV/PELV and/or a low voltage (Band II) circuit shall not be contained within the same wiring system of nominal voltage exceeding that of low voltage. Unless every cable is insulated for the highest voltage present, one of the following methods shall be adopted:

a) each conductor in a multicore cable is insulated for the highest voltage present in the cable, or is enclosed within an earthed metallic screen of current-carrying capacity equivalent to that of the largest conductor enclosed within the screen, or

b) the cables are insulated for the respective system voltages and installed in a separate compartment of a cable ducting or cable trunking system or have an earthed metallic covering.

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NOTES

1 IS 12360 defines voltage bands for a.c. Band I voltage is up to 50 V between line and earth, line to line, between phases or isolated earth, on the same line. Band II voltage is above 50V up to 600 V between line and earth, up to 1 000V line to line/isolated earth.

2 For d.c., Band I voltage is up to 120V between pole and earth, pole to pole/isolated earth, on the same line Band II voltage is above 120 V up to 600 V between pole and earth, up to 1 000 V between pole to pole/isolated earth.

5.16.2 A low voltage circuit shall be separated from an extra-low voltage circuit.

5.16.3 Where an installation comprises circuits for fire-alarm or emergency lighting systems as well as circuits operating at low voltage and connected directly to a mains supply system, appropriate precautions shall be taken to prevent electrical contact between the cables of the various types of circuit.

5.16.4 Fire alarm and emergency lighting circuits shall be segregated from all other cables and from each other.

5.16.5 Where a common conduit, trunking, duct or ducting is used to contain cables of category 1 and category 2 circuits, all cables of category 1 circuits shall be effectively partitioned from the cables of category 2 circuits, or alternatively the latter cables shall be insulated for the highest voltage present in the category 1 circuits (*see also* **5.16.8**).

5.16.6 Where a category 3 circuit is installed in a channel or trunking containing a circuit of any other category, the circuits shall be segregated by a continuous partition such that the specified integrity of the category 3 circuit is not reduced. Partitions shall also be provided at any common outlets in a trunking system accommodating a category 3 circuit and a circuit of another category. Where mineral-insulated cable, or cable whose performance complies with appropriate Indian Standard to maintain circuit integrity under fire conditions is used for the category 3 circuit, such a partition is not normally required.

5.16.7 In conduit, duct, ducting or trunking systems where controls or outlets for category l and category 2 circuits are mounted in or on a common box, switch plate or block, the cables and connections of the two categories of circuit shall be segregated by a partition which shall be earthed, if metallic.

5.16.8 Where cores of a category 1 and a category 2 circuit are contained in a common multicore cable, flexible cable or flexible cord, the cores of the category 2 circuit shall be insulated individually or collectively as a group, for the highest voltage present in the category 1 circuit, or alternatively shall be separated from the cores of the category 1 circuit by an earthed metal screen of equivalent current-carrying capacity to that of the cores of the category 1 circuit. Where terminations of the two categories of circuit are mounted in or on a common box, switch-plate, or block, they shall be segregated in accordance with **5.16.7**.

5.16.9 *Telecommunication Cables*

In event of crossing or proximity of underground telecommunication cables and underground power cables, minimum clearance of 100 mm shall be maintained or following shall be fulfilled:

a) a fire retardant partition shall be provided between cables such as bricks, cable protecting caps (clay/ concrete), shaped blocks (concrete), or additional protection provided by cable conduit or troughs shall be made of fire retardant material; or

b) mechanical protection between the crossing cables shall be provided through cable conduit, concrete cable protecting caps or shaped blocks.

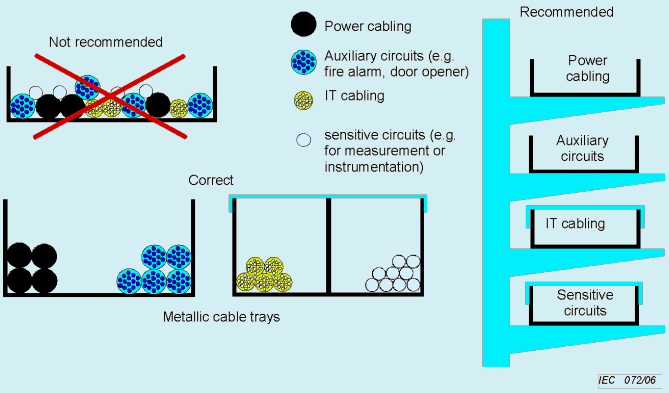


FIG. 19 SEPARATION OF CABLES IN WIRING SYSTEMS

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5.16.10 *IT Networking/Data Cables*

Where power and data cables are installed within the same containment system or within close proximity to each other, suitable segregation shall be used. For guidance on segregation, refer EN 50174-1 : 2018.

NOTES

1 Category 1 Circuit — A circuit (other than a fire alarm or emergency lighting circuit) operating at low voltage and supplied directly from a mains supply system.

2 Category 2 Circuit — With the exception of fire alarm and emergency lighting circuits, any circuit for telecommunication (for example, radio, telephone, sound distribution, intruder alarm, bell, call and data transmission circuits) which is supplied from a safety source.

3 Category 3 Circuit — A fire alarm circuit or an emergency lighting circuit.

5.17 Proximity to Other Services – Non-Electrical

5.17.1 Where a wiring system is located in close proximity to a non-electrical service following conditions both shall be met:

a) the wiring system shall be suitably protected against the hazards likely to arise from the presence of the other service in normal use; and

b) protection against indirect contact shall be provided.

5.17.2 A wiring system shall not be installed in the vicinity of a service which produces heat, smoke or fume likely to be detrimental to the wiring, unless protected from harmful effects by shielding arrangement so as not to affect the dissipation of heat from the wiring.

5.17.3 Where a wiring system is routed near a service liable to cause condensation (such as water, steam or gas service), precautions shall be taken to protect the wiring system from deleterious effects.

5.17.4 Where a wiring system is to be installed in proximity to a non-electrical service it shall be so arranged that any foreseeable operation carried out on either service does not cause damage to the other.

5.17.5 Any metal sheath or armour of a cable operating at low voltage or metal conduit, duct, ducting and trunking or bare protective conductor associated with the cable which might make contact with fixed metalwork of other services shall be either segregated or bonded to it.

5.18 Electrical Installation for Lifts and Escalators

Electrical Installation for Lifts shall conform to IS 1466 (Part 2) and for escalators shall conform to IS 4591 along with the statutory requirements mandated by respective state/UT.

NOTES

1 Scope is limited to provision of point of supply to lift machine related equipment and illumination with power outlet at every floor level in lift shaft.

2 'Lift' and 'Elevator' shall be treated as synonymous.

5.18.1 *Size and Type of Electrical Supply Cables*

Cables used for electric supply points for light and power outlet within lift shaft shall be armoured. Size shall be as specified in the manufacturer's requirement and Lift Rules but shall not be less than 2.5 mm^2.

5.18.2 *Fire Protection*

For lifts, cables used for electrical supply points (light and power outlet) in the lift shaft shall be of appropriate category of FS type as per IS 17505(Part 1).

5.18.3 *Circuits*

The electric supply for the lifts shall be separate from other building services, shall have separate circuits from the main switchrooms and shall be taken through armoured cables separately through respective lift shafts. The route of the armoured cable shall be safe from fire. Further there shall be separate cables for power supply and lighting from meter room to machine room and shall have independent protection. (Specific rules of respective state shall be adhered to).

5.18.4 *Cable Routes*

Both power cable for machine equipment and lighting load (light and power outlet points at each floor) cable shall be routed through lift shaft to the machine location first. Supply to the system of both cables shall be controlled

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from the location of machine in such a way that cable providing supply return through shaft for light and power outlets.

NOTE — Lift shaft shall not be used for electrical installation of any other service.

5.18.5 *Lighting*

Machine room and all other rooms containing lift equipment should be provided with adequate illumination with lux level not less than 200 and with a switch fixed adjacent to the entrance. At least, one socket outlet suitable for hand lamp or tools should be provided in each room.

6 DESIGN AND INSTALLATION OF ELECTRICAL DISTRIBUTION

To avail safety, ease of operation, trouble free service, power quality and redundancy of electric supply, appropriate sectionalizing of electrical distribution from point of source of supply to utility points is absolutely necessary. Following points provide guidance in this regard.

6.1 Single Line Diagram (SLD)

It is an important tool and basic requirement in electrical design to coordinate various components of distribution system of wiring installation for satisfactory and safe working. It also helps to trace faults, plan carrying out modifications, additions and alteration in the existing installation. Therefore, it shall form inherent part of documentation of any electrical installation to be possessed by owner and maintained as a record. It shall be duty of electrical contractor to display the diagram at respective distribution location and handover the drawings to the user/owner for his record.

6.1.1 *Sequence of Preparation of SLD*

It is always convenient to start preparation of SLD from the utility points and ending to main supply source. This facilitates deciding capacities of different components.

6.1.2 *Components of SLD*

SLD shall show following components starting from point of supply as per applicability:

a) Main control switch at point of supply;
b) Main distribution panel/DB;
c) Mains;
d) Sub-distribution switchboard;
e) Sub-mains;
f) Distribution and sub-distribution Boards (DB);
g) Circuit mains/branch circuit; and
h) Switch board controlling outlet points.

6.1.3 *Details of Components - Ratings and Specifications*

Switch Board-	Total Number of points and load
	(*for example*, 10 points of 240 W each)
Circuit main-	Size and number of conductors in mm^2
	(*for example*, 2 × 2.5 + 1 × 2.5 Earth/CPC)
DB-	Single (SP)/three phase (TP) and ways
	Power/Lighting
	MCB B/C/D, No. of poles and Amp
	RCD- Poles, Amp, sensitivity mA

for example, 8-way SPN LDB

1 No. 16A DPMCB B series in coming

5 Nos. 6A SPMCBs B series outgoing

2 Nos. spare ways

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Load on each circuit

Total load on DB

Sub-main- Size and number of conductors

for example, 2 × 4.0 + 1 × 4 Earth

Control switch- SP/TP and ways

MCB B/C/D, No. of poles and Amp

32A DP MCB B series

Mains- Size and number of conductors

for example, 4 × 6.0 + 1 × 6.0 Earth

Main switch- No. of poles, Amp B/C/D

for example, 32A TPN C series MCB

6.1.4 *Identification/Numbering*

Alphanumeric Identification shall be assigned and shall be explicitly shown on SLD for:

a) Switch-boards;
b) Distribution boxes;
c) Circuit-mains, sub-mains, mains; and
d) Electrical panel boards and switchgears on SLD.

6.2 Labeling/Tagging and Traceability

6.2.1 It is important to label the components of wiring installation with the appropriate Identification assigned to them as per SLD (*see* **6.1.3**).

6.2.2 This step shall be executed in such a way that all points of distribution system could be traced with incoming source and outgoing destination. *For example*, within switch board of point wiring, circuit numbers shall be labeled indicating circuit feeding supply to the switch-board etc.

6.2.3 The step shall be completed before the installation is handed over for use.

6.3 Point Wiring – Lighting and Power

6.3.1 *Scope*

6.3.1.1 *Lighting*

Part of wiring starting from Switch-Board (including switch-board and accessory) and terminating into outlet accessory of utility point like lamp-holder, ceiling-rose, plug-outlet up to 6 A capacity is generally treated as point wiring for lighting.

NOTE — For the purpose of lighting fixtures, point wiring may be extended from one outlet to required number of outlets as per design but termination/extension must be through an appropriate accessory.

6.3.1.2 *Power*

Final circuit starting from DB feeding supply to power outlet of 16 A plug socket is generally treated as power point.

6.3.2 *Size of Wires*

Size of wires shall not be less than 1.5 mm^2 copper for lighting and 2.5 mm^2 for power (s*ee* Table 6). This includes earth wire wherever mandatory (*see* **6.3.3**).

6.3.3 *Provision of Earth/Protective Conductor*

Proviso under Regulation 41(XIV) of CEA Safety Regulations 2010 gives relaxation from providing earth for apparatus consisting of wall tubes, light-brackets, ceiling-fans etc. It also excludes hand-lamps or portable apparatus unless provided with earth terminal and class-II apparatus/appliance having voltage less than 250 V.

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NOTE — If earth terminal is provided on the apparatus/appliance by the manufacturer, provision of suitable accessory to terminate protective conductor shall be made.

6.3.4 *Switch Boards*

6.3.4.1 *Load on switch-board-lighting*

Considering that not more than one circuit shall feed supply to switchboards, the total load of number of light, fan, 6 A plug outlets shall not exceed 30percent of the maximum current carrying capacity of the circuit main as per **5.5** and Annex C or 1 000 W or 24 points**,** whichever reaches its limit first.

Table **12** may be referred for assessing load on a lighting switch-board.

Table 12 Determination of Load of Lighting Points

(*Clause* 6.3.4.1)

Sl No.	Connected Device on the outlet of point wiring	Load consideration
(1)	(2)	(3)
i)	Light point	50 W
ii)	Fan point	75 W
iii)	Power outlet 6A	100 W

NOTES

1 Conventional light point includes incandescent lamps/Tube light with ballast of any types. For energy saving LED or equivalent, lesser wattage may be considered. In non-residential establishments where series of lights are controlled by single switch, actual load shall be taken into consideration.

2 Fan shall include all types and sweeps.

3 If actual rating of appliance is known, it may be taken into consideration subject to envisaged changes.

6.3.4.2 *Load on switch-board – power*

Table 13 gives general guidelines for power load calculation. It may be considered as envisaged minimum load of appliance. However, where an appliance of higher power rating is to be connected, actual rating shall be considered.

Table 13 Determination of Load of Power Points

(*Clause* 6.3.4.2)

Sl No.	Commonly Connected Devices on the Outlet of Power Point	Load Consideration in W
(1)	(2)	(3)
1)	Bathroom	
	a) Storage type water heater	2000
	b) Instant hot water geyser	3000
2)	Dry balcony	
	a) Washing machine	2000
	b) Dish washer	1500
3)	Kitchen	
	a) Electric hot plate	2000
	b) Induction hot plate	2000
	c) Electric oven	2000
	d) Microwave	2000
	e) Mixer/grinder	500
	f) Fridge	500
	g) Toaster/kettle	800

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Table 13 (*Concluded*)

Sl No.	Commonly Connected Devices on the Outlet of Power Point	Load Consideration in W
(1)	(2)	(3)
	h) Air Fryer	1500
	j) Kitchen exhaust hood	700/1000
4)	Other	
	a) A.C. 1TR/1.5 TR/2 TR	1250/1500/2000
	b) Room heater	1000
	c) Computer	150
	d) TV	100
	e) Iron	800
	f) EV charging	1000-3300[1)]

[1)] Actual requirement may be checked with OEM.

6.3.4.3 *Connections within switch-board*

Following points shall be observed while making connections within switch boards:

a) Switches shall be provided on line conductor/phase wires only;
b) Supply of line conductor to the plug socket on board shall be given through switch and right side terminal (seen from front) as per convention and neutral shall be connected left terminal directly;
c) Care shall be taken so that neutral doesn't isolate at places, other than two pole switch (SPN) which operates simultaneously on both terminals;
d) No part of exposed live part of conductor, solid or stranded (stripped off insulation) shall remain open outside the area of terminal;
e) Cross sectional area of conductor used for inter connections within board shall not be less than cross sectional area of circuit mains; and
f) Within switch-board, there shall not be any joints except at terminals.

6.3.4.4 *Labeling*

See **6.2**

6.4 Circuit Mains Final/Sub-circuit

Circuit from DB protected by over-current and short circuit protective devices, feeding supply to current using appliances and power outlets, directly or through branches and without any further disconnecting arrangement by fuse/MCB (*for example*, cables providing supply to switch-board from DB etc.)

6.4.1 *Lighting Load Circuits – Residential Premises*

For the purpose of convenience and redundancy, it is recommended that there shall be separate/independent circuit/s of lighting load for:

a) all rooms with door where entry can be restricted (attached balcony/terrace may be included);
b) common areas like passage, verandah; and
c) Toilets.

Switch board providing supply exclusively for plug outlets may be provided with separate circuit.

6.4.2 *Lighting Load Circuits – Non-residential Premises*

Circuit design of non-residential premises may be done considering following factors:

a) enclosed area considering access;
b) maximum allowable load to suite the assessed current carrying capacity of circuit mains;
c) utility - light/fan/power outlets; and
d) routes – ceiling/false ceiling, walls/partitions/under floor raceways.

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6.4.3 *Power Load Circuits – Residential Premises*

There shall be separate circuit for each area as mentioned in **6.4.1.** For all air-conditioners and water heaters, there shall be provision of independent circuit. Load on one single power circuit shall not exceed 3kW and number of 16A power outlets shall not be more than two (*for example,* for an equipment with load 3kW such as instant hot water geyser is connected on a power outlet, there shall not be second power out let on the same circuit).

6.4.4 *Power Load Circuits – Non-residential Premises*

Design of circuits shall be depend on premise area (a circuit shall not enter in to premises area for which entrance is through another door/area). Other factors to be considered shall include load of appliance/equipment, supply redundancy with minimum outage in case of fault etc.

6.4.5 *Essential Loads - Emergency Supply UPS/Inverter*

Essential loads shall be sorted and such circuits shall be bifurcated to avail standby source of supply. Depending on necessity further categorization and sorting shall be done for required back-up time period. *See* Table G-1 under Annex G.

6.5 Mains and Sub-mains

6.5.1 *Load Diversity/Simultaneous Demand*

Size of conductor shall depend on the installed load and its diversity/simultaneous demand. For general guidelines, Table F-1 of Annex F may be referred to assess simultaneous demand.

6.5.2 *Type of Load – Inductive/Resistive*

Depending on type of load and the power factor, VA shall be considered to assess required current carrying capacity.

6.5.3 *Cross Sectional Area*

Cross sectional area shall be worked out as per the guidelines under **5.5** to **5.8.**

6.5.4 *Ring Circuits*

For availing supply redundancy use of ring circuit may be made with appropriate protection and due precaution of particular phase.

6.5.5 *Balancing the Load*

In single phase distribution, care shall be taken to optimize the load balance on three phases to avoid neutral current.

6.5.6 *Terminations*

While terminating care shall be taken that no part of conductor core (solid/stranded) shall escape outside the cross section of terminal. Generally, conductors up to 32A current carrying capacity do not need special preparation (leads soldering/lug crimping). However, if conductor is considered to carry current above 32A, its terminating leads shall be specially prepared.

6.5.7 *Battery Based Inverter/UPS Wiring*

While installing UPS/Inverter, it shall be provided with back-feed protection as per IS 16242-1 : 2014/IEC 62040-1 : 2008 and following points shall be observed.

i) There shall be provision of two pole transfer switch (preferably, solid state) in the UPS/Inverter to isolate both line and neutral, so that after power supply interruption from the utility's distribution network, it remains totally isolated from the UPS/inverter power output and no back-feed/hazardous energy is transferred to the input power terminals of UPS/Inverter and no Electric shock hazard exists after 1 s at this juncture.

ii) For every outgoing wiring circuit, connected to the output supply of UPS/Inverter, the neutral shall be separately run and utmost care shall be taken that no looping occurs at any point with the neutral of any other load circuit and shall not form a part of inverter load. The figures given below show the incorrect and correct methods to use UPS/Inverter system with battery back-up as per IS 732 : 2019.

iii) When UPS systems have galvanic isolation through Isolation transformer or by some other methods, output neutral of UPS shall be earthed with separate protective conductor. This helps to avoid stray noise

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in the earth and neutral affecting the sensitive loads. The output a.c. circuit shall be referenced to the protective earth of the equipment in which UPS is intended to operate. The bonding of protective earth and neutral conductors applies to all modes of operation of the unit. The physical bonding point may be external to the UPS as per IS 16242 series of standards.

iv) Body earthing (protective earthing of UPS) - Extraneous conductive parts of UPS which might assume a hazardous voltage in the event of a single insulation fault, shall be reliably connected to a protective earthing terminal within the UPS.

v) It is advisable to consider neutral conductor of adequate cross section as most of the loads on UPS are SMPS or electronic loads which cause harmonics..

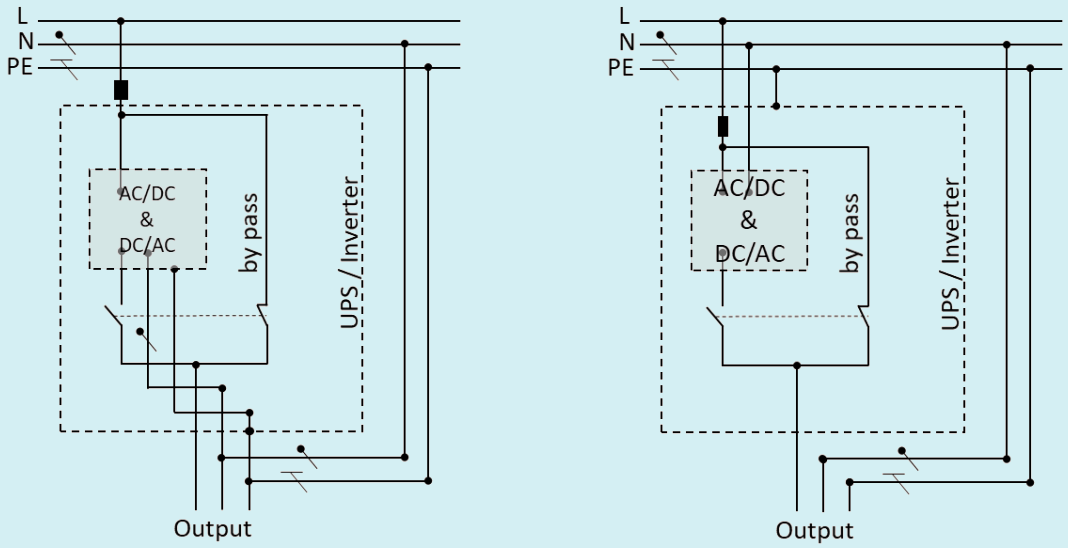


FIG. 20 BLOCK DIAGRAM OF WRONG CONNECTION OF INVERTER LEADING TO BACK FEED OF OUTPUT POWER TOWARDS THE INPUT

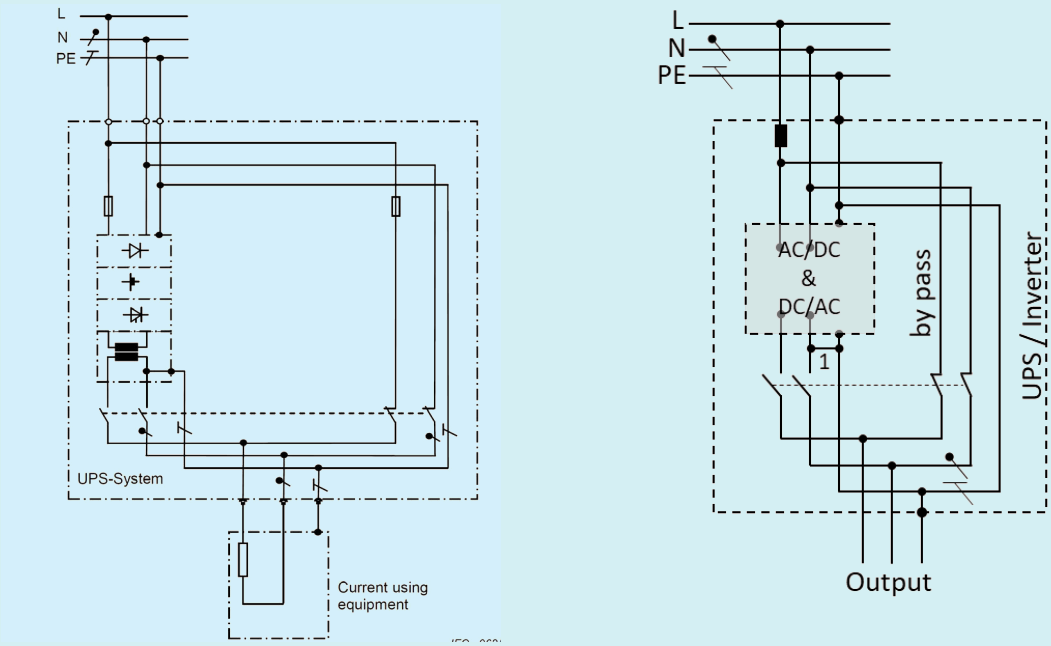


FIG. 21 OUTPUT SIDE OF THE INVERTER NEUTRAL EARTHED INSIDE THE INVERTER TO THE EARTH TERMINAL

INVERTER/UPS WITH 2 POLE ISOLATION AT INVERTER OUTPUT AND AT BYPASS CIRCUIT (ISOLATION ENSURED FOR LINE AND NEUTRAL)

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6.6 Distribution Boxes

Distribution box is an important component of electrical installation which streamlines electrical power from its source to utility point with an arrangement for wiring protections at different levels. Electrical design shall comprise distribution boxes of appropriate type at appropriate locations. Feeding of single phase DB from another single phase DB shall be avoided.

6.6.1 *Types – Phases, Ways*

Depending on source of electrical supply (single phase or three phase), quantum of electrical load area and plan of building/premises, distribution boxes of single pole neutral (SPN)/three pole neutral (TPN) with required number of ways (two, four, eight, twelve, twenty-four etc.) shall be installed. Options of three phase incoming and single-phase outgoing or three-phase incoming and three-phase/single phase outgoing are available.

6.6.2 *DB Types – Fuse, MCB and MCCB*

Distribution boxes are available comprising protection provided in the form of fuses, miniature circuit breakers (MCB) and moulded case circuit breaker (MCCB). Both types of DBs (Fuse and MCB/MCCB) are available in single phase (SPN) as well as three-phase. (TPN). In MCB DBs there is provision to incorporate MCB/MCCB for incoming supply. However, for traditional DB with fuses, it is necessary to install separate switchgear for incoming supply, usually, metal Clad/Iron Clad DP/TP switch with fuses and neutral link.

NOTES

1 Distribution of old conventional fuse box DB is not recommended.

2 High risk is involved in replacement of fuses.

Though replacement of fuse wire is an easier and economic option as compared to replacement of MCB, availability of appropriate size of fuse wire and of qualified electrician capable of choosing the correct size to suit wiring installation. It may be noted that CEA Regulations does not permit non-qualified person with no work permit issued by government to perform such task. Under these circumstances of non-availability of correct fuse wire and non-availability of qualified person to the task, the situation may become accident prone.

6.6.3 *Types – Enclosure Designs*

6.6.3.1 MCBDBs shall conform to IS 13032. They are available with various designs and mounting arrangements such as flush mounted, surface mounted, etc. with covers or hinged doors of different types and of different materials to suit the situation, accessibility and visibility requirements for MCBs.

6.6.3.2 In TPN DBs, individual phase isolation facility is also available where two pole RCDs/RCBOs can be fixed for each phase so that in case of fault in one of the phases, supply of faulty phase isolates without affecting supply of other phases.

6.6.3.3 DBs are available with facility to fix MCB/MCCB/RCD/RCBO and with required number of ways on incoming side. DBs are also available with provision to fix MCCB both on incoming and outgoing side.

6.6.3.4 The bus-bar, neutral link and earth link shall be as specified in relevant Indian Standard to carry current under normal and fault condition the links shall have sufficient number and size of terminals to accommodate number of cables with different cross sections.

6.6.3.5 Bus bar shall be 100A or 200A capacity.

6.6.3.6 Space within the DB shall be sufficient to accommodate the number and size of cables with required loops without over-crowding.

6.6.4 *Location*

Following points shall be taken into consideration while fixing location of distribution box:

a) There shall be a load center to limit length of circuit mains and voltage drop;
b) It shall be installed in common areas where there is no hindrance to reach and operate especially during emergency conditions;
c) suggested height shall be above ground such that it is beyond the reach of children. But the replacement/ reset of protective devices shall be in accessible position without aid of any tackle, for example, at an average height between 1.8 m and 2.1 m;
d) The distribution box shall not be located at structural expansion joints of the building.

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6.6.5 *Selection*

6.6.5.1 *Stages of distribution*

DBs may be selected as TPN type primary/sub-DB, through which supply is provided to local/secondary/final DB which may be TPN or SPN, depending on the scope and stages of distribution design.

6.6.5.2 *Features to be considered for selection*

While selecting DB following points may be taken into consideration:

a) Safety level, (*also see* footnote 2 of **6.6.2**);
b) **6.6.1** - Phases, ways;
c) **6.6.2** - Fuse, MCB;
d) **6.6.3** - Enclosure designs;
e) **6.6.4** - Location;
f) sustainability under respective environment;
g) Protection against external influences, IP class (*see* **5.4**); and
h) shall have easy access while installing and making internal connections (*for example*, sufficient spacing to accommodate wires, adequate terminal with minimum contact resistance etc.

6.6.6 *Labeling/Marking*

DB and all its circuits shall be labeled with appropriate identification mark (*see* **6.2).**

6.7 Switchgears/Protective Devices

All circuits shall be provided with basic protection to safeguard them from over-current and short-circuit faults. It is important and mandatory to provide protection against leakages with RCDs. Adequate protection against over-voltages/surge may also be provided. Within wiring installations, the number, rating, and locations shall be so chosen that it provides adequate safety against electric shock and fire hazard to safeguard life and property as well as to avoid false tripping and un-neccessary outages.

NOTE — It is pertinent to provide the protective devices according to safe current carrying capacity assessed with respect to cross sectional area of conductor under particular situation and reference method of installation (*see* Annex B and Annex C), *For example,* as per Table B-1 current carrying capacity of 2.5 mm^2 Cu conductor, if installed as per reference method A2 is 18.5 A and if installed as per Reference Method D1 is 29A. This indicates that the overload rating of protection shall be different for method of construction.

6.7.1 *Fuse and Switch-fuse Units*

Fuses shall conform to IS 60269 series of standards. For SD/SDF IS/IEC 60947-3 shall be referred.

6.7.1.1 *Rewireable fuse*

Fuse wire embedded between two terminals in porcelain cutout is an old, conventional and economical option. It is important to use correct size/gauge of fuse wire made of correct material/alloy having required characteristics to heat up and melt/fuse in prescribed time when current exceeds nominal value in the circuit (*see* footnote of **6.6.2**)

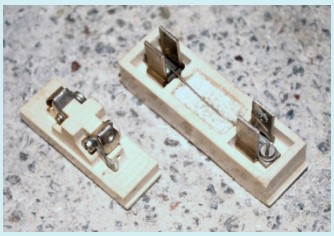


FIG. 22 PORCELAIN CUT-OUT WITH FUSE WIRE

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6.7.1.2 *HBC fuses*



FIG. 23 BLADE/BOLT/CARTRIDGE TYPE HBC FUSES

High breaking capacity (HBC) type fuses, also, known as high rupturing capacity (HRC) fuses are suited to work where high fault energy is required to be restricted along with the electromagnetic stresses which may cause mechanical damages to the current carrying components. Such types of fuses are replaced once operated. Some HBC fuses are also provided with an indicator to display condition of fuse. These fuses operate very fast and have very high short circuit current handling capacity as compared to circuit breakers. Such fuses are, therefore, also used for backup/secondary protection.

6.7.1.3 *Switch and fuse units*

Linked switches – DP or SPN/TP/TPN along with suitable fuse(s) on phase(s) and a link for neutral have been used traditionally to provide protection against overload and short-circuit along with isolation of current. These are available with rewirable and HBC fuses.

Such types of control switches are available in different varieties with iron clad/metal clad enclosure, suitable to mount on fabricated frame/skeleton type panels and without enclosure suitable for fabricated cubical panels.

While using such type of control switch gears, it shall be kept in mind that such types of protective devices are manually operated. There is no tripping mechanism. During fault, only fuse(s) of faulty phase(s) blows. Remaining phase(s) continue to supply power. This may lead to unbalancing of load/supply.

6.7.2 *MCBs*

Miniature circuit breakers (MCB) have replaced traditional fuse-based protections. MCBs have many fold advantages like compactness, ease of resetting, identical sizes for large range of current capacities up to 125 A, ease of erection and maintenance, facility to choose suitable tripping characteristics depending on type of load, etc. MCBs shall conform to IS/IEC 60898-1.



FIG. 24 MCBs

6.7.2.1 *Number of poles*

MCBs are available in single pole (SP), double-pole (DP), single-pole neutral (SPN), triple pole (TP), triple-pole neutral (TPN) and four pole (FP) types. It shall be noted that where 'N' appears on a pole that does not provide any particular protection against overload or short circuit, provides isolation. Double pole in place of SPN or four pole in place of TPN are used when there are chances of large current flow in neutral due harmonics or unbalanced loading.

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6.7.2.2 *Tripping characteristics*

MCBs are available with different instantaneous tripping range as shown in Table 14A. Based on the table, suitable MCB shall be selected to avoid nuisance tripping suitable for type of load having inrush of current/surge.

Table 14A Ranges of Instantaneous Tripping

(*Clause* 6.7.2.2)

Sl No.	Type	Range
(1)	(2)	(3)
i)	B	Above 3 I_n up to and including 5 I_n
ii)	C	Above 5 I_n up to and including 10 I_n
iii)	D	Above 10 I_n up to and including 20 I_n [a)]

[a)] For special cases, value up to 50 I_n may also be used.

Generally, for resistive loads, 'B' type MCBs are suited. But for appliances such as air conditioners and water pump motor, 'C' type MCB shall be provided. For inductive loads, 'C' type MCB may be used. For devices with very high inductive load, SMPS power supply units, UPS, etc., 'D' type MCB shall be used.

Table 14B Time Operating Characteristics

Sl No.	Type	Current (I_n)	Time (t)	Result
(1)	(2)	**(3)**	(4)	(5)
i)	B, C, D	1.13 I_n	$t < 1h$ ($I_n < 63$A)	No trip when cold[a)]
			$t < 2h$ ($I_n > 63$A)	
ii)	B, C, D	1.45 I_n	$t < 1h$ ($I_n < 63$A)	Trip when not cold
			$t < 2h$ ($I_n < 63$A)	
iii)	B, C, D	2.55 I_n	1 s < t < 60 s ($I_n < 32$A)	Trip when cold
			1 s < t < 120 s ($I_n > 32$A)	
iv)	B	3 I_n		No trip when cold
	C	5 I_n	$t < 0.1$ s	
	D	10 I_n		
v)	B	5 I_n		Trip when cold
	C	10 I_n	$t > 0.1$ s	
	D	20 I_n		

[a)] The term cold means without previous loading

NOTE — Conventional non-tripping current of circuit breaker is 1.13 I_n and conventional tripping current is 1.45 I_n. Precise selection shall be done considering these points, overloading and in-surge of current.

6.7.2.3 *Short-circuit current rating of MCB*

MCBs are generally available at 3kA, 6kA and 10kA short-circuit current rating. If details are available to calculate fault current rating, suitable MCB shall be selected. However, when the details of suppliers' distribution network are not available, it is recommended that MCB of 10kA short-circuit current rating shall be selected.

NOTE — Electrical installation which is next to/very near to the distribution transformer of higher capacity may have higher fault level. Under such cases, it may be necessary to increase size of cable. For such cases, MCB of rated current capacity may not match requirement of fault level/terminal size. Under these circumstances, in place of MCB, use of MCCB is recommended.

6.7.3 *Isolators – Use and Limitations*

Isolators and MCBs look similar. It may noted that an isolating device is manually operated and does not provide any protection against overload and short-circuit faults. Its use is not advisable, especially, when there is no nearby back-up circuit protection. Under such circumstances, there are chances of welded contacts leading to fire.

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6.7.4 *Surge Protective Devices (SPD)*

Surge Protective Devices are intended to limit surge voltages and divert surge currents. SPDs shall conform to IS 16463-11/IEC 61643-11.

6.7.4.1 *Classification*

As per the tests, SPDs are classified as Test Class I/[T1], Test Class II [T2] andTest Class III [T3]. Other parameters include one/two ports, outdoor etc.

6.7.4.2 *Use*

Under specific conditions, provision of SPDs shall be made in electrical systems and sensitive equipments to protect from various over-voltages such as lightning surge, switching surge, temporary over voltages and impulse currents during lightning and switching surges.

6.7.4.3 *Selection*

Selection of type 1/type 2/type 3 SPD or their combination and location depends on various factors. Consider the following arrangement:

a) If there is no lightning conductor/grounded metal structures on building or in the vicinity – Type 2 SPD may be provided at incoming circuit breaker/main panel.
b) If lightning conductor/grounded metal structures is provided on building/installation or at nearby area – Type 1 and Type 2 SPDs may be provided at incoming circuit breaker/panels
c) If the structure is supplied by an aerial line considering risk of direct flash on the line – Type 1 or combined Type 1and Type 2 SPD shall be provided.
d) If distance between main panel (fitted with Type 1 and/or type 2 SPD) and the sensitive equipment is more than 10m - Type 3 SPD near sensitive equipment shall be provided.

NOTE – For detailed information about selection of SPD, IS 16463-12 may be referred.

6.7.4.4 *Installation*

Within the distribution specific location intended for particular class of SPD, (i.e. origin of installation or in the main distribution assembly, close to installation/equipment) shall be observed and shall be available for inspection. Where situation requires use of more than one SPD proper coordination shall be maintained.

NOTE — For more details, refer 5.3.5 of IS 732 : 2019.

6.7.5 *RCDs- RCCBs*

Residual current device (RCD)/residual current circuit breaker (RCCB) shall conform to IS 12640 (Part 1)/IEC 61008-1. These devices are intended to be operated by uninstructed persons and designed not to require any maintenance.

6.7.5.1 *Use*

Earth leakages and electric shocks pose threat to human beings and livestock. Under the context RCD intend to provide protection against indirect contact and exposed conductive parts of the installation connected to an appropriate earth electrode. This device may also be used to provide protection against fire hazards without operation of over current protective device.

These devices are intended to be used for household and similar uses.

6.7.5.2 *Statutory provision*

Reg. 42 of CEA (Measures related to Safety and Electric Supply) Regulations[1)] mandates with respect to provision of protective devices against the hazard of earth leakages depending on load. Accordingly, it is obligatory to make provision of RCD[2)] for installations not exceeding[3)] 250 V, with a limit of sensitivity[4)].

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1) As per the latest amendment (Amendment 2015), this provision was made applicable for appliances/equipments rated for 2kW and above (from previous threshold of 5kW load). Amendments are under consideration with respect to sensitivity, voltage level, load and nomenclature of the device.
2) The present nomenclature of the device under CEA Regulations is Earth Leakage Protective Device. Renaming the Residual Current Device (RCD) is under consideration. Previously, 'ELCB' was used for voltage operated type device with two earth terminals for connection of earthing terminal of installation and for connection to earth electrode. The device had some drawbacks.
3) Applicability to voltage level as per IS12640 (Part 1)/IEC 61008 : 2012 is under consideration.
4) As mentioned under CEA Regulations 2015, sensitivity is 30 mA for domestic installations and 100mA for other installations considering the safe limit for humans.

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6.7.5.3 *Applicability/use*

Provision of RCCBs with sensitivity of 30mA shall be made for all household and similar installations for load of 1kW and above, with voltage levels up to 440 V and 125 A..

NOTE — As per CEA Reg. 2015, existing threshold exempt limit for load is up to 2kW, revision of decreasing load to 1 kW is under consideration. It is recommended to exempt load limit for providing additional safety towards complete elimination of shock hazard.

6.7.5.4 *Locations/sectionalizing*

Provision of RCCBs shall be made at suitable locations within wiring installations such that in case of fault, supply of only that particular section of wiring installation is deflected and investigation to clear the fault is restricted to limited section making procedure faster and easier.

NOTE — Individual phase Isolation type DBs shall be of help which will trip the supply of particular phase only.

RCDs having 300mA sensitivity, intended for fire protection may be placed at main switchboards/incoming source of supply or at such a location to address fire prevention and spread of fire.

For electrical loads exceeding 125 A, sectionalizing shall be done considering maximum current rating of 125 A.

6.7.5.5 *False tripping*

Proper sectionalizing is necessary to avoid false tripping. Where RCCBs are installed in series, discrimination shall be such that nearest RCCs shall trip first. To achieve such condition, S type RCCBs with time delay setting may be used. Increasing sensitivity level shall not be permitted.

NOTE — Accumulated currents in protective conductor may cause RCD to operate under non fault condition (*for example*, current developed by SMPS of multiple computers, when too many computers are connected on a circuit etc.). To avoid such circumstances, proper sectionalizing is necessary.

6.7.6 *RCDs - RCBOs*

Residual current breaker with overload and short circuit protection (RCBO) shall conform to IS 12640 (Part 2)/ IEC 61009-1. This device is intended to be operated by uninstructed persons and designed not to require maintenance.

6.7.6.1 *Use*

This device provides protection from harmful leakage current of the order of 30mA and above with integral protection against over-current and short-circuit. It is useful for wiring installations in household and similar places, to protect people against indirect contact with exposed conductive parts of installation. This device is suitable for voltages up to 440V, rated current 125A and short circuit breaking capacities up to 25kA.

NOTE — For protection against shock, from extraneous conductive part, it is necessary to connect it to earth through protective conductor.

6.7.6.2 *Locations*

This device can be located suitably in DBs within distribution network requiring both functions at that particular location. The location at main supply source may be selected considering the possibility of complete blackout in premises.

6.7.6.3 *Suitability*

Before installation, following points shall be considered:

a) It is easier to use single device for two functions instead of two separate devices as it saves space and is economical;
b) Terminations and connections are required for one device which help in reducing contact losses and number of inspection points;
c) The devices trips the supply due to either of the fault and affect complete portion which, in some cases, is undesirable;
d) Where possibility and frequency of one of the faults is more, under such cases, combined device prove disadvantageous; and
e) Tripping of device does not indicate the type of fault – earth leakage or overload/short-circuit and hence, is not helpful for fault finding.

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6.7.7 *Circuit Breakers*

In the wiring Installations of industrial or similar purposes, where there is requirement of making and breaking a circuit of higher current rating and higher short-circuit current rating, Circuit breakers shall be used. Circuit breakers shall conform to IEC 60947 series of standards. The breakers also have adjustable setting for overload and short-circuit.

6.7.7.1 *Category A or B*

According to IS/IEC 60947-2, category A breakers do not have deliberate time delay in the operation of the instantaneous short-circuit magnetic tripping device. The breaking occurs before first peak of the current waveform is reached. Category B breakers have ability to withstand one or more cycles and hence, helps to discriminate and maintain tripping sequence.

6.7.7.2 *Suitability*

Circuit breakers must be capable of safely interrupting the maximum potential of short circuit current at their location in the circuit. Hence, they shall have breaking capacity higher than potential short circuit current and shall be suitable for add-on auxiliary functions, if required.

NOTE — Correct fault level calculations are important to choose breaker with precise breaking capacity. It shall be noted that cost of breaker increases with breaking capacity.

6.7.7.3 *Use*

In wiring installations, breakers are used prior to downstream LV distribution and one of the type – MCBDBs, MCCBs and ACBs. It is recommended to check manufacturer's specifications and the design requirements prior to use of MCCBs and ACBs in wiring installation.

6.7.7.4 *MCCBs*

Moulded case circuit breakers (MCCB) generally come under category A. They are preferred in downstream applications. Due to technological advancements, breaking capacities of MCCBs (though not comparable with higher limits of ACB) are improving and hence, up to particular range, design parameters of both with ACBs and MCCBs are similar.

Cost wise MCCBs are cheaper than ACBs. Its compactness may advantageous but from the point of view of termination of higher size of cables it may cause some inconvenience and may require spreaders increasing contact resistance.

MCCBs are typically available up to 3200 A, but its use at lower current rating is found to be more effective. Frame size of MCCBs may not be identical and hence point shall be considered while designing panel.

It may be noted that feature of rated short time withstand current (category B) is, generally, not available in MCCB.

Capacity to clear number of faults is relatively less.

Due to internal maintenance, recurring cost is negligible.

6.7.7.5 *ACBs*

The rated current (I_n) for Air Circuit Breakers (ACB), typically, ranges from 630 A to 6300 A. Under category B, ACBs have high short-circuit withstand capacity (I_{CW}) and rated breaking capacity (I_{CU}), hence, are suited upstream/on incoming side. Short-circuit withstand time of up to 1 s helps providing discrimination in the system.

ACBs can be fixed or draw-out type. The racking-out can be mechanical or electrical.

Service life of ACBs is higher compared to MCCBs but ACBs need regular maintenance and is expensive.

6.7.7.6 *Arc Flash Detection Device (AFDD)*

This device is intended to mitigate effect of arcing faults by disconnecting the circuit when the arc fault is detected. It shall be noted that RCDs are recognised as efficient to reduce the risk of fire by detection of leakage current and arcing to ground. But they cannot reduce risk of electrical fire due to series or parallel arcing between live conductors. In series fault, impedance of series fault reduces current which may be below the threshold of circuit breaker tripping. Another point of consideration is frequency under arcing fault may be higher than 50 Hz. Hence, AFDD is effective to mitigate risk of fire ignition when arcing persists and also, protects against fire ignition due to over-voltages caused by broken neutral in three phase installation. It shall be used in single phase and three phase installation up to 440 V a.c. with rated current not exceeding 63 A.

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6.7.7.7 *Selection*

Selection of breaker shall consider the features in above mentioned clauses. Rating shall suit the ambient temperature and maximum current carrying capacity of cable. Variable setting is preferable to suit varying load pattern. Other auxiliary protections shall be provided as per requirement of system and equipments to be connected.

6.7.8 *Switchboards*

A switchboard is an assembly consisting of switching devices along with associated control, measuring, indicating, and protective equipment for distribution of electric power.

Based on area of application, switchboards are classified into different types and shall conform to IS/IEC 61439 series of standards for voltage upto 1000 V a.c. or 1500 V d.c.

Switchboards can be of wall-mounted or floor-mounted structures clad in metallic or non-metallic enclosure. The one or more incoming/outgoing feeders are either of fixed or withdrawable type.

These are designed to meet the required dielectric withstand properties and insulation co-ordination based on location of the installation as per the over-voltage category and pollution degree of the environment at the installation.

These are meant to be commissioned in both indoor and outdoor environments meeting the required climatic conditions like ambient air temperature, relative humidity, altitude, condensation and effects of UV radiation.

Switchboards shall have a minimum degree of protection of IP 2X with '*forms of internal separation*' ranging from 'form 2a to form 4b'.

Typical switchboards come with rated current of the assembly (I_{nA}) from 63 A to 6300 A and short-circuit withstand strength between 10 kA and 100 kA.

7 MATERIAL

7.1 All material used in wiring installation shall conform to relevant national and international standards.

7.2 Selected material shall have property to sustain under respective environmental, working conditions, effects of external influences and shall be safe and functional throughout its desired service life.

7.3 Adequate precautions related to transportation, handling and storage shall be taken. In case any damage occurs, such material shall not be used before confirming its technical parameters.

7.4 It is advised that in project works, sample(s) from the material brought on site may be tested from the accredited test laboratory and records may be maintained.

7.5 It is recommended that the basic material and its accessories/different components forming a unit of wiring system shall be from same manufacturer, Also, there shall not be use of multiple brands/type of same manufacturer for any material component used on particular site. For example:

a) in conduit system, conduits and its accessories like junction boxes, elbows, tees, etc.
b) in PVC trunking system, trunking and its accessories;
c) in cable ladder and tray system of all sections, supports, accessories etc;
d) for switchboards, switches, sockets, fan regulators, dimmers, blanking plates, boxes, and cover-plates; and
e) for distribution boxes; MCBs, isolators, RCDs, SPDs, blanking plates etc. and the fit in boxes.

8 WIRING ACCESSORIES

All accessories, unless mentioned, shall be rated for 250V, 6A. All accessories shall be designed and constructed so as to conform to relevant standards and shall be suitable[1)] under particular environment/location to sustain external influences. The material used may be plastic[2)], metal or combination which suits the application.

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1) Under hazardous conditions, material shall conform to respective norms to prevent hazard, for example, at fire prone sites, locations exposed to flammable/explosive dust, accessories along with their enclosures shall be flame proof and shall have ingress protection etc.
2) Plastic is a broad term and under family of 'Plastics', categorization is made depending on specific properties required (*for example*, thermoplastics, phenolic moulded resins, thermosetting resins etc.) with respect to particular function.

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In wiring installations, the accessories shall be so installed as to suit the user requirements and shall function in reliable manner without causing any danger to persons or surroundings.

NOTE — For more information, *see* **12**.

Various accessories which are generally used are as under:

a) lamp holders;
b) Ceiling roses;
c) Connectors;
d) switches – 6 A/16 A;
e) plug sockets – 6 A/16 A or combination;
f) Plug tops – 6 A/16 A; and
g) Boards/boxes/plates.

8.1 Lamp Holders

Lamp holder is a means of supplying current to a lamp and providing mechanical support to the lamp. Lamp holders shall conform to IS 1258.

8.1.1 *Types*

Lamp holders are of two types – Bayonet type/Bayonet Connector (BC) and Edison Screw (ES) type.



FIG. 25 BC TYPE PENDENT, ANGLE, BATTEN AND METAL LAMP HOLDER WITH EARTH TERMINAL

These holders are identified by 'BXX' for Bayonet type and 'EXX' for Edison type. The 'XX' denotes the diameter in mm of the lamp cap (*for example*, B22 or E27. In case of Edison type, lamp holder diameter across the peaks of the thread on the male is taken.

8.1.2 *Suitability/Use*

Standard rated current for B15 and B22 holders shall be minimum 2 A. In case of requirement of higher ratings, manufacturer's specification shall be referred. Lamp holders shall not be used for external electrical installation without conforming to required IP class.



FIG. 26 EDISON SCREW TYPE LAMP HOLDERS

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8.1.3 *Selection*

Before installation, care shall be taken to select lamp holder suitable to particular lamp cap. The style Batten/ Angle/Pendent type or other types mentioned under standard may be selected depending on the location or required position of lamp. B15 lamp holders shall not be used in circuits with ignitors and B22 shall be used subject to approval by the manufacturer. Exterior material of Lamp Holder may be plastic, ceramic or metal. Usually in fixed wiring installations, plastic material is recommended. For plastic lamp holders, a protective shield similar to skirt shall be provided to avoid accidental contact with lamp cap. Metal lamp holders are used for decorative lamp fixtures. For such holders, earth terminal or other means of earthing shall be in effective electrical contact with all exposed non-current carrying metal parts. Lamp holders with integrated switch shall conform to requirements specified in the respective standard.

8.2 Ceiling Roses



FIG. 27 CEILING ROSES

8.2.1 *Use*

Ceiling Rose is a means of supplying current from fixed wiring to a pendent lamp holder or other movable accessory like bell push or a lighting fixture, ceiling fan, bell/buzzer or similar apparatus with a flexible wire cord. It shall conform to IS 371.

8.2.2 *Earth terminal*

All ceiling roses shall be provided with earth terminal and it shall be visibly distinguishable.

8.2.3 *Location*

Location of ceiling rose shall be close to the intended location of appliance to avoid loose hanging wires.

8.2.4 *Connections*

Ceiling roses are intended for use with cables complying to IS 694. In three-plate ceiling rose, third plate may be used for looping the wire. Ceiling-roses may be intended to sustain mechanical load by means of flexible cord complying to IS 694. Before using the ceiling-rose for such application, manufacturer's specifications regarding safe working, mechanical loading limit and method of fixing to mounting surfaces shall be checked (*see* **9.1.2.6**).

8.3 Switches

Switch is a wiring accessory which is used for making or breaking the current supply to the outlet/utility point and shall comply with IS 3854.

8.3.1 *Types*

Switches generally used in wiring installations can be broadly classified depending on:

a) *Poles* — Single pole/two pole;
b) *Ways* — One way/two way;
c) *Activation* — Tumbler/rocker/push button/rotary/cord-operated;
d) *Application* — Surface type/flush type/modular;
e) *Method of Installation* — Cover removable by disturbing conductors/without disturbing conductors;
f) *Operation* — Manual/remote; and
g) With/without indicator.

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8.3.2 *Suitability, Installation and Use*

Switches are, generally, available for current rating – 6A/10A/16A/32A and are single-pole/two-pole to suit the requirement as per the design and load.

8.3.3 *Current Rating*

Current rating of switch shall suit the load, its type and size of conductor. For point wiring of light and fan circuits, 6A switch shall be used. For plug points on board or independent plug point, switch may be of capacity 6A/10A. For power points, minimum 16A switch shall be used.



FIG. 28 DIFFERENT TYPES OF SWITCHES

8.3.4 *Precaution - Phase and Neutral Isolation*

Installation of switches shall always be on phase/line conductor. Switch shall not disconnect neutral wire unless it is a two-pole switch where neutral disconnects simultaneously with phase conductor of the same circuit provided the neutral is not looped further to any other circuit/point.

8.3.5 *Precaution – Safety*

Depending on type of switch, its mounting on plate/board may be press fit type or may be through screws and nuts. After the switches are mounted and wired, no live parts shall remain open and accessible to the user.

8.3.6 *Two Way Points*

Points requiring control from two locations, where two-way switches are used, it shall be ensured that neutral wire is not fed from either side and the phase wire used from both ends is of the same circuit.

8.3.7 *Switches of Power Points*

For power points 16 A and above, indicating switches are recommended so that ON/OFF supply is noticeable an alert signal.

8.3.8 *Marking on Switches*

Switches with marking help in distinction of switches for light, fan or bell etc. especially where there are a number of switches.

8.4 Plug and Socket Outlets

Plug and sockets with/without earth contact shall conform to IS 1293, which is intended for household and similar purposes and applicable to 250V and rated current up to 16A.

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NOTE — In view of prevalence of two pin plugs and socket outlets in household purposes, it is necessary to use standardized plugs. However, the user must ensure proper earthing practices in line with IS 732 and IS 3043. Two pin plugs are intended to be used only for class II appliances.

8.4.1 *Plug*



FIG. 29 THREE-PIN PLUG TYPE D AND TWO-PIN PLUG TYPE C

It is an accessory having pins designed to engage with the contacts of socket outlet, and incorporating the means for the electrical connection and mechanical retention of flexible cables.

8.4.2 *Plug Types*

Plugs are classified according to:

a) current rating 2.5 A, 6 A, 16 A;
b) without earth pin (for 2.5A and 6 A) – limited to class II appliances (non-rewireable plugs only);
c) with earth pin (for 6 A, 16 A, 6/16 A) – all class I appliances;
d) rewirable, non-rewirable; and
e) type of terminals screw type and screw-less.

NOTES

1 In case of re-wirable plugs there shall be provision of grommet which prevents cutting/damaging insulation of wire at the point at entry/exit point.

2 IS 1293 may be referred for the latest provisions.

8.4.3 *Socket Outlet*

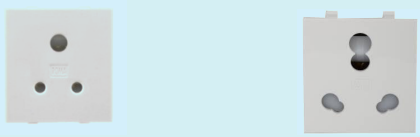


FIG. 28 6A 3 PIN, 6/16A COMBINED SOCKET-OUTLET

It is an accessory having socket contacts designed to engage with the pins of a plug along with terminals for the connection of cable(s)

NOTE — 16.5 mm pitch and 5 pin plug design is deleted from revised IS 1293.

8.4.4 *Types*

Sockets-outlets are classified as with earth/without earth terminal, rating - 6A/16A or combined 6/16A, shuttered/ non shuttered, mounting - flush/surface; fixing - screwed/press-fit/modular etc.

NOTES

1 It shall not be possible to engage a plug of Class I appliance with socket outlets exclusively designed to accept plugs for Class II appliances.

2 Generally, shuttered plug sockets shall be used. In case of un-shuttered sockets, its location shall not be within the reach of children. Plug boards at skirting level shall always be shuttered type.

8.4.5 *Wiring Connection to Plug Socket*

Supply to plug socket shall be given through a switch of current rating not less than that of socket be placed at adjacent position in the switch board. Plug socket provided on lighting circuit switch board shall not be more than 6A. For power circuits, 16A or combined 6/16A sockets shall be used.

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8.4.6 *Control of Supply to Multiple Sockets*

Where multiple 6A sockets are to be controlled with a single switch, they shall be located on a single board and a permanent marking shall be done on such sockets to identify such situations. Considering the total possible load, rating of switch shall be selected. Circuit to each such switch board shall be independent and shall not be looped from any other lighting switch board.

NOTE — As far as possible such situation shall be avoided, but in case of requirement for number of equipment forming a part of a single system and requiring simultaneous operation and equipment connected having an individual built in switch, such method of may be adopted (*for example*, CPU, monitor, add-on speakers, printer of CPU etc.).

8.5 Enclosures for Accessories for Household and Similar Purposes

The enclosure which is integral part of electrical accessory and provides protection in the form covers, cover-plates, boxes intended for mounting or suspension of luminaries shall conform to IS 14772.

8.5.1 *Types*

Enclosures can be classified according to material – metallic/insulating; method of installation – flush/surface; location of installation – walls/ceiling/flooring; base of installation; in/on – masonry wall/concrete/insulated wall/ hollow wall; protection class etc.

8.5.2 *Suitability*

Enclosure shall be suitable to use under the particular situation to provide mechanical protection, ingress protection, fire protection, shock protection, protection against corrosion/rusting etc. as per requirement. Boxes shall be of suitable size to accommodate accessories maintaining required clearance between terminals of accessories and rear plate of box, wire or leads. There shall be provision for earth terminal on the metal box.

8.5.3 *Selection*

Selection of enclosure shall be as per **8.5.1** and **8.5.2** on the basis of number of accessories/modules.

8.5.4 *Installation*

All boxes shall be firmly fixed. No gap shall be left between enclosure and the surface on which it is fixed. Electrical continuity wherever expected, in case of metal conduits and boxes shall be confirmed after installation.

9 FIXTURES/FANS/APPLIANCES

This section gives guidelines for lighting fixtures for providing sufficient illumination, fans for providing adequate ventilation for human comfort and hygiene and other fixed appliances forming a part of wiring installations to be integrated with the system from the point of view of design, purpose, utility and safety within the premises.

9.1 Lighting Fixtures/Luminaries

Lighting fixtures are used with the lighting devices to provide adequate illumination. Lighting fixtures and their integrated parts shall conform to IS 10322 series of standards.

9.1.1 *Selection*

Lighting fixture shall be selected keeping in view the required functionality. Number and wattage of fittings shall be selected depending on required illumination level as per Table 4 of Part 8/Section 1 of NBC 2016. While selecting lighting fixture, factors of external influences and safety requirements as envisaged under IS 302 as well as energy conservation aspect shall also be taken into consideration.

NOTE — For further selection of Luminaries, Part 4/Section 1 of SP 72 may also be referred.

9.1.2 *Installation*

The means for fixing shall be capable of supporting a mass of not less than 5 kg. Where the mass of the luminaire is greater than 5 kg, it shall be ensured that the means for fixing is capable of supporting the mass of the luminaire.

9.1.2.1 *Location*

As far as possible, the installation of fitting shall be near to the outlet point. However, if it is not possible to keep the outlet point near to the fitting, it shall be clipped properly so that it does not hinders the light.

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9.1.2.2 *Connections*

Connection with lighting fixture shall be done with a two core or three core cord, when the fixture has an earthing terminal (*see* **6.3.3**). Proper tightening of wire leads shall be done at terminals. No live part shall remain exposed and accessible.

NOTE — Cords to be concealed in hollow portions (*for example*, false ceiling) shall be provided additional protection of flexible conduits to protect them from external influences like rodents etc.

9.1.2.3 *Grouping*

Depending on design parameters, more than one lighting fixtures may be grouped on one controlling switch.

9.1.2.4 *Precaution against possible harm due to heat dissipation*

Heat dissipation factor of luminaire and its integral part shall be taken into consideration while positioning, especially, in false ceilings, on wooden furniture or similar bases.

9.1.2.5 *Fittings in false ceiling*

A cut out for flush type of fitting in the false ceiling or the similar base shall be made with a proper template of precise size. There shall be proper coordination in positioning with the sweep of fan so that no shadows occur.

NOTE — The false ceiling shall be capable of bearing the weight of the fitting to be installed. Generally, false ceilings are suitable for light weight fittings. In case of heavy/bigger size fittings, arrangement shall be made to support the fitting by a wire, rope or a similar material anchored in the structural part of the ceiling above false ceiling.

9.1.2.6 Suspended type Luminaire shall be fixed with proper accessories (*for example*, ball suspension plates, down rods/chain/bracket etc.), having sufficient strength to bear the weight of luminaire. If fitting is to be suspended through wire/cord, Table 16 shall be referred to check allowable weight.

Table 16 Maximum Permissible Weight on Cord

(*Clause* 9.1.2.6)

Sl No.	Nominal Cross-sectional Area of Twin Cord mm^2	Maximum Permissible Weight kg
(1)	(2)	(3)
i)	0.5	2.0
ii)	0.75	3.0
iii)	1.0	5.0
iv	1.5	5.3
v	2.5	8.8
vi	4.0	14.0

9.2 Fans

9.2.1 *Ceiling Fans*

Ceiling fan shall have the functional to provide adequate ventilation. Ceiling fans shall conform to IS 374.

9.2.1.1 *Selection*

Selection of the fans shall be on the basis of technical parameters such as:

a) Sweep in mm (900/1050/1200/1400/1500);
b) Air delivery in m^3/min;
c) Maximum power input in W; and
d) Service value in m^3/min/W.

For proper ventilation there shall be provision of adequate number of fans at appropriate locations depending upon area. For reference, see Table I.1 under Annex I.

NOTE — In view of 'Star Rating' guidelines by Bureau of Energy Efficiency (BEE), updated specific norms shall be referred.

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Updated Star rating index as per BEE guidelines as given in Table 17.

Table 17 Star Rating Index as per BEE Guidelines

(*Clause* 9.2.1.1)

Sl No.	Star Rating Index Calculation for Ceiling Fans	
	Star Rating	Service Value for Ceiling Fans
(1)	(2)	(3)
i)	1 Star	> 3.1 to < 3.6
ii)	2 Star	≥ 3.6 to < 4.1
iii)	3 Star	≥ 4.1 to < 4.6
iv)	4 Star	≥ 4.6 to < 5.1
v)	5 Star	≥ 5.1

NOTES

1 For the installation where there is limit for allowable temperature rise, 11.2.2 of Part 8/Section 3 of NBC 2016 may be referred.

2 For battery rooms, recommendations of manufacturer shall be followed.

9.2.1.2 *Installation*

a) *Suspension System* — The suspension of ceiling fan shall withstand tensile load of 1 000 kg and torsion load of 500 kg without breakage.

Some of the arrangements for suspension of fan to ceiling are shown below. Concealed type fan box is shown in Fig. 31. It shall be fixed in RCC slab by entangling the rod in the steel and embedding it in RCC slab during casting. Alternatively, where concealed type box is not needed, a bar without box shall be fixed. Post casting of slab, suspension arrangement is to be made with the use of truss member.

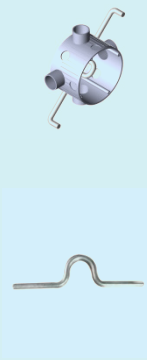


FIG. 31 FAN HOOK BOX CONCEALED TYPE AND BAR TO BE FASTENED/ENTANGLED WITH STEEL IN RCC



FIG. 32 TYPE OF HOOKS TO BE GROUTED WITH ANCHOR BOLTS IN RCC SLAB



FIG. 33 SHACKLE AND BOLT TYPE ARRANGEMENT FOR FAN SUSPENSION, FAN CLAMP

Rod shall be of 10mm diameter and M.S. flat of clamp shall not be less than 30 mm × 5 mm.

It shall be noted that electrical continuity is disrupted with use of rubber shackle from fan to the metallic part of ceiling. Rubber shackle also helps to dampen torsion forces.

b) *Down Rod* — Down rod or suspension rod of ceiling fan are of standard length, usually of 225 mm, and with necessary holes for nut and bolts, wire to pass through and cut for clamping fan shaft with proper grip (*see* Fig. 34). In case of ceiling height more than 3 m, extra long down rod may be required. Under such circumstances check, manufacturer's specifications shall be checked for recommended maximum height of blades from floor level for optimum output/useful air delivery.

Down rods with extra lengths shall be continuous without joint and shall carry same mechanical properties.

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NOTE — If joints in down rod are unavoidable, then, such joints shall be screwed to special couplers of minimum length of 50 mm and both ends of the rod shall be secured by means of split pins or may be by welding.

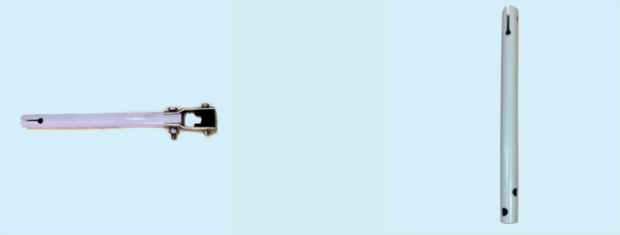


FIG. 34 DOWN ROD WITH ARRANGEMENT FOR WIRES AND SUSPENSION

Alternatively, screwed type suspension may be allowed subject to condition that the threads tightens when the fan is in motion.

1) *Clearances* — Recommended clearances of fan blades from finished level of flooring and ceiling shall not be less than 2400 mm and 300 mm respectively.
2) *Connections* — Connection shall be made with twin core copper wire of size not less than 1.5 mm^2 qualifying under class II appliances or three core 1.5 mm^2 qualifying under class I appliances. Earth wire of three core cord shall be terminated on the earth terminal of fan provided by the manufacturer.

   Wiring connections on switch board shall be from switch through fan speed regulator.
3) *Canopies* — Canopies on top and bottom of suspension rods shall be so positioned that it conceals suspension and connections to fan motor. However, care shall be taken to maintain sufficient gap between motor body and bottom rim of canopy so that it does not hinder rotation.

9.2.2 *Exhaust Fans*

Where air changes are required to maintain fresh air flow to maintain air quality, provision of exhaust Fans shall be made. Exhaust fans shall conform to IS 2312. Exhaust fan are also available with reversible flow (fresh air intake) facility which can be availed through toggle switch.

9.2.2.1 *Selection*

Selection of exhaust fans can be done on the basis of:

a) blade sweep size in mm;
b) air changes, in CFM or m^3/min;
c) service value, m^3/min/W;
d) voltage level 240 V/415 V; and
e) power input W.

Recommended values of air changes depending on application are given under 5.2.2.1 of Volume 2/Part 8 of NBC 2016. Some of the common applications are as in the Table 17.

Table 17 Recommended Air-Changes

(*Clause* 9.2.2.1)

Sl No.	Application	Air Changes/Hour*
(1)	(2)	(3)
i)	Bathrooms	6-10
ii)	Bed rooms	2-4
(iii)	Canteens	8-12
iv)	Garages	6-8
v)	Lavatories	6-15

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Table 17 (*Concluded*)

Sl No.	Application	Air Changes/Hour*
(1)	(2)	(3)
vi)	Offices	6-10
vii)	Restaurants	8-12
viii)	Shower baths	15-20
ix)	Stores and warehouses	3-6
x)	Toilets	6-10

* Volume of air to be replaced contained in a room/envelope in an hour

Example:

To find required CFM (cubic feet per minute – imperial measure) or m^3/min (System of International units, SI) for a bathroom:

Bath room size > 4 in × 7 in × 10 in or 1.2 m × 2.1 m × 3 m

Volume = 280 cu. ft or 7.56 m^3

Number of air changes considered = 8

Volume of air is to be replaced in an hour

= 280 × 8 or 7.56 × 8

= 2440 cu.ft or 60.48 m^3

Required *cfm* or m^3/min capacity of fan

= 2440/60 or 60.48/60

= 40.67 *cfm* or 1.008 m^3/min

Accordingly, size of fan having capacity not less than calculated above shall be selected. Details with respect to *cfm* if not available on name plate may be sought from the manufacturer.

9.2.2.2 *Installation*

a) *Related Civil Work*

Installation of exhaust fan needs coordination with civil work agencies. A recess/opening suiting the required size of exhaust fan with mounting arrangement is necessary. The opening may be on wall/ window frame. There shall be protection from ingress of water. There shall be arrangement for entry of fresh air so that negative pressure does not develop within the area (*see* **4.4.10**).

b) *Mounting*

Mounting shall be done with suitable measures to reduce vibrations. Suitably designed guard shall be fixed to prevent entry of flora/fauna.

c) *Connections*

Connections from ceiling rose shall be made with twin core copper wire of size not less than 1.5 mm^2 for fan qualifying under class II appliances or three core 1.5 mm^2 qualifying under class I appliances. Earth wire of three core cord shall be terminated on the earth terminal of fan provided by the manufacturer.

9.3 Other Fixed Appliances

With respect to other fixed appliances, the cord connecting the power outlet and the appliance shall be insulated and sheathed. Its core shall contain colour coded earth wire. Cord shall be so arranged that it shall not entangle and damage. It shall remain at suitable distance from heat source. For water heater, washing machine, dishwasher etc. connected with the water pipes may be provided with independent Residual Current Devices (RCDs).

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10 TESTING AND COMMISSIONING

Before making beneficial use of the installation, it is recommended that verification shall be done as per 6 of IS 732 : 2019. Some of the important steps are given as under:

10.1 Visual Check

Before switching on supply, following check points shall be observed.

10.1.1 *Finishing Works- Civil*

Finishing with respect to civil works carried out for electrical installation work. *For example,* openings in wall, false ceiling, core cutting, concealing, under floor raceways etc. are finished in approved/appropriate manner. Ducts, and shafts are provided with appropriate doors and at flooring level sealing is carried out with fire resistant material.

10.1.2 *Hindrance to Other Services*

Electrical Installation shall not cause inconvenience and hindrance to any other utility service installed in the vicinity for its operation and maintenance activities and vice versa.

10.1.3 *Electrical Cables and Wires*

Installation of cables and wires shall be as per design and after completion, shall be suitable to survive under effects of external influences. Bunching within enclosure, *for example*, conduits and trunking shall satisfy space/ fill factor requirements. Colour coding and ferruling to identify circuit number shall be in an approved manner. There shall be no overcrowding within any switch board, DB, panel and there shall be no visible damages to insulation.

10.1.4 *Terminations*

Terminations shall be firm. There shall be no loose contacts. All strands shall be properly inserted and lugs, where necessary, shall be of right material and crimped properly.

10.1.5 *Bus Ways and Race Ways*

Adequate care shall be taken from the point of view of external influences. Supporting, joints, crossings fixing of accessories shall be firm and satisfactory. (*See also* **10.1.2**).

10.1.6 *Earth/Protective Conductor*

Sizes, material and connections with earth terminals shall be made in a proper manner so as to maintain continuity.

10.1.7 *Switch-boards*

Position, location and accessibility shall be appropriate from the point of view of operation, safety and maintenance. In case of modular accessories, vacant modules shall be plugged with blanking plates. Sockets at lower level shall be shuttered.

10.1.8 *DBs, Switchgears and Panels*

Locations, positions and accessibility shall satisfy required conditions from the point of view of operation, safety clearances and maintenance. Ratings, class/category, types, setting facilities of MCBs, RCDs, SPDs, MCCBs, other switchgears/breakers/fuses shall be as per design. Identification marking shall be clear and legible. SLD in respect of major panel boards shall be affixed. 'Danger' sign board shall be affixed at suitable locations. Boundaries in front of panels shall be marked.

10.1.9 *Fans, Luminaries*

Suspension of fans with nut-bolt/split-pin shall be appropriate. Clearance from ceiling and flooring shall be satisfactory.

10.1.10 *Appliances/Equipment*

Location and position of appliances and equipments shall be are safe. Cords shall be intact and shielded. Earth connections shall be proper.

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10.1.11 *Fire Prevention*

Requirements in the fire prevention regulations, if any, shall be complied with.

10.1.12 *Maintenance Facility, Tools and Safety*

In installations, where inhouse electrical maintenance facility is available, required tools, tackles and safety devices as recommended under CEA Regulations shall be maintained and related record shall be preserved. Where access is intended only for the instructed persons, necessary provisions shall be made to restrict access/entry/ maintain safe clearance.

10.2 Testing

a) Subsequent to the visual inspection, Installation shall be tested and record of the results shall be maintained for further reference.
b) Inspection and testing of the installation shall be carried out as per 6 of IS 732:2019. For comprehensive guidelines, also refer Part/Section 17 of this code.

11 MAINTENANCE AND PERIODIC INSPECTION

Periodic inspection shall conform to 6.3 of IS 732.

12 ELECTRICAL ARCHITECTURE OF WIRING INSTALLATIONS (UNDER CONSIDERATION)

This section provides new dimension to wiring installation from the point of view of ergonomics, utility, ease and comfort of operation, aesthetics, and ambience which influence layouts, selection of material without impairing safety.

Following points are under consideration:

a) Concealed/surface/under floor/hybrid;
b) Location of switch boards/DBs (room wise, utility points);
c) Painting;
d) Lighting illumination and ambiance;
e) Position of lighting fixtures (for example, bedroom etc.);
f) Lighting fixtures can be classified on the basis of technical parameters like correlated colour temperature (CCT), colour rendering index (CRI), efficacy, glare index etc.;
g) air conditioner point;
h) Study table;
j) Kitchen;
k) Bed;
m) Balcony;
n) Glare;
p) Reading lights;
q) Two-way points;
r) CRI;
s) CCT;
t) Circuits;
u) Cover plates;
v) Placement of switches on board;
w) LV utilities;
y) Telephone wiring/EPABX ;
z) Cable TV;
aa) LAN, servers, switch, racks;
ab) CCTV;

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ac) Looping/extended points;
ad) Night lamp/path light;
ae) Heat dissipation;
af) Sound boxes/speakers;
ag) Computer and accessories;
ah) Lights in showcases/furniture items;
aj) Spot lights;
ak) Study table;
am) Mosquito repellants;
an) Bell;
ap) Arrangements for festive lightings;
aq) Task lighting;
ar) Flush/surface lights; and
as) Emergency load.

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ANNEX A

(*Clause* 5.3)

METHODS OF INSTALLATIONS

Table A-1 Methods of Installation in Relation to Conductors and Cables

NOTE — For more information, refer Annex R of IS 732 : 2019. Annex R of IS 732 : 2019.

Sl No.	Conductors and Cables		Method of Installation							
			Without Fixings	Clipped Direct	Conduit Systems	Cable trunking Systems (including Skirting Trunking, Flush Floor Trunking)	Cable Ducting Systems	Cable Ladder, Cable Tray, Cable Brackets	On Insulators	Support Wire
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Bare conductors		–	–	–	–	–	–	+	–
ii)	Insulated conductors[b]		–	–	+	+[a]	+	–	+	–
iii)	Sheathed cables (including armoured and mineral insulated)	Multi-core	+	+	+	+	+	+	0	+
iv)		Single-core	0	+	+	+	+	+	0	+

+ Permitted.

– Not permitted.

0 Not applicable, or not normally used in practice.

[a] Insulated conductors are admitted if the cable trunking systems provide minimum degree of protection as IP4X or IPXXD and if the cover can only be removed by means of a tool or a deliberate action.

[b] Insulated conductors which are used as protective conductors or protective bonding conductors may use any appropriate method of installation and need not be laid in conduits, trunking or ducting systems.

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Table A-2 Erection of Wiring Systems

NOTE — For more information, refer Annex R of IS 732 : 2019.

Sl No.	Situations	Method of Installation							
		Without Fixings	Clipped Direct	Conduit Systems	Cable trunking Systems (including Skirting Trunking, Flush Floor Trunking)	Cable Ducting Systems	Cable Ladder, Cable Tray, Cable Brackets	On Insulators	Support Wire
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Building voids Accessible	40	33	41, 42	6, 7, 8, 9, 12	43, 44	30, 31, 32, 33, 34	–	0
ii)	Not accessible	40	0	41,42	0	43	0	0	0
iii)	Cable channel	56	56	54, 55	0		30, 31, 32, 34	–	–
iv)	Buried in ground	72, 73	0	70, 71	–	70, 71	0	–	–
v)	Embedded in structure	57, 58	3	1, 2, 59, 60	50, 51, 52, 53	46, 45	0	–	–
vi)	Surface mounted	–	20, 21, 22, 23, 33	4, 5	6, 7, 8, 9, 12	6, 7, 8, 9	30, 31, 32, 34	36	–
vii)	Overhead/free in air	–	33	0	10, 11	10,11	30, 31, 32,34	36	35
viii)	Window frames	16	0	16	0	0	0	-	-
ix)	Architrave	15	0	15	0	0	0	–	–
x)	Immersed 1	+	+	+	–	+	0	–	–

– Not permitted.

0 Not applicable or not normally used in practice.

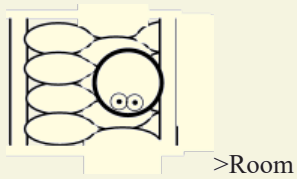
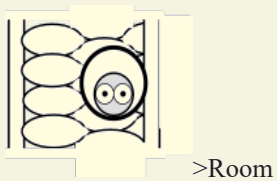
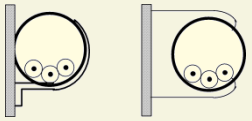
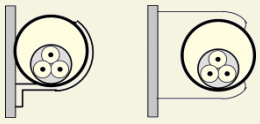
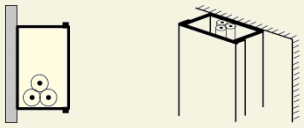
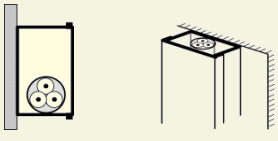
\+ Follow manufacturer's instructions.

NOTE — The numeral in table refers to S. No. of method of installation in Table A-3.

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Table A-3 Examples of Methods of Installation Providing Instructions for Obtaining Current-carrying Capacity

NOTE — For more information, refer Annex R of IS 732 : 2019.

Item No.	Methods of Installation	Description	Reference Method of Installation to be Used to Obtain Current-carrying Capacity (*see* Annex B)
(1)	(2)	(3)	(4)
1		Insulated conductors or single-core cables **in conduit in a thermally insulated wall**[a,c]	A1
2		Multi-core cables **in conduit in a thermally insulated wall** [a,c]	A2
3		Multi-core cable direct **in a thermally in sulated wall** [a,c]	A1
4		Insulated conductors or single-core cables **in conduit on a wooden or masonry wall** or spaced less than 0.3 × conduit diameter from it[c]	B1
5		Multi-core cable **in conduit on a wooden or masonry wall** or spaced less than 0.3 × conduit diameter from it [c]	B2
6		Insulated conductors or single-core cables **in cable trunking** (includes multi-compartment trunking) **on a wooden or masonry wall**	B1
7	6 7	– run horizontally[b] – run vertically[b, c]	
8		Multi-core cable **in cable trunking** (includes multi-compartment trunking) **on a wooden or masonry wall**	Under consideration[d] Method B2 may be used
9	8 9	– run horizontally[b] – run vertically[b, c]	

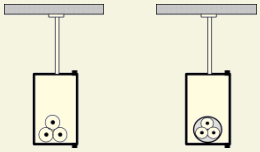
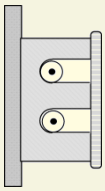
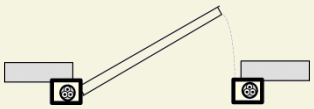
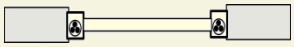
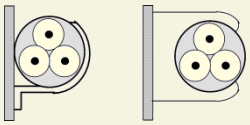
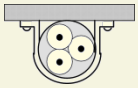
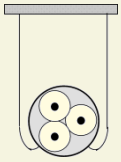
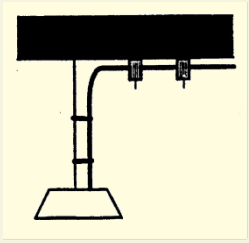
NOTES

1 The illustrations are not intended to depict actual product or installation practices but are indicative of the described method.

2 All footnotes are specified at the end of Table A-3.

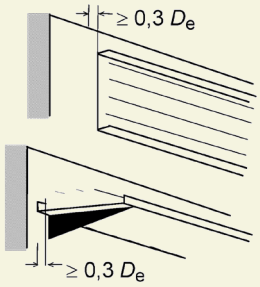
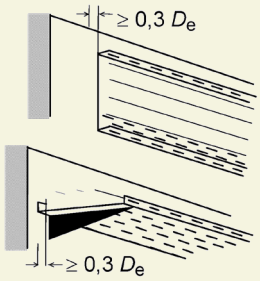
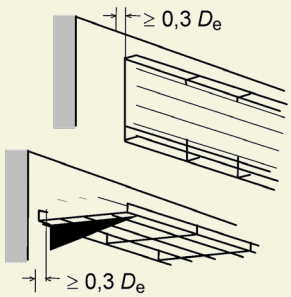
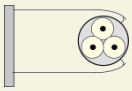
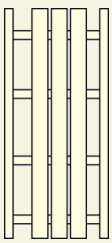
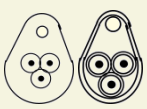
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Table A-3 (*Continued*)

Item No.	Methods of Installation	Description	Reference Method of Installation to be Used to Obtain Current-carrying Capacity (*see* Annex B)
(1)	(2)	(3)	(4)
10		Insulated conductors or single-core cable **in suspended cable trunking**[b]	B1 B2
11	10 M 11	Multi-core cable **in suspended cable trunking**[b]	
12		Insulated conductors or single-core cable run **in mouldings**[c, e]	A1
15		Insulated conductors in conduit or single-core or multi-core cable **in architrave**[c, f]	A1
16		Insulated conductors in conduit or single-core or multi-core cable **in window frames**[c, f]	A1
20		Single-core or multi-core cables: – **fixed on, or spaced** at less than 0.3x cable diameter **from a wooden or masonry wall**[c]	C
21		Single-core or multi-core cables: – fixed **directly under a wooden or masonry ceiling**	C and S. No., 3 of Table B-17
22		Single-core or multi-core cables: – **spaced from a ceiling**	Under consideration Method E may be used
23		Fixed installation of **suspended** current- using equipment	C and S. No., 3 of Table B-17

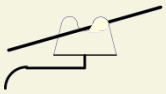
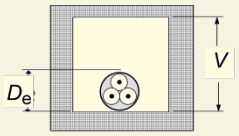
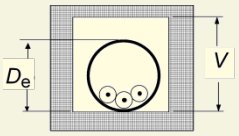
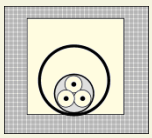
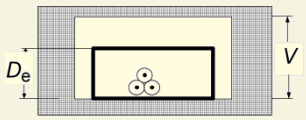
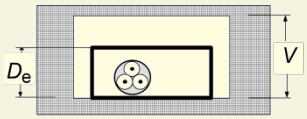
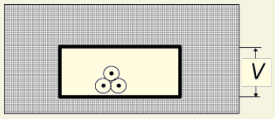
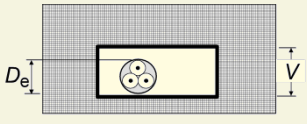
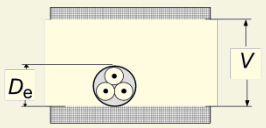
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Table A-3 (*Continued*)

Item No.	Methods of Installation	Description	Reference Method of Installation to be Used to Obtain Current-carrying Capacity (*see* Annex B)
(1)	(2)	(3)	(4)
30		Single-core or multi-core cables **On unperforated tray** run horizontally or vertically[c, h]	C and S. No., 2 of Table B-17
31		Single-core or multi-core cables **On perforated tray** run horizontally or vertically[c, h] NOTE — For more details, refer B.6.	E or F
32		Single-core or multi-core cables **On brackets or on a wire mesh tray** run horizontally or vertically[c, h]	E or F
33		Single-core or multi-core cables **On wall Spaced** more than 0.3 times cable diameter from a wall	E or F or G
34		Single-core or multi-core cables **On ladder** [c]	E or F
35		Single-core or multi-core cable **suspended from or incorporating a support wire or harness**	E or F

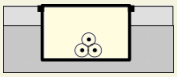
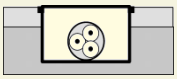
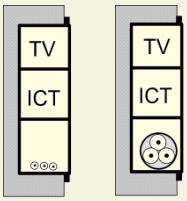
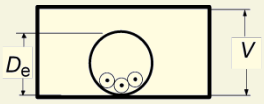
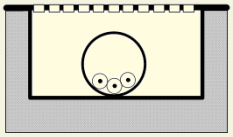
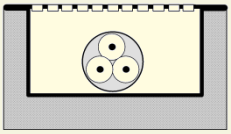
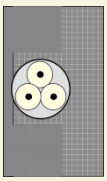
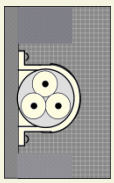
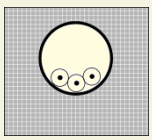
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Table A-3 (*Continued*)

Item No.	Methods of Installation	Description	Reference Method of Installation to be Used to Obtain Current-carrying Capacity (*see* Annex B)
(1)	(2)	(3)	(4)
36		Bare or insulated conductors **on insulators**	G
40		Single-core or multi-core cable **in a building void**[c, h, i]	1.5 *De*≤*V*<*D*e B2 5 *De*≤*V*<20 *De* B1
41		Insulated conductor **in conduit in a building void**[c, i, j, k]	1.5 *De*≤*V*<20 *De* B2 *V*≥ 20 *De* B1
42		Single-core or multi-core cable **in conduit in a building void**[c, k]	Under consideration The following may be used: 1.5 *De*≤ *V*<20 *De* B2 *V*≥ 20 *De* B1
43		Insulated conductors **in cable ducting in a building void,** [c, i, j, k]	1.5 *De*≤*V*<20 *De* B2 *V*≥ 20 *De* B1
44		Single-core or multi-core cable **in cable ducting in a building void**[c, k]	Under consideration The following may be used: 1.5 *De*≤*V*<20 *De* B2 *V*≥ 20 *De* B1
45		Insulated conductors **in cable ducting in masonry** having a thermal resistivity not greater than 2 K·m/W[c, h, i]	1.5 *De*≤*V*<5 *De* B2 5 *De*≤*V*<50 *De* B1
46		Single-core or multi-core cable **in cable ducting in masonry** having a thermal resistivity not greater than 2 K·m/W[c]	Under consideration The following may be used 1.5 *De*≤*V*<20 *De* B2 *V*≥ 20 *De* B1
47		Single-core or multi-core cable: – **in a ceiling void** – **in a raised floor**[h, i]	1.5 *De*≤ *V*< 5 *De* B2 5 *De*≤*V*<50 *De* B1

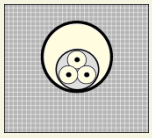
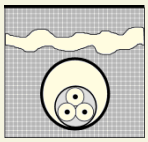
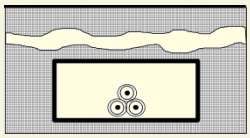
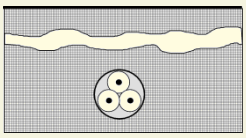
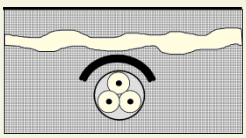
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Table A-3 (*Continued*)

Item No.	Methods of Installation	Description	Reference Method of Installation to be Used to Obtain Current-carrying Capacity (*see* Annex B)
(1)	(2)	(3)	(4)
50		Insulated conductors or single-core cable **in flush cable trunking in the floor**	B1
51		Multi-core cable **in flush cable trunking in the floor**	B2
52		Insulated conductors or single-core cables **in flush cable trunking**[c]	B1
53	52 53	Multi-core cable **in flush trunking**[c]	B2
54		Insulated conductors or single-core cables **in conduit in an unventilated cable channel** run horizontally or vertically[c, i, l, n]	1.5 *D*e ≤ *V* < 20 *D*e B2 *V* ≥ 20 *D*e B1
55		Insulated conductors in conduit **in an open or ventilated cable channel in the floor**[m, n]	B1
56		Sheathed single-core or multi-core cable **in an open or ventilated cable channel run flush** horizontally or vertically[n]	B1
57		Single-core or multi-core cable **direct in masonry** having a thermal resistivity not greater than 2 K·m/W Without added mechanical protection[o, p]	C
58		Single-core or multi-core cable **direct in masonry** having a thermal resistivity not greater than 2 K·m/W With added mechanical protection[o, p]	C
59		Insulated conductors or single-core cables in **conduit in masonry**[p]	B1

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Table A-3 (*Concluded*)

Item No.	Methods of Installation	Description	Reference Method of Installation to be Used to Obtain Current-carrying Capacity (*see* Annex B)
(1)	(2)	(3)	(4)
60		Multi-core cables in **conduit in masonry**[p]	B2
70		Multi-core cable in conduit or in cable **ducting in the ground**	D1
71		Single-core cable in conduit or in cable **ducting in the ground**	D1
72		Sheathed single-core or multi-core cables **direct in the ground** – without added mechanical protection[q]	D2
73		Sheathed single-core or multi-core cables **direct in the ground** – with added mechanical protection[q]	D2

[a] The inner skin of the wall has a thermal conductance of not less than 10 W/m^2·K.

[b] Values given for installation methods B1 and B2 in Annex B are for a single circuit. Where there is more than one circuit in the trunking the group reduction factor given in Table B-17 is applicable, irrespective of the presence of an internal barrier or partition.

[c] Care shall be taken where the cable runs vertically and ventilation is restricted. The ambient temperature at the top of the vertical section can be increased considerably. The matter is under consideration.

[d] Values for reference method B2 may be used.

[e] The thermal resistivity of the enclosure is assumed to be poor because of the material of construction and possible air spaces. Where the construction is thermally equivalent to methods of installation 6 or 7, reference method B1 may be used.

[f] The thermal resistivity of the enclosure is assumed to be poor because of the material of construction and possible air spaces. Where the construction is thermally equivalent to methods of installation 6, 7, 8, or 9, reference methods B1 or B2 may be used.

[g] The factors in Table B-17 may also be used.

[h] *De* is the external diameter of a multi-core cable:

- 2.2 × the cable diameter when three single core cables are bound in trefoil, or
- 3 × the cable diameter when three single core cables are laid in flat formation.

[i] *V* is the smaller dimension or diameter of a masonry duct or void, or the vertical depth of a rectangular duct, floor or ceiling void or channel. The depth of the channel is more important than the width.

[j] *De* is the external diameter of conduit or vertical depth of cable ducting.

[l] *De* is the external diameter of the conduit.

[m] For multi-core cable installed in method 55, use current-carrying capacity for reference method B2.

[n] It is recommended that these methods of installation are used only in areas where access is restricted to authorized persons so that the reduction in current-carrying capacity and the fire hazard due to the accumulation of debris can be prevented.

[o] For cables having conductors not greater than 16 mm^2, the current-carrying capacity may be higher.

[p] Thermal resistivity of masonry is not greater than 2 K·m/W, the term "masonry" is taken to include brickwork, concrete, plaster and other than thermally insulating materials.

[q] The inclusion of directly buried cables in this item is satisfactory when the soil thermal resistivity is of the order of 2.5 K·m/W. For lower soil resistivities, the current-carrying capacity for directly buried cables is appreciably higher than for cables in ducts.

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ANNEX B

(*Clause* 5.5)

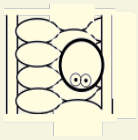
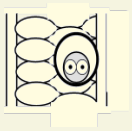
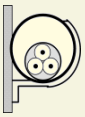
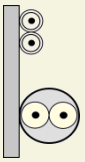
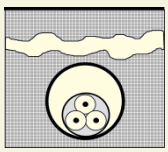
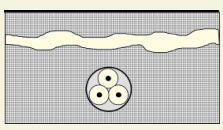
CURRENT CARRYING CAPACITIES

NOTES

1 For more information, refer Annex S of IS 732:2019.

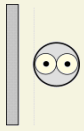
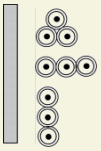
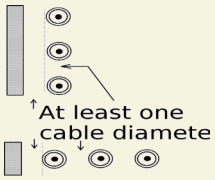
2 The tables specifies the current carrying capacities both for copper and aluminium conductor. However, for conductor cross-sectional area upto 16 mm^2 use of copper conductor are recommended (*see* **5.8.1**).

Table B-1 Installation Reference Methods forming basis of tabulated Current Carrying Capacities

Reference Method of Installation		Table and Column							
		Current-carrying Capacities for Single Circuits					Ambient Temperature Factor	Group Reduction Factor
		Thermoplastic Insulated		Thermosetting Insulated		Mineral Insulated		
		Number of Cores						
		2	3	2	3	2 and 3		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
 Room	Insulated conductors (single- core cables) in conduit in a thermally insulated wall	A1	Col(2) of Table B-2	Col(2) of Table B-4	Col(2) of Table B-3	Col(2) of Table B-5	–	Table B-14	Table B-17
 Room	Multi-core cable in conduit in a thermally insulated wall	A2	Col(3) of Table B-2	Col(3) of Table B-4	Col(3) of Table B-3	Col(3) of Table B-5	–	TableB-14	Table B-17 except D (Table B-19 applies)
	Insulated conductors (single-core cables) in conduit on a wooden wall	B1	Col(4) of Table B-2	Col(4) of Table B-4	Col(4) of Table B-3	Col(4) of Table B-5	–	Table B-14	Table B-17
	Multi-core cable in conduit on a wooden wall	B2	Col(5) of Table B-2	Col(5) of Table B-4	Col(5) of Table B-3	Col(5) of Table B-5	–	Table B-14	Table B-17
	Single-core or multi-core cable on a wooden wall	C	Col(6) of Table B-2	Col(6) of Table B-4	Col(6) of Table B-3	Col(6) of Table B-5	70 °C Sheath Table B-6 105 °C Sheath Table B-7	Table B-14	Table B-17
	Multi-core cable in ducts in the ground	D	Col(7) of Table B-2	Col(7) of Table B-4	Col(7) of Table B-3	Col(7) of Table B-5	–	Table B-15	Table B-19
	Sheathed single-core or multi-core cables direct in the ground.	D2	Col (8)		Col (8)		Col (8)	Col (8)	Col (8)

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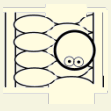
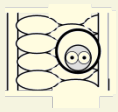
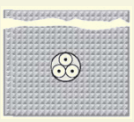
Table B-2 (*Concluded*)

Reference Method of Installation		Table and Column							
		Current-carrying Capacities for Single Circuits					Ambient Temperature Factor	Group Reduction Factor
		Thermoplastic Insulated		Thermosetting Insulated		Mineral Insulated		
		Number of Cores						
		2	3	2	3	2 and 3		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
 Clearance to wall not less than 0,3 times cable diameter	Multi-core cable in free air	E	Copper Table B-10 Aluminium Table B-11		Copper Table B-12 Aluminium Table B-13		70 °C Sheath Table B-8 105 °C Sheath Table B-9	Table B-14	Table B-20
 Clearance to wall not less than one cable diameter	Single-core cables, touching in free air	F	Copper Table B-10 Aluminium Table B-11		Copper Table B-12 Aluminium Table B-13		70 °C Sheath Table B-8 105 °C Sheath Table B-9	Table B-14	Table B-21
	Single-core cables, spaced in free air	G	Copper Table B-10 Aluminium Table B-11		Copper Table B-12 Aluminium Table B-13		70 °C Sheath Table B-8 105 °C Sheath Table B-9	Table B-14	–

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Table B-2 Current-carrying Capacities in Amperes for Methods of Installation in Table B-1 – PVC Insulation/two Loaded Conductors, Copper or Aluminium – Conductor Temperature: 70 °C, Ambient Temperature: 30 °C in air and 20 °C at Ground

NOTE — For more information, refer Annex S of IS 732 : 2019.

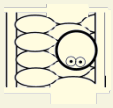
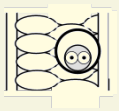
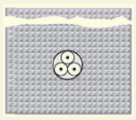
Nominal Cross-sectional Area of Conductor mm²	Installation Methods of Table B-1						
	A1	A2	B1	B2	C	D1	D2
							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Copper							
1.5	14.5	14	17.5	16.5	19.5	22	22
2.5	19.5	18.5	24	23	27	29	28
4	26	25	32	30	36	37	38
6	34	32	41	38	46	46	48
10	46	43	57	52	63	60	64
16	61	57	76	69	85	78	83
25	80	75	101	90	112	99	110
35	99	92	125	111	138	119	132
50	119	110	151	133	168	140	156
70	151	139	192	168	213	173	192
95	182	167	232	201	258	204	230
120	210	192	269	232	299	231	261
150	240	219	300	258	344	261	293
185	273	248	341	294	392	292	331
240	321	291	400	344	461	336	382
300	367	334	458	394	530	379	427
Aluminium							
2.5	15	14.5	18.5	17.5	21	22	
4	20	19.5	25	24	28	29	
6	26	25	32	30	36	36	
10	36	33	44	41	49	47	
16	48	44	60	54	66	61	63
25	63	58	79	71	83	77	82
35	77	71	97	86	103	93	98
50	93	86	118	104	125	109	117
70	118	108	150	131	160	135	145
95	142	130	181	157	195	159	173
120	164	150	210	181	226	180	200
150	189	172	234	201	261	204	224
185	215	195	266	230	298	228	255
240	252	229	312	269	352	262	298
300	289	263	358	308	406	296	336

NOTE — In Col (3), (5), (6), (7) and (8), circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

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Table B-3 Current-carrying Capacities in Amperes for Methods of Installation in Table B-1 – XLPE or EPR Insulation, Two Loaded Conductors/copper or Aluminium – Conductor Temperature: 90 °C, Ambient Temperature: 30 °C in Air and 20 °C at Ground

NOTE — For more information, refer Annex S of IS 732 : 2019.

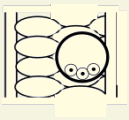
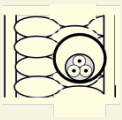
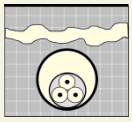
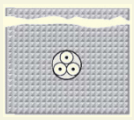
Nominal Cross-Sectional Area of Conductor mm²	Installation Methods of Table B-1						
	A1	A2	B1	B2	C	D1	D2
							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Copper							
1.5	19	18.5	23	22	24	25	27
2.5	26	25	31	30	33	33	35
4	35	33	42	40	45	43	46
6	45	42	54	51	58	53	58
10	61	57	75	69	80	71	77
16	81	76	100	91	107	91	100
25	106	99	133	119	138	116	129
35	131	121	164	146	171	139	155
50	158	145	198	175	209	164	183
70	200	183	253	221	269	203	225
95	241	220	306	265	328	239	270
120	278	253	354	305	382	271	306
150	318	290	393	334	441	306	343
185	362	329	449	384	506	343	387
240	424	386	528	459	599	395	448
300	486	442	603	532	693	446	502
Aluminium							
2.5	20	19.5	25	23	26	26	
4	27	26	33	31	35	33	
6	35	33	43	40	45	42	
.10	48	45	59	54	62	55	
16	64	60	79	72	84	71	76
25	84	78	105	94	101	90	98
35	103	96	130	115	126	108	117
50	125	115	157	138	154	128	139
70	158	145	200	175	198	158	170
95	191	175	242	210	241	186	204
120	220	201	281	242	280	211	233
150	253	230	307	261	324	238	261
185	288	262	351	300	371	267	296
240	338	307	412	358	439	307	343
300	387	352	471	415	508	346	386

NOTE — In Col (3), (5), (6), (7) and (8), circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

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Table B-4 Current-carrying Capacities in Amperes for Methods of Installation in Table B-1– PVC insulation, Three Loaded Conductors/copper or Aluminium – Conductor Temperature: 70 °C, Ambient Temperature: 30 °C in Air and 20 °C at Ground

NOTE — For more information, refer Annex S of IS 732 : 2019.

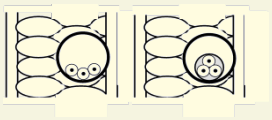
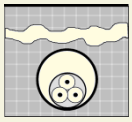
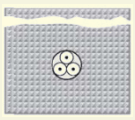
Nominal Cross-Sectional Area of Conductor	Installation Methods of Table B-1						
	A1	A2	B1	B2	C	D1	D2
mm²							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Copper							
1.5	13.5	13	15.5	15	17.5	18	19
2.5	18	17.5	21	20	24	24	24
4	24	23	28	27	32	30	33
6	31	29	36	34	41	38	41
10	42	39	50	46	57	50	54
16	56	52	68	62	76	64	70
25	73	68	89	80	96	82	92
35	89	83	110	99	119	98	110
50	108	99	134	118	144	116	130
70	136	125	171	149	184	143	162
95	164	150	207	179	223	169	193
120	188	172	239	206	259	192	220
150	216	196	262	225	299	217	246
185	245	223	296	255	341	243	278
240	286	261	346	297	403	280	320
300	328	298	394	339	464	316	359
Aluminium							
2.5	14	13.5	16.5	15.5	18.5	18.5	
4	18.5	17.5	22	21	25	24	
6	24	23	28	27	32	30	
10	32	31	39	36	44	39	
16	43	41	53	48	59	50	53
25	57	53	70	62	73	64	69
35	70	65	86	77	90	77	83
50	84	78	104	92	110	91	99
70	107	98	133	116	140	112	122
95	129	118	161	139	170	132	148
120	149	135	186	160	197	150	169
150	170	155	204	176	227	169	189
185	194	176	230	199	259	190	214
240	227	207	269	232	305	218	250
300	261	237	306	265	351	247	282

NOTE — In Col (3), (5), (6), (7) and (8), circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

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Table B-5 Current-carrying Capacities in Amperes for Methods of Installation in Table B-1–XLPE or EPR Insulation Three Loaded Conductors/copper or Aluminium – Conductor Temperature: 90 °C, Ambient Temperature: 30 °C in Air and 20 °C at Ground

NOTE — For more information, refer Annex S of IS 732 : 2019.

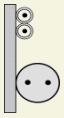
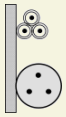
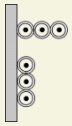
Nominal Cross-Sectional Area of Conductor mm²	Installation Methods of Table B-1						
	A1	A2	B1	B2	C	D1	D2
							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Copper							
1.5	17	16.5	20	19.5	22	21	23
2.5	23	22	28	26	30	28	30
4	31	30	37	35	40	36	39
6	40	38	48	44	52	44	49
10	54	51	66	60	71	58	65
16	73	68	88	80	96	75	84
25	95	89	117	105	119	96	107
35	117	109	144	128	147	115	129
50	141	130	175	154	179	135	153
70	179	164	222	194	229	167	188
95	216	197	269	233	278	197	226
120	249	227	312	268	322	223	257
150	285	259	342	300	371	251	287
185	324	295	384	340	424	281	324
240	380	346	450	398	500	324	375
300	435	396	514	455	576	365	419
Aluminium							
2.5	19	18	22	21	24	22	
4	25	24	29	28	32	28	
6	32	31	38	35	41	35	
10	44	41	52	48	57	46	
16	58	55	71	64	76	59	64
25	76	71	93	84	90	75	82
35	94	87	116	103	112	90	98
50	113	104	140	124	136	106	117
70	142	131	179	156	174	130	144
95	171	157	217	188	211	154	172
120	197	180	251	216	245	174	197
150	226	206	267	240	283	197	220
185	256	233	300	272	323	220	250
240	300	273	351	318	382	253	290
300	344	313	402	364	440	286	326

NOTE — In Col (3), (5), (6), (7) and (8), circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

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Table B-6 Current-carrying Capacities in Amperes for Methods of Installation C of Table B-1 — Mineral Insulation, Copper Conductors and Sheath – PVC Covered or Bare Exposed to Touch — Metallic Sheath Temperature: 70 °C, Reference Ambient Temperature: 30 °C

NOTE — For more information, refer Annex S of IS 732 : 2019.

Nominal Cross-Sectional Area of Conductor mm^2	Number and Arrangement of Conductors for Method C of Table B-1		
	Two Loaded Conductors Twin or Single-core	Three Loaded Conductors	
		Multi-core or Single-core in Trefoil Formation	Single-core in Flat Formation
			
(1)	(2)	(3)	(4)
500 V			
1.5	23	19	21
2.5	31	26	29
4	40	35	38
750 V			
1.5	25	21	23
2.5	34	28	31
4	45	37	41
6	57	48	52
10	77	65	70
16	102	86	92
25	133	112	120
35	163	137	147
50	202	169	181
70	247	207	221
95	296	249	264
120	340	286	303
150	388	327	346
185	440	371	392
240	514	434	457

NOTES

1 For single-core cables, sheaths of cables of the circuit are connected together at both ends.

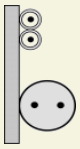
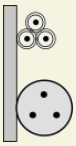
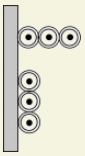
2 For bare cables exposed to touch, values should be multiplied by 0.9.

3 500 V and 750 V are rated voltages of the cable.

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Table B-7– Current-carrying Capacities in Amperes for Methods of Installation C of Table B-1 – Mineral Insulation, Copper Conductors and Sheath — Bare Cable not Exposed to Touch and not in Contact with Combustible Material Metallic Sheath Temperature: 105 °C, Reference Ambient Temperature: 30 °C

NOTE — For more information, refer Annex S of IS 732 : 2019.

Nominal Cross-Sectional Area of Conductor mm²	Number and Arrangement of Conductors for Method C of Table B-1		
	Two Loaded Conductors Twin or Single-core	Three Loaded Conductors	
		Multi-core or Single-core in Trefoil Formation	Single-core in Flat Formation
			
(1)	(2)	(3)	(4)
500 V			
1.5	28	24	27
2.5	38	33	36
4	51	44	47
750 V			
1.5	31	26	30
2.5	42	35	41
4	55	47	53
6	70	59	67
10	96	81	91
16	127	107	119
25	166	140	154
35	203	171	187
50	251	212	230
70	307	260	280
95	369	312	334
120	424	359	383
150	485	410	435
185	550	465	492
240	643	544	572

NOTES

1 For single-core cables, sheaths of cables of the circuit are connected together at both ends.

2 No correction for grouping is required.

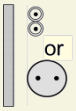
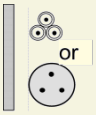
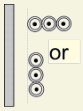
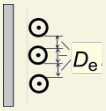
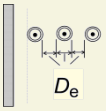
3 For this table, reference method C refers to a masonry wall because the high sheath temperature is not normally acceptable for a wooden wall.

4 500 V and 750 V are rated voltages of the cable.

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Table B-8 Current-carrying Capacities in Amperes for Methods of Installation E, F and G of Table B-1 – Mineral Insulation, Copper Conductors and Sheath/PVC Covered or Bare Exposed to Touch — Metallic Sheath Temperature: 70 °C, Reference Ambient Temperature: 30 °C

NOTE — For more information, refer Annex S of IS 732 : 2019.

Nominal cross-sectional area of conductor mm²	Number and Arrangement of Conductors for Methods E, F and G of Table B-1				
	Two Loaded Conductors Twin or Single-core	Three Loaded Conductors			
	Method E and F	Multi-core or single-core in Trefoil Formation Method E or F	Single-core Touching Method F	Single-core flat Vertical Spaced Method G	Single-core Horizontal Spaced Method G
					
(1)	(2)	(3)	(4)	(5)	(6)
500 V					
1,5	25	21	23	26	29
2,5	33	28	31	34	39
4	44	37	41	45	51
750 V					
1.5	26	22	26	28	32
2.5	36	30	34	37	43
4	47	40	45	49	56
6	60	51	57	62	71
10	82	69	77	84	95
16	109	92	102	110	125
25	142	120	132	142	162
35	174	147	161	173	197
50	215	182	198	213	242
70	264	223	241	259	294
95	317	267	289	309	351
120	364	308	331	353	402
150	416	352	377	400	454
185	472	399	426	446	507
240	552	466	496	497	565

NOTES

1 For single-core cables, sheaths of cables of the circuit are connected together at both ends.

2 For bare cables exposed to touch, values should be multiplied by 0.9.

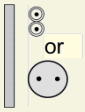
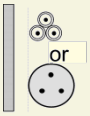
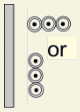
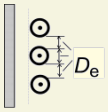
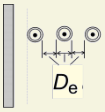
3 *D*e is the external diameter of the cable.

4 500 V and 750 V are the rated voltages of the cable.

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Table B-9 Current-carrying Capacities in Amperes for Methods E, F and G of Table B-1 Mineral Insulation, Copper Conductors and Sheath — Bare Cable not Exposed to Touch – Metallic Sheath Temperature: 105 °C, Reference Ambient Temperature: 30 °C

NOTE — For more information, refer Annex S of IS 732 : 2019.

Nominal cross-sectional Area of conductor mm²	Number and Arrangement of Cables for Methods E, F and G of Table B-1				
			Three Loaded Conductors		
	Two Loaded Conductors Twin or Single-core	Multi-core or single-core in Trefoil Formation	Single-core Touching	Single-core Flat Vertical Spaced	Single-core Horizontal Spaced
	Method E and F	Method E or F	Method F	Method G	Method G
					
(1)	(2)	(3)	(4)	(5)	(6)
500 V					
1.5	31	26	29	33	37
2.5	41	35	39	43	49
4	54	46	51	56	64
750 V					
1.5	33	28	32	35	40
2.5	45	38	43	47	54
4	60	50	56	61	70
6	76	64	71	78	89
10	104	87	96	105	120
16	137	115	127	137	157
25	179	150	164	178	204
35	220	184	200	216	248
50	272	228	247	266	304
70	333	279	300	323	370
95	400	335	359	385	441
120	460	385	411	441	505
150	526	441	469	498	565
185	596	500	530	557	629
240	697	584	617	624	704

NOTES

1 For single-core cables, sheaths of cables of the circuit are connected together at both ends.

2 For bare cables exposed to touch, values should be multiplied by 0.9.

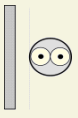
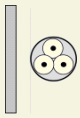
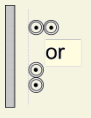
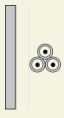
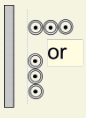
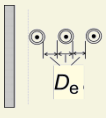
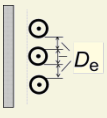
3 *D*e is the external diameter of the cable.

4 500 V and 750 V are the rated voltages of the cable.

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Table B-10 Current-carrying Capacities in Amperes for Installation Methods E, F and G of Table B-1– PVC insulation, Copper Conductors –Conductor Temperature: 70 °C, Reference Ambient Temperature: 30 °C

NOTE — For more information, refer Annex S of IS 732 : 2019.

Nominal Cross-Sectional Area of Conductor mm²	Installation methods of Table B-1						
	Multi-core Cables		Single-core Cables				
	Two Loaded Conductors	Three Loaded Conductors	Two Loaded Conductors Touching	Three Loaded Conductors Trefoil	Three Loaded Conductors (Flat)		
					Touching	Spaced	
						Horizontal	Vertical
							
	Method E	Method E	Method F	Method F	Method F	Method G	Method G
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.5	22	18.5	–	–	–	–	–
2.5	30	25	–	–	–	–	–
4	40	34	–	–	–	–	–
6	51	43	–	–	–	–	–
10	70	60	–	–	–	–	–
16	94	80	–	–	–	–	–
25	119	101	131	110	114	146	130
35	148	126	162	137	143	181	162
50	180	153	196	167	174	219	197
70	232	196	251	216	225	281	254
95	282	238	304	264	275	341	311
120	328	276	352	308	321	396	362
150	379	319	406	356	372	456	419
185	434	364	463	409	427	521	480
240	514	430	546	485	507	615	569
300	593	497	629	561	587	709	659
400	–	–	754	656	689	852	795
500	–	–	868	749	789	982	920
630	–	–	1 005	855	905	1 138	1 070

NOTES

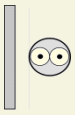
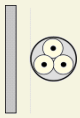
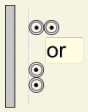
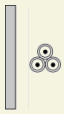
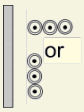
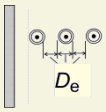
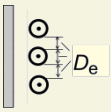
1 Circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

2 *D*e is the external diameter of the cable.

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Table B-11 Current-carrying Capacities in Amperes for Installation Methods E, F and G of Table B-1 – PVC Insulation, Aluminium Conductors — Conductor Temperature: 70 °C, Reference Ambient Temperature: 30 °C

NOTE — For more information, refer Annex S of IS 732 : 2019.

Nominal Cross-Sectional Area of Conductor mm²	Installation Methods of Table B-1						
	Multi-core Cables		Single-core Cables				
	Two Loaded Conductors	Three Loaded Conductors	Two Loaded Conductors Touching	Three Loaded Conductors Trefoil	Three Loaded Conductors (Flat)		
					Touching	Spaced	
						Horizontal	Vertical
							
	Method E	Method E	Method F	Method F	Method F	Method G	Method G
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2,5	23	19,5	–	–	–	–	–
4	31	26	–	–	–	–	–
6	39	33	–	–	–	–	–
10	54	46	–	–	–	–	–
16	73	61	–	–	–	–	–
25	89	78	98	84	87	112	99
35	111	96	122	105	109	139	124
50	135	117	149	128	133	169	152
70	173	150	192	166	173	217	196
95	210	183	235	203	212	265	241
120	244	212	273	237	247	308	282
150	282	245	316	274	287	356	327
185	322	280	363	315	330	407	376
240	380	330	430	375	392	482	447
300	439	381	497	434	455	557	519
400	–	–	600	526	552	671	629
500	–	–	694	610	640	775	730
630	–	–	808	711	746	900	852

NOTES

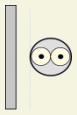
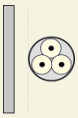
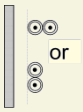
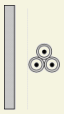
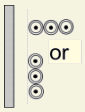
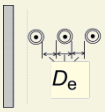
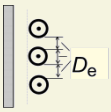
1 Circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

2 *D*e is the external diameter of the cable.

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Table B-12 Current-carrying Capacities in Amperes for Installation Methods E, F and G of Table B-1 – XLPE or EPR Insulation, Copper Conductors — Conductor Temperature : 90 °C, Reference Ambient Temperature : 30 °C

NOTE — For more information, refer Annex S of IS 732 : 2019.

Nominal Cross-Sectional Area of Conductor mm²	Installation methods of Table B-1						
	Multi-core cables		Single-core cables				
	Two Loaded Conductors	Three Loaded Conductors	Two Loaded Conductors Touching	Three Loaded Conductors Trefoil	Three Loaded Conductors (Flat)		
					Touching	Spaced	
						Horizontal	Vertical
							
	Method E	Method E	Method F	Method F	Method F	Method G	Method G
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.5	26	23	–	–	–	–	–
2.5	36	32	–	–	–	–	–
4	49	42	–	–	–	–	–
6	63	54	–	–	–	–	–
10	86	75	–	–	–	–	–
16	115	100	–	–	–	–	–
25	149	127	161	135	141	182	161
35	185	158	200	169	176	226	201
50	225	192	242	207	216	275	246
70	289	246	310	268	279	353	318
95	352	298	377	328	342	430	389
120	410	346	437	383	400	500	454
150	473	399	504	444	464	577	527
185	542	456	575	510	533	661	605
240	641	538	679	607	634	781	719
300	741	621	783	703	736	902	833
400	–	–	940	823	868	1085	1008
500	–	–	1083	946	998	1253	1169
630	–	–	1 254	1 088	1 151	1 454	1 362

NOTES

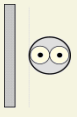
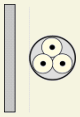
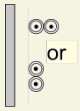
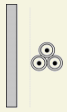
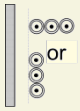
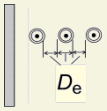
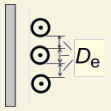
1 Circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

2 *D*e is the external diameter of the cable.

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Table B-13 Current-carrying Capacities in Amperes for Installation Methods E, F and G of Table B-1– XLPE or EPR Insulation Aluminium Conductors – Conductor Temperature: 90 °C, Reference Ambient Temperature: 30 °C

NOTE — For more information, refer Annex S of IS 732 : 2019.

Nominal Cross-sectional Area of Conductor mm²	Installation Methods of Table B-1						
	Multi-core Cables		Single-core Cables				
	Two Loaded Conductors	Three Loaded Conductors	Two Loaded Conductors Touching	Three Loaded Conductors Trefoil	Three Loaded Conductors (Flat)		
					Touching	Spaced	
						Horizontal	Vertical
							
	Method E	Method E	Method F	Method F	Method F	Method G	Method G
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2.5	28	24	–	–	–	–	–
4	38	32	–	–	–	–	–
6	49	42	–	–	–	–	–
10	67	58	–	–	–	–	–
16	91	77	–	–	–	–	–
25	108	97	121	103	107	138	122
35	135	120	150	129	135	172	153
50	164	146	184	159	165	210	188
70	211	187	237	206	215	271	244
95	257	227	289	253	264	332	300
120	300	263	337	296	308	387	351
150	346	304	389	343	358	448	408
185	397	347	447	395	413	515	470
240	470	409	530	471	492	611	561
300	543	471	613	547	571	708	652
400	–	–	740	663	694	856	792
500	–	–	856	770	806	991	921
630	–	–	996	899	942	1 154	1 077

NOTES

1 Circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

2 *D*e is the external diameter of the cable.

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Table B-14 Correction Factor for Ambient Air Temperatures Other than 30 °C to be Applied to the Current-carrying Capacities for Cables in the Air

NOTE — For more information, refer Annex S of IS 732 : 2019.

Ambient Temperaturea °C	Insulation			
	PVC	XLPE and EPR	Mineral[a)]	
			PVC Covered or Bare and Exposed to Touch 70 °C	Bare not Exposed to Touch 105 °C
(1)	(2)	(3)	(4)	(5)
10	1.22	1.15	1.26	1.14
15	1.17	1.12	1.20	1.11
20	1.12	1.08	1.14	1.07
25	1.06	1.04	1.07	1.04
30	1.00	1.00	1.00	1.00
35	0.94	0.96	0.93	0.96
40	0.87	0.91	0.85	0.92
45	0.79	0.87	0.78	0.88
50	0.71	0.82	0.67	0.84
55	0.61	0.76	0.57	0.80
60	0.50	0.71	0.45	0.75
65	–	0.65	–	0.70
70	–	0.58	–	0.65
75	–	0.50	–	0.60
80	–	0.41	–	0.54
85	–	–	–	0.47
90	–	–	–	0.40
95	–	–	–	0.32

[a)] For higher ambient temperatures, consult the manufacturer.

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Table B-15 Correction Factors for Ambient Ground Temperatures other Than 20 °C to be Applied to the Current-carrying Capacities for Cables in Ducts in the Ground

NOTE — For more information, refer Annex S of IS 732 : 2019.

Ground Temperature	Insulation	
°C	PVC	XLPE and EPR
(1)	(2)	(3)
10	1.10	1.07
15	1.05	1.04
20	1.00	1.00
25	0.95	0.96
30	0.89	0.93
35	0.84	0.89
40	0.77	0.85
45	0.71	0.80
50	0.63	0.76
55	0.55	0.71
60	0.45	0.65
65	–	0.60
70	–	0.53
75	–	0.46
80	–	0.38

Table B-16 Correction Factors for Cables Buried Direct in the Ground or in Buried Ducts for Soil Thermal Resistivities other than 2.5 K·m/W to be Applied to the Current-carrying Capacities for Reference Method D

NOTE — For more information, refer Annex S of IS 732 : 2019.

Thermal Resistivity, K·m/W	0.5	0.7	1	1.5	2	2.5	3
Correction Factor for Cables in Buried Ducts	1.28	1.20	1.18	1.1	1.05	1	0.96
Correction Factor for Direct Buried Cables	1.88	1.62	1.5	1.28	1.12	1	0.90

NOTES

1 The correction factors mentioned are averaged over the range of conductor sizes and types of installation included in Tables B-2 to Table B-5. The overall accuracy of correction factors is within 5 percent.

2 The correction factors are applicable to cables drawn into buried ducts and for cables laid direct in the ground. The correction factors for thermal resistivities less than 2.5 K·m/W will be higher. Where more precise values are required. Calculation methods prescribed in the IEC 60287 series may be used.

3 The correction factors are applicable to ducts buried at depths of up to 0.8 m.

4 It is assumed that the soil properties are uniform. No allowance had been made for the possibility of moisture migration which can lead to a region of high thermal resistivity around the cable. If partial drying out of the soil is foreseen, the permissible current rating should be derived by the methods specified in the IEC 60287 series.

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Table B-17 Reduction Factors for One Circuit or One Multi-core Cable or for a Group of more than One Circuit, or More than One Multi-core Cable to be Used with Current-carrying Capacities of Tables B-2 to Table B-13

NOTE — For more information, refer Annex S of IS 732 : 2019.

Item	Arrangement (Cables Touching)	Number of Circuits or Multi-core Mables												To be Used with Current-Carrying Capacities
		1	2	3	4	5	6	7	8	9	12	16	20	
1	Bunched in air, on a surface, embedded or enclosed	1.00	0.80	0.70	0.65	0.60	0.57	0.54	0.52	0.50	0.45	0.41	0.38	Table B-2 to Table B-13 Methods A to F
2	Single layer on wall, floor or unperforated cable tray systems	1.00	0.85	0.79	0.75	0.73	0.72	0.72	0.71	0.70	No further reduction factor for more than nine circuits or multicore cables			Table B-2 to Table B-7 Method C
3	Single layer fixed directly under a wooden ceiling	0.95	0.81	0.72	0.68	0.66	0.64	0.63	0.62	0.61				
4	Single layer on a perforated horizontal or vertical cable tray systems	1.00	0.88	0.82	0.77	0.75	0.73	0.73	0.72	0.72				Table B-8 to Table B-13 Methods E and Fw
5	Single layer on cable ladder systems or cleats etc.,	1.00	0.87	0.82	0.80	0.80	0.79	0.79	0.78	0.78				

NOTES

1 These factors are applicable to uniform groups of cables, equally loaded.

2 Where horizontal clearances between adjacent cables exceeds twice their overall diameter, no reduction factor need to be applied.

3 The same factors are applied to:

a) groups of two or three single-core cables; and

b) multi-core cables.

4 If a system consists of both two- and three-core cables, the total number of cables is taken as the number of circuits, and the corresponding factor is applied to the tables for two loaded conductors for the two-core cables, and to the tables for three loaded conductors for the three-core cables.

5 If a group consists of *n* single-core cables it may either be considered as *n*/2 circuits of two loaded conductors or *n*/3 circuits of three loaded conductors.

6 The values given have been averaged over the range of conductor sizes and types of installation included in Table B-2 to Table B-13. The overall accuracy of tabulated values is within 5 percent.

7 For some installations and for other methods not provided for in the above table, it may be appropriate to use factors calculated for specific cases, see for example Table B-20 and Table B-21.

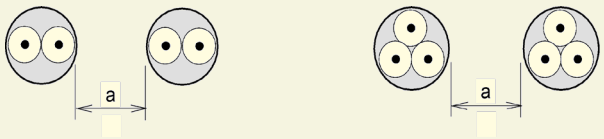
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Table B-18 Reduction Factors for More than One Circuit, Cables Laid Directly in the Ground – Installation Method D2 in Tables B-2 to B-5 – Single-core or Multi-core Cables

NOTE — For more information, refer Annex S of IS 732 : 2019.

Number of Circuits	Cable to Cable Clearance				
	Nil (Cables Touching)	One Cable Diameter	0.125 m	0.25 m	0.5 m
(1)	(2)	(3)	(4)	(5)	(6)
2	0.75	0.80	0.85	0.90	0.90
3	0.65	0.70	0.75	0.80	0.85
4	0.60	0.60	0.70	0.75	0.80
5	0.55	0.55	0.65	0.70	0.80
6	0.50	0.55	0.60	0.70	0.80
7	0.45	0.51	0.59	0.67	0.76
8	0.43	0.48	0.57	0.65	0.75
9	0.41	0.46	0.55	0.63	0.74
12	0.36	0.42	0.51	0.59	0.71
16	0.32	0.38	0.47	0.56	0.38
20	0.29	0.35	0.44	0.53	0.66

a Multi-core cables



a Single-core cables



NOTES

1 Values given apply to an installation depth of 0.7 m and a soil thermal resistivity of 2.5 K·m/W. These are average values for the range of cable sizes and types in Tables B-2 to Table. The process of averaging together with rounding off can result in errors up to 10 percent in some cases. (Where more precise values are required, it may be calculated by methods given in IEC 60287-2-1.)

2 In case of a thermal resistivity lower than 2.5 K·m/W the corrections factors can, in general, be increased and can be calculated by the methods given in IEC 60287-2-1.

3 If a circuit consists of *m* parallel conductors per phase, then for determining the reduction factor, this circuit should be considered as *m* circuits.

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Table B-19 Reduction Factors for More than One Circuit, Cables Laid in Ducts in the Ground — Installation Method D1 in Tables B-2 to B-5

NOTE — For more information, refer Annex S of IS 732 : 2019.

A) Multi-core Cables in Single-way Ducts

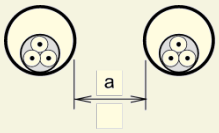
Number of Cables	Duct to Duct Clearance[a]			
	Nil (Ducts Touching)	0.25 m	0.5 m	1.0 m
(1)	(2)	(3)	(4)	(5)
2	0.85	0.90	0.95	0.95
3	0.75	0.85	0.90	0.95
4	0.70	0.80	0.85	0.90
5	0.65	0.80	0.85	0.90
6	0.60	0.80	0.80	0.90
7	0.57	0.76	0.80	0.88
8	0.54	0.74	0.78	0.88
9	0.52	0.73	0.77	0.87
10	0.49	0.72	0.76	0.86
11	0.47	0.70	0.75	0.86
12	0.45	0.69	0.74	0.85
13	0.44	0.68	0.73	0.85
14	0.42	0.68	0.72	0.84
15	0.41	0.67	0.72	0.84
16	0.39	0.66	0.71	0.83
17	0.38	0.65	0.70	0.83
18	0.37	0.65	0.70	0.83
19	0.35	0.64	0.69	0.82
20	0.34	0.63	0.68	0.82
B) Single-core Cables in Non-magnetic Single-way Ducts				
2	0.80	0.90	0.90	0.95
3	0.70	0.80	0.85	0.90
4	0.65	0.75	0.80	0.90
5	0.60	0.70	0.80	0.90
6	0.60	0.70	0.80	0.90
7	0.53	0.66	0.76	0.87
8	0.50	0.63	0.74	0.87
9	0.47	0.61	0.73	0.86
10	0.45	0.59	0.72	0.85
11	0.43	0.57	0.70	0.85
12	0.41	0.56	0.69	0.84
13	0.39	0.54	0.68	0.84

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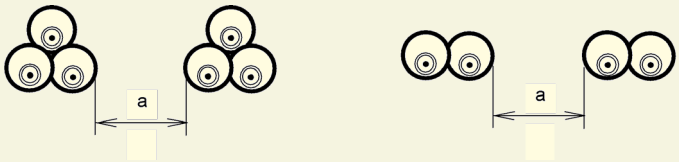
Table B-19 *(Concluded)*

Number of Cables	Duct to Duct Clearance[a]			
	Nil (Ducts Touching)	0.25 m	0.5 m	1.0 m
(1)	(2)	(3)	(4)	(5)
14	0.37	0.53	0.68	0.83
15	0.35	0.52	0.67	0.83
16	0.34	0.51	0.66	0.83
17	0.33	0.50	0.65	0.82
18	0.31	0.49	0.65	0.82
19	0.30	0.48	0.64	0.82
20	0.29	0.47	0.63	0.81

a Multi-core cables



b Single-core cables



NOTES

1 Values given apply to an installation depth of 0.7 m and a soil thermal resistivity of 2.5 K·m/W. These are average values for the range of cable sizes and types in Tables B-2 to Table. The process of averaging together with rounding off can result in errors up to 10 percent in some cases. (Where more precise values are required, it may be calculated by methods given in IEC 60287-2-1.)

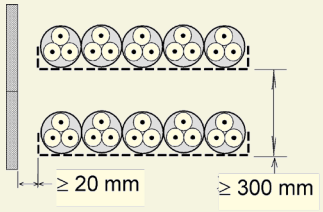
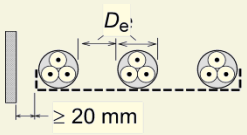
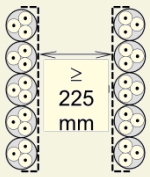
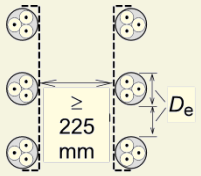
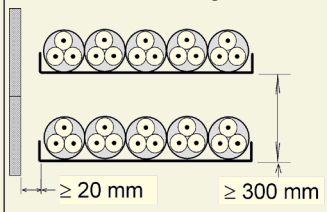
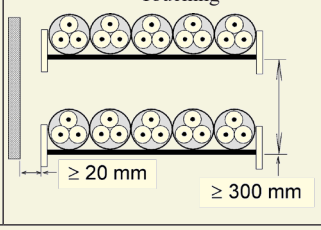
2 In case of a thermal resistivity lower than 2.5 K·m/W, the corrections factors can, in general, be increased and can be calculated by the methods given in IEC 60287-2-1.

3 If a circuit consists of *m* parallel conductors per phase, then, for determining the reduction factor, this circuit should be considered as *m* circuits.

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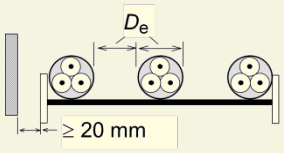
Table B-20 Reduction Factors for Group of More than One Multi-core Cable to be Applied to Reference Current-carrying Capacities for Multi-core Cables in Free Air — Method of Installation E in Table B-8 to Table B-13

NOTE — For more information, refer Annex S of IS 732 : 2019.

Method of Installation in Table A-3			Number of Trays or Ladders	Number of Cables per Tray or Ladder					
				1	2	3	4	6	9
Perforated cable tray systems (*see* Note 3)	31	Touching 	1	1.00	0.88	0.82	0.79	0.76	0.73
			2	1.00	0.87	0.80	0.77	0.73	0.68
			3	1.00	0.86	0.79	0.76	0.71	0.66
			6	1.00	0.84	0.77	0.73	0.68	0.64
		Spaced 	1	1.00	1.00	0.98	0.95	0.91	–
			2	1.00	0.99	0.96	0.92	0.87	–
			3	1.00	0.98	0.95	0.91	0.85	–
Vertical perforated cable tray systems (*see* Note 4)	31	Touching 	1	1.00	0.88	0.82	0.78	0.73	0.72
			2	1.00	0.88	0.81	0.76	0.71	0.70
		Spaced 	1	1.00	0.91	0.89	0.88	0.87	–
			2	1.00	0.91	0.88	0.87	0.85	–
Unperforated cable tray systems	31	Touching 	1	0.97	0.84	0.78	0.75	0.71	0.68
			2	0.97	0.83	0.76	0.72	0.68	0.63
			3	0.97	0.82	0.75	0.71	0.66	0.61
			6	0.97	0.81	0.73	0.69	0.63	0.58
Cable ladder systems, cleats, etc. (*see* Note 3)	32 33 34	Touching 	1	1.00	0.87	0.82	0.80	0.79	0.78
			2	1.00	0.86	0.80	0.78	0.76	0.73
			3	1.00	0.85	0.79	0.76	0.73	0.70
			6	1.00	0.84	0.77	0.73	0.68	0.64

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Table B-20 *(Concluded)*

Method of Installation in Table A-3			Number of Trays or Ladders	Number of Cables per Tray or Ladder					
				1	2	3	4	6	9
		Spaced 	1 2 3	1.00 1.00 1.00	1.00 0.99 0.98	1.00 0.98 0.97	1.00 0.97 0.96	1.00 0.96 0.93	– – –

NOTES

1 Values given are averages for the cable types and range of conductor sizes considered in Tables A-8 to Table A-13. The spread of values is generally less than 5 percent.

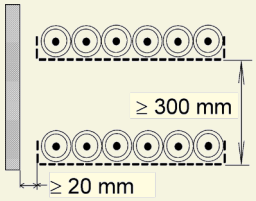
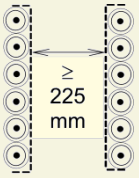
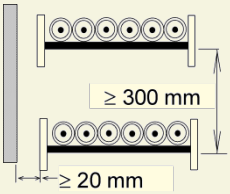
2 The factors apply to single layer groups of cables as shown above and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and has to be determined by an appropriate method.

3 Values are given for vertical spacing between cable trays of 300 mm and at least 20 mm between cable trays and wall. For closer spacing, the factors should be reduced.

4 Values are given for horizontal spacing between cable trays of 225 mm with cable trays mounted back to back. For closer spacing, the factors should be reduced.

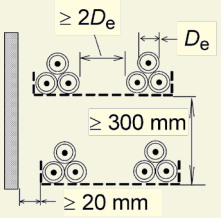
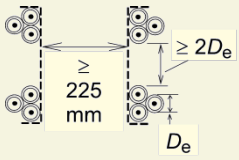
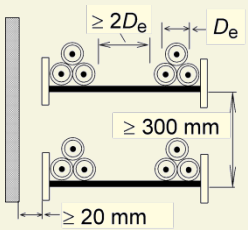
Table B-21 Reduction Factors for Groups of One or More Circuits of Single-core Cables to be applied to Reference Current-carrying Capacity for One Circuit of Single-core Cables in Free air — Method of Installation F in Table B-8 to Table B-13

NOTE — For more information, refer Annex S of IS 732 : 2019.

Method of Installation in Table A-3			Number of Trays or Ladders	Number of Three-Phase Circuits per Tray or Ladder			Use as a Multiplier to Current-carrying Capacity for
				1	2	3	
Perforated cable tray systems (*see* Note 3)	31	Touching 	1 2 3	0.98 0.96 0.95	0.91 0.87 0.85	0.87 0.81 0.78	Three cables in horizontal formation
Vertical perforated cable tray systems (*see* Note 4)	31	Touching 	1 2	0.96 0.95	0.86 0.84	– –	Three cables in vertical formation
Cable ladder systems, cleats, etc. (*see* Note 3)	32 33 34	Touching 	1 2 3	1.00 0.98 0.97	0.97 0.93 0.90	0.96 0.89 0.86	Three cables in horizontal formation

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Table B-21 *(Concluded)*

Method of Installation in Table A-3			Number of Trays or Ladders	Number of Three-Phase Circuits per Tray or Ladder			Use as a Multiplier to Current-carrying Capacity for
				1	2	3	
Perforated cable tray systems (*see* Note 3)	31		1 2 3	1.00 0.97 0.96	0.98 0.93 0.92	0.96 0.89 0.86	Three cables in trefoil formation
Vertical perforated cable tray systems (*see* Note 4)	31	Spaced 	1 2	1.00 1.00	0.91 0.90	0.89 0.86	
Cable ladder systems, cleats, etc. (*see* Note 3)	32 33 34		1 2 3	1.00 0.97 0.96	1.00 0.95 0.94	1.00 0.93 0.90	

NOTES

1 Values given are averages for the cable types and range of conductor sizes considered in Table B-8 to Table B-13. The spread of values is generally less than 5 percent.

2 The factors are given for single layers of cables (or trefoil groups) as shown in the table and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and should be determined by an appropriate method.

3 Values are given for vertical spacing between cable trays of 300 mm and at least 20 mm between cable trays and wall. For closer spacing, the factors should be reduced.

4 Values are given for horizontal spacing between cable trays of 225 mm with cable trays mounted back to back. For closer spacing, the factors should be reduced.

5 For circuits having more than one cable in parallel per phase, each set of conductors per three phase should be considered as a circuit for the purpose of this table.

6 If a circuit consists of *m* parallel conductors per phase, then, for determining the reduction factor this circuit should be considered as *m* circuits.

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ANNEX C

(*Clause* 5.5.5)

EXAMPLE OF A METHOD OF SIMPLIFICATION OF THE TABLES

Table C-1 Current-carrying Capacity in Amperes

NOTE — For more information, refer Annex T of IS 732 : 2019.

Reference Methods in Table B-1	Number of Loaded Conductors and Type of Insulation											
A1		3 PVC	2 PVC		3 XLPE	2 XLPE						
A2	3 PVC	2 PVC		3 XLPE	2 XLPE							
B1				3 PVC	2 PVC		3 XLPE		2 XLPE			
B2			3 PVC	2 PVC		3 XLPE	2 XLPE					
C					3 PVC		2 PVC	3 XLPE		2 XLPE		
E						3 PVC		2 PVC	3 XLPE		2 XLPE	
F							3 PVC		2 PVC	3 XLPE		2 XLPE
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Size (mm^2) Copper												
1.5	13	13.5	14.5	15.5	17	18.5	19.5	22	23	24	26	–
2.5	17.5	18	19.5	21	23	25	27	30	31	33	36	–
4	23	24	26	28	31	34	36	40	42	45	49	–
6	29	31	34	36	40	43	46	51	54	58	63	–
10	39	42	46	50	54	60	63	70	75	80	86	–
16	52	56	61	68	73	80	85	94	100	107	115	–
25	68	73	80	89	95	101	110	119	127	135	149	161
35	–	–	–	110	117	126	137	147	158	169	185	200
50	–	–	–	134	141	153	167	179	192	207	225	242
70	–	–	–	171	179	196	213	229	246	268	289	310
95	–	–	–	207	216	238	258	278	298	328	352	377
120	–	–	–	239	249	276	299	322	346	382	410	437
150	–	–	–	–	285	318	344	371	395	441	473	504
185	–	–	–	–	324	362	392	424	450	506	542	575
240	–	–	–	–	380	424	461	500	538	599	641	679
Aluminium												
2.5	13.5	14	15	16.5	18.5	19.5	21	23	24	26	28	–
4	17.5	18.5	20	22	25	26	28	31	32	35	38	–
6	23	24	26	28	32	33	36	39	42	45	49	–
10	31	32	36	39	44	46	49	54	58	62	67	–
16	41	43	48	53	58	61	66	73	77	84	91	–
25	53	57	63	70	73	78	83	90	97	101	108	121
35	–	–	–	86	90	96	103	112	120	126	135	150
50	–	–	–	104	110	117	125	136	146	154	164	184
70	–	–	–	133	140	150	160	174	187	198	211	237
95	–	–	–	161	170	183	195	211	227	241	257	289
120	–	–	–	186	197	212	226	245	263	280	300	337
150	–	–	–	–	226	245	261	283	304	324	346	389
185	–	–	–	–	256	280	298	323	347	371	397	447
240	–	–	–	–	300	330	352	382	409	439	470	530

NOTE — The appropriate table of current-carrying capacity given in Annex B should be consulted to determine the range of conductor sizes for which the above current-carrying capacities are applicable, for each installation method.

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Table C-2 Current-carrying Capacities in Amperes

NOTE — For more information, refer Annex T of IS 732 : 2019.

Installation Method	Size mm²	Number of Loaded Conductors and Type of Insulation			
		2 PVC	3 PVC	2 XLPE	3 XLPE
D1/D2	Copper				
	1.5	22	18	26	22
	2.5	29	24	34	29
	4	38	31	44	37
	6	47	39	56	46
	10	63	52	73	61
	16	81	67	95	79
	25	104	86	121	101
	35	125	103	146	122
	50	148	122	173	144
	70	183	151	213	178
	95	216	179	252	211
	120	246	203	287	240
	150	278	230	324	271
	185	312	258	363	304
	240	361	297	419	351
	300	408	336	474	396
D1/D2	Aluminium				
	2.5	22	18.5	26	22
	4	29	24	34	29
	6	36	30	42	36
	10	48	40	56	47
	16	62	52	73	61
	25	80	66	93	78
	35	96	80	112	94
	50	113	94	132	112
	70	140	117	163	138
	95	166	138	193	164
	120	189	157	220	186
	150	213	178	249	210
	185	240	200	279	236
	240	277	230	322	272
	300	313	260	364	308

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Table C-3 Reduction Factors for Groups of Several Circuits or of Several Multi-core Cables (To be used with Current-carrying Capacities of Table C-1)

NOTE — For more information, refer Annex T of IS 732 : 2019.

Sl No.	Arrangement	Number of Circuits or Multi-core Cables								
(1)	(2)	(3)								
		1	2	3	4	6	9	12	16	20
1	Bunched in air, on a surface, embedded or enclosed	1.00	0.80	0.70	0.65	0.55	0.50	0.45	0.40	0.40
2	Single layer on walls, floors or on unperforated trays	1.00	0.85	0.80	0.75	0.70	0.70	–	–	–
3	Single layer fixed directly under a ceiling	0.95	0.80	0.70	0.70	0.65	0.60	–	–	–
4	Single layer on perforated horizontal trays or on vertical trays	1.00	0.90	0.80	0.75	0.75	0.70	–	–	–
5	Single layer on cable ladder supports or cleats, etc.	1.00	0.85	0.80	0.80	0.80	0.80	–	–	–

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ANNEX D

(*Clause* 5.9)

SELECTION OF CONDUIT SYSTEMS

Table D-1 Suggested Characteristics for Conduit

[Classification according to IS 14930 (Part 1 and Part 2)]

NOTE — For more information, refer Annex W of IS 732 : 2019.

Situation			Resistance to Compression	Resistance to Impact	Minimum Operating Temperature	Maximum Operating Temperature
Outdoor installation	Exposed installation		3	3	2	1
Indoors use	Exposed installation		2	2	2	1
	Under floor installations (floor screed)		2	3	2	1
	Embedded	Concrete	3	3	2	1
		Hollow wall/on wood (inflammable material)	2	2	2	1
		In masonry				
		Building voids				
		Ceiling voids				
	Overhead mounting		4	3	3	1

NOTES

1 These values are only a sample of the characteristics for conduit given in IS 14930 (Part 1 and 2).

2 According to resistance to flame propagation, conduit systems of orange colour are only permitted when embedded in concrete.

3 For other methods for installation all colours are permitted with the exception of yellow, orange or red.

Table D-2 Dimensions of Rigid Steel Conduits

NOTE — For more information, refer 7.1 of IS 9537 (Part 2) : 1981.

Sl No.	Nominal Size of Conduit	Outside Diameter	Maximum Wall Thickness	Internal Cross Sectional Area of Conduit
	mm	mm	mm	mm^2
(1)	(2)	(3)	(4)	(5)
i)	16	16	1.8	121
ii)	20	20	1.8	211
iii)	25	25	1.8	360
iv)	32	32	1.8	633
v)	40	40	2.2	995
vi)	50	50	2.2	1633
vii)	63	63	2.2	2697

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Table D-3 Dimensions of Non-metallic Conduits (PVC)

(*Clause* 5.9.3.6)

NOTE — For more information, refer 7.1 of IS 9537 (Part 2) : 1981.

Sl No.	Nominal Size	Outside Diameter	Light (LMS)		Medium (MMS)		Heavy (HMS)	
			Min Inside Diameter	Cross Sectional Area	Min Inside Diameter	Cross Sectional Area	Min Inside Diameter	Cross Sectional Area
	mm	mm	mm	mm^2	mm	mm^2	mm	mm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	16	16	13.7	147	13.0	133	12.2	117
ii)	20	20	17.4	238	16.9	224	15.8	196
iii)	25	25	22.1	384	21.4	360	20.6	333
iv)	32	32	28.6	642	27.8	607	26.6	556
v)	40	40	35.8	1007	35.4	984	34.4	929
vi)	50	50	45.1	1598	44.3	1541	43.2	1466
vii)	63	63	57.0	2552				

Table D-4 Dimensions of Single Core Non-Sheathed Cables with Rigid Conductor Class 1 or Class 2

NOTES

1 For more information, refer 16.1.2 and 16.1.3 of IS 694 : 2010.

2 Class 1 is solid conductor and class 2 is stranded conductor, for further details, refer Table 3 of IS 694.

Sl No.	Nominal Cross Sectional Area of Conductor	Class of Conductor	Thickness of Insulation	Maximum Overall Diameter	Crosssectional Area of Cable
	mm^2		mm	mm	mm^2
(1)	(2)	(3)	(4)	(5)	(6)
i)	0.5	1	0.6	2.3	4.15
ii)	0.75	1	0.6	2.5	4.91
iii)	1	1	0.6	2.7	5.73
iv)	1.5	1	0.7	3.2	8.04
v)	1.5	2	0.7	3.3	8.55
vi)	2.5	1	0.8	3.9	11.95
vii)	2.5	2	0.8	4	12.57
viii)	4	1	0.8	4.4	15.21
ix)	4	2	0.8	4.6	16.62
x)	6	1	0.8	5	19.64
xi)	6	2	0.8	5.2	21.24
xii)	10	1	1	6.4	32.17
xiii)	10	2	1	6.7	35.26
xiv)	16	2	1	7.8	47.78
xv)	25	2	1.2	9.7	73.90

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Table D-5 Spacing of Supports for Conduits

(*Clause* 5.9.4.2)

Sl No.	Nominal Size of Conduit	Maximum Distance Between Supports					
	mm	Rigid Metal		Rigid Insulation		Pliable	
		Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
		m	m	m	m	m	m
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Not exceeding 16	0.75	1.0	0.75	1.0	0.3	0.5
ii)	Exceeding 16 and not 25	1.75	2.0	1.5	1.75	0.4	0.6
iii)	Exceeding 25 and not exceeding 40	2.0	2.25	1.75	2.0	0.6	0.8
iv)	Exceeding 40	2.25	2.5	2.0	2.0	0.8	1.0

NOTE — A flexible conduit is not normally required to be supported in its run.

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ANNEX E

(*Clause* 5.13.4)

COLOUR CODING FOR CONDUCTORS AND CABLES

Table E-1 Recommended Colours for Identification of Conductors

NOTE — For more information, refer Table 1 of IS 11353 : 1985.

Designation of Conductors		Identification by Colour
Supply a.c. system 3 phase	Phase 1	Red
	Phase 2	Yellow
	Phase 3	Blue
	Neutral	Black
Apparatus a.c. system	Phase 1	Red
	Phase 2	Yellow
	Phase 3	Blue
d.c. system	Positive	Red
	Negative	Blue
	Mid-wire	Black
Supply a.c.[1)] system 1 phase	Phase	Red
	Neutral	Black
Protective Conductor	—	Green Yellow
Functional earth conductor	—	cream

[1)] For single phase a.c. systems, the red and black coloured cables are recommended if the circuit is in isolation. In case single phase conductors, associated with the 3-phase system, the phase conductor shall use the same colour as that phase from which it is derived.

Table E-2 Core Identification for Fixed Wiring and Flexible Cables

(*Clause* 5.13.4.5)

Sl No.	No. of Cores	Cables for Fixed Wiring and Cords	Flexible Cables
(1)	(2)	(3)	(4)
i)	1	Red/black/yellow/blue/white/grey	Red/black/yellow/blue/white/grey
ii)	2	Red, -black	Red, black
iii)	3	Red, yellow, blue	Red, black, yellow-green or red, yellow, blue
iv)	4	Red, yellow, blue, black	Red, yellow, blue, yellow-green or red, yellow, blue, black
v)	5		Red, yellow, blue, black and grey or yellow, blue, green, white and yellow-green

NOTES

1 For more information, refer Table 2 of IS 694 : 2010.

2 For further details and for cores 6 to 25, refer Table 2 of IS 694 : 2010.

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ANNEX F

(*Clause* 6.5.1)

Table F-1 Typical Allowances for Diversity

Sl No.	Purpose of Final Circuit Fed from Conductors or Switchgear to which Diversity Applies	Type of Premises		
		Individual House- Hold Installations, Including Individual Dwelling of a Block	Small Shops, Stores Offices and Business Premises	Small Hotels, Boarding Houses etc.
(1)	(2)	(3)	(4)	(5)
i)	Lighting	66 Percent of total current demand	90 Percent of total current demand	75 Percent of total current demand
ii)	Heating and power	100 Percent of total current demand up to 10A	100 Percent of full load of largest appliance	100 Percent of full load of largest appliance
		+ 50 Percent of any current demand in excess of 10A	+75 Percent of remaining appliances	+80 Percent of second largest appliance
				+60 Percent of remaining appliances
iii)	Cooking appliances	16A	100 Percent of full load of largest appliance	100 Percent of full load of largest appliance
		+ 30 Percent of full load of connected cooking appliances in excess of 16A	+ 80 Percent of full load of second largest appliance	+ 80 Percent of full load of second largest appliance
		+ 6A if outlet socket is incorporated in unit	+ 60 Percent of full load of remaining appliances	+ 60 Percent of full load of remaining appliances
iv)	Motors other than lift motors which are subject to special considerations	—	100 Percent of full load of largest motor	100 Percent of full load of largest motor
			+ 80 Percent of full load of second largest motor	+ 50 Percent of full load of remaining motors
			+ 60 Percent of full load of remaining motors	
v)	Water heater instantaneous type [1)]	100 Percent of full load of largest appliance	100 Percent of full load of largest appliance	100 Percent of full load of largest appliance
		+100 Percent of full load of second largest appliance	+100 Percent of full load of second largest appliance	+100 Percent of full load of second largest appliance
		+25 Percent of full load of remaining appliances	+25 Percent of full load of remaining appliances	+25 Percent of full load of remaining appliances
vi)	Water heater thermostatically controlled	No diversity allowable [2)]	—	—
vii)	Floor warming installations	No diversity allowable [2)]	—	—
viii)	Water heaters thermal storage space heating installations	No diversity allowable [2)]	—	—
ix)	Standard arrangements of final circuits n accordance with IS 732	100 Percent of current demand of largest circuit	100 Percent of current demand of largest circuit	—
		+40 Percent of current demand of every other circuit	+50 Percent of current demand of every other circuit	—
x)	Socket outlets other than those included in Sl. No. (ix) above and stationary equipment other than those listed above	100 Percent of current demand of largest point	100 Percent of current demand of largest point	100 Percent of current demand of largest point
		40 Percent of current demand of every other point	75 Percent of current demand of every other point	75 Percent of current demand of every point in main rooms (dining rooms, etc.)
				40 Percent of current demand of every other point

[1)] For the purpose of the table, an instantaneous water heater is deemed to heat water only when the tap is turned on and therefore, uses electricity intermittently.

[2)] It is important to ensure that the distribution boards are of sufficient rating to take the total load connected to them without the application of any diversity.

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ANNEX G

GUIDANCE FOR EMERGENCY LIGHTING

Table G-1 – Guidance for Emergency Lighting

NOTE — For more information, refer Annex HH of IS 732 : 2019.

Examples of Applications	Requirements								
	1	2	3	4	5	6	7	8	9
	Extended Duration or Remote Controlled Circuit	Escape Sign Luminaires in Maintained Mode	Central Power Supply System	Low Power Supply System	Self-contained Battery Unit	Motor-Generator Unit with no Break (0 s)	Motor-Generator Unit with Short Break (< 0.5 s)	Motor-Generator Unit with Medium Break (< 15 s)	Dual Supply System
Assembly halls, assembly rooms	**	✓	✓	✓	✓	✓	✓	✓	✓
Exhibition halls	**	✓	✓	✓	✓	✓	✓	✓	✓
Theatres, cinemas	**	✓	✓	✓	✓	✓	✓	✓	✓
Sports arenas	**	✓	✓	✓	✓	✓	✓	✓	✓
Sales areas	**	✓	✓	✓	✓	✓	✓	✓	✓
Restaurants	**	✓	✓	✓	✓	✓	✓	✓	✓
Hospitals, treatment centres	**	✓	✓	✓	✓	✓	✓	✓	✓
Hotels, guest houses *	**	✓	✓	✓	✓	✓	✓	✓	✓
Residential care homes *	**	✓	✓	✓	✓	✓	✓	✓	✓
High-rise buildings *	**	✓	✓	✓	✓	✓	✓	✓	✓
Schools	**	✓	✓	✓	✓	✓	✓	✓	✓
Enclosed car parks		✓	✓	✓	✓	✓	✓	✓	✓
Escape routes in workplaces		✓	✓	✓	✓	✓	✓	✓	✓
High risk task areas		✓	✓	✓	✓	✓	✓	✓	✓
Stages	**	✓	✓	✓	✓	✓	✓	✓	✓

✓ denotes suitable systems.

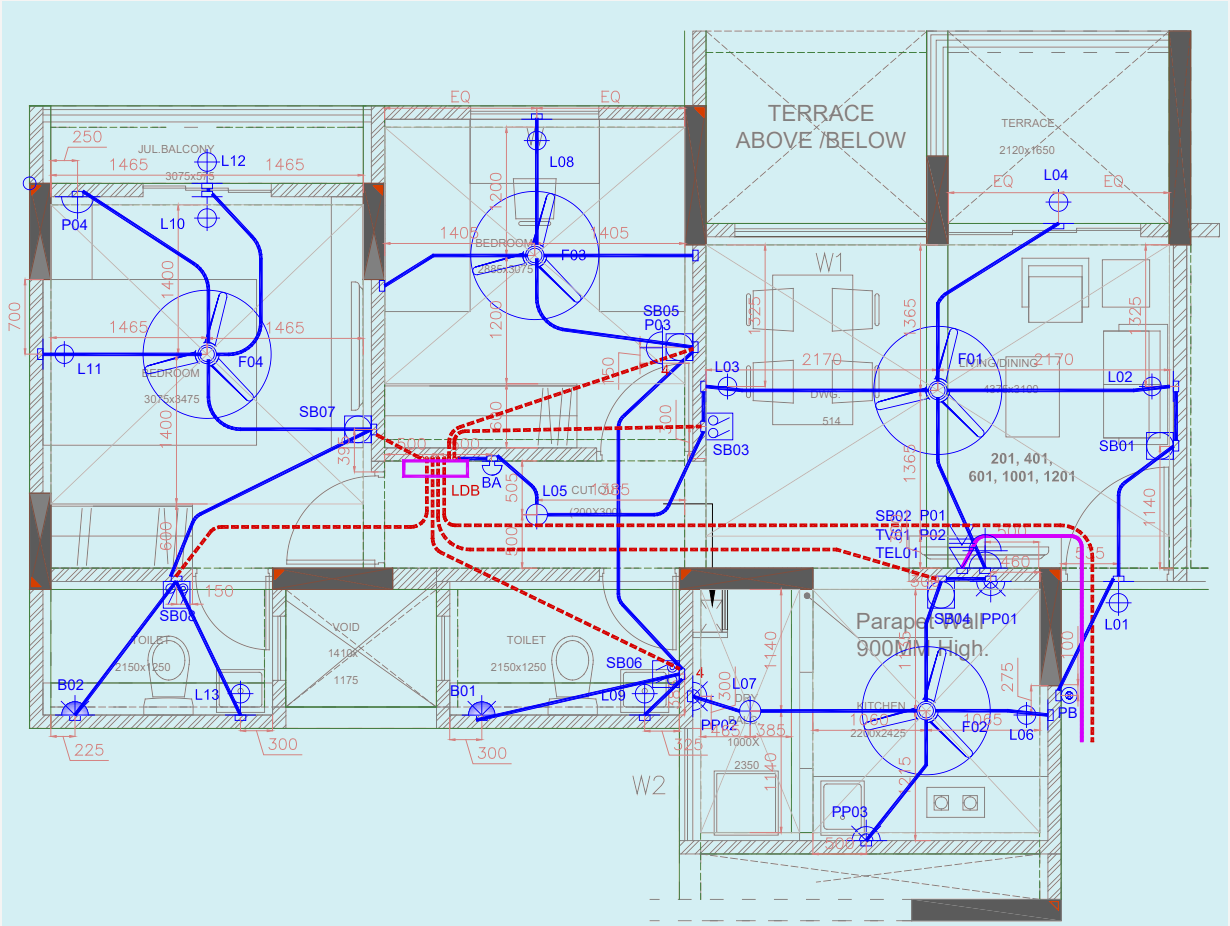
* Premises (*for example,* guest houses, hotels, residential care homes and high-rise buildings) requiring all day operations, the rated operating time for the emergency lighting should be 8 h or shall be operatable with illuminated push buttons for a fixed time by the occupants. In this case, the push buttons and the timing equipments should also run on the emergency mode supply.

** Denotes applications which require either extended duration or a circuit like the remote-controlled circuit to ensure protection for longer than 60 min.

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ANNEX H

TYPICAL 2 BHK FLAT CONDUIT LAYOUT



	1200MM CEILING FAN
	CEILING LIGHT POINT.
	WALL LIGHT POINT
	SWITCH BOARD WITH LIGHT SWITCHES
	SWITCH BOARD WITH LIGHT SWITCHES FAN REGULATOR
	SWITCH BOARD WITH LIGHT & BOILER SWITCHES
	5A SOCKET WITH SWITCH.
	5A/15A SOCKET WITH SWITCH
	T.V. ANTENNA SOCKET OUTLET
	SINGLE TELEPHONE SOCKET OUTLET
	BELL PUSH
	BUZZER
	20A SOCKET ONLY FOR BOILER
	DISTRIBUTION BOARD (DB)
	Ø25 mm FRPVC 2mm THICK CONDUIT FOR TEL/DATA WIRING
	Ø25mm FRPVC 2mm THICK CONDUIT FOR MAINS/SUBMAINS
	Ø25mm FRPVC 2mm THICK CONDUIT FOR POINT WIRING
	CEILING LIGHT POINT ON TIMER 2.

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SWITCH BOARD SCHEDULE – 2 BHK EVEN FLOOR FTALS

ROOM NAME	SWITCH BOARD	HEIGHT FROM FFL in mm	POINT	COMMENTS	MODULE	REQUIRED MODULES	STANDARD MODULES
ENTRANCE LOBBY		1250	PB	1 NO. OF 5A SWITCH FOR BELL PUSH	1	1	1
LIVING/DINING ROOM+ LOBBY	SB01	1250	PB	1 NO. OF 5A SWITCH FOR CONTROL FOR BELL PUSH	1	6	6
			L01	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1		
			L02	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1		
			F01	1 NO. OF 5A SWITCH WITH FAN REGULATOR	3		
	SB02	900	TV01	1 NO. SOCKET FOR TV	1	8	8
			TEL 1	1 NO. SOCKET FOR TELEPHONE	1		
			P01	1 NO. OF 5A SOCKET & SWITCH ON BOARD	3		
			PO2	1 NO. OF 5A SOCKET & SWITCH ON BOARD	3		
	SB03	1250	L03	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1	3	3
			L04	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1		
			L05	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1		
KITCHEN + DRY BALCONY	SB04	1250	F02	1 NO. OF 5A SWITCH FOR FAN REGULATOR	3	5	6
			L06	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1		
			L07	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1		
		1250	PP01	1 NO. OF 5/15A SOCKET & SWITCH FOR REFRIGERATOR	3	3	3
		1200	PP02	1 NO. OF 5/15A SOCKET & SWITCH FOR AQUAGUARD	3	3	3
		1250	PP03	1 NO. OF 5/15A SOCKET & SWITCH FOR WASHING M/C	3	3	3

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Table (*Concluded*)

BEDROOM -1	SB05	1250	L08	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1	7	7
			P03	1 NO. OF 5A SOCKET & SWITCH ON BOARD	3		
			F03	1 NO. OF 5A SWITCH WITH FAN REGULATOR	3		
TOILET -1	SB06	1350	L09	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1	2	2
			B01	1 NO. OF 20A SWITCH FOR GEYSER WITH INDICATOR	1		
		2100	B01	1 NO. OF 20 A SOCKET OUTLET FOR GEYSER	2	2	2
BEDROOM -2	SB07	1250	L10	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1	6	6
			L11	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1		
			L 12	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1		
			F03	1 NO. OF 5A SWITCH WITH FAN REGULATOR	3		
		600	P04	1 NO OF 5A SOCKET & SWITCH INDEPENDANT	3		
TOILET 2	SB08	1250	L12	1 NO. OF 5A LIGHT SWITCH FOR WALL LIGHT POINT	1	2	2
			B01	1 NO. OF 20A SWITCH FOR GEYSER WITH INDICATOR	1		
		2100	B01	1 NO OF 20A SOCKET OUTLET FOR GEYSER	2	2	2
PASSAGE		ON BEAM	BA	BELL ANNOUNCER	-		
		2100	DB	DISTRIBUTION BOARD	-		

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ANNEX I

(*Clause* 9.2.1)

Table I.1 Optimum Size/Number of Fans for Rooms of Different Sizes

NOTE — For more details, refer Table 13 and 5.7.4 of Part 8/Sec 1 of NBC 2016.

Sl No.	Room width m	Optimum Size (mm/Number of Fans for Room Length)										
		4 m	5 m	6 m	7 m	8 m	9 m	10 m	11 m	12 m	14 m	16 m
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	3	1 200/1	1 400/1	1 500/1	1050/2	1 200/2	1 400/2	1 400/2	1 400/2	1 200/3	1 400/3	1 400/3
ii)	4	1 200/1	1 400/1	1 200/2	1 200/2	1 200/2	1 400/2	1 400/2	1 500/2	1 200/3	1 400/3	1 500/3
iii)	5	1 400/1	1 400/1	1 400/2	1 400/2	1 400/2	1 400/2	1 400/2	1 500/2	1 400/3	1 400/3	1 500/3
iv)	6	1 200/2	1 400/2	900/4	1050/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
v)	7	1 200/2	1 400/2	1050/4	1050/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
vi)	8	1 200/2	1 400/2	1 200/4	1 200/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
vii)	9	1 400/2	1 400/2	1 400/4	1 400/4	1 400/4	1 400/4	1 400/4	1 500/4	1 400/6	1 400/6	1 500/6
viii)	10	1 400/2	1 400/2	1 400/4	1 400/4	1 400/4	1 400/4	1 400/4	1 500/4	1 400/6	1 400/6	1 500/6
ix)	11	1 500/2	1 500/2	1 500/4	1 500/4	1 500/4	1 500/4	1 500/4	1 500/4	1 500/6	1 500/6	1 500/6
x)	12	1 200/3	1 400/3	1 200/6	1 200/6	1 200/6	1 400/6	1 400/6	1 500/6	1 200/7	1 400/9	1 400/9
xi)	13	1 400/3	1 400/3	1 200/6	1 200/6	1 200/6	1 400/6	1 400/6	1 500/6	1 400/9	1 400/9	1 500/9
xii)	14	1 400/3	1 400/3	1 400/6	1 400/6	1 400/6	1 400/6	1 400/6	1 500/6	1 400/9	1 400/9	1 500/9

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ANNEX K

(*Clause* 2)

LIST REFERRED OF STANDARDS

IS/Other Publications	*Title*
371 : 1999	Ceiling roses
374 : 2019	Electrical ceiling fans and regulators
694 : 2010	PVC insulated unsheathed and sheathed cables/cords with rigid and flexible conductors
732 : 2019	Code of practice for wiring installations
1255 : 1983	Code of practice for installation and maintenance of cables up to and including 33kV rating
1258 : 2005	Bayonet lamp holders
1293 : 2019	Plugs and socket-outlets of rated voltage upto and including 250 volts and ratted current upto and 16 amperes — Specification (*fourth revisions*)
2032 : 1987	Graphical symbols in the field of electro-technology
3854 : 1997	Switches for domestic and similar purposes
9537 (Part 1) : 1980	Conduits for electrical installations: Part 1 General
9537 (Part 2) : 1981	Conduits for electrical installations: Part 2 Rigid steel
9537 (Part 3) : 1983	Conduits for electrical installations: Part 3 Insulating material
9537 (Part 4) : 1983	Conduits for electrical installations: Part 4 Pliable self-recovering
9537 (Part 5) : 2000	Conduits for electrical installations: Part 5 Pliable insulating material
9537 (Part 6) : 2000	Conduits for electrical installations: Part 6 Pliable metal
10322 (Part 1) : 2014	Luminaires: Part 1 General Requirements
12360 : 1988	Voltage bands for electrical installations
12640 (Part 1) : 2016	Residual current operated circuit breakers for household and similar purposes
12640 (Part 2) : 2018	Residual current operated circuit breakers with integral over current protection (RCBOs)
13032 : 1991	AC MCB Boards for voltage not exceeding 1 000 V
13703 : 1993	Low voltage fuses for voltage not exceeding 1 000 V a..c. or 1500 V d.c.
14772 : 2000	Enclosures for accessories for household and similar fixed electrical installations
14927 (Part 1) : 2001	Cable trunking systems and cable ducting systems for electrical Installation: Part 1 General requirements
14927 (Part 2) : 2001	Cable trunking systems and cable ducting systems for electrical Installation: Part 2 Intended for mounting on walls or ceilings
16205(Part 1) : 2017	Conduit systems for cable management — General requirements
16205 (Part 21) : 2017	Conduit systems for cable management — Particular requirements — Rigid conduit systems
16205 (Part 22) : 2017	Conduit systems for cable management — Particular requirements — Pliable conduit systems
16205 (Part 23) : 2017	Conduit systems for cable management — Particular requirements — Flexible conduit systems
16205 (Part 24) : 2017	Conduit systems for cable management — Particular requirements — Conduit systems buried under ground
IEC 60061-2 : 1969	Lamp caps and holders together with gauges for the control of interchangeability and safety — Part 2 Lampholders

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IS/Other Publications	*Title*
IEC 60364-5-52 : 2009-10	Low voltage electrical installations — Selection and erection of electrical equipment — Wiring systems
IEC 60670	Boxes and enclosures for electrical accessories for household and similar fixed electrical installations
IEC 61008-1 : 2010	Residual current operated circuit breakers without integral over current protection — Part 1 General rules
IEC 61084 : 2017	Cable trunking systems and cable ducting systems for electrical installation
IEC 61439-1 : 2020	Low voltage switchgears and control gear assemblies — General rules
IEC 61439-6 : 2012	Low voltage switchgears and control gear assemblies — Busbar trunking systems
IEC 61534-1 : 2011	Power-track systems — Part 1 General requirements
IEC 61534-21 : 2021	Power-track systems — Part 21 For wall and ceiling mounting
IEC 61534-22 : 2021	Power-track systems —Part 22 On floor and under floor mounting
IEC 61537 : 2006	Cable management — Cable trey system and cable ladder systems
NBC 2016	National Building Code

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SECTION 10 PROTECTION FOR SAFETY — PROTECTION AGAINST ELECTRIC SHOCK

FOREWORD

Electrical shock is a physiological reaction caused by electric current passing through the human body. Usually electrical shock occurs when body part comes in contact with a live conductor. The severity of the shock depends on the magnitude of the current, the parts of the body through the current flows and the duration of the current flow.

A current of greater than 40 mA for more than 3 s passing through a human being is fatal, unless interrupted iin a relatively short time. The four zones of current-magnitude/time- duration, giving the path physiological effects of the electric shock are described in IS/IEC 60479-1 : 2005 and are given in Annex A.

1 SCOPE

This section of the code (Part 1/Sec 10) deals with protection against electric shock as applied to electrical installations. It is based on 4.2 of IS 732, which is a basic safety standard that applies to the protection of persons and livestock. The fundamental rule of protection against electric shock, is that hazardous live parts shall not be accessible and accessible conductive parts shall not be hazardous live, neither under normal conditions nor under single fault conditions. The protection under normal conditions is provided by basic protective provisions and protection under single fault conditions is provided by fault protective provisions.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC Number	*Title*
12640 (Part 1/Sec 2)	Residual current operated circuit breakers for household and similar use
IS/IEC 60479-1 : 2018	Effects of current on human beings and livestock: Part 1 General aspects
IEC 60755	General safety requirements for residual current operated protective devices

3 TERMINOLOGY

3.1 Direct Contact — When a person comes in contact with a live conductor, it is called electric shock by direct contact.



FIG. 1A DIRECT CONTACT

3.2 Indirect Contact — When a person comes in contact with an exposed conductive-part, which is normally not live but has become live mainly due to insulation failure, is called electric shock by indirect contact.

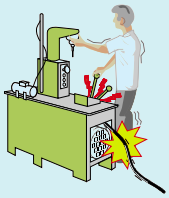


FIG. 1B INDIRECT CONTACT

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4 PROTECTION AGAINST ELECTRIC SHOCK

Three steps towards protection against electric shock are briefly described below. For details, please refer 4.2 of IS 732:

a) Basic protection (protection against direct contact);
b) Fault protection (protection against indirect contact); and
c) Additional protection.

4.1 Basic Protection

4.1.1 Basic protection is provided by basic insulation of live parts or by barriers or enclosures.

4.1.2 According to IS 732 (*see* 4.2.11.3.3 of IS 732), additional protection by means of 30 mA RCD shall be provided for circuits supplying socket-outlets with a rated current of 20 A at all locations, and for circuits supplying mobile equipment with a rated current 32 A for outdoor use.

4.2 Fault Protection

Fault protection is provided by protective equipotential bonding and automatic disconnection in case of occurrence of a fault. Exposed-conductive-parts of an electrical equipment are separated from the live parts of the equipment by the "basic insulation". Failure of the basic insulation can result in the exposed-conductive-parts being alive. Coming in contact with electrical equipment which is dead under normal conditions but is alive due to insulation failure is referred to as an indirect contact.

In all parts of an installation, one or more protective measures shall be applied, considering the conditions of external influence. The following protective measures are generally permitted:

a) automatic disconnection of supply;
b) double or reinforced insulation;
c) electrical separation for the supply of one item of current-using equipment; and
d) extra-low-voltage (SELV and PELV).

1) Automatic Disconnection for Fault Protection:

First step: The earthing of all exposed-conductive-parts of electrical equipment in the installation shall be connected with an equipotential bonding network.

Second step: Automatic disconnection of the supply of the section of the installation concerned, in such a way that the touch-voltage/time safety requirements are respected for any level of touch voltage.

4.2.1 *Selection of Devices for Automatic Disconnection of Supply*

As per IS 732, all circuits shall be provided with an overcurrent protection device. If the earth fault loop impedance is low enough to cause these devices to operate within the specified times, (that is, sufficient current can flow to earth under fault conditions), such devices may be relied upon to give the requisite automatic disconnection of supply. If the earth fault loop impedance does not permit the overcurrent protective devices to give automatic disconnection of the supply under earth fault conditions, measures shall be taken to reduce the impedance. It may be achieved by using protective multiple earthing or by additional earth electrodes. However, there are practical limitations to both approaches.

In case of impedance/arcing faults, series protective devices may be ineffective to clear the faults. Automatic disconnection of supply shall be provided by residual current devices, with a sensitivity adapted to the earth loop impedance (for example, 300 mA or 500 mA RCDs).

Also, a.c. circuit may be provided with additional protection using 30 mA RCD.

For TT and TN earthing system, Table 1 of IS 732 specifies tripping time for each system for safe protection.

a) Double or reinforced insulation

   Requirements for Double or reinforced Insulation shall be in accordance with 4.2.12 of IS 732.

b) Electrical separation for the supply of one item of current-using equipment

   Requirements for electrical separation for the supply of one item of current-using equipment shall be in accordance with 4.2.13 of IS 732.

c) Extra-low-voltage (SELV and PELV)

   Requirements for extra-low-voltage (SELV and PELV) shall be in accordance with 4.2.14 of IS 732.

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4.3 Additional Protection

In a.c. system, additional protection by means of a 30 mA residual protective device (RCD) in accordance with 4.2.15.1 of IS 732 shall be provided for:

a) At the incomer of every sub-distribution board with one or more outgoing circuits with fixed installation and socket-outlets for safety of users from earth leakage.

b) Mobile equipment.

System voltage independent RCD not exceeding 30 mA shall be used for domestic and similar application.

5 TYPES OF RCD DEFINED BY THE STANDARDS

IEC 60755 defines four types of RCDs, for a.c. applications, aiming at covering the various types of residual current waveshape. These types are known as type AC, type A, type F and type B. All these devices are intended to be used on a.c. supply systems.

NOTE — IEC/TS 63053 is published for DC-RCD.

5.1 Residual Current Devices of Type AC

In most cases, the expected fault current is of the same frequency and waveshape as that of supply (sinusoidal 50 Hz), either because the fault may occur only on the supply conductors (for example, if the appliance itself is of class 2), or because the load is resistive.

Residual current devices intended to detect sinusoidal residual currents are defined by IEC 60755 as type AC, and are marked with a following standard symbol.



"An RCD for which tripping is ensured for residual sinusoidal alternating currents, whether suddenly applied or slowly rising."

RCDs of type AC are used for general purposes applications.

5.2 Residual Current Devices of Type A

The expected fault current may contain pulsating DC waveshape (for example, the fault current flowing through a rectifier, as shown in Fig. 2). This is the case where the RCD supplies a load containing rectifiers, and occurrence of fault could create such residual current. The waveshape of the fault current is, then, defined as pulsating DC residual current. Residual current devices able to detect such waveshape are known as type A RCD.

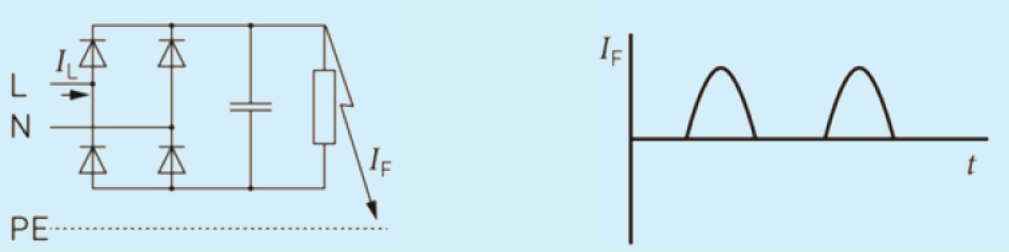


FIG. 2 EXAMPLE OF APPLICATION WHICH MAY CREATE TYPE A FAULT CURRENT AND CORRESPONDING WAVESHAPE (I_F)

In addition, such devices are able to "withstand" smooth DC residual current of 6 mA superimposed on the residual current. It is important to note that an RCD of type A is able to detect pulsating DC residual current and in addition sinusoidal residual current.

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Residual current devices of type A are defined in IEC 60755 and are marked with the following standard symbol.



RCD of type A shall be used where the application may create pulsating DC residual current. For example single phase Class 1 devices with rectifying circuit like cooking plates.

5.3 Residual Current Devices of Type F

The expected fault current may contain composite residual currents, with frequencies ranging from a few hertz up to 1 000 Hz, as shown in Fig. 3. This is the case where the RCD supplies a load with single phase motor drive. The waveshape of the fault current is then defined as composite residual current. Residual current devices able to detect such waveshape are known as type F RCD.

Such devices are also able to withstand smooth DC residual current of 10 mA superimposed on the residual current. In addition an RCD of type F is also able to detect all the residual currents detected by a type A RCD. Therefore, a type F RCD can also be used when a type A RCD (or type AC RCD) is required by installation standards.

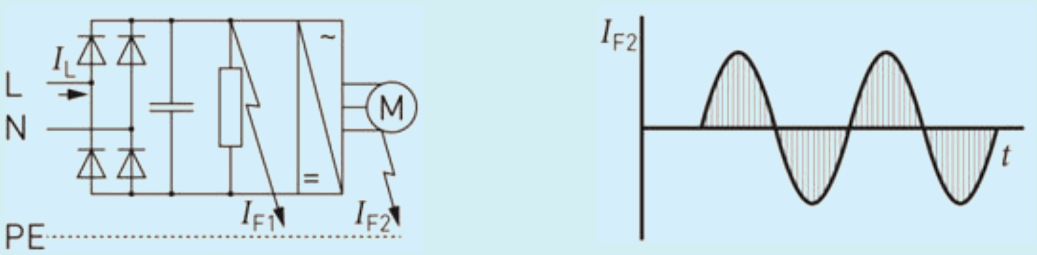
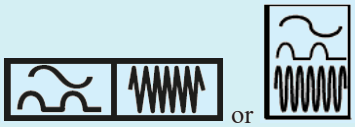


FIG. 3 EXAMPLE OF APPLICATION WHICH MAY CREATE TYPE F FAULT CURRENT AND CORRESPONDING WAVESHAPE (I_{F2})

Residual current devices of type F are defined in IEC 60755 and are marked with one of the following standard symbol, showing that an RCD of type F complies also with the requirements for type A.



RCDs of type F shall be used in the cases where the application may create composite residual current. For example single phase Class 1 devices containing a motor controlled by a variable speed drive. This is the case of heat pump or air conditioner.

5.4 Residual Current Devices of Type B

The waveshape of the residual current may contain various other components, such as frequencies higher than 50 Hz or 60 Hz, non-sinusoidal waveshape, waveshape resulting from rectifying circuits with six diodes bridge, or even smooth DC, as shown in Fig. 4. This is the case when the RCD supplies, for example, a motor with three phase speed-drive. Residual current devices able to detect such waveshape are known as type B RCD.

Such devices are also able to withstand smooth DC residual current of 10 mA superimposed on the residual current. In addition an RCD of type B is also able to detect all the residual currents detected by a type F RCD. Therefore, a type B RCD can be used when a type F RCD (or type A or type AC RCD) is required by installation standards.

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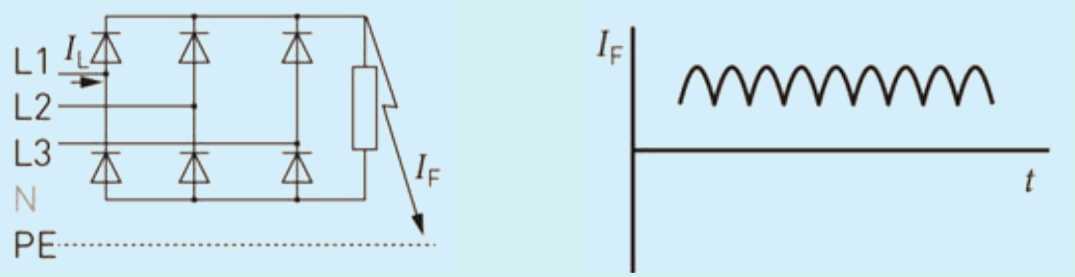


FIG. 4 EXAMPLE OF APPLICATION WHICH MAY CREATE TYPE B FAULT CURRENT AND CORRESPONDING WAVESHAPE (I_F)

Residual current devices of type B are defined in IEC 60755.

An RCD for which tripping is ensured as for type F and, in addition:

a) for residual sinusoidal alternating currents up to 1 000 Hz;
b) for residual alternating currents superimposed on a smooth direct current of 0.4 times the rated residual current ($I_{\Delta n}$) or 10 mA whichever is the highest value;
c) for residual pulsating direct currents superimposed on a smooth direct current of 0.4 times the rated residual current ($I_{\Delta n}$) or 10 mA, whichever is the highest value;
d) for residual direct currents which may result from rectifying circuits, that is,
    1) two-pulse bridge connection line to line for two-, three- and four-pole devices; and
    2) three-pulse star connection or six-pulse bridge connection for three- and four-pole devices.
e) for residual smooth direct currents.

The above specified residual currents may be suddenly applied or slowly increased independently of polarity.

RCDs of type B are marked with one of the following standard symbol.



RCDs of type B shall be used in case where the application may create smooth DC residual current, or contain frequencies higher than 50 Hz. For example, three-phase Class 1 devices containing a motor controlled by a three phase variable speed drive. This is the case of certain types of three phase air conditioner, or pumps, or when supplying an electric vehicle.

5.5 Time-delay and Selective RCDs

For RCDs with rated residual current strictly higher than 30 mA, the RCD standards define a selective RCD, also known as type S. Such devices are delayed as they are able to withstand a residual current during a specified time without tripping. Type S residual current device can withstand 2 times $I_{\Delta n}$ during 60 ms without tripping.

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ANNEX A

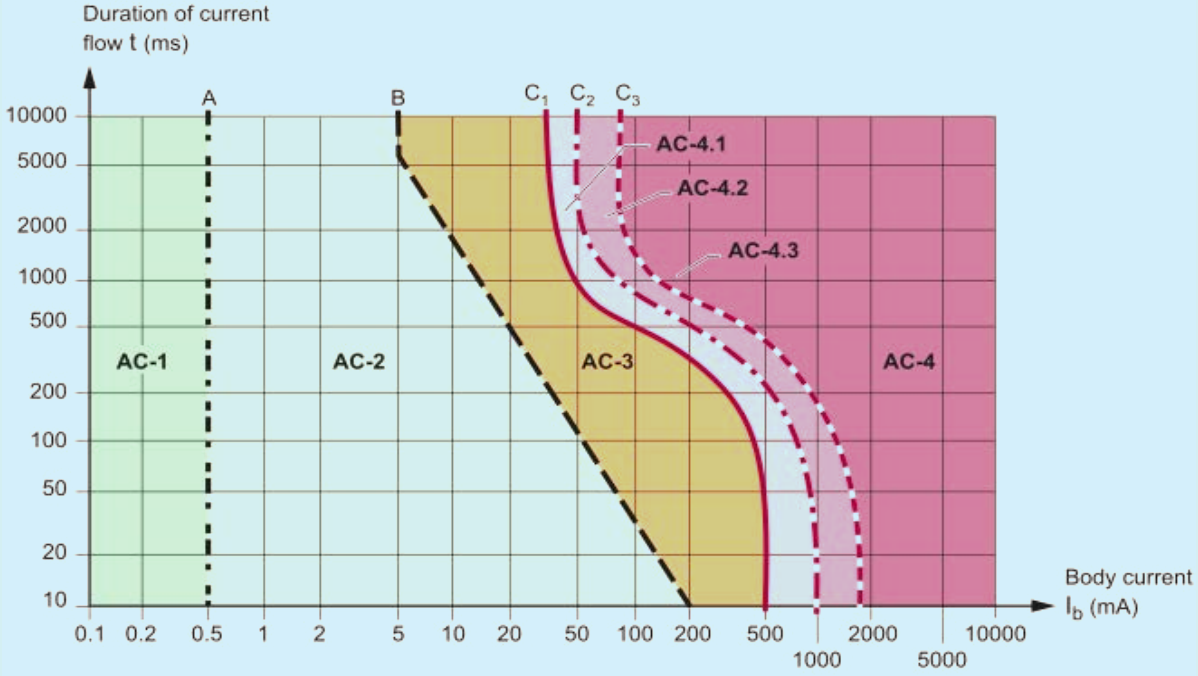
(*Foreword*)

Electrical shock is a physiological reaction caused by electric current passing through the human body. Usually electrical shock occurs when body part comes in contact with a live conductor. The severity of the shock depends on the magnitude of the current, the parts of the body through which the current flows and the duration of the current flow.

IS/IEC 60479-1 defines four zones of current-magnitude/time-duration, in each of which the pathophysiological effects are described (*see* Fig. A-1). Any person coming into contact with live conductive part risks an electric shock. Curve C1 shows that when a current greater than 40 mA passes through a human being from one hand to feet. The person concerned is likely to die unless the current is interrupted in a relatively short time.

NOTE — In fact, the asymptote of curve C1 is 40 mA. The RCDs of 30 mA trip at 30 mA maximum and therefore, have a safety margin compared to the maximum dangerous value.

The point 500 ms/100 mA close to the curve C1 corresponds to a probability of heart fibrillation of the order of 0.14 percent.



AC-1 zone: Imperceptible
AC-2 zone: Perceptible
AC-3 zone : Reversible effects: muscular contraction
AC-4 zone: Possibility of irreversible effects
AC-4-1 zone: Up to 5 % probability of heart fibrillation
AC-4-2 zone: Up to 50 % probability of heart fibrillation
AC-4-3 zone: More than 50 % probability of heart fibrillation

A curve: Threshold of perception of current
B curve: Threshold of muscular reactions
C_1 curve: Threshold of 0 % probability of ventricular fibrillation
C_2 curve: Threshold of 5 % probability of ventricular fibrillation
C_3 curve: Threshold of 50 % probability of ventricular fibrillation

FIG. A-1 PATHOPHYSIOLOGICAL EFFECTS IN FOUR ZONES OF CURRENT-MAGNITUDE/TIME-DURATION

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SECTION 11 PROTECTION FOR SAFETY — PROTECTION AGAINST THERMAL EFFECTS AND PROTECTION AGAINST FIRE DUE TO ARCING

FOREWORD

Accidents from electricity especially ignition of fire from electricity in buildings is a major electrical safety hazard which require careful design, selection and erection of an electrical installation. This section explains the methods which need to be implemented to reduce such accidents.

1 SCOPE

This section of the code (Part 1/Sec 11) deals with protection against thermal effects. It is based on 4.3 of IS 732, which is a basic safety standard that applies to the protection of an installation from thermal effects.

Additional measures required are explained in this section.

This section also recommends usage of arc fault detection devices (AFDDs) for household and similar uses, intended to be used in a.c. circuits, for rated voltages not exceeding 240 V a.c, with rated frequencies of 50 Hz, 60 Hz or 50/60 Hz and rated currents not exceeding 63 A.

An AFDD is designed by the manufacturer:

a) either as a single device with provision of operating the protected circuit under specified conditions;

b) as a single device integrating a protective device; or

c) as a separate unit, according to Annex D of IS 17121, assembled on site with a declared protective Device.

NOTE — Refer IS 17121, for further details.

2 REFERENCES

The standards listed below contain provisions which, through reference in this text, constitute provision of this standard. At the time of publication, the edition indicated were valid. All standards are subject to revision and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC No.	*Title*
732 : 2019	Code of practice for electrical wiring installations
17121 : 2019/IEC 62606 : 2017	General requirements for arc fault detection devices

3 TERMINOLOGY

For the purposes of this standard, the terms and definitions given in IS 12640 (Part 1), IS 12640 (Part 2), IS/IEC 60898-1, IEC TR 60755 and IEC 62423 and the following shall apply.

NOTE — Where the terms “voltage” or “current” are used, they shall imply rms. values, unless otherwise specified.

3.1 Arc/Arcing — Luminous discharge of electricity across an insulating medium, usually accompanied by the partial volatilization of the electrodes.

NOTE — A complete sinusoidal current half cycle is not considered to be an arcing half cycle.

3.2 Arc Fault/Arcing Fault — Dangerous unintentional arc.

3.3 Arc Fault Detection Device (AFDD) — Device intended to mitigate the effects of arcing faults by disconnecting the circuit when an arc fault is detected.

3.4 Arc Fault Detection Unit (AFD Unit) — Part of the AFDD ensuring the function of detection and discrimination of dangerous earth, parallel and series arc faults and initiating the operation of the device to cause interruption of the current.

3.5 Detection — Function consisting of sensing the presence of an arc fault current.

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3.6 Interruption — Function consisting of bringing automatically the main contacts of the AFDD from the closed position into the open position, thereby interrupting the arc fault current(s) flowing through them.

3.7 Earth Arc Fault — Arc fault where the current is flowing from active conductor to the earth.

3.8 Parallel Arc Fault — Arc fault where the arc current is flowing between active conductors in parallel with the load of the circuit.

3.9 Series Arc Fault — Arc fault where the current is flowing through the load(s) of the final circuit protected by an AFDD.

3.10 Closed Position — Position in which the predetermined continuity of the main circuit of the AFDD is secured.

4 PROTECTION AGAINST FIRE CAUSED BY ELECTRICAL EQUIPMENT

4.1 General Requirement

4.1.1 Persons, livestock and property shall be protected against damage or injury caused by heat or fire which may be generated or propagated in electrical installations by considering the requirements of this code and the instructions of equipment manufacturers.

4.1.2 The heat generated by electrical equipment shall not cause danger or harmful effects to adjacent fixed material or to material which may foreseeable be in proximity to such equipment. Electrical equipment shall not present a fire hazard to adjacent materials.

Damage, injury or ignition may be caused by following effects:

a) heat accumulation, heat radiation, hot elements;
b) reduction of the safe function of electrical equipment, for example, protective devices, such as protective switchgear, thermostats, temperature limiters, seals of cable penetrations and wiring systems;
c) overcurrent;
d) insulation faults and/or arcs causing interference;
e) harmonic currents;
f) lightning strikes (*see* the IS/IEC 62305 series of standards);
g) overvoltages (*see* 4.5.3 of IS 732); and
h) inappropriate selection or erection of equipment.

4.2 Precautions where particular risks of Fire exist

4.2.1 *General*

4.2.1 Necessary electrical equipment shall be restricted for use at these locations.

4.2.2 Electrical equipment shall be so selected and erected that its temperature in normal use and foreseeable temperature rise during a fault shall not cause a fire.

These arrangements may be affected by the construction of equipment or its conditions of installation.

4.2.3 *Thermal cut-out devices shall have manual resetting only.*

4.3 Protection against Fire due to Leakage Current

Laboratory experiment shows that a leakage current above 250 mA causes fire ignitions. IS 732 have recommended for protection against such high leakage current.

Final circuits and current-using equipment shall be protected against insulation faults as follows:

a) In TN and TT systems, RCDs with a rated residual operating current $I_{\Delta n}$ of 300 mA shall be used. Where resistive faults may cause a fire, for example, for overhead heating with heating film elements, the rated residual operating current shall be $I_{\Delta n}$ -30 mA.
b) In IT systems, insulation monitoring devices monitoring the whole installation or RCMs (residual current monitoring devices) in the final circuits, both with audible and visual signals, shall be provided.

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Alternatively, RCDs with a rated residual operating current as specified in a) may be used. In the event of a second fault, *see* 4.2.11 of IS 732 for disconnection times.

Mineral insulated cables and busbar trunking systems are considered not likely to cause a fire from insulation faults and therefore, may not be protected. However, if used in environment having flammable material like flammable gases, the necessary leakage current protection measures should be provided.

NOTE — Cables with metallic coverings are recommended. The metallic covering should be connected to the protective conductor.

4.4 Protection against Burns

Accessible parts of electrical equipment within arm's reach shall not attain a temperature likely to cause burns to persons and shall comply with the appropriate limit stated in Table 1. All parts of the installation in normal service likely to attain, even for short periods, temperatures exceeding the limits stated in Table 1 shall be guarded so as to prevent any accidental contact. However, the values in Table 1 do not apply to equipment complying with relevant Indian standards.

NOTE — Lower temperatures may be applicable where condition BA2 (children) applies.

Table 1 Temperature limits in Normal Service for Accessible Parts of Equipment within Arm's Reach

(*Clause* 4.4)

Sl No.	Accessible Part	Material of Accessible Surface	Maximum Temperature °C
(1)	(2)	(3)	(4)
i)	Hand-held means of operation	Metallic	55
		Non metallic	65
ii)	Parts intended to be touched but not hand-held	Metallic	70
		Non metallic	80
iii)	Parts which need not be touched for normal operation	Metallic	80
		Non metallic	90

4.5 Protection against Overheating

4.5.1 *Forced Air Heating Systems*

Forced air heating systems shall be such that their heating elements, other than those of central storage heaters, cannot be activated until the prescribed air flow has been established and are deactivated when the air flow is less than the prescribed value. In addition, they shall have two temperature limiting devices independent of each other which prevent permissible temperatures from being exceeded in air ducts.

Supporting parts, frames and enclosures of heating elements shall be of non-combustible material.

4.5.2 *Appliances Producing Hot Water or Steam*

All appliances producing hot water or steam shall be protected by design or erection against overheating in all service conditions. Unless the appliances comply as a whole with the appropriate IS standards, the protection shall be by means of an appropriate non-self-resetting device, functioning independently of the thermostat.

If an appliance has no free outlet, it shall also be provided with a device which limits the internal water pressure.

4.5.3 *Space Heating Appliances*

The frame and enclosure of space heating appliances shall be of non-combustible material.

NOTE — At operating areas with a fire risk, space heating appliances may not be operated if the air from these areas is guided through the appliance.

The side walls of radiant heaters should have a sufficient distance from flammable parts. In case of a reduction of the distance by a non-flammable partition, this partition should have a distance of at least 1 cm to the enclosure of the radiant heater and to flammable parts.

Unless otherwise declared by the manufacturer, radiant heaters should be mounted so that in the direction of radiation a safety distance of at least 2 m from flammable parts is ensured.

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5 PROTECTION AGAINST ARC FAULT

5.1 Arc Fault

Fires by electrical installations are often initiated by arc faults that result from parallel arcs or series arcs caused by insulation defects between active conductors or loose terminal connections.

During a series arc fault, there is no leakage current to earth, therefore, RCDs cannot detect, such a fault. Moreover, the impedance of the series arc fault reduces the load current and the current remains below the tripping threshold of a circuit-breaker or a fuse.

In the case of a parallel arc between line and neutral conductor, the current is limited by the impedance of the installation and the arc itself. Therefore, the resulting fault current could be lower than the operating current of the overcurrent protective device.

5.2 Arc Fault Detection Devices (AFDD)

Arc fault detection devices are capable of detecting fault conditions that result from a sustained arcing junction either limited by the available current from the distribution wiring (considered as parallel arc faults) or limited by a load within the protected circuit (considered as series arc faults).

In a.c. circuits, the use of arc fault detection devices (AFDD) in compliance with IS 17121 can further contribute to the reduction of risk to persons, livestock and property resulting from extensive fires being propagated from electrical installations and appliances.

5.3 Classification

The following three devices are specified in IS 17121:

a) AFDD as one single device, comprising an AFD unit and opening means and intended to be connected in series with a suitable short-circuit protective device declared by the manufacturer as complying with one or more of the following standards – IS/IEC 60898-1, IS 12640 (Part 2) or the IEC 60269 series;

b) AFDD as one single device, comprising an AFD unit integrated in a protective device complying with one or more of the following standards – IS/IEC 60898-1, IS 12640 (Part 2) or IEC 62423; and

c) AFDD comprised of an AFD unit and a declared protective device, intended to be assembled on site.

NOTE — Refer IS 17121, for further details of classifications of AFDD.

5.4 Special Measures

Special measures shall be taken to protect against the effects of arc fault in final circuits.

Arc fault detection devices (AFDDs) shall be provided for single-phase a.c systems with an operating current not higher than 63A at following:

a) in premises with sleeping accommodation;

b) In bedrooms and habitable rooms in kindergarten and day care centers for children, disabled and elderly people (for example, nurseries for children or old people's homes);

c) In bedrooms or habitable rooms, in barrier-free accommodations for handicapped persons; and

d) In locations:

   1) With risks of fire due to the nature of processed or stored materials, that is, BE2 locations, (for example, barns, wood-working shops, stores of combustible material.

   2) With combustible constructional material, that is, CA2 locations (for example, wooden buildings).

   3) with endangering of irreplaceable good.

In a.c. circuits, the use of arc fault detection devices (AFDD) in compliance with IS 17121 satisfies the above-mentioned recommendation.

If used, an AFDD shall be placed at the origin of the circuit to be protected.

The use of AFDDs does not obviate the need to apply one or more measures provided in other clauses in this code.

Family rooms, dining rooms, living rooms, parlors, libraries, dens, sunrooms, recreation rooms, closets, hallways or other rooms where movement or placement of furniture or movement by persons increases the likelihood of damaged/exposed cables.

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SECTION 12 PROTECTION FOR SAFETY PROTECTION AGAINST OVERCURRENT AND FAULT CURRENTS

FOREWORD

Safe and reliable electrical network is possible through the protection against overcurrent. This Section provides requirements for the protection of live conductors from the effects of overcurrent. This section describes how live conductors are protected by one or more devices for the automatic disconnection of the supply in the event of overload and short-circuit except where the conditions described in omission of devices for protection are met.

Assistance for this section has been derived from 4.4 of IS 732 'Protection for safety — Protection against overcurrent'.

1 SCOPE

This section of the code (Part 1/Sec 12) deals with protection against overcurrent. It is based on 4.4 of IS 732, which is a basic safety standard that applies to the protection of an installation from over current (overload and short circuit current). The fundamental rule of protection against over current, according to 4.4 of IS 732 is applicable.

Additional measures required are explained in this section.

2 REFERENCES

The standards listed below contain provisions which, through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC No.	*Title*
732 : 2019	Code of practice for electrical wiring installations
17345 (Part 1) : 2020	Powertrack systems: Part 1 General requirements
IS/IEC 61439-6	Low-voltage switchgear and controlgear assemblies: Part 6 Busbar trunking systems (busways)

3 GENERAL CONSIDERATIONS

3.1 General

Protective devices shall be provided to disconnect any overcurrent in the circuit conductors before such a current could cause danger due to thermal or mechanical effects detrimental to insulation, joints, terminations or material surrounding the conductors.

4 REQUIREMENTS AS PER THE NATURE OF THE CIRCUITS

4.1 Protection of Line Conductors

4.1.1 Detection of overcurrent shall be provided for all line conductors, and it shall cause the disconnection of the conductor in which the overcurrent is detected but not necessarily other live conductors; except where, disconnection of a single phase may cause danger, for example in the case of a three-phase motor.

4.1.2 In a TT or TN system, for a circuit supplied between line conductors and in which the neutral conductor is not distributed, overcurrent detection need not be provided for one of the line conductors, provided that the following conditions are simultaneously fulfilled:

a) there exists, in the same circuit or on the supply side, protection intended to detect unbalanced loads and intended to cause disconnection of all the line conductors; and

b) the neutral conductor is not distributed from an artificial neutral point of the circuits situated on the load side of the protective device mentioned in (a).

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4.2 Protection of the Neutral Conductor

4.2.1 *TT or TN Systems*

Protection of the neutral conductor in TT and TN systems shall be as per Table 1.

Table 1 Protection of the Neutral Conductor in TT and TN Systems

(*Clause* 4.2.1)

Neutral Conductor[2][3]		Over Current	Short Circuit Protection
Cross Section Area	Current	Detection	
`=Line conductor	<= Line conductor	Not necessary	Required
< Line conductor	<= Line conductor	Necessary[1]	Required
All possibility	> Line conductor[4][5]	Necessary[1]	Required

1) Appropriate to the cross-sectional area of that conductor; this detection shall cause the disconnection of the line conductors, but not necessarily of the neutral conductor.

2) If Protection is achieved by overcurrent protective devices in the line conductors, it is not necessary to provide overcurrent disconnecting device for the neutral conductor.

3) PEN conductor should never be disconnected.

4) Caused due to harmonic content in line current.

5) Current in the neutral conductor is expected to exceed the Iz of that conductor.

4.2.2 *IT Systems*

In IT systems, it is strongly recommended that the neutral conductor should not be distributed. If the neutral conductor is distributed and no protection is provided on the supply side/origin of the installation, overcurrent detection shall be provided for the neutral conductor of every circuit and this shall cause the disconnection of all the live and neutral conductors of the corresponding circuit.

This measure is not necessary if the particular circuit is protected by a residual current device (RCD) with a rated residual current not exceeding 0.20 times current carrying capacity(I_Z) of the neutral conductor.

NOTE — In IT systems, it is strongly recommended that the neutral conductor should not be distributed.

4.3 Disconnection and Reconnection of the Neutral Conductor in Multi-phase Systems

The neutral conductor shall not be disconnected before the line conductors and shall be reconnected at the same time as or before the line conductors.

4.4 Nature of Protective Devices

4.4.1 The operating characteristics of overcurrent protective devices shall comply with those specified in, for example, IS 12640 (Part 2), IS 13703 (Part 2), IS 13730 (Part 4), IS/IEC 60898, IS/IEC 60947-2, IS/IEC 60947-3, IS/IEC 60947-6-2 or IEC 60269-3.

4.4.2 Devices ensuring overload current protection only may have an interrupting capacity below the prospective short-circuit current at the point where the devices are installed.

4.4.3 Devices with short-circuit current protection only shall comply with requirements of **4.4.1** where in overload protection is achieved by other means or overload protection to be dispensed with as per **5** of this section.

4.4.4 The operating characteristics of overcurrent protective devices shall comply with those specified in, for example, IS/IEC 60898, IS/IEC 60947-2, IS/IEC 60947-6-2, IS 12640 (Part 2), IS 13703 (Part 2), IEC 60269-3, IS 13730 (Part 4) or IS/IEC 60947-3.

4.5 Protection against Overload Current

4.5.1 *Coordination between Conductors and Overload Protective Devices*

A device protecting a cable against overload shall satisfy the two following conditions:

$$I_B \leq I_n \leq I_Z \quad \text{.....(1)}$$

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$$I_2 \leq 1.45 \times I_Z \quad \text{.....(2)}$$

Where,

I_B = design current for that circuit; (the line or neutral current in case of harmonic after applying correction factors);

I_Z = continuous current-carrying capacity of the cable;

I_n = is the rated current or current setting selected of the protective device; and

I_2 = is the current ensuring effective operation in the conventional time of the protective device.

A cable with larger cross-sectional area shall be used where sustained overcurrent < I_2 occurs.

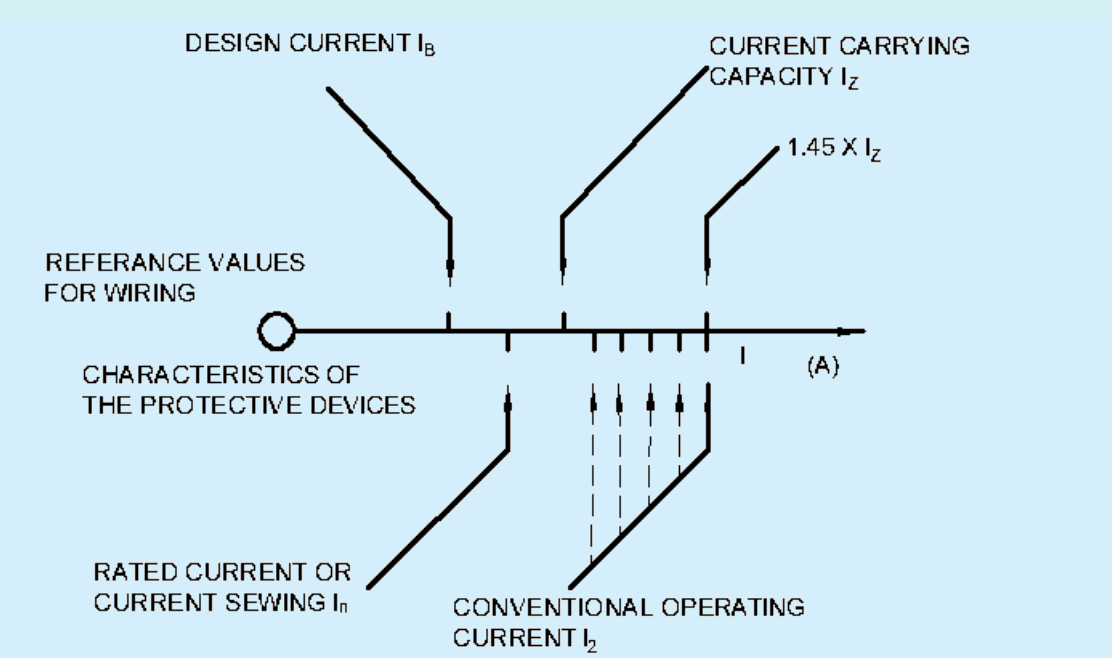


FIG. 1 ILLUSTRATION OF CONDITION 1 AND 2

4.6 Protection Against Short-circuit Currents

4.6.1 The prospective short-circuit current at every relevant point of the installation shall be determined by calculation or by measurement.

NOTE — The prospective short-circuit current at the supply point may be obtained from the supply utility.

4.6.2 *Characteristics of Short-circuit Protective Devices*

4.6.2.1 The rated breaking capacity shall be not less than the prospective maximum short-circuit current at the place of its installation, except where the following paragraph applies.

4.6.2.2 A lower rated breaking capacity is permitted if another protective device having the necessary breaking capacity is installed on the supply side. In that case energy let through by these two devices does not exceed the withstood limit of the device and conductor on the load side.

4.6.2.3 For cables and insulated conductors, short-circuit current interruption time shall not exceeding the permitted limit temperature of the insulation of the conductor.

For operating times of protective devices <0.1 s where asymmetry of the current is of importance and for current-limiting devices $k^2S^2 > I^2t$ (let-through energy) of the protective device.

For short-circuits of duration up to 5 s, the time t, in which short-circuit current will raise the insulation of the conductors from the highest permissible temperature to the limit temperature shall be calculated from the formula:

$$t = (k * S/I)^2 \quad \text{.....(3)}$$

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Where,

t = is the duration, in s;

S = is the cross-sectional area, in mm^2;

I = is the effective short-circuit current, in A, expressed as an rms value; and

k = is a factor taking account of the resistivity, temperature coefficient and heat capacity of the conductor material, and the appropriate initial and final temperatures.

4.7 Position of Devices for Overload and Short-circuit Protection

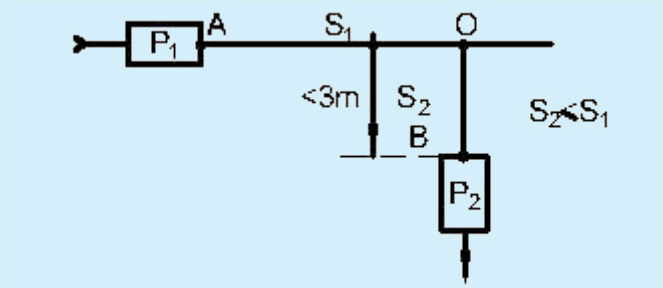
4.7.1 A device ensuring protection against overcurrent shall be placed at the point where a change, such as a change in cross-sectional area, nature, method of installation or in constitution, causes a reduction in the value of current-carrying capacity of the conductors.

4.7.2 The protection device may be placed other than **4.7.1**, under the following conditions,

In the part of the conductor between the point of reduction of cross-sectional area or other change and the position of the protective device there shall be no branch circuits nor socket-outlet circuits and that part of the conductor shall:

a) not exceed 3 m in length, and

b) be installed in such a manner as to reduce the risk of a short-circuit to a minimum, and to reduce risk of fire or danger to person.



NOTE — S – Cross section area of conductor

FIG. 2 LIMITED CHANGE OF POSITION OF SHORT-CIRCUIT PROTECTIVE DEVICE (P2) ON THE BRANCH CIRCUIT

c) not be placed close to combustible material.

4.7.3 A protective device may be placed on the supply side provided that it protects the wiring situated on the load side against short-circuit.

5 OMISSION OF DEVICE FOR PROTECTION AGAINST OVERCURRENT

5.1 Cases where omission of devices for overcurrent protection shall be considered for safety reasons or for circuits supplying current-using equipment where unexpected disconnection of the circuit could cause danger or damage. Examples as under:

a) exciter circuits of rotating machines;

b) supply circuits of lifting magnets;

c) secondary circuits of current transformers;

d) circuits which supply fire extinguishing devices;

e) circuits supplying safety services (burglar alarm, gas alarms, etc.); and

f) Certain measuring circuits, signalling, telecommunication, control and similar.

NOTE —In such cases, consideration should be given to the provision of an overload alarm.

5.2 Omission of protective device shall be permitted at the origin of an installation where the distributor provides an overcurrent device and agrees that it affords protection between the origin and the main distribution point of the installation where further overcurrent protection is provided.

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5.3 For considering omission of short circuit protection as per **4.7.2** and **4.7.3** the wiring installation shall be in such a way to reduce the risk of short-circuit to a minimum and wiring is not placed close to combustible material.

5.4 For conductor not likely to carry overload current, overload protection shall be omitted provided that this conductor is protected against short-circuit.

5.5 In IT systems without a neutral conductor, the overload protective device may be omitted in one of the phase conductors if a RCD is installed in each circuit.

5.6 Alternative position or omission of devices for protection against overload are not applicable to IT systems unless each circuit not protected against overload is protected by RCD for each circuit or by permanently supervised systems only use of insulation monitoring which either disconnect the circuit for the first fault or gives a signal indicating a fault.

6 OVERCURRENT PROTECTION OF CONDUCTORS IN PARALLEL

6.1 Where a single protective device protects several conductors in parallel, there shall be no branch circuits or devices for isolation or switching in the parallel conductors. This sub-clause does not preclude the use of final ring circuits.

6.2 If parallel conductors shares equal currents the value of *Iz* is the sum of the *Iz* of the various conductors.

6.3 In case of unequal current sharing between parallel conductors overload protection for each conductor shall be considered individually.

NOTE — Currents in parallel conductors are considered to be unequal if the difference between any currents is more than 10 percent of the design current for each conductor.

6.4 For short circuit protection, if operation of a single protective device is not effective, then for two conductors in parallel, a short-circuit protective device shall be provided at the supply end of each parallel conductor or For more than two conductors in parallel, short-circuit protective devices shall be provided at the supply and load ends of each parallel conductor.

6.5 For busbar trunking systems complying with IS/IEC 61439-6 and powertrack complying with the IS 17345 (Part 1), one of the following requirements in Table 2 shall apply:

Table 2 Protection for Busbar Trunking or Powertrack System

(*Clause* 6.5)

Busbar Trunking or Powertrack System	Condition	Protective Device
The rated short-time withstand current (ICW)	>	prospective short-circuit current (rms)
The rated peak withstand current	>	Prospective short-circuit current (peak)
The maximum time for the ICW	>	Maximum operating time of the protective device
The rated conditional short-circuit current	>	Prospective short-circuit current

7 COORDINATION OF OVERLOAD AND SHORT-CIRCUIT PROTECTION WHEN PROTECTION IS AFFORDED BY SEPARATE DEVICES

The requirements of **4.4**, **4.5** and **4.6** apply, to the overload protective and short-circuit protective device.

The characteristics of the devices shall be coordinated so that the energy let through by the short-circuit protective device does not exceed that which can be withstood without damage by the overload protective device.

NOTE — This requirement does not exclude the type of coordination specified in IS/IEC 60947 series.

8 LIMITATION OF OVERCURRENT BY CHARACTERISTICS OF SUPPLY

Conductors are considered to be protected against overcurrent when they are supplied from a source incapable of supplying a current exceeding the I_z of the conductors (for example, certain bell transformers, certain welding transformers and certain types of thermoelectric generating sets).

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SECTION 13 PROTECTION AGAINST VOLTAGE DISTURBANCES, ELECTROMAGNETIC DISTURBANCES AND VOLTAGE SURGES

FOREWORD

Reliability of electrical network throughout its service life is possible only by protecting it from different kinds of over voltages. This section provides requirements for the protection against over voltages, the maximum allowed over voltages in a network and the selection and erection of an SPD in an installation.

Assistance for this section has been derived from 4.5 and 5.3.5 of IS 732.

1 SCOPE

This section of the code (Part 1/Sec 13) covers protection against voltage disturbances, electromagnetic disturbances and voltage surges. It is based on 4.5 and 5.3.5 of IS 732, which is a basic safety standard that applies to the safety of persons, livestock and property against dangers and damage which may arise in the reasonable use of electrical installations and to provide for the proper functioning of those installations.

2 PROTECTION OF LOW-VOLTAGE INSTALLATIONS AGAINST TEMPORARY OVER VOLTAGES DUE TO EARTH FAULTS IN THE HIGH-VOLTAGE SYSTEM AND DUE TO FAULTS IN THE LOW-VOLTAGE SYSTEM

Requirements for protection of low-voltage installations against temporary over voltages due to earth faults in the high-voltage system and due to faults in the low-voltage system shall be in accordance with 4.5.2 of IS 732.

3 PROTECTION AGAINST TRANSIENT OVERVOLTAGES OF ATMOSPHERIC ORIGIN OR DUE TO SWITCHING

Requirements for protection against transient overvoltages of atmospheric origin or due to switching shall be in accordance with 4.5.3 of IS 732. Additional measures required are explained in this section.

3.1 Risk Assessment to determine Protection against Transient Over Voltage of Atmospheric Origin

3.1.1 *Terminology*

3.1.1.1 *Urban environment* — Area with a high density of buildings or densely populated communities with tall buildings (for example, a town centre is an example of an urban environment).

3.1.1.2 *Suburban environment* — Area with a medium density of buildings (for example, Town outskirts are an example of a suburban environment).

3.1.1.3 *Rural environment* — Area with a low density of buildings.

3.1.1.4 *Surge protective device (SPD)* — Device that contains at least one non-linear component that is intended to limit surge voltages and divert surge currents.

3.1.1.5 *Calculated risk level (CRL)* — Calculated value of risk used to evaluate the need for transient overvoltage protection.

3.1.1.6 *Rated impulse voltage (U_W)* — Impulse withstand voltage value assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against transient over voltages.

3.1.1.7 *Overvoltage control* — Protection against transient overvoltage shall be provided where the consequence caused by overvoltage affects:

a) human life, for example, safety services, medical care facilities;

b) public services and cultural heritage, for example, loss of public services, IT centers, museums; and

c) commercial or industrial activity, for example, hotels, banks, industries, commercial markets, farms.

For all other cases, a risk assessment according to **3.2** shall be performed in order to determine if protection against transient overvoltage is required. If the risk assessment is not performed, the electrical installation shall be provided with protection against transient overvoltage.

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Protection against switching over voltages should be considered in the case of equipment likely to produce switching over voltages or disturbances exceeding the values according to the overvoltage category of the installation for example, where a LV generator supply the installation or where inductive or capacitive loads (for example, motors, transformers, capacitor banks, etc.), storage units or high current loads are installed.

NOTE — Annex C provides guidance for overvoltage control where utility provided SPDs are installed on overhead lines.

For a low-voltage installation supplied from a high-voltage distribution network through a separate transformer (that is, an industrial application), additional means for protection against overvoltages due to lightning should be installed on the high-voltage side of the transformer.

Protection against transient overvoltage shall be provided where over voltages affect individuals for example, residential buildings and small offices if the risk assessment according to **3.2** requires the protection against transient over voltages of atmospheric origin.

If no risk assessment is performed protection against transient over voltages of atmospheric origin shall be provided, except for single dwellings where only overvoltage category III or IV equipment are the only equipment at this location.

3.2 *Risk Assessment Method* — Calculated risk level (CRL) is used to determine if protection against transient overvoltages of atmospheric origin is required.

NOTE — For protection of a structure and its electrical systems against lightning and surges of atmospheric origin, IS/IEC 62305 applies.

The CRL is found by the following formula:

$$CRL = f_{env}/(L_p \times N_g)$$

where

a) f_{env} is an environmental factor and the value of f_{env} shall be calculated according to Table 1.

Table 1 Calculation of f_{env}

(*Clause* 3.2)

Sl No.	Environment	f_{env}
(1)	(2)	(3)
i)	Rural and suburban environment	85 × F
ii)	Urban environment	850 × F

The value of coefficient F shall be taken equal to 1 for all installations. However, National Committees may adjust the value of coefficient F from 1 to 3 for dwellings.

b) Ng is the lightning ground flash density (flash per km^2 per year) relevant to the location of the power line and connected structure;

NOTE — According to A-1 of IS/IEC 62305-2, 25 thunderstorm days per year are equivalent to a value of 2.5 flashes per km^2 per year. This is derived from the formula $Ng = 0.1 \times T_d$, where T_d is the number of thunderstorm days per year (keraunic level).

c) the risk assessment length, L_p is calculated as below:

$$L_p = 2\ L_{PAL} + L_{PCL} + 0.4\ L_{PAH} + 0.2\ L_{PCH}$$

Where,

L_{PAL} = the length (km) of low-voltage overhead line;

L_{PCL} = the length (km) of low-voltage underground cable;

L_{PAH} = the length (km) of high-voltage overhead line; and

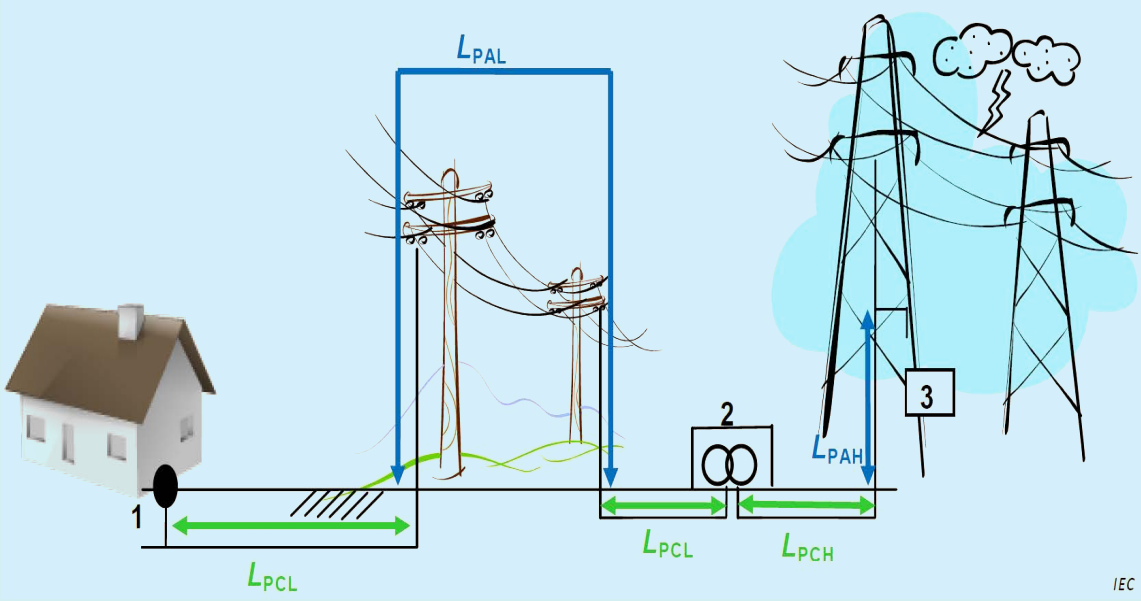
L_{PCH} = the length (km) of high-voltage underground cable.

The total length ($L_{PAL} + L_{PCL} + L_{PAH} + L_{PCH}$) is limited to 1 km or by the distance from the first overvoltage protective device installed in the power network to the entrance of the installation, whichever is the smaller.

If the distribution networks lengths are totally or partially unknown then L_{PAL} shall be taken equal to the remaining distance to reach a total length of 1 km.

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For example, if only the distance of underground cable is known (for example, 100 m), then the L_{PAL} shall be taken equal to 90 m. An illustration of an installation showing the lengths to consider is given in Fig. 1.



Key

1 — Origin of the installation
2 — LV/HV transformer
3 — Surge arrestor (overvoltage protective device)

FIG. 1 ILLUSTRATION OF AN INSTALLATION SHOWING THE LENGTHS TO CONSIDER

If CRL ≥ 1 000, no protection against transient overvoltages of atmospheric origin is needed.

If CRL < 1 000, protection against transient overvoltages of atmospheric origin is required.

NOTE — Examples of calculations of CRL are given in Annex B.

4 MEASURES AGAINST ELECTROMAGNETIC INFLUENCES

Requirements for measures against electromagnetic influences shall be in accordance with 4.5.4 of IS 732. Additional measures required are explained in this section.

4.1 Segregation of Circuits

4.1.1 *General*

Power supply cables (or conductors), and information and communication technology cables which share the same cable management system or the same route, shall be installed according to the requirements of **4.1**.

NOTE — For the purposes of this subclause, cable management systems are considered to include busbar trunking systems.

Electrical safety and electromagnetic compatibility may produce different requirements for electrical segregation and electrical separation. Electrical safety always has the higher priority.

4.2 Design Requirements

The following requirements apply unless **4.3** applies.

Where the specification and/or intended application of the information and communication technology cable is not available, the cable separation distance between the power and information and communication technology cables shall be not less than 200 mm in free air, provided:

a) the total current in a LV cable or in a bundle of LV cables does not exceed 600 A,
b) the applications supported by the cabling are designed to operate using the information and communication technology cabling installed or to be installed, and

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c) the information and communication technology cables are: balanced cables having electromagnetic immunity performance in accordance with IEC 61156 (all parts) for Category 5 and above, or coaxial cables having electromagnetic immunity performance in accordance with IEC 61196-7.

In all other cases, the requirements and recommendations of 7.9.2 of ISO/IEC 14763-2, apply.

The 200 mm separation distance may be reduced according to Table 2.

Where a screened power cable is used, the separation distance may be reduced in accordance with the specification provided by the screened power cable manufacturer, provided that the screen is earthed at both ends.

Power cables that also carry information are not considered to be information and communication technology cables.

Table 2 Summary of Minimum Separation Distances where the Specification and/or Intended Application of the Information and Communication Technology Cable is not available

(*Clause* 4.2)

Containment applied to the power supply cabling			
Separation without electromagnetic barrier	Open metallic Containment[a)] A	Perforated metallic containment[b)]	Solid metallic containment[c)]
200 mm	150 mm	100 mm	0 mm

[a)] Applicable to containment with screening performance (DC-100 MHz) equivalent to welded mesh steel basket of mesh size 50 mm × 100 mm. This screening performance is also achieved with steel tray even if the wall thickness is less than 1.0 mm and/or the evenly distributed perforated area is greater than 20 percent.

[b)] Applicable to containment with screening performance (DC-100 MHz) equivalent to steel tray of at least 1.0 mm wall thickness and no more than 20 percent evenly distributed perforated area. The screens or armouring of power cables are considered to act as perforated metallic containment if they do not meet this constructional equivalent of solid metallic containment.

[c)] Applicable to containment with screening performance (DC-100 MHz) equivalent to a steel conduit of at least 1.5 mm wall thickness.

The minimum separation between the ICT cables and power supply cables shall include all allowances for cable movement between their fixing points or other restraints (*see* example in Fig. 2).

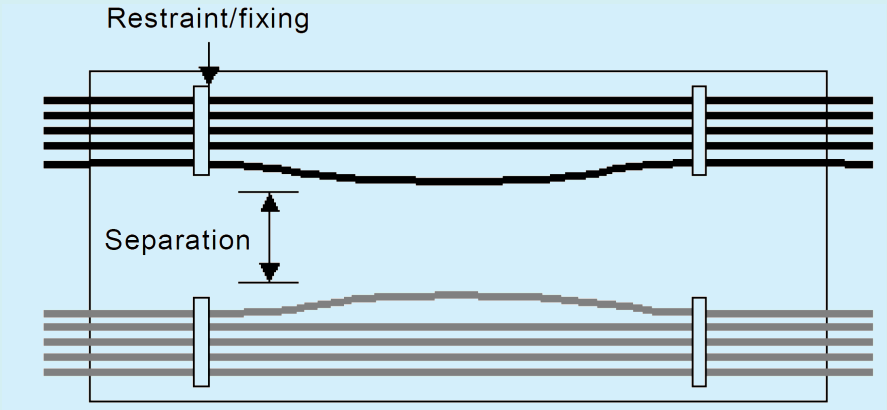


FIG. 2 EXAMPLE OF CABLE SEPARATION DISTANCE

The minimum separation requirement applies in three dimensions. However, where information and communication technology cables and power supply cables are required to cross and required minimum separation cannot be maintained then the angle of their crossing shall be maintained at approximately 90° on either side of the crossing for a distance no less than the applicable minimum separation requirement.

4.3 Conditions for Zero Segregation

No segregation is required between information and communication technology cabling and power supply cabling (other than 5.2 of IS 732) provided that the information and communication technology cabling is application(s)-specific and the application(s) support(s) a zero segregation relaxation.

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No segregation is required between information and communication technology cabling and power supply cabling where all the following conditions are met the:

a) information and communication technology cables are in accordance with IEC 61156 (all parts) for Category 5 and above, or are coaxial cables having electromagnetic immunity performance in accordance with IEC 61196-7;

b) environmental classification of the space containing the information and communication technology cabling complies with electromagnetic classification E1 of ISO/IEC TR 29106 (or ISO/IEC 11801-1); and

c) power supply conductors comprising a circuit are either:

   1) within an overall sheath and provide a total current no greater than 100 A, or

   2) twisted, taped or bundled together and provide a total power no greater than 10 kVA.

5 PROTECTION AGAINST UNDERVOLTAGE

5.1 General Requirements

5.1.1 Where a drop in voltage, or a loss and subsequent restoration of voltage could imply dangerous situations for persons or property, suitable precautions shall be taken. Also, precautions shall be taken where a part of the installation or current-using equipment may be damaged by a drop in voltage.

An undervoltage protective device is not required if damage to the installation or to current-using equipment is considered to be an acceptable risk, provided that no danger is caused to persons.

5.1.2 The operation of undervoltage protective devices may be delayed if the operation of the appliance protected allows without danger a brief interruption or loss of voltage.

5.1.3 If use is made of contactors, delay in their opening and reclosing shall not impede instantaneous disconnection by control or protective devices.

5.1.4 The characteristics of the undervoltage protective device shall be compatible with the requirements of the relevant standards for starting and use of equipment.

5.1.5 Where the reclosure of a protective device is likely to create a dangerous situation, the reclosure shall not be automatic.

6 PROTECTION AGAINST VOLTAGE SURGES

Requirements for protection against voltage surges shall be in accordance with 5.3.5 of IS 732. Additional measures required are explained in this section.

6.1 SPD Location and SPD Test Class

SPDs shall be installed as close as possible to the origin of the installation. For protection against effects of lightning and against switching overvoltages, class II tested SPDs (Type T2) shall be used.

Where the structure is equipped with an external lightning protection system or protection against effects of direct lightning is otherwise specified, class I tested SPDs (Type T1) shall be used.

Where the structure is not equipped with an external lightning protection system and where the occurrence of direct lightning strike to the overhead lines between the last pole and the entrance of the installation is to be taken into consideration, class I tested SPDs at or near the origin of the electrical installation may be also selected according to Annex D.

NOTES

1 The origin of the installation could be the location where the supply enters the building or the main distribution board.

2 Following the product standard, the marking of the product is as follows:

   i) for test class I: “test class I” and/or Type T1 “T1” (T1 in a square);

   ii) for test class II: “test class II” and/or Type T2 “T2” (T2 in a square); and

   iii) for test class III: “test class III” and/or Type T2 “T3” (T3 in a square).

Additional class II tested or class III tested SPDs may be needed to sufficiently protect the installation according to **6.2** and shall be located downstream in the fixed electrical installation, for example in the sub-distribution

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boards or at the socket outlets. These SPDs shall not be used without SPDs being installed at the origin of the installation and shall be coordinated with SPDs located upstream.

If a class I tested SPD is not able to provide voltage protection to an equipment lower than its rated impulse withstand (U_W), it shall be accompanied by a coordinated class II tested or class III tested SPD to ensure the required voltage protection level.

Additional class II tested SPDs or class III tested SPDs may be needed close to sensitive equipment to sufficiently protect the equipment and shall be coordinated with SPDs located upstream.

Additional SPDs may be necessary to provide transient overvoltage protection regarding threats coming from other sources such as:

a) switching overvoltages produced by current using equipment located within the installation;

b) overvoltages on other incoming services such as telephone lines, internet connections; and

c) overvoltages on other services feeding other structures such as secondary buildings, external installations/ lighting, power lines feeding external sensors in which case one should consider installing SPDs located as close as possible to the origin of such threats. For more details, please refer IS 16463 (Part 12).

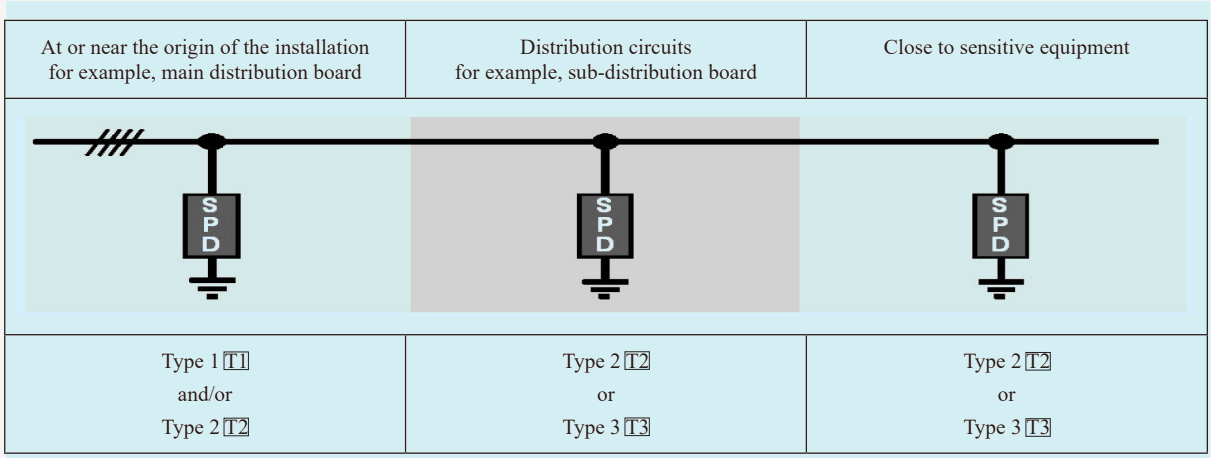


FIG. 3 EXAMPLE OF INSTALLATION OF TYPE 1, TYPE 2 AND TYPE 3 SPDS

The presence of SPDs installed downstream of a distribution board (for example, in a socket-outlet) shall be permanently indicated (for example, by a label) in this distribution board.

6.2 Transient Overvoltage Protection Requirements

Protection against transient overvoltages may be provided:

a) between live conductors and PE (common mode protection); and

b) between live conductors (differential mode protection).

NOTES

1 Connection type (CT1), primarily, provides common mode protection. If differential mode protection is also necessary, this will in most cases require additional SPDs between live conductors.

2 Connection type (CT2) provides a combination of common mode protection and differential mode protection.

Protection between live conductors and PE (including neutral to PE if there is a neutral conductor) is compulsory.

Protection between line conductors and neutral (if there is a neutral conductor) is recommended to ensure equipment protection.

Protection between line conductors (in the case of multiple phases) is optional.

Some equipment may require both common mode protection (for impulse withstand) and differential mode protection (for impulse immunity).

NOTE — For example, electronic class I equipment or class II equipment with FE-connection requires common mode as well as differential mode protection to ensure overall protection against transient overvoltages due to switching or from atmospheric origin.

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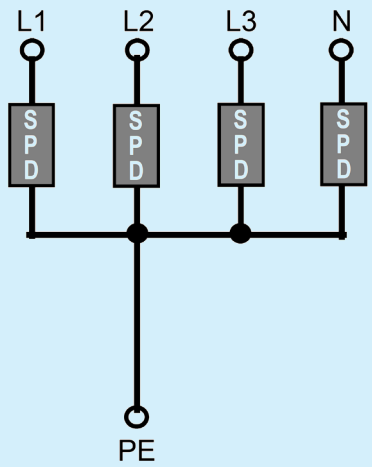


FIG. 4 CONNECTION TYPE CT1 (4+0-CONFIGURATION) FOR A THREE-PHASE SYSTEM WITH NEUTRAL

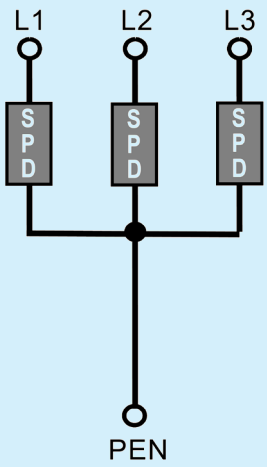


FIG. 5 CONNECTION TYPE CT1 (3+0-CONFIGURATION) FOR A THREE-PHASE SYSTEM

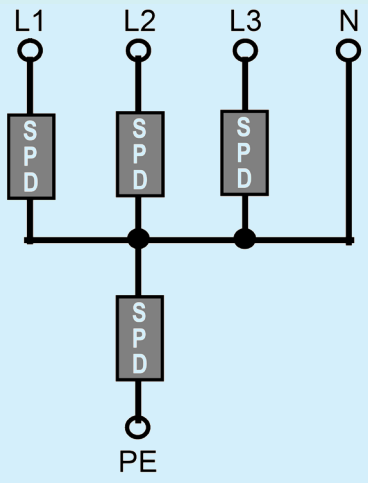


FIG. 6 CONNECTION TYPE CT2 (E.G. 3+1-CONFIGURATION) FOR A THREE-PHASE SYSTEM WITH NEUTRAL

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ANNEX A

(*Clause* 2)

LIST OF REFERRED STANDARDS

IS No/Other Publication	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
13252 (Part 1) : 2010/ IEC 60950-1 : 2005	Information technology equipment — Safety — Part 1 General requirements (*second revision*)
14493 (all Parts)	Multicore and symmetrical pair/quad cables for digital communication
14700 (Part 6/Sec 1) : 2019/ IEC 61000-6-1 : 2016	Electromagnetic compatibility (EMC) — Part 6 Generic standards, Section 1 Immunity standard for residential, commercial and light-industrial environments (*first revision*)
14700 (Part 6/Sec 2) : 2019/ IEC 61000-6-2 : 2016	Electromagnetic compatibility (EMC) — Part 6 Generic standards, Section 2 Immunity standard for industrial environments (*first revision*)
14700 (Part 6/Sec 3) : 2018/ IEC 61000-6-3 : 2018	Electromagnetic compatibility (EMC) — Part 6 Generic Standards — Section 3 Emission standards for residential, commercial and light-industrial environments (*first revision*)
16463 (Part 11) : 2016	Low - voltage surge protective devices — Part 11 Surge protective devices connected to low — Voltage power systems — Requirements and test methods
16463 (Part 12) : 2017	Low - voltage surge protective devices — Part 12 Surge protective devices connected to low — Voltage power distribution systems — Selection and application principles
IS/IEC 60479-1 : 2018	Effects of current on human beings and livestock: Part 1 General aspects
IS/IEC 62305 (*all parts*)	Protection against lightning (*all parts*)
IEC 60364-4-44 : 2018	voltage electrical installations — Part 4-44: Protection for safety — Protection against voltage disturbances and electromagnetic disturbances
IEC 60664-1 : 2020	Insulation coordination for equipment within low-voltage supply systems — Part 1: Principles, requirements and tests
IEC 60050-195 : 2021	International electrotechnical vocabulary (IEV) — Part 195: Earthing and protection against electric shock
IEC 60050-826 : 2004	International electrotechnical vocabulary (IEV) — Part 826: Electrical installations
IEC TR 61000-2-5 : 2017	Electromagnetic compatibility (EMC) — Part 2-5: Environment — Description and classification of electromagnetic environments
IEC 61000-5 (all sections)	Electromagnetic compatibility (EMC) — Part 5: Installation and mitigation guidelines
IEC 61000-6-4 : 2018	Electromagnetic compatibility (EMC) — Part 6-4: Generic standards — Emission standard for industrial environments
IEC 61936-1 : 2021	Power installations exceeding 1 kV AC and 1.5 kV DC — Part 1: AC
IEC TR 62066 : 2002	Surge overvoltages and surge protection in low-voltage a.c. power systems — General basic information
ISO/IEC 30129 : 2015	Information technology — Telecommunications bonding networks for buildings and other structures

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ANNEX B

(*Informative*)

EXAMPLES OF CALCULATED RISK LEVEL CRL FOR THE USE OF SPDS

B-1 EXAMPLE 1 – BUILDING IN RURAL ENVIRONMENT

Ground flash density $N_g = 1$

Environmental factor $f_{env} = 85$

Risk assessment length $L_P = 2\ L_{PAL} + L_{PCL} + 0.4\ L_{PAH} + 0.2\ L_{PCH}$

$= (2 \times 0.4) + (0.4 \times 0.6)$

$= 1.04$

Where,

L_{PAL} = the length (km) of low-voltage overhead line= 0.4;

L_{PAH} = the length (km) of high-voltage overhead line= 0.6;

L_{PCL} = the length (km) of low-voltage underground cable = 0; and

L_{PCH} = the length (km) of high-voltage underground cable = 0.

$CRL = f_{env}/(L_P \times N_g) = 85/(1.04 \times 1) = 81.7$

In this case, SPD protection shall be installed as the CRL is less than 1 000.

B-2 EXAMPLE 2 – BUILDING IN RURAL ENVIRONMENT POWERED IN HV

Ground flash density $N_g = 0.4$

Environmental factor $f_{env} = 85$

Risk assessment length $L_P = 2\ L_{PAL} + L_{PCL} + 0.4\ L_{PAH} + 0.2\ L_{PCH}$

$= 0.2 \times 1$

$= 0.2$

Where,

L_{PAL} = the length (km) of low-voltage overhead line = 0;

L_{PAH} = the length (km) of high-voltage overhead line = 0;

L_{PCL} is the length (km) of low-voltage underground cable = 0; and

L_{PCH} is the length (km) of high-voltage underground cable = 1.

$CRL = f_{env}/(L_P \times N_g) = 85/(0.2 \times 0.4) = 1\ 062.5$

In this case, SPD protection is not mandatory as the CRL is greater than or equal to 1 000.

B-3 EXAMPLE 3 – BUILDING IN URBAN ENVIRONMENT POWERED BY OVERHEAD LINES

Ground flash density $N_g = 1$

Environmental factor $f_{env} = 850$

Risk assessment length $L_P = 2\ L_{PAL} + L_{PCL} + 0.4\ L_{PAH} + 0.2\ L_{PCH}$

$= 2 \times 0.4 + 0.4 \times 0.6$

$= 1.04$

Where,

L_{PAL} = the length (km) of low-voltage overhead line = 0.4;

L_{PAH} = the length (km) of high-voltage overhead line = 0.6;

L_{PCL} = the length (km) of low-voltage underground cable = 0; and

L_{PCH} = the length (km) of high-voltage underground cable = 0.

$CRL = f_{env}/(L_P \times N_g) = 850/(1 \times 1.04) = 817$

In this case, SPD protection shall be installed as the CRL is less than 1 000.

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B-4 EXAMPLE 4 – BUILDING IN URBAN ENVIRONMENT POWERED BY UNDERGROUND CABLES

Ground flash density $N_g = 0.5$

Environmental factor $f_{env} = 850$

Risk assessment length $L_P = 2\ L_{PAL} + L_{PCL} + 0.4\ L_{PAH} + 0.2\ L_{PCH}$

$= 1$

Where,

L_{PAL} = the length (km) of low-voltage overhead line = 0;

L_{PAH} = the length (km) of high-voltage overhead line = 0;

L_{PCL} = the length (km) of low-voltage underground cable= 1; and

L_{PCH} = the length (km) of high-voltage underground cable = 0.

$CRL = f_{env}/(L_P \times N_g) = 850/(1 \times 0.5) = 1\ 700$.

In this case, an SPD is not mandatory as the CRL is greater than or equal to 1 000.

ANNEX C

(*Informative*)

GUIDANCE ON OVERVOLTAGE CONTROL BY SPDS APPLIED TO OVERHEAD LINES

Where an installation is supplied by, or includes, an overhead line and an SPD is required for over voltage control, the protective control of the overvoltage level may be obtained either by installing surge protective devices directly in the installation close to the origin of installation, or with the consent of the network operator, in the overhead lines of the supply distribution network.

As an example, the following measures may be applied:

a) in the case of overhead supply distribution networks, overvoltage protection is erected at network junction points and especially at the end of each feeder longer than 0.5 km. Surge protective devices should be erected at every 0.5 km distance along the supply distribution lines. Nevertheless, the distance between surge protective devices should in no case exceed 1 km;

b) if a supply distribution network is erected partly as overhead network and partly as underground network, overvoltage protection in the overhead lines should be applied in accordance with a) at each transition point from and overhead line to an underground cable;

c) in a TN distribution network supplying electrical installations, where the protective measure automatic disconnection of supply is applied, the earthing conductors of the surge protective devices connected to the line conductors are connected to the PEN conductor or to the PE conductor; and

d) in a TT distribution network supplying electrical installations, where the protection measure automatic disconnection of supply is applied, surge protective devices are provided for the line conductors and for the neutral conductor. At the place where the neutral conductor of the supply network is effectively earthed, a surge protective device for the neutral conductor is not necessary.

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ANNEX D

(*Informative*)

SELECTION OF IMPULSE DISCHARGE CURRENT (I_{IMP}) OF SPD'S UNDER VARIOUS CONDITIONS

D-1 INSTALLATION SUPPLIED BY OVERHEAD LINES

Where overvoltage protection according to 4.5.3 of IS 732 is required, where the lines entering the building are overhead and where the case of lightning strike to the last pole of the overhead lines close to the building is taken into account, SPDs at the origin of the installation shall be selected according to Table D-1.

Table D-1 Selection of Impulse Discharge Current (I_{imp})

(*Clause* D-1)

Connection	I_{imp} (kA)			
	Supply system			
	Single phase		Three phase	
	CT1	CT2	CT1	CT2
L-N	—	5	—	5
L-PE	5	—	5	—
N-PE	5	10	5	20
NOTE — This table refers to lightning protection levels III and IV.				

D-2 Where class I tested SPDs are required at or near the origin of the installation as per IS/IEC 62305, one of the following cases applies:

a) Where no risk analysis according to IS/IEC 62305-2 has been carried out, the impulse discharge current (I_{imp}) shall be not less than as given in Table D-2.

b) Where the risk analysis according to IS/IEC 62305-2 has been carried out, the impulse discharge current (I_{imp}) shall be determined according to the IS/IEC 62305 series.

Table D.2 Selection of Impulse Discharge Current (I_{imp}) where the Building is Protected against Direct Lightning Strike

(*Clause* D-2)

Connection	I_{IMP} in kA			
	Supply System			
	Single Phase		Three Phase	
	CT1	CT2	CT1	CT2
L-N		12.5		12.5
L-PE	12.5		12.5	
N-PE	12.5	25	12.5	50
NOTE — This table refers to lightning protection level (LPL) III and IV				

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SECTION 14 SHORT-CIRCUIT AND VOLTAGE DROP CALCULATIONS

FOREWORD

Circuit calculations are performed for checking the adequacy of the electrical equipment for any electrical system that is characterized by the type of distribution system comprising of transformers, bus, cables etc.

The essential requirements and methods associated with following calculations are covered in this Section:

a) Short circuit calculations in 3 phase ac systems,

b) Calculation of the effects of short circuit currents, and

c) Current carrying capacity and voltage drop calculation for cables and flexible cords

Assistance for this Section has been derived from IS 13234, IS 13235 and IEC 60364-5-52.

1 SCOPE

This section of the code (Part 1/Sec 14) covers guidelines and general requirements associated with circuit calculations, namely, short circuit current calculations, short circuit impedance, electromagnetic and thermal effects of short circuit currents and voltage drop calculations for cables and flexible cords.

NOTE — Information on cascading, limitation and selectivity is given at Annex A.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No./Other Publications	*Title*
2086 : 1993	Carriers and bases used in rewirable type electric fuses for voltages up to 650 V — Specification (*third revision*)
9926 : 1981	Specification for fuse-wire used in rewirable type electric fuses up to 650 volts
12640 (Part 1) : 2016/ IEC 61008-1 : 2013	Residual current operated circuit breakers without integral overcurrent protection for household and similar uses (RCCBs): Part 1 General rules (*second revision*)
12640 (Part 2) : 2016/ IEC 61009-1 : 2013	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs): Part 2 General rules (*second revision*)
13703 (Part 2/Sec 1) : 1993/ IEC Pub 269-2 (1986)	Specification for low-voltage fuses for voltages not exceeding 1 000 V a.c. or 1 500 V d.c.: Part 2 Fuses for use by authorized persons, Section 1 Supplementary requirements
13703 (Part 2/Sec 2) : 1993/ IEC Pub 269-2-1 (1987)	LV fuses for voltages not exceeding 1 000 V a.c. or 1500 V d.c.: Part 2 Fuses for use by authorized persons, Section 2 Examples of standardized fuses
13234 (Part 0) : 2017/ IEC 60909-0 : 2016	Short circuit currents in three-phase a.c. systems: Part 0 Calculation of currents (*first revision*)
13235 (Part 1) : 2019/ IEC 60865-1 : 2011	Short-circuit currents — Calculation of effects: Part 1 Definitions and calculation methods (*first revision*)
IS/IEC 60898-1 : 2015	Electrical accessories — Circuit breakers for overcurrent protection for household and similar installations: Part 1 Circuit breakers for a.c. operation (*first revision*)
IEC 60364-5-52 : 2009	Low-voltage electrical installations — Part 5-52: Selection and erection of electrical equipment — Wiring systems

3 GENERAL CONSIDERATIONS

3.1 This subject of circuit calculations covers the guidelines relating to the short circuit withstand capability of the electrical equipment and to check permissible voltage drop in cables and flexible cords upto the equipment terminals.

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3.2 The objective of the circuit calculation is to ensure that the selection of equipment under consideration is designed for safe and reliable long period of operation.

3.3 The duration of flow of fault current in any section of the circuit should be considered as the maximum time required by the back-up protection to operate to isolate that particular section in case of flow of the calculated maximum short circuit current (maximum of all cases). This time will depend on the devices used for isolation e.g. in case of relays and circuit breakers, the total time from inception of fault till the interruption of the circuit by the circuit breaker including relay operation time should be considered.

4 CIRCUIT CALCULATIONS

4.1 Short Circuit Calculations

4.1.1 *Design Considerations*

4.1.1.1 A complete calculation of the short-circuit currents should give the currents as a function of time at the short circuit location from the initiation of the short circuit up to its end, corresponding to the instantaneous value of the voltage at the beginning of the short-circuit.

4.1.1.2 In most of the practical cases, it is sufficient to determine the rms value of symmetrical AC component and the peak value i_p of short-circuit current following the occurrence of a short circuit. The value of i_p depends on time constant of the decaying aperiodic component i_{DC} with frequency depending on the X/R ratio of the short-circuit impedance.

4.1.1.3 For determination of asymmetrical short–circuit breaking current, the decaying aperiodic component i_{DC} may be calculated with sufficient accuracy by:

$$i_{DC} = \sqrt{2} I''_k e^{-2\pi f t \tau} \quad (1)$$

Where,

I''_k = initial symmetrical short circuit current (A);

f = nominal system frequency (Hz);

t = time duration of fault(s); and

τ = time constant based on system X/R.

4.1.1.4 The calculations of maximum and minimum short circuit current are based on the following considerations:

a) For the duration of the short-circuit there is no change in the number of circuits involved, that is, a three phase short-circuit remains as three phase and similarly a line-to-earth short-circuit remains line-to-earth during the short circuit;

b) Tap changers of the transformer are at nominal position; and

c) Arc resistances are not taken into account.

4.1.1.5 In situations where there will be no significant change in ac component decay due to far distance from generator (*see* Fig. 1), short-circuit current can be considered as the sum of the following two components:

a) The ac component with constant amplitude during the whole short-circuit; and

b) The aperiodic component beginning with initial value *A* and decaying to zero.

4.1.1.6 For the systems where there will be significant change in ac component decay due to close location near generator (*see* Fig. 2), short circuit-current can be considered as the sum of the following two components:

a) The a.c. component with decaying amplitude during the whole short circuit; and

b) The aperiodic component beginning with initial value *A* and decaying to zero.

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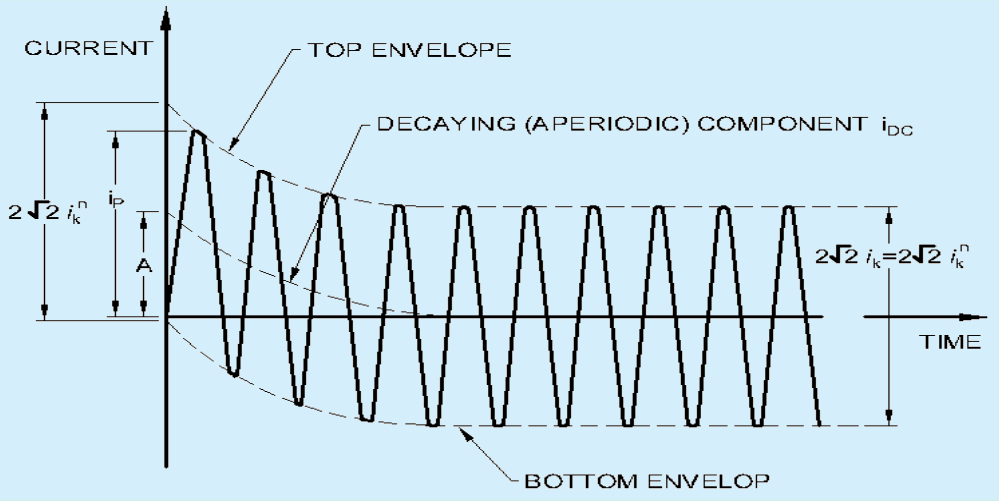
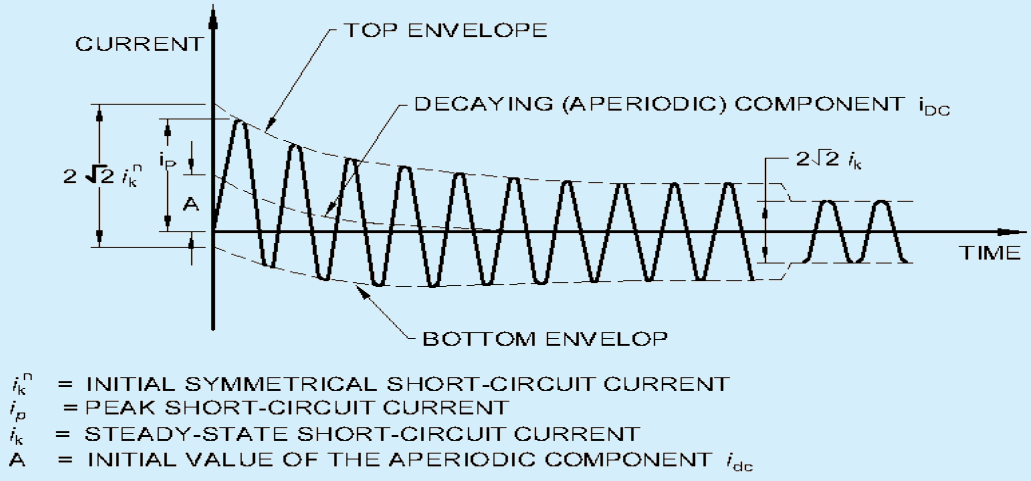


FIG. 1 SHORT-CIRCUIT CURRENT AT A SYSTEM FAR-FROM GENERATOR



i_k'' = INITIAL SYMMETRICAL SHORT-CIRCUIT CURRENT
i_p = PEAK SHORT-CIRCUIT CURRENT
i_k = STEADY-STATE SHORT-CIRCUIT CURRENT
A = INITIAL VALUE OF THE APERIODIC COMPONENT i_{dc}

FIG. 2 SHORT-CIRCUIT CURRENT AT A SYSTEM NEAR-TO GENERATOR

4.1.2 *Calculation Methods*

4.1.2.1 *General*

Equivalent circuits are to be drawn for the system before calculation of short circuit currents with example as per Fig. 3.

4.1.2.1.1 *Balanced short-circuit*

The balanced three-phase short-circuit of a three-phase ac system (*see* Fig. 4a) often leads to the highest values of prospective (available) short-circuit current and the calculation becomes particularly simple on account of the balanced nature of the short circuit.

In calculating the short-circuit current, it is sufficient to take into account only the positive sequence short-circuit impedance, $Z_{(1)} = Z_k$ as seen from the fault location.

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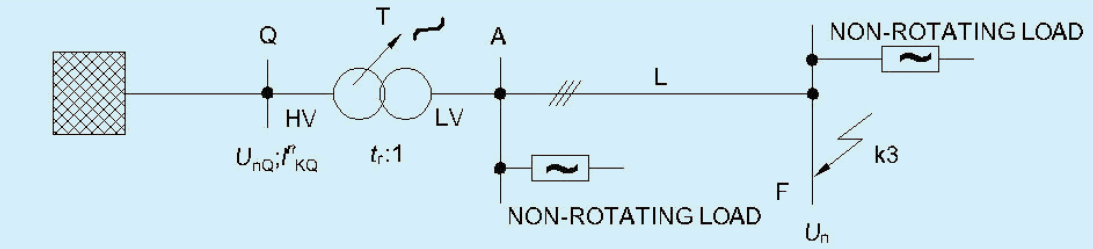


FIG. 3a SYSTEM DIAGRAM

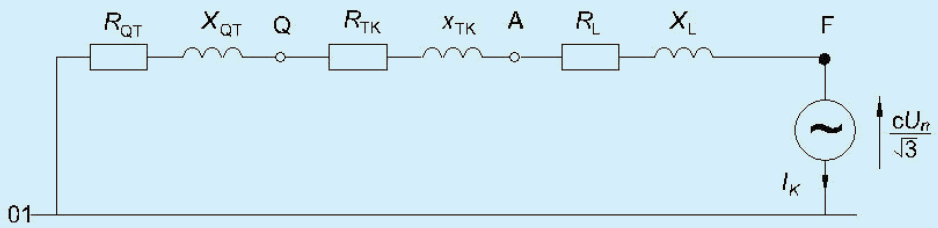


FIG. 3b EQUIVALENT CIRCUIT DIAGRAM OF THE POSITIVE-SEQUENCE SYSTEM

FIG. 3 ILLUSTRATION FOR CALCULATING THE INTIAL SYMMETRICAL SHORT-CIRCUIT i_k'' IN COMPLIANCE WITH THE PROCEDURE FOR THE EQUIVALENT VOLTAGE SOURCE

4.1.2.1.2 *Unbalanced short-circuit*

The following types of unbalanced (asymmetrical) short-circuits are to be considered:

a) line-to-line short-circuit without earth connection (*see* Fig. 4b);
b) line-to-line short-circuit with earth connection (*see* Fig. 4c); and
c) line-to-earth short-circuit (*see* Fig. 4d).

Normally, the three-phase short-circuit current is the largest among the above listed type of faults. In the event of short-circuit near to a transformer with neutral earthing or a neutral earthing transformer, the line-to-earth short-circuit current may be greater than the three-phase short-circuit current. This applies in particular to transformers of vector group Yz, Dy and Dz when earthing the y-winding or z-winding on the low voltage side of the transformer.

4.1.2.1.3 *Application of symmetrical components*

In three-phase systems the calculation of the current values resulting from unbalanced short-circuits is simplified by the use of the method of symmetrical components which requires the calculation of three independent system components, avoiding any coupling of mutual impedances. Using this method, the currents in each line are found by superposing the currents of three symmetrical component systems:

a) positive-sequence current $I_{(1)}$;
b) negative-sequence current $I_{(2)}$; and
c) Zero-sequence current $I_{(0)}$.

Taking the line L1 as reference the currents I_{L1}, I_{L2} and I_{L3} are given by:

$$I_{L1} = I_{(1)} + I_{(2)} + I_{(0)} \quad \text{..... (2a)}$$

$$I_{L2} = a^2 I_{(1)} + a I_{(2)} + I_{(0)} \quad \text{.....(2b)}$$

$$I_{L3} = a I_{(1)} + a^2 I_{(2)} + I_{(0)} \quad \text{..... (2c)}$$

Where, $a = -\frac{1}{2} + j\frac{1}{2}\sqrt{3}; a^2 = -\frac{1}{2} - j\frac{1}{2}\sqrt{3}$

Each of the three symmetrical component systems has its own impedance.

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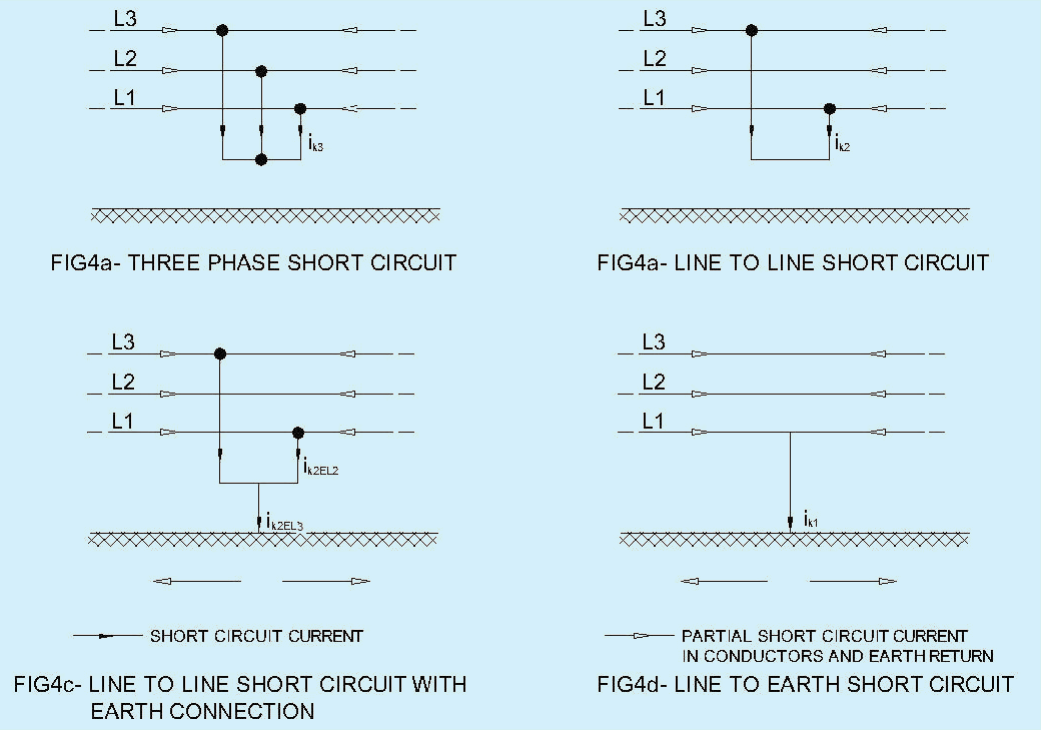


FIG. 4 CHARACTERIZATION OF SHORT CIRCUITS AND THEIR CURRENT

The method of the symmetrical components postulates that the system impedances are balanced (*for example*, in the case of transposed lines). The results of the short-circuit calculation have an acceptable accuracy in the case of un-transposed lines.

4.1.2.1.4 *Maximum and minimum short – circuit currents*

When calculating maximum and minimum short circuit currents voltage factor c_{max} or c_{min} from Table 1 shall be applied to compute maximum or minimum short circuit currents respectively.

Table 1 Voltage Factor *c*

(*Clause* 4.1.2.1.4)

Sl No.	Nominal Voltage U_n	Voltage Factor c for the Calculation of	
		Maximum Short-circuit Currents C_{max} [1)]	Minimum Short-circuit Currents C_{min}
(1)	(2)	(3)	(4)
i)	**Low voltage**		
	100 V to 1 000 V	1.05[3)]	0.95
	(IEC 60038, table I)	1.10 [4)]	
ii)	**Medium Voltage**		
	>1 kV to 35 kV		
	(IEC 60038, table III)	1.10	1.00
iii)	**High voltage**[2)]		
	>35 kV		
	(IEC 60038, table IV)		

NOTES

1 C_{max} U_n should not exceed the highest voltage U_m for equipment of power systems.

2 If no nominal voltage is defined C_{max} $U_n = U_m$ *or* C_{min} $U_n = 0.90 \times U_m$ should be applied.

3 For low-voltage systems wilh a tolerance of ±6 percent, for example systems renamed from 380 to 400 V.

4 For low-voltage systems with a tolerance of +10 percent.

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4.1.3 *Calculation of Short Circuit Currents*

4.1.3.1 *Three phase short circuit*

In general, the initial symmetrical short-circuit current $I_k^{"}$ shall be calculated using the below equation with the equivalent voltage source $\frac{CU_n}{\sqrt{3}}$ at the short-circuit location and the short-circuit impedance $Z_k = R_k + jX_k$.

$$I_k^{"} = \frac{CU_n}{\sqrt{3}Z_k} = \frac{CU_n}{\sqrt{3}\left(\sqrt{R_k^2 + X_k^2}\right)} \quad \text{.....(3)}$$

4.1.3.2 *Single fed short circuit*

For a far-from-generator short circuit fed from a single source (*see* Fig.**1**), the short-circuit current is calculated using equation (3).

$$R_k = R_{Qt} + R_{Tk} + R_L \quad \text{.....(4)}$$

$$X_k = X_{Qt} + X_{Tk} + X_L \quad \text{.....(5)}$$

where,

R_k and X_k are the sum of the series-connected resistances and reactance of the positive-sequence system respectively, in accordance with Fig. 5. R_L is the line resistance for a conductor temperature of 20°C, when calculating the maximum short-circuit currents. Subscript Q and T refer feeder connecting point and transformer respectively.

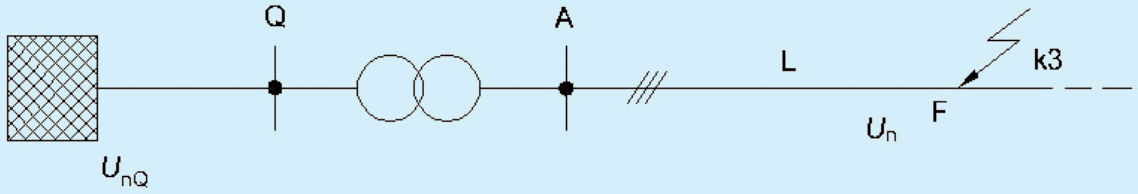


FIG. 5 SHORT CIRCUIT FED FROM A NETWORK FEEDER *VIA* A TRANSFORMER

4.1.3.3 *Short circuits fed from non-meshed networks*

When there is more than one source contributing to the short-circuit current, and the sources are unmeshed, as shown for instance in Fig. 6, the initial symmetrical short-circuit current $I_k^{"}$ at the short-circuit location F is the sum of the individual branch short-circuit currents.

Each branch short-circuit current can be calculated as an independent single-source three-phase short-circuit current in accordance with equation (3) and the information given in **4.1.3.2**. The initial short-circuit current at the short- circuit location F is the phasor sum of the individual partial short-circuit currents (*see* Fig. 6).

$$I_k^{"} = \sum_i I_k^{"} \quad \text{..... (6)}$$

4.1.3.4 *Peak short-circuit current* i_p

For three-phase short circuits fed from non-meshed networks as in Fig. 5 and Fig. 6, the contribution to the peak short-circuit current from each branch can be expressed by:

$$i_p = \kappa\sqrt{2}I_k^{"} \quad \text{.....(7)}$$

The factor k for the *R/X* or *X/R* ratio shall be obtained from Fig. 7 or calculated by following expression:

$$\kappa = 1.02 + 0.98e^{-3R/X} \quad \text{.....(8)}$$

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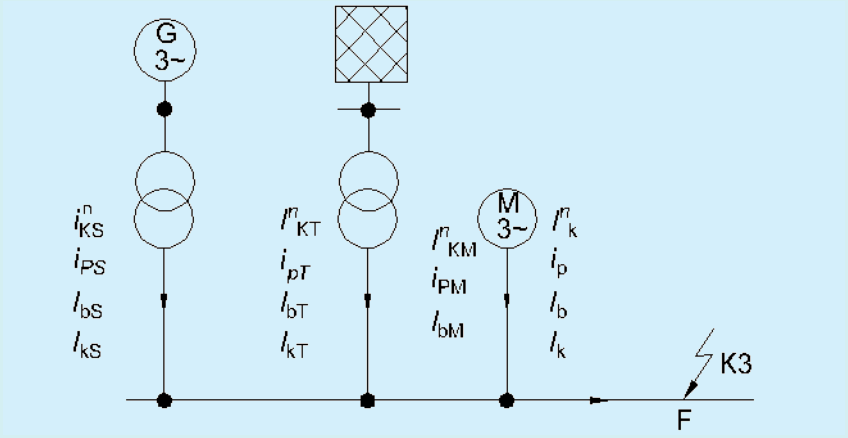


FIG. 6 EXAMPLE OF A NON-MESHED NETWORK

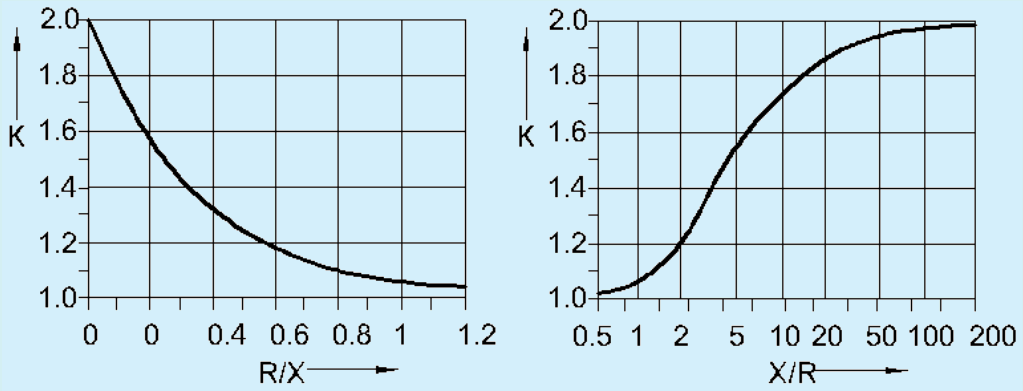


FIG. 7 FACTOR K FOR SERIES CIRCUIT AS A FUNCTION OF RATION R/X OR X/R

4.1.4 *Short-circuit Impedances*

In network feeders, transformers, overhead lines, cables, reactors and similar equipment, positive-sequence and negative-sequence short-circuit impedances are equal: $Z_{(1)} = Z_{(2)}$.

The zero-sequence short-circuit impedance $Z_{(0)} = U_{(0)}/I_{(0)}$ is determined by assuming an a.c. voltage between the three paralleled conductors and the joint return (for example, earth, earthing arrangement, neutral conductor, earth wire, cable sheath, and cable armouring). In this case, the three-fold zero-sequence current flows through the joint return.

While calculating the impedances, there shall be clear distinction between short-circuit impedances at the short-circuit location and short-circuit impedances of individual electrical equipment (*see* Table 2).

4.2 Effects due to Short Circuit

4.2.1 *Electromagnetic Effect on Rigid and Slack (Line) Conductors*

With the calculation methods, forces on insulators, stresses in rigid conductors and tensile forces in slack conductors are to be estimated.

4.2.1.1 *Mechanical forces due to short-circuit Currents*

Currents in parallel conductors will induce electromagnetic forces between the conductors. When the parallel conductors are long compared to the distance between them, the forces will act evenly distributed along the conductors.

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When the currents are in opposite directions the electromagnetic force is a repulsion which tends to induce deformations that would increase inductance of the circuit.

$$F = \frac{\mu_0}{2\pi} i_1 i_2 \frac{l}{a} \qquad \text{.....(9)}$$

Where,

a) i_1 and i_2 are the instantaneous values of the currents;

b) l Center-line distance between the supports; and

c) a Center-line distance between the conductors.

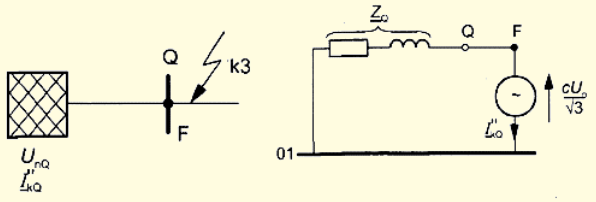
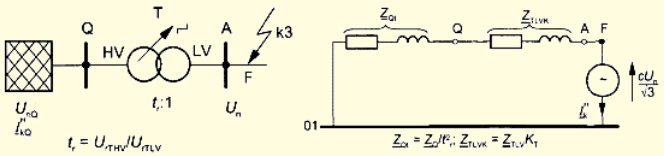
The value of the force in a given direction can be calculated by considering the work done in the case of a virtual displacement in the actual direction. As the work is done by the electromagnetic force, it must be equal to the change in the energy in the magnetic field caused by this virtual displacement.

The force between two conductors is proportional to the square of the current, or to the product of the two currents. As the current is a function of time, the force will also be a function of time. In the case of a short-circuit current without a d.c. component the force will vary with twice the frequency of the current. A d.c. component in the short-circuit current will give rise to an increase of the peak value of the force and to a component of force varying with the same frequency as the current. The peak value of the force is of particular interest in the case of mechanically rigid structures.

The force will result in bending stress on rigid conductors, tension stress and deflection in flexible conductors and bending, compression or tension loads on the supports.

Table 2 Short-circuit Impedances of Various Electrical Power Supply Components

(*Clauses* 4.1.4 *and* 4.2.1.2)

Component	Impedance formula	Reference
Network feeder with known R/X ratio	$Z_Q = \frac{c U_{nQ}}{\sqrt{3}\, I''_{kQ}}$ $X_Q = \frac{Z_Q}{\sqrt{1+(R_Q / X_Q)^2}}$	
Network feeder with known R/X ratio, Fault on LV side of transformer	$Z_{Qt} = \frac{c U_{nQ}}{\sqrt{3}\, I''_{kQ}} \cdot \frac{1}{t_r^2}$ $R_Q = 0.1\, X_Q$ $X_Q = 0.995\, Z_Q$.	
Two winding transformer	$Z_T = \frac{u_{kr}}{100\,\%} \cdot \frac{U_{rT}^2}{S_{rT}}$ $R_T = \frac{u_{kr}}{100\,\%} \cdot \frac{U_{rT}^2}{S_{rT}} = \frac{P_{krT}}{3 I_{rT}^2}$ $X_T = \sqrt{Z_T^2 - R_T^2}$ $\underline{Z}_{TK} = K_T \underline{Z}_T$	Impedance correction factor, $K_T = 0.95 \frac{c_{max}}{1+0.6 x_T}$ $\quad x_T = X_T/(U_{rT}^2/S_{rT})$ U_{rT} is the rated voltage of the transformer on the high-voltage or low-voltage side; Irr is the rated current of the transformer on the high-voltage or low-voltage side; S_{rT} is the rated apparent power of the transformer; P_{krT} is the total loss of the transformer in the windings at rated current; U_{kr} is the short-circuit voltage at rated current in per cent; U_{Rr} is the rated resistive component of the short-circuit voltage in per cent.

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Table 2 (*Concluded*)

Overhead lines and cables	$\underline{Z}_L = R_L + jX_L$ $R'_L = \frac{\rho}{q_n}$ $X'_L = 2\pi f \frac{\mu_0}{2\pi}\left(\frac{1}{4n} + \ln\frac{d}{r}\right) = f\mu_0\left(\frac{1}{4n} + \ln\frac{d}{r}\right)$	Copper $\rho = \frac{1}{54}\frac{\Omega mm^2}{m}$; Aluminium $\rho = \frac{1}{34}\frac{\Omega mm^2}{m}$; Aluminium alloy $\rho = \frac{1}{31}\frac{\Omega mm^2}{m}$ q_n - Nominal cross sectional area ρ - Resistivity d - $\sqrt[3]{d_{L1L2}d_{L2L3}d_{L3L1}}$ geometric mean distance between conductors, or the centre of bundles; r - is the radius of a single conductor. In the case of conductor bundles, r is to be substituted by $r_B = \sqrt[n]{nrR^{n-1}}$, where R is the bundle radius (see IEC 60909-2); n - is the number of bundled conductors; for single conductors n = 1; μ_o - $4\pi \times 10^{-7}$ H/m.
Synchronous generators (Motors with voltage regulator)	$\underline{Z}_{GK} = K_G \underline{Z}_G = K_G (R_G + jX''_d)$ $K_G = \frac{U_n}{U_{rG}} \cdot \frac{c_{max}}{1 + x''_d \sin\varphi_{rG}}$	U_{rG} - the rated voltage of the generator; $\underline{Z}_{GK}$ - the corrected subtransient impedance of the generator; $\underline{Z}_G$ - the subtransient impedance in the positive-sequence system: $\underline{Z}_G = R_G + jX''_d$ φ_{rG} - the phase angle between IrG and $U_{rG}/\sqrt{3}$ x''_d - the relative subtransient reactance of the generator related to the rated impedance: $x''_d = X''_d/Z_{rG}$ where $Z_{rG} = U^2_{rG}/S_{rG}$ The fictitious resistances R_{Gf} may be used for the calculation of the peak shortcircuit current with sufficient accuracy $R_{Gf} = 0{,}05\ X''_d$ for generators with $U_{rG} > 1$ kV and $S_{rG} \geq 100$ MVA $R_{Gf} = 0{,}07\ X''_d$ for generators with $U_{rG} > 1$ kV and $S_{rG} < 100$ MVA $R_{Gf} = 0{,}15\ X''_d$ for generators with $U_{rG} \leq 1\,000$ V

4.2.1.2 *Stresses in rigid conductors and forces on supports*

The conductors may be supported in different manners, either fixed or simple or in a combination of both, and may have two, three, four or several supports. Depending on the kind of support and the number of supports, the stress in the conductors and the forces on the supports will be different for the same short-circuit current.

The stresses in the conductors and the forces on supports also depend on the ratio between the natural frequency of the mechanical system (f_c) and the frequency of the electromagnetic force (f). Especially in the case of resonance, or near to resonance, the stresses and forces in the system may be amplified. If $f_c/f < 0.5$ the response of the system decreases and the maximum stresses are in the outer phases.

Bending stress caused by the forces between main conductors is given by:

$$\sigma_m = V_A V_r \beta \frac{F_m l}{8Z} \quad \text{.....(10)}$$

Bending stress caused by the forces between sub-conductor is given by:

$$\sigma_s = V_{\sigma s} V_{rs} \frac{F_s l_s}{16 Z_s} \quad \text{.....(11)}$$

The dynamic force F_d shall be calculated from:

$$F_d = V_F V_r \alpha F_m \quad \text{.....(12)}$$

Where,

a) F_m and F_s are Forces according to equation (9);
b) Z and Z_s are section modulus of main and sub conductor;
c) $V_\sigma V_r$ and $V_{\sigma s} V_{rs} V_F$ are factor which take into account the dynamic phenomena referred from Table 3; and
d) β and α are factor depending on type and number of supports taken from Table 4.

4.2.1.3 *Tensile forces in slack conductors (line conductors)*

A short-circuit current in a slack conductor will cause a tensile force in the conductor which will affect insulators, support structures and apparatus. It is necessary to distinguish between the tensile force during short-circuit and the tensile force after short circuit, when the conductor falls back to its initial position.

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4.2.2 *Thermal Effect on Bare Conductors*

The heating of conductors due to short-circuit currents involves several phenomena of a non-linear character and other factors that have to be either neglected or approximated in order to make a mathematical approach possible. For the purpose of this calculation, the following assumptions can be made:

a) Proximity-effect (magnetic influence of nearby parallel conductors) is disregarded;
b) Resistance-temperature characteristic is assumed linear;
c) The specific heat of the conductor is considered constant; and
d) The heating is generally considered adiabatic.

4.2.2.1 *Calculation of temperature rise*

The loss of heat from a conductor during the short-circuit is very low, and the heating can generally be considered adiabatic. Hence, the calculation for this can also be based on adiabatic conditions.

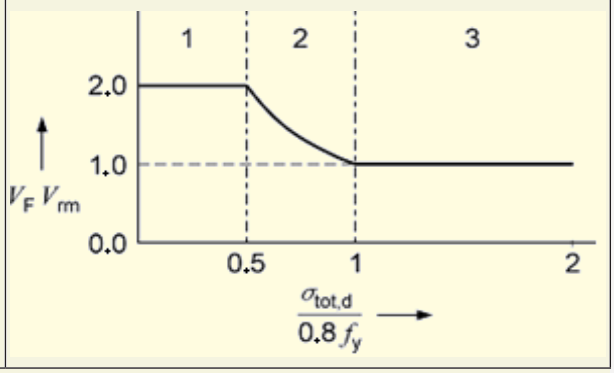
When repeated short-circuits occur with a short-time interval between them (that is rapid auto-reclosure) the cooling down in the short dead-time is of relatively low importance, and the heating can still be considered adiabatic. In cases where the dead-time interval is of longer duration (that is delayed auto-reclosure), the heat loss may be taken into account.

The calculation need not take into account the skin effect, that, is the current is regarded as evenly distributed over the conductor cross-section area. This approximation is not valid for large cross-sections, and therefore for cross-sections above 600 mm², the skin effect shall be taken into account.

NOTE — If the main conductor is composed of sub-conductors, uneven current distribution between the sub-conductors will influence the temperature rise of sub-conductors.

Table 3 Maximum Possible Values of $V_\sigma V_r, V_{\sigma s} V_{rs}, V_F V_r$

(*Clause* 4.2.1.2)

	System			
Type of Short-Circuit	**Without Three-Phase Automatic Reclosing**	**With Three-phase Automatic Reclosing**		**With and Without Three-phase Automatic Reclosing**
	$V_{\sigma m} V_{rm}, V_s V_{rs}$	$V_{\sigma m} V_{rm}$, $V_{\sigma s} V_{rs}$		$V_F V_{rm}$
		First current flow	Second current flow	
Line-to-line	1.0	1.0	1.8	$2.0 \quad \text{for} \quad \frac{\sigma_{tot,d}}{0.8 f_y} \le 0.5$ (range 1) $\frac{0.8 f_y}{\sigma_{tot,d}} \quad \text{for} \quad 0.5 < \frac{\sigma_{tot,d}}{0.8 f_y} < 1.0$ (range 2) $1.0 \quad \text{for} \quad 1.0 \le \frac{\sigma_{tot,d}}{0.8 f_y}$ (range 3) 

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Table 3 (*Concluded*)

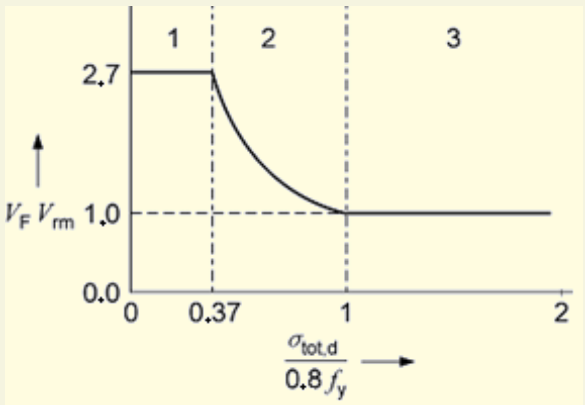
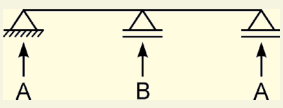
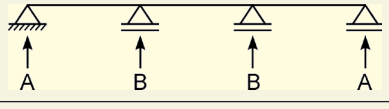
Three-phase	1.0	1.0	1.8	2.7 for $\frac{\sigma_{tot,d}}{0.8 f_y} \le 0.37$ — range 1 $\frac{0.8 f_y}{\sigma_{tot,d}}$ for $0.37 < \frac{\sigma_{tot,d}}{0.8 f_y} < 1.0$ — range 2 1.0 for $1.0 \le \frac{\sigma_{tot,d}}{0.8 f_y}$ — range 3 

Table 4 Factors *α*, *β*, *γ* for different Busbar Support Arrangements

(*Clause* 4.2.1.2)

Type of Beam and Support			*α*	*β**)	*γ*
Single span beam	A and B: simple supports		A: 0.5 B: 0.5	1.0	1.57
	A: fixed support B: simple support		A: 0.625 B: 0.375	$\frac{8}{11} = 0.73$	2.45
	A and B: fixed supports		A: 0.5 B: 0.5	$\frac{8}{16} = 0.5$	3.56
Continuous beam with equidistant simple supports	Two spans		A: 0.375 B: 1.25	$\frac{8}{11} = 0.73$	2.45
	Three or more spans		A: 0.4 B: 1.1	$\frac{8}{11} = 0.73$	3.56

* Plasticity effects included.

4.2.2.2 *Calculation of thermal equivalent short-circuit current*

The thermal equivalent short-circuit current is to be calculated using the short-circuit current rms value and the factors *m* and *n* for the time-dependent heat effects of the dc and ac components of the short-circuit current.

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The thermal equivalent short-circuit current can be expressed by:

$$I_{th} = I_k'' \sqrt{m+n} \quad \text{.....(13)}$$

Where,

a) m and n are numerical factors, and

b) I_k'' the rms value of the initial symmetrical short-circuit current.

In a three-phase system, the balanced three-phase short circuit is decisive. The values m and n are usually defined as functions of the duration of the short-circuit current. For a distribution network usually $n = 1$.

NOTE — The relation I_k'' / I_k is dependent on the impedance between the short-circuit and the source.

When a number of short-circuits occur with a short time interval in between, the resulting thermal equivalent short-circuit current is obtained from:

$$I_{th} = \sqrt{\frac{1}{T_k} \sum_{i=1}^{n} I_{thi}^2 T_{ki}} \quad \text{.....(14)}$$

and

$$T_k = \sum_{i=1}^{n} T_{ki} \quad \text{.....(15)}$$

4.2.2.3 *Calculation of temperature rise and rated short-time current density for conductors*

The temperature rise in a conductor caused by a short-circuit is a function of the duration of the short-circuit current, the thermal equivalent short-circuit current and the conductor material.

NOTE — The maximum permitted temperature of the support has to be taken into account.

4.2.2.4 *Calculation of the thermal short-circuit strength for different durations of the short-circuit current*

Electrical equipment has sufficient thermal short- circuit strength as long as the following relations hold for the thermal equivalent short-circuit current I_{th}:

$$I_{th} \leq I_{thr} \text{ for } T_k \leq T_{kr} \quad \text{.....(16)}$$

$$I_{th} \left\langle I_{thr} \sqrt{\frac{T_{kr}}{T_k}} \text{ for } T_k \right\rangle T_{kr} \quad \text{.....(17)}$$

where I_{thr} is the rated short-time current and T_{kr} the rated short-time.

The thermal short-circuit strength for a bare conductor is sufficient when the thermal equivalent short-circuit current density S_{th} satisfies the following relation:

$$S_{th} < S_{thr} \sqrt{\frac{T_{kr}}{T_k}} \quad \text{.....(18)}$$

With T_{kr} = 1 s and for all T_k, the rated short time current density S_{thr} is shown in Fig. 4.

Below equation shall be used instead of equation (18):

$$\int i^2 dt = I_{th}^2 . T_k \leq K^2 . A^2 \quad \text{.....(19)}$$

Where

a) I_{th} shall be taken from equation (13) or (14)

b) T_k shall be taken from equation (15)

$$K = S_{thr} \sqrt{T_{kr}} \quad \text{.....(20)}$$

4.3 Calculations for Current Carrying Capacity and Voltage Drop for Cables and Flexible Cords

4.3.1 *Conductor Operating Temperature*

The current to be carried by any conductor for sustained periods during normal operation shall be such that the conductor operating temperature given in the appropriate table of current-carrying capacity in this section is not exceeded.

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Where a conductor operates at a temperature exceeding 70°C it shall be ascertained that the equipment connected to the conductor is suitable for the conductor operating temperature.

4.3.2 *Cables Connected in Parallel*

Except for a ring final circuit, cables connected in parallel shall be of the same construction, cross sectional area, length and disposition, without branch circuits and arranged so as to carry substantially equal currents.

4.3.3 *Cables Connected to Bare Conductors or Bus Bars*

Where a cable is to be connected to a bare conductor or busbar its type of insulation and/or sheath shall be suitable for the maximum operating temperature of the bare conductor or busbar.

4.3.4 *Cables in Thermal Insulation*

Where a cable is to be run in a space to which thermal insulation is likely to be applied, the cable shall, wherever practicable, be fixed in a position such that it will not be covered by the thermal insulation. Where fixing in such a position is impracticable, the cross-sectional area of the cable shall be appropriately increased.

For a single cable likely to be totally surrounded by thermally insulating material over a length of more than 0.5 m, the current-carrying capacity shall be taken, in the absence of more precise information, as 0.5 times the current-carrying capacity for that cable clipped direct to a surface and open.

Where a cable is to be totally surrounded by thermal insulation for less than 0.5 m, the current-carrying capacity of the cable shall be reduced appropriately depending on the size of cable, length insulation and thermal properties of the insulation. The de-rating factors have to be appropriate to conductor sizes.

4.3.5 *Metallic Sheaths and/or Non-magnetic Armour of Single-core Cables*

The metallic sheaths and/or non-magnetic armour of single-core cables in the same circuit shall be normally bonded together at both ends of their run (solid bonding). Alternatively, the sheaths or armour of such cables having conductors of cross-sectional area exceeding 50 mm^2 and a non-conducting outer sheath may be bonded together at one point in their run (single point bonding) with suitable insulation at the un-bonded ends, in which case the length of the cables from the bonding point shall be limited so that, at full load, voltages from sheaths and/or armour to earth:

a) do not exceed 25 V;
b) do not cause corrosion when the cables are carrying their full load current; and
c) do not cause danger or damage to property when the cables are carrying short-circuit current.

4.3.6 *Correction Factors for Current-carrying Capacity*

The current-carrying capacity of cable for continuous service is affected by various environmental conditions. This clause provides correction factors in these respects as follows:

4.3.6.1 *Ambient temperature*

In practice the ambient air temperatures may be determined by thermometers placed in free air as close as practicable to the position at which the cables are installed or are to be installed, subject to the provison that the measurements are not to be influenced by the heat arising from the cables. Thus, if the measurements are made while the cables are loaded, the thermometers should be placed about 0.5 m or ten times the overall diameter of the cable whichever is the lesser, from the cables, in the horizontal plane, or 150 mm below the lowest of the cables.

Where cables are subject to such radiation due to solar or other infra-red, the current-carrying capacity may need to be specially calculated.

4.3.6.2 *Grouping*

Appropriate correction factors to be applied to the manufacture declared current-carrying capacity where cables or circuits are grouped.

4.3.7 *Effective Current-carrying Capacity*

The current-carrying capacity of cable corresponds to the maximum current that can be carried in specified conditions without the conductors exceeding the permissible limit of steady state temperature for the type of insulation concerned.

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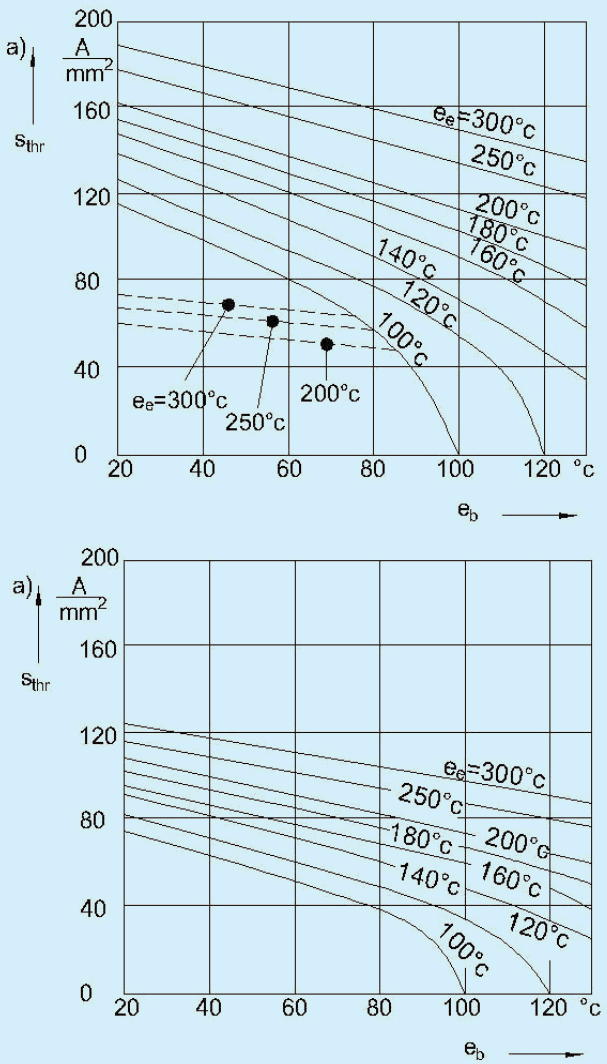


FIG. 8 RELATION BETWEEN RATED SHORT-TIME CURRENT DENSITY (T_{kr} = 1*S*) AND CONDUCTOR TEMPERATURE

The values of current calculated represent the effective current-carrying capacity only where no correction factor is applicable. Otherwise, the current-carrying corresponds to the value multiplied by the appropriate factors for ambient temperature, soil thermal resistivity, grouping and thermal insulation, as applicable.

Irrespective of the type of over current protective device associated with the conductors concerned, the ambient temperature correction factors are to be used when calculating current-carrying capacity (as opposed to those used when selecting cable size).

4.3.8 *Overload Protection*

Where overload protection is required, the type of protection provided does not affect the current- carrying capacity of a cable for continuous service (I_z) but it may affect the choice of conductor size. The operating conditions of a cable are influenced not only by the limiting conductor temperature for continuous service, but also by the conductor temperature which might be attained during the conventional operating time of the overload protection device, in the event of an overload.

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This means that the operating current of the protective device must not exceed $1.45I_z$. Where the protective device is a fuse as per IS 13703 (Part 2/Sec 1) and IS 13703 (Part 2/Sec 2) or IS 2086 or a miniature circuit breaker as per IS/IEC 60898, this requirement is satisfied by selecting a value of I_z not less than I_n.

In practice, because of the standard steps in nominal rating of fuse and circuit breakers, it is often necessary to select a value of I_n exceeding I_b. In that case, because it is also necessary for I_z in turn to be not less than the selected value of In, the choice of conductor cross-sectional area maybe dictated by the over load conditions and the current-carrying capacity (I_z) of the conductors will not always by fully used.

The size needed for a conductor protected against overload by a fuse fix (IS 9926) in rewireable type fuse can be obtained by the use of a correction factor, 1.45/2 = 0.725 which results in the same degree of protection as that afforded by other overload protective devices. This factor is to be applied to the nominal rating of the fuse as a divisor, thus, indicating the minimum value of I_t required of the conductor to be protected. In this case also, the choice of conductor size is dictated by the overload conditions and the current carrying capacity (I_z) of the conductors cannot be fully used.

4.3.9 *Determination of the Size of Cable to be Used*

Having established the design current (I_b) of the circuit under consideration, the conductor size has to be sized necessarily from consideration of the conditions of normal load and overload is then determined. All correction factors affecting I_z (that is, the factor for ambient temperature, grouping and thermal insulation) can, if desired, be applied to the values of I_t as multipliers. This involves a process of trial and error until a cross-sectional area is reached which ensures that I_z is not less than I_b and not less than I_n of any protective device it is intended to select. In any event, if a correction factor for protection by a semi-enclosed fuse is necessary, this has to be applied to I_n as a divisor. It is, therefore, more convenient to apply all the correction factors to I_n as divisors.

In polyphase circuits carrying balanced currents, the associated neutral conductor need not be taken into consideration. Where the neutral conductor in a multi-core cable carries current as a result of an unbalance in the phase currents, conductor shall have a cross-section area adequate to afford the current to be carried by any conductor for sustained periods during normal operation.

If the neutral conductor carries current without corresponding reduction in load of the phase conductors, the neutral currents may be caused by a significant harmonic current in three-phase circuits. If the harmonic content is greater than 10 percent the neutral conductor shall not be smaller than the phase conductors. Thermal Effects due to the presence of harmonic currents and the corresponding reduction factors for higher harmonic currents shall be considered.

4.3.10 *Voltage Drop in Consumers Installations*

4.3.10.1 *Acceptable values of voltage drop*

Under normal service conditions, the voltage at the terminals of any fixed current-using equipment shall be greater than the lower limit corresponding to the Indian Standard relevant to the equipment.

Where the fixed current-using equipment concerned is not the subject of Indian Standard, the voltage at the terminals shall be such as not to impair the safe functioning of the equipment.

The voltage drop between the origin of an installation and any load point should not be greater than the values in Table 5 expressed with respect to the value of the nominal voltage of the installation as per IEC 60364-5-52.

Table 5 Voltage Drop

(*Clause* 4.3.10.1)

Type of Installation	Lighting Percent	Other Uses Percent
(1)	(2)	(3)
A - Low voltage installations supplied directly from a public low voltage distribution system	3	5
B - low voltage installations supplied from private LV supply [3]	6	8

NOTES

1 It is recommended that voltage within the final circuits should not exceed those indicated in installations type A..

2 When the main wiring systems of the installations are longer than 100 m, these voltage drops may be increased by 0.005 percent per metre beyond 100 m, without this supplement being greater than 0.5 percent

3 Voltage drop is determined from the demand by the current using equipment, applying diversity factors where applicable, or from the values of the design current of the circuits.

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NOTES

1 A greater voltage drop may be accepted

a) for motor during starting periods; and

b) for other equipment with high inrush current;

provided that in both cases, it is ensured that the voltage variations remain within the limits specified in the relevant equipment standard.

2 The following temporary conditions are excluded:

a) voltage transients; and

b) voltage variation due to abnormal operation.

4.3.10.2 *Calculation of voltage drop*

If the tables of voltage drop are known for a current of one ampere for a meter run, that is, for a distance of 1 m along the route taken by the cables, and represent the result of the voltage drops in all the circuit conductors. Then, to calculate the voltage drop (mV/A/m) for a given run, the value for the cable concerned has to be multiplied by the length of the run in meters and by the current the cable is intended to carry, namely the design current of the circuit (I_b) in amperes.

For three-phase circuits the calculated mV/A/m values relate to the line voltage and balanced conditions have to be assumed.

The direct use of the calculated resistive component (mV/A/m)R or reactive component (mV/A/m)X or (mV/A/m)Z impedance values, as appropriate, may lead to pessimistically high calculated values of voltage drop or in other words, to unnecessarily low values of permitted circuit lengths.

Where the design current of a circuit is significantly less than the effective current-carrying capacity of the cable chosen, the actual voltage drop would be less than the calculated value because the conductor temperature (and its resistance) will be less than that on which the calculated mV/A/m had been based.

In some cases, it may be advantageous to take account of the load power factor while calculating voltage drop.

Voltage drops may be determined using the following formula:

$$u = b\left(\rho_1 \frac{L}{S} cos\varphi + \lambda L sin\varphi\right) I_B \qquad \text{.....(21)}$$

Where,

a) u is the voltage drop in volts;

b) b is the coefficient equal to 1 for three-phases circuits, and equal to 2 for single-phase circuits;

NOTE — Three-phase circuits with the neutral completely unbalanced are considered a single-phase circuits.

c) ρ_1 is the resistivity of conductors in normal service, taken equal to the resistivity at the temperature in normal service, that is, 1.25 times the resistivity at 20°C, or 0.022 5 Ω mm^2/m for copper and 0.036 Ω mm^2/m for aluminum;

d) L is the straight length of the wiring systems, in meters;

e) S is the cross-sectional area of conductors, mm^2;

f) cos φ is the power factor; in the absence of precise details, the power factor is taken as equal to 0.8 (sin φ = 0.6);

g) λ is the reactance per unit length of conductors, which is taken to be 0.08 mΩ/m in the absence of other details; and

h) I_B is the design current (in amps).

The relevant voltage drop in per cent is equal to:

$$\Delta u = 100 \frac{u}{U_0} \qquad \text{.....(22)}$$

U_0 is the voltage between line and neutral, in volts.

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4.3.10.3 *Correction Factor for operating temperature*

For cables having conductors of cross-sectional area 16 mm² or less the design value of mV/A/m is obtained by multiplying the calculated value by a factor C_t and is, given by:

$$C_t = \frac{230 + t_p - \left(C_a^2 C_g^2 - \frac{I_b^2}{I_t^2} \right)\left(t_p - 30 \right)}{230 + t_p} \quad \text{.....(23)}$$

Where,

t_p = maximum permitted normal operating temperature, in °C.

NOTE — For convenience, the above formula is based on the resistance-temperature coefficient of 0.004 per °C at 20°C for both copper and aluminum conductors.

For very large conductor sizes where the resistive component of voltage drop is much less than the corresponding reactive part (that is when $x/r \geq 3$) this correction factor need not be considered.

4.3.10.4 *Correction for load power factor*

For cables with conductors' cross-sectional area of 16 mm² or less the design value of mV/A/m is obtained approximately by multiplying the calculated value by the power factor of the load (cos φ).

For cables with conductors' cross-sectional area greater than 16 mm², the design value of m/V/A/m is approximately:

Cos φ [Calculated $(mV/A/m)_r$] + sin φ [Calculated $(mV/A/m)_x$]

For single-core cables in flat formation the calculated values apply to the outer cables and may underestimate for the voltage drop between an outer cable and the center cable for cross-sectional areas above 240 mm² and power factors greater than 0.8.

4.3.10.5 *Combined correction for both operating temperature and load power factor*

Where it is considered appropriate to correct the calculated mV/A/m value for both operating temperature and load power factor, the design values of mV/A/m are given by:

a) for cable having conductors of 16 mm² or less cross-sectional area:

   C_t cos φ (Calculated mV/A/m)

b) for cables having conductors of cross-sectional area greater than 16 mm²:

   C_t cos φ $(Calculated\ mV/A/m)_r$) + sin φ

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ANNEX A

(*Clause* 1)

CASCADING, COORDINATION AND LIMITATION

A-1 CASCADING

The utilization of the current limiting capacity of a circuit-breaker at a given point to enable installation of lower-rated circuit-breakers in branch is known as 'cascading' or 'back-up protection'. The main (upstream) circuit-breakers acts as a barrier against short-circuit currents and branch (downstream) circuit breakers with lower breaking capacities than the prospective short-circuit (at their point of installation) operate under their normal breaking conditions. The limiting circuit-breaker helps the circuit-breaker placed downstream by limiting high short-circuit currents thus, enabling use of downstream circuit-breaker with a breaking capacity lower than the short-circuit current calculated at its installation point and thereby, enabling economical selection of circuit-breakers.

Cascading concerns all devices installed downstream of the circuit-breaker, and can be extended to several consecutive devices, even if they are used in different switchboards. The upstream device must have an ultimate breaking capacity greater than or equal to the assumed short-circuit current at the installation point. For downstream circuit-breakers, the ultimate breaking capacity to be considered is the ultimate breaking capacity enhanced by coordination.

The association of the upstream and downstream circuit breakers allows an increase in performance of the breakers. Thus, the electromagnetic, electrodynamic and thermal effects of short-circuit currents are reduced. Installation of a single limiting circuit-breaker along with lower rated circuit-breakers results in considerable economy and simplification of installation work.

D_1 and D_2 are the two circuit-breakers (*see* Fig. A-1). As soon as the two circuit-breakers trip (as from point I_B), an arc voltage U_{AD1} on separation of the contacts of D_1 is added to voltage U_{AD2} and helps, by additional limitation, circuit-breaker D_2 to open.

The association $D_1 + D_2$ allows an increase in performance of D_2 as shown in Fig. A-2, which depicts limitation curve of $D_{2,}$ enhanced limitation curve of D_2 by D_1 and I_{cu} D_2 enhanced by D_1.

Annex A of IS/IEC 60947-2 defines coordination under short-circuit conditions between circuit-breaker and another short-circuit protective device (SCPD) associated in the same circuit and the tests to be performed. Cascading is normally verified by tests for critical points. The tests are performed with an upstream circuit-breaker D_1 with a maximum overcurrent setting and a downstream circuit-breaker D_2 with a minimum setting.

A-2 LIMITATION

A-2.1 The technique of limitation allows the circuit breaker to considerably reduce short-circuit currents. It ensures attenuation of the harmful electromagnetic, thermal and mechanical effects of short-circuits and is the basis of the cascading technique.

The assumed fault current I_{sc} is the short-circuit current that would flow at the point of the installation where the circuit-breaker is placed, if there were no limitation. Since the fault current is eliminated in less than one half-period, only the first peak current (asymmetrical peak *I*) is considered. Reduction of this peak *I* to limited I_L characterizes circuit-breaker limitation. Limitation consists of creating a back-electromotive force opposing the growth of the short-circuit current. Effectiveness of limitation depends on intervention time, that is the time t_s when the back-electromotive force (b_{emf}) appears, the rate at which b_{emf} increases and the value of b_{emf}. The back-electromotive force is the arc voltage ($U_{a)}$ due to the resistance of the arc developing between the contacts on separation. Its speed of development depends on the contact separation speed. As shown in Fig. A-3, as from the time t_s when the contacts separate, less than the assumed fault current flow through when a short-circuit occurs.

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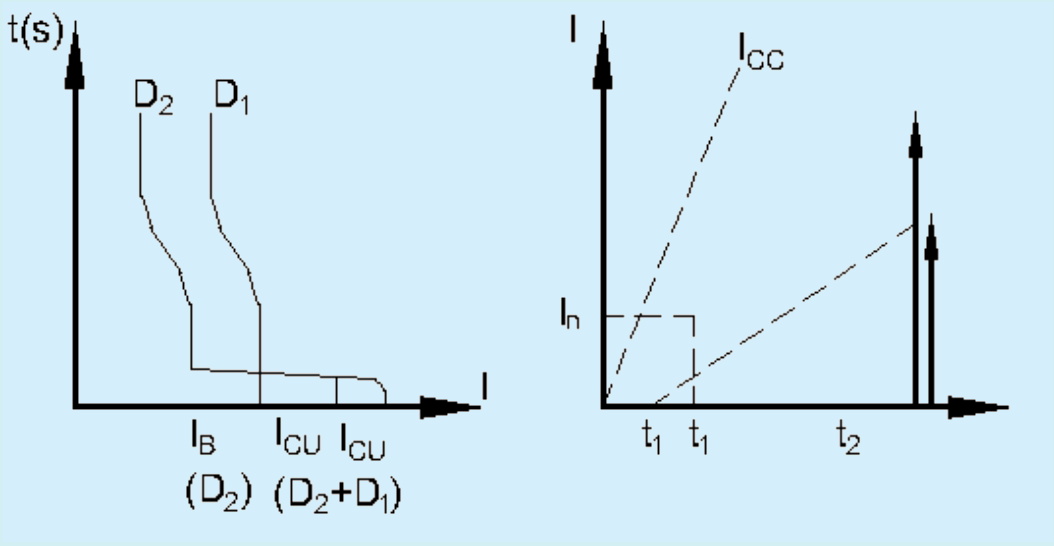


FIG. A-1 OPERATION OF CIRCUIT-BREAKERS IN CASCADE

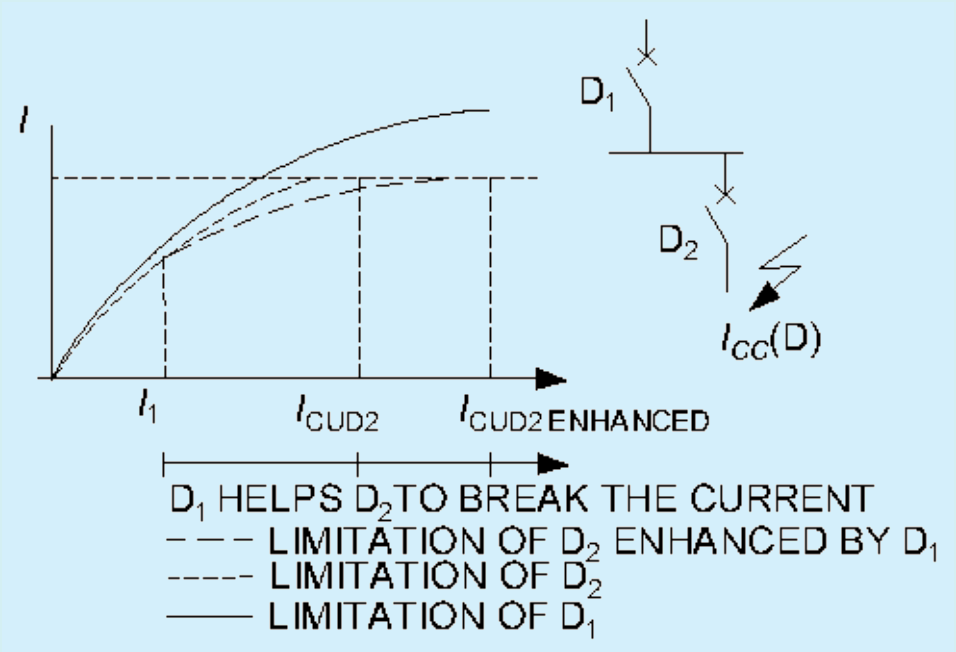


FIG. A-2 LIMITATION CURVES FOR CIRCUIT-BREAKERS

A-2.2 Circuit-Breaker Limitation Capacity

The circuit-breaker limitation capacity defines the way how it reduces the let through current in short-circuit conditions (*see* Fig. A-4 and Fig. A-5). The thermal stress of the limited current is the area (shaded) defined by the curve of the square of the limited current $I_{sc}^2(t)$. If there is no limitation, this stress would be the area, far larger, that would be defined by the curve of the square of the assumed current. For an assumed short-circuit current I, limitation of this current to 10 percent results in less than 1 percent of assumed thermal stress. The cable temperature rise is directly proportional to the thermal stress.

NOTE — On a short-circuit, adiabatic temperature-rise of conductors occurs (without heat exchange with the outside due to the speed of the energy supply). The increased temperature for a conductor with a cross-section S is:

$$B_e = \frac{K}{S^2} V_o^1 I^2 dt$$

where $I^2 dt$ is the thermal stress (A^2s)

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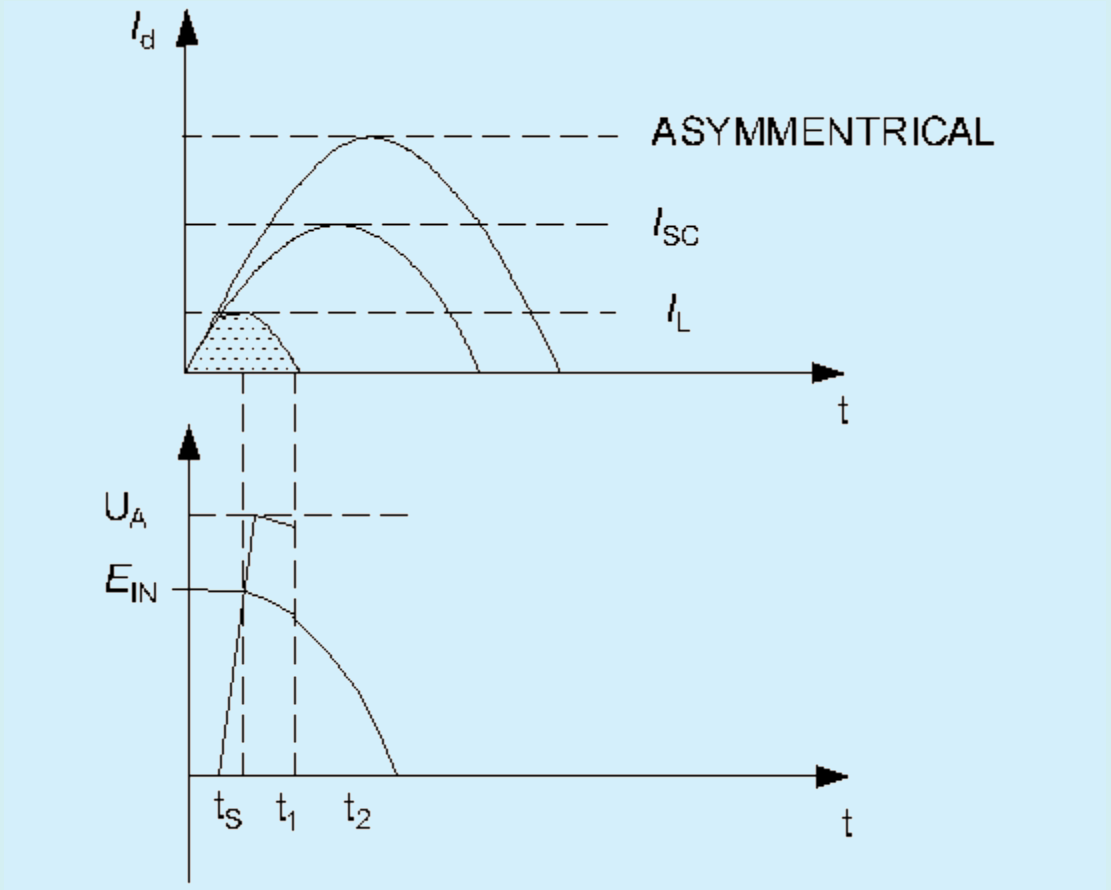


FIG. A-3 EFFECT OF LIMITATION ON FAULT CURRENT

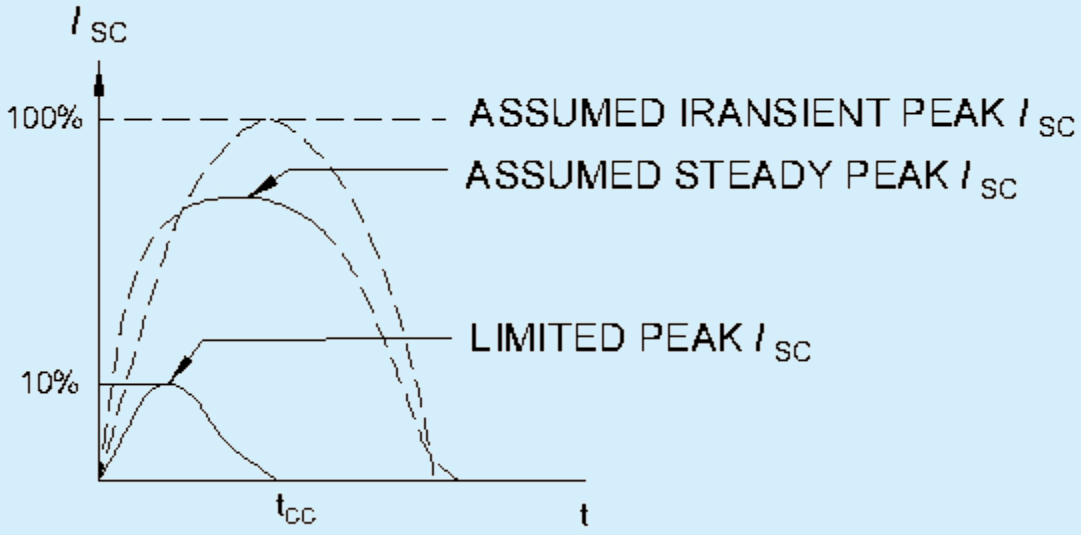


FIG. A-4 CURRENT LIMITATION

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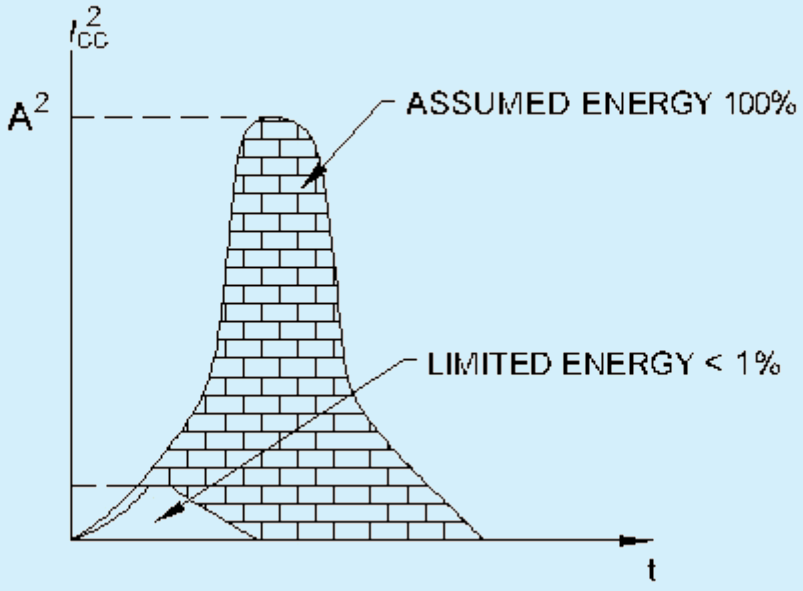


FIG. A-5 THERMAL STRESS LIMITATION

Limitation considerably, attenuates the harmful effects of short-circuits on the installation. Consequently, limitation contributes to the durability of electrical installations. Due to limitation, the harmful effects of short-circuits on a motor feeder are greatly attenuated. Proper limitation ensures easy access to a Type 2 coordination as per IS/IEC 60947-4-1, without oversizing of components. This type of coordination ensures optimum use of their motor feeders.

A-2.3 Limitation Curves

A circuit-breaker's limiting capacity is expressed by limitation curves that give:

a) the limited peak current as a function of the rms current of the assumed short-circuit current. For example, on a 160 A feeder where the assumed I_{sc} is 90 kA rms, the non-limited peak I_{sc} is 200 kA (asymmetry factor of 2.2) and the limited I_{sc} is 26 kA peak.

b) the limited thermal stress (in A2s) as a function of the rms current of the assumed short-circuit current. For example, on the previous feeder, the thermal stress moves from more than 100 × 106 A2s to 6 × 106 A2s.

A-3 SELECTIVITY

A-3.1 Selectivity is the co-ordination of the operating characteristics of two or more over-current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the other(s) does (do) not (*see* Fig. A-6).

Distinction is made between series coordination or selectivity involving different over-current protective devices passing substantially the same over-current and network Selectivity involving identical protective devices passing different proportions of the overcurrent. In LV networks, Selectivity is recommended in order to obtain higher levels of supply continuity and protection, ensuring better safety of installations and minimum cost overruns.

Cascading principle in limiting CBs can enhance selectivity levels. It is recommended that the manufacturer provides the relevant data in terms of selectivity charts and cascading levels for various combination of CBs (upstream and downstream) and fault current as per the laboratory test results.

A selectivity current I_s is defined, such that if:

a) $I_{fault} > I_s$: both circuit-breakers trip; and

b) $I_{fault} < I_s$: only D_2 eliminates the fault.

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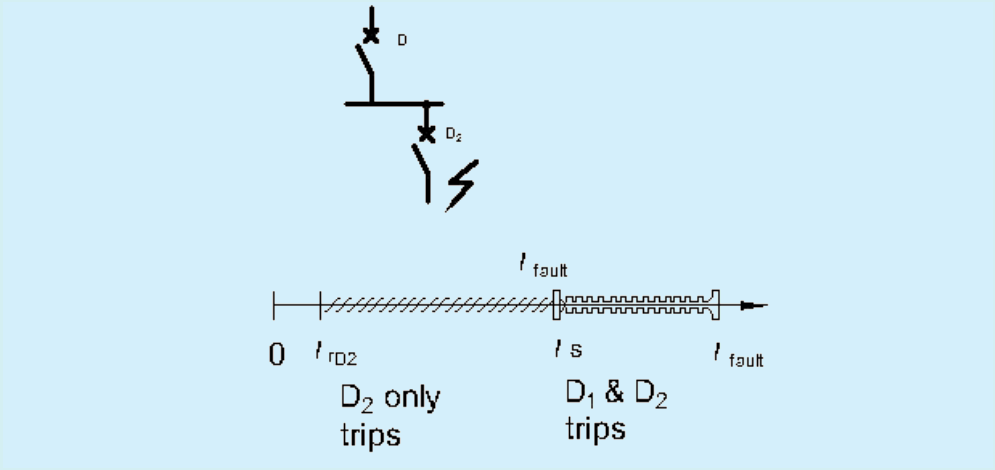


FIG. A-6 SELECTIVITY AND SEQUENCE OF TRIPPING

A-3.2 Selectivity Quality

The value I_s is compared with assumed I_{sc} (D_2) at point D_2 of the installation.

a) total coordination or selectivity coordination or selectivity: $I_s > I_{sc}(D_2)$; coordination or selectivity coordination or selectivity is qualified as total, that is, whatever the value of the fault current, only D_2 eliminates it.

b) partial coordination or selectivity coordination or selectivity: $I_s < I_{sc}$ (D_2); coordination or selectivity coordination or selectivity is qualified as partial, that is up to I_s, only D_2 eliminates the fault. Beyond I_s, both D_1 and D_2 open.

Where,

I_{sc} (D_1): short-circuit current at the point where D_1 is installed,

I_{cu} D_1: ultimate breaking capacity of D_1.

A-3.3 Types of Selectivity

A-3.3.1 *Current Selectivity*

This technique is directly linked to the staging of the

Long Time (LT) tripping curves of two serial-connected circuit-breakers (*see* Fig. A-7).

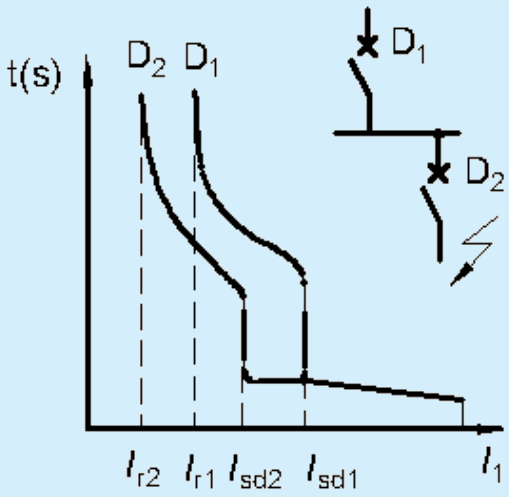


FIG. A-7 CURRENT SELECTIVITY

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The Selectivity limit I_s is:

a) $I_s = I_{sd2}$ if the thresholds I_{sd1} and I_{sd2} are too close or merge; and

b) $I_s = I_{sd1}$ if the thresholds I_{sd1} and I_{sd2} are sufficiently far apart.

Current Selectivity is achieved when:

a) $I_{r1}/I_{r2} < 2$

b) $I_{sd1}/I_{sd2} > 2$

The Selectivity limit being:

$$I_s = I_{sd1}$$

A-3.3.1.1 *Selectivity quality*

Selectivity is total, if $I_s > I_{sc}(D_2)$, that is $I_{s\,d1} > I_{sc}(D_2)$.

This normally implies,

a relatively low level $I_{sc}(D_2)$,

a large difference between the ratings of circuit-breakers D_1 and D_2.

Current Selectivity is normally used in final distribution.

A-3.3.2 *Time Selectivity*

This is the extension of current selectivity and is obtained by staging over time of the tripping curves. This technique consists of giving a time delay of t to the Short Time (ST) tripping of D_1 (*see* Fig. A-8).

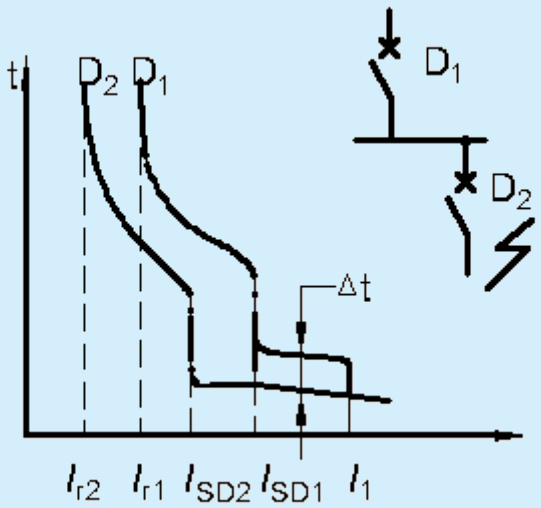


FIG. A-8 TIME SELECTIVITY

The thresholds (I_{r1}, I_{sd1}) of D_1 and (I_{r2}, I_{sd2}) comply with the staging rules of current Selectivity. The Selectivity limit I_s of the association is at least equal to I_{i1}, the instantaneous threshold of D_1.

A-3.3.2.1 *Selectivity quality*

For Selectivity on final and/or intermediate feeders, A category circuit-breakers can be used with time- delayed tripping of the upstream circuit-breaker. This allows extension of current Selectivity up to the instantaneous threshold I_{i1} of the upstream circuit-breaker: $I_s > I_{i1}$. If $I_{sc}(D_2)$ is not too high (in case of a final feeder), total selectivity can be obtained.

On the incomers and feeders of the MSB, as continuity of supply takes priority, the installation characteristics allow use of B category circuit-breakers designed for time-delayed tripping. These circuit-breakers have a high thermal withstand (I_{cw} > 50 percent I_{cn} for t = I_s): $I_s > I_{cw1}$. Even for high $I_{sc}(D_2)$, time Selectivity normally provides total Selectivity: $I_{cw1} > I_{sc}$(D2).

NOTE — Use of B category circuit-breakers means that the installation must withstand high electrodynamic and thermal stresses. Consequently, these circuit-breakers have a high instantaneous threshold I_i that can be adjusted and disabled in order to protect the busbars if necessary.

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A-3.4 Enhancement of Current and Time Selectivity

A-3.4.1 *Enhancement by Limiting Downstream Circuit-Breakers*

Use of a limiting downstream circuit-breaker enables the Selectivity limit to be pushed back.

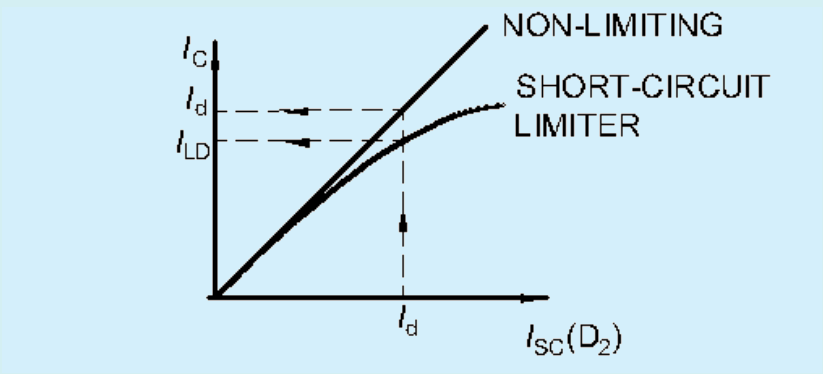


FIG. A-9 ENHANCEMENT OF SELECTIVITY

On referring to Fig. A-9, a fault current I_d will be seen by D_1,

equal to I_d for a non-limiting circuit-breaker, and equal to $I_{Ld} < I_d$ for a limiting circuit-breaker.

The limit of current and time Selectivity I_s of the association $D_1 + D_2$ is, thus, pushed back to a value that increases when the downstream circuit-breaker is rapid and limiting.

A-3.4.2 *Selectivity Quality*

Use of a limiting circuit-breaker is extremely effective for achievement of total selectivity when threshold settings (current selectivity) and/or the instantaneous tripping threshold (time selectivity) of the upstream circuit-breaker D_1 are too low with respect to the fault current I_d in D_2- $I_{sc}(D_2)$.

A-3.4.2.1 *Logic Selectivity or "Logic Selectivity Zone (ZSI)"*

This type of Selectivity can be achieved with circuit-breakers equipped with specially designed electronic trip units. Only, the short time protection (STP) and ground fault protection (GFP) functions of the controlled devices are managed by logic selectivity. In particular, the Instantaneous Protection function (inherent protection function) is not concerned.

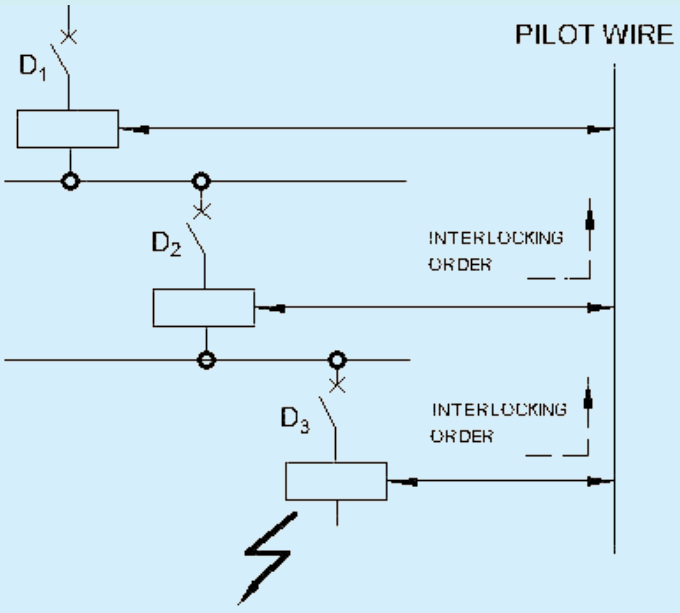


FIG. A-10 LOGIC SELECTIVITY (ZSI)

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A-3.4.2.2 *Settings of controlled circuit-breakers:*

a) Time delay: staging (if any) of the time delays of time Selectivity to be applied ($t_{D1} > t_{D2} > t_{D3}$), and

b) Thresholds: natural staging of the protection device ratings must be complied with ($I_{crD1} > I_{crD2} > I_{crD2}$).

NOTE — This technique ensures Selectivity even with circuit-breakers of similar ratings.

A-3.4.2.3 *Principles*

Activation of the logic Selectivity function is via transmission of information on the pilot wire for ZSI input:

a) *Low level (no downstream faults)* — The protection function is on standby with a reduced time delay (< 0.1s).

b) *High level (presence of downstream faults)* — The relevant protection function moves to the time delay status set on the device.

Activation of the logic Selectivity function is *via* transmission of information on the pilot wire for ZSI output:

1) *Low level* — The trip unit detects no faults and sends no orders.

2) *High level* — The trip unit detects a fault and sends an order.

A-3.4.2.4 *Operation*

A pilot wire connects in cascading form, the protection devices of an installation (*see* Fig. A-10). When a fault occurs, each circuit-breaker upstream of the fault (detecting a fault) sends an order (high level output) and moves the upstream circuit-breaker to its natural time delay (high level input). The circuit breaker placed just above the fault does not receive any orders (low level input) and thus, trips almost instantaneously.

A-3.4.2.5 *Selectivity quality*

This technique enables easy achievement as standard of selectivity on 3 levels or more, easy achievement of downstream Selectivity with non-controlled circuit-breakers, elimination of important stresses on the installation, relating to time-delayed tripping of the protection device, in event of a fault directly on the upstream busbars. All the protection devices are, thus, virtually instantaneous.

A-3.5 Selectivity Rules

A-3.5.1 *Overload Protection*

For any overcurrent value, Selectivity is guaranteed on overload if the non-tripping time of the upstream circuit-breaker D_1 is greater than the maximum breaking time of circuit-breaker D_2.

The condition is fulfilled if the ratio of Long Time (LT) and Short Time (ST) settings is greater than 2. The Selectivity limit I_s is, at least, equal to the setting threshold of the upstream Short Time (ST) time delay.

A-3.5.2 *Short-circuit Protection*

A-3.5.2.1 *Time selectivity*

Tripping of the upstream device D_1 is time delayed by *t*, the conditions required for current Selectivity must be fulfilled and the time delay t of the upstream device D_1 must be sufficient for the downstream device to be able to eliminate the fault. Selectivity increases the Selectivity limit I_s up to the instantaneous tripping threshold of the upstream circuit-breaker D_1 (*see* Fig. A-11).

Selectivity is always total if circuit-breaker D_1 is of category B, has an I_{cw} characteristic equal to its I_{cu}. Selectivity is total in the other cases if the instantaneous tripping threshold of the upstream circuit-breaker D_1 is greater than the assumed I_{sc} in D_2.

A-3.5.2.2 *Logic selectivity*

Selectivity is always total.

A-3.5.2.3 *General case*

There are no general Selectivity rules. The time/current curves clearly supply a value of I_{sc} (limited or assumed) less than the short time tripping of the upstream circuit-breaker; selectivity is then total. If this is not the case, only tests can indicate selectivity limits of coordination, in particular when circuit-breakers are of the limiting type. The Selectivity limit I_s is determined by comparison of curves:

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a) in tripping energy for the downstream circuit breaker; and

b) in non-tripping energy for the upstream circuit-breaker.

The potential intersection point of the curves gives the Selectivity limit I_s. The manufacturers indicate in tables the tested performance of coordination.

A-3.6 Earth Leakage Protection Selectivity

A-3.6.1 According to the earthing system, Selectivity only uses coordination of overcurrent protection devices. When the insulation fault is treated, specifically, by earth leakage protection devices (for example, in the TT system), selectivity of the residual current devices (RCDs) with one another must also be guaranteed. Selectivity of earth leakage protection devices must ensure that, should an insulation fault occur, only the feeder concerned by the fault is de-energized. The aim is to optimize energy availability.

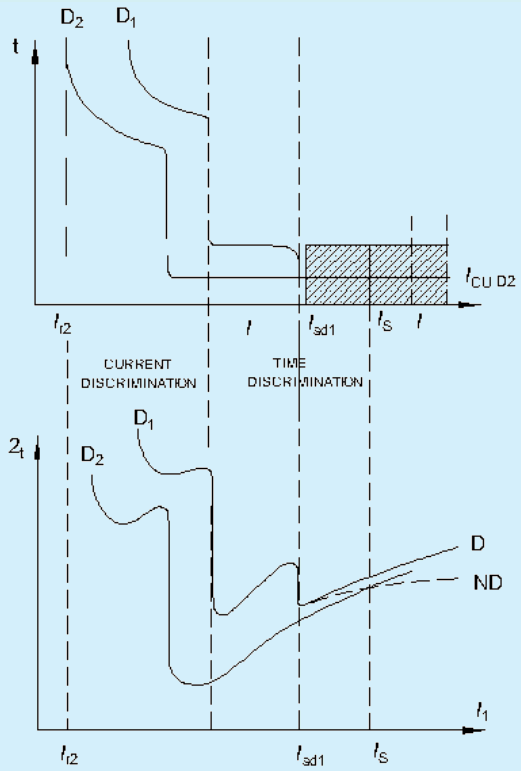


FIG. A-11 SELECTIVITY AT VARIOUS FAULT CURRENTS

A-3.6.2 *Types of Earth Leakage Protection Selectivity*

A-3.6.2.1 *Vertical coordination*

In view of requirements and operating standards, Selectivity must simultaneously meet both the time and current conditions (*see* Fig. A-12).

A-3.6.2.1.1 *Current condition*

The RCD must trip between I_n and $I_n/2$, where I_n is the declared operating current. There must therefore exist a minimum ratio of 2 between the sensitivities of the upstream device and the downstream device. In practice, the standardized values indicate a ratio of 3.

A-3.6.2.1.2 *Time condition*

The minimum non-tripping time of the upstream device must be greater than the maximum tripping time of the downstream device for all current values.

NOTE — The tripping time of RCDs must always be less than or equal to the time specified in the installation standards to guarantee protection of people against indirect contacts.

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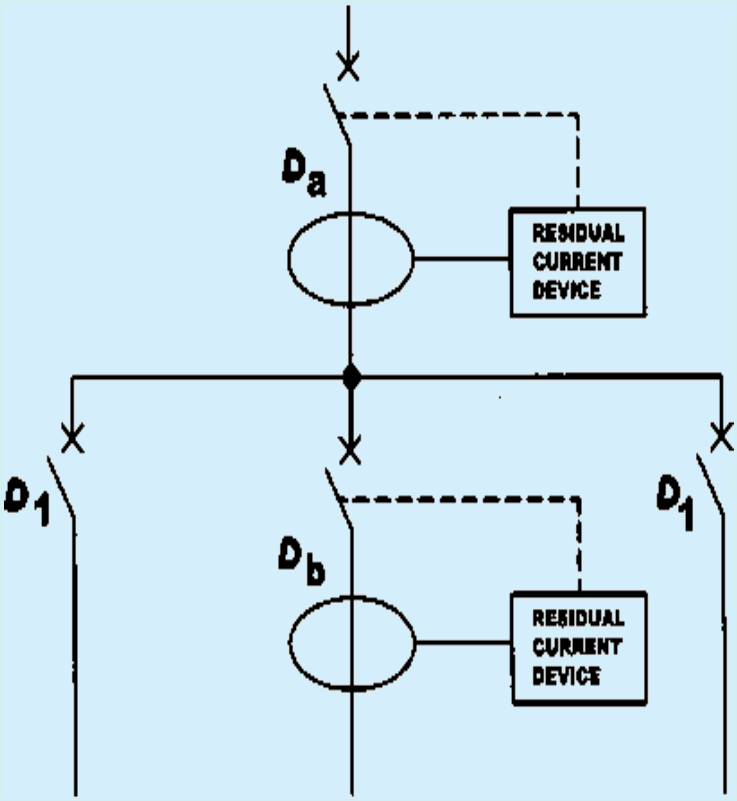


FIG. A-12 VERTICAL COORDINATION

For the domestic area, IS 12640 (Part 1) (residual current circuit-breakers) and IS 12640 (Part 2) (residual current devices) define operating times. The values in the table correspond to curves G and Curve S. Curve G (general) correspond to non-delayed RCDs and S (selective) to those that are voluntarily delayed (*see* Fig. A-13).

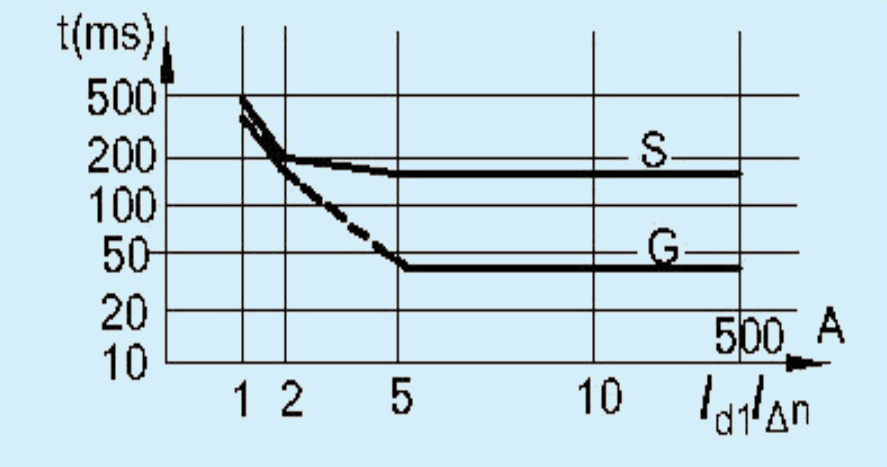


FIG. A-13 OPERATING TIME CURVES

A-3.6.2.2 *Horizontal coordination*

Sometimes known as circuit selection, it allows savings at the supply end of the installation of an RCD placed in the cubicle if all its feeders are protected by RCDs. Only the faulty feeder is de-energized, the devices placed on the other feeders do not see the fault (*see* Fig. A-14).

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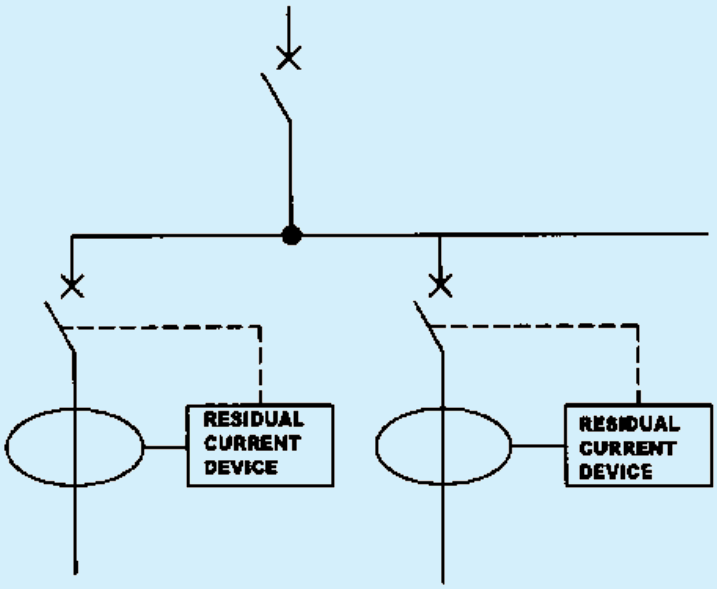


FIG. A-14 HORIZONTAL COORDINATION

(*Clause* 3.6.2.2)

Standardized Values of Operating Time							
Type	**I_n**	**I/Δ_n**	**Standardized Values of Operating Time and Non-operating Time (in s) at:**				
			$I\,\Delta_n$	$2I\,\Delta_n$	$5I\,\Delta_n$	500A	
General instantaneous	All values	All values	0.3	0.15	0.04	0.04	Maximum operating time
Selective	>25	>0.030	0.5	0.2	0.15	0.15	Maximum operating time
			0.13	0.06	0.05	0.04	Maximum operating time

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SECTION 15 ELECTRICAL ASPECTS OF BUILDING SERVICES

FOREWORD

No building can be treated as complete and ready to occupy without the infrastructure of services. Out of total capital expenditure of building, share of services may go up to 40 percent, from which its value and importance can be envisaged. Under Part 8 of National Building Code (NBC) following services have been enlisted under sections:

Section 1	Lighting and natural ventilation
Section 2	Electrical and allied installation
Section 3	Air-conditioning and heating, and mechanical ventilation
Section 4	Acoustics, sound insulation and noise control
Section 5 A	Lifts
5 B	Escalators and moving walks
Section 6	Information and communication enabled installations

1 SCOPE

This section of Code (Part 1/Sec 15) covers electrical aspects (including electronics) required to be considered with respect to installation/construction, working/operation of building services.

NOTE — Each of these services may require statutory approval, details of which are covered in the respective sections

2 REFERENCES

The standards listed in Annex A contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 ORIENTATION OF BUILDING

Next to geographical region, the factor influencing need and scope of building services is orientation of building. Orientation of building help utilize natural resources to provide physically and psychologically comfortable living inside the buildings by creating conditions which suitably and successfully ward off the undesirable effects of severe weather to a considerable extent by judicious use of the recommendations and knowledge of climatic factors.

IS 7662 (Part 1) gives recommendations on orientation of buildings.

4 LIGHTING AND NATURAL VENTILLATION

From the point of view of lighting and ventilation, the following climatic factors influence orientation of the buildings and desired fenestration to optimize use of natural resources:

a) Solar radiation and temperature,
b) Relative humidity, and
c) Prevailing winds.

4.1 Lighting - Natural

During the daytime, use of natural light to the possible extent shall form one of the principles of Good Lighting. It is nature's call and conserving energy is today's need to save and protect environment. Good visibility and other parameters are easily met with natural light source.

4.2 LIGHTING – ARTIFICIAL

4.2.1 When the daylight starts diminishing or there are limitations to use daylight, artificial lighting becomes inevitable. Illumination Engineering is a specialized branch which gives inputs for good lighting design.

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For detailed aspects of illumination, National Lighting Code 2010 and IS 3646 (Part 1) shall be referred. Important aspects of lighting are:

a) *Lux Level* — A functional requirement from the point of view of visibility. (Lux=Lumen/m^2). Depending on application, uniform, task oriented, average and allowable maximum and minimum lux levels are taken in to consideration while designing.

b) *CRI* — Colour Rendering Index, is a parameter used to measure ability of light source to reveal natural colour of object. It is measured in percentage. 100 indicates accurate, 90 indicate good colour rendering.

c) CCT — Correlated colour temperature measured in Kelvin helps to indicate colour appearance, for example, cool white 5 000 K, yellowish warm-light 3 000 K which are selected to create required ambiance.

d) *Glare* — It is measured as Glare Index which relates to the discomfort/difficulty of seeing.

4.2.2 Following applications decide design parameters and selection of light source:

a) *Indoor* — Functional requirement:
   1) Dwellings,
   2) Commercial,
   3) Industrial,
   4) Educational,
   5) Auditoriums/theaters, and
   6) Exhibition centers, art galleries, museums.
   7) Sports

b) *Indoor* — Aesthetic:
   1) Mood,
   2) Ambiance, or
   3) Spot

c) *Outdoor* — Functional requirement
   1) Streets/paths, or
   2) Garden.

d) *Outdoor/external* — Aesthetic
   1) Façade, or
   2) Ceremonial.

4.3 Electrical Aspects of Lighting

4.3.1 *Wiring Installation*

Illumination design of required artificial lighting, which considers various factors mentioned under **4.2** above decides selection of type, wattage and required number of light fittings. The layouts are prepared locating positions of lighting fixtures not conflicting with the sweep of fan blades. It is one of the basic requirements for design of wiring installation.

4.3.2 *Safety*

Light sources dissipating heat shall be carefully wired, located and installed so that they shall not cause hazard during their service life.

4.3.3 *Emergency Lighting*

Important areas where visibility during emergency is necessary and mandatory, lighting fixture shall be suitable to sustain under such situation and shall be provided with standby source of electric supply.

4.3.4 *Energy Conservation*

a) Lighting fixtures shall be selected which have good efficacy (Lumen/watt). LED lights are giving improved efficacy day by day.

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b) Circuits shall be so designed that portion of lighting where daylight is available can be switched off.

c) Occupancy sensors help automatic switching off lights when the particular portion is not occupied/used by persons.

d) Under green building concept lighting power density is one of parameter in deciding rating.

4.4 Ventilation

4.4.1 Ventilation of buildings is required to supply fresh air for respiration of occupants, to dilute inside air to prevent vitiation by body odours and to remove any products of combustion or other contaminants in air and to provide such thermal environments as will assist the maintenance of heat balance of the body in order to prevent discomfort and injury to health of the occupants.

4.4.2 The following govern design considerations:

a) Supply of fresh air for respiration,

b) Removal of combustion products or other contaminants and to prevent vitiation by body odours,

c) Recommended schedule of values of air changes for various occupancies, and

d) The limits of comfort and heat tolerance of the occupants.

4.5 Methods of Ventilation

General ventilation involves providing a building with relatively large quantities of outside air in order to improve general environment of building. This may be achieved in one of the following ways:

a) Natural supply and natural exhaust of air,

b) Natural supply and mechanical exhaust of air,

c) Mechanical supply and natural exhaust of air, and

d) Mechanical supply and mechanical exhaust of air.

4.5.1 *Ventilation – Natural/Artificial*

Adequate fenestration with due consideration to wind directions help avail natural resource of ventilation. Design considering natural air circulation cross ventilation, convection currents saves electrical energy cost. Renewable natural resources shall hence be explored to optimum level to conserve energy and protect environment.

For human comfort artificial ventilation is needed which is provided with various types of fans.

4.5.2 *Ventilation – Mechanical*

Ventilation is integrated in Air-conditioning system where concern is human comfort. However, forced/mechanical ventilation is needed in specific areas and purposes. It is important where dust free environment, positive pressure, smoke evacuation is needed. Reference should be made to IS 3103 and IS 3362 which cover methods of mechanical ventilation.

4.6 Electrical Aspects of Mechanical Ventilation

4.6.1 As per the design equipment requiring electrical supply shall be provided with electrical installation of required specifications and guidelines given under Section 9 of Part 1.

4.6.2 When mechanical ventilation system relates with human life safety, in emergency, electrical supply integrity must be ensured for its operation till certain predetermined time. The electrical installation and material shall be of such grade, specifications and quality.

4.6.3 In case of ducting provision of dampers shall there to restrict spread of fire.

5 ELECTRICAL AND ALLIED INSTALLATION

5.1 General

Electrical Installation is a prime utility service to become any building functional. Many other building services also depend on electrical supply for its operation. It has some architectural and civil work requirements. Reference

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is made to all other sections from different parts of this code and especially Section 9 of Part 1, where various aspects have been elaborated in detail.

5.2 Design

Design shall be based on basic principles of:

a) Safety,
b) Quality, or
c) Integrity and continuity.

Safety is of prime importance and statutory requirement. Supply quality and continuity are also basic needs of building service. Prolonged failure of electrical supply may bring life to standstill especially in high-rise buildings. Standby supply source of required capacity, shall therefore be designed, installed and maintained. Depending on capacity and time duration it may be battery based or a Generating set.

5.3 Risk of Fire

Electrical supply and installation, apart from its need and use, carries high risk of fire endangering safety of life and property. Stringent norms are required to be followed. Improper installation, use, handling, operation and maintenance may lead to serious hazards. Reference is made to Section 10 to 13 and Section 22 from Part 1 of this code.

5.4 Supply Integrity

Supply integrity under emergency conditions and evacuation operation is most important requirement. Electrical installation supplying critical load, shall be of such material, which withstands under fire conditions till desired time of 2 or more hours anticipated for evacuation operation. It shall also be backed up with required capacity of standby supply arrangement. Emergency lights shall be tested once in 30 days for 30 s and once in a year for 1.5 h. It is recommended that records for the same shall be maintained.

6 AIR-CONDITIONING AND HEATING

6.1 General

Air conditioning is process of treating air to:

a) Cool/heat to regulate temperature;
b) Humidify/dehumidify to regulate moisture;
c) Filter to reduce contaminants;
d) Ventilate to regulate fresh air requirement, air quality and odour; and
e) Circulate to regulate air motion-no drafts, no suffocation.

Its application can be divided in to two categories, comfort air-conditioning and process air-conditioning. Comfort air-conditioning relates to human comfort. Process air conditioning is to provide above controlled parameters of air suitable for a process, for example, preservation of food items, controlled temperature may be 4°C or -20°C; for operation theatres cleanliness of air shall be of prime importance; and textile mill needs higher humidity.

NOTE — Under ‘air-conditioning’, heating and ventilation form a part of the system and are referred as Heating, Ventilation, and Air-Conditioning (HVAC).

6.2 Design

6.2.1 For the design of the system studying existing situation and set target of desired level of Indoor Air Quality (IAQ) for required application, in possible climatic condition all around the year is of prime importance. IAQ if not monitored and maintained properly, may lead to discomfort, sickness loss of efficiency or loss of product under process air-conditioning.

6.2.2 In design of the system assessment of following factors is important:

a) Climatological data;
b) Outdoor air quality and properties of air;
c) Psychometry;

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d) Orientation, of building;
e) Use, occupancy
f) Heat load/cooling load; and
g) Air distribution.

6.2.3 *Systems*

Depending on requirement, worked out on area, use and Tonnage of Refrigeration (TR) system may be:

a) Unitized, window, split for small areas;
b) Packaged, VRF for medium areas; and
c) Central; for large areas.

Window, split units are factory assembled and are generally available up to 3 TR capacity. Split types which are more popular due to very low noise levels comprises indoor and outdoor unit connected with refrigerant piping. It requires additional condensate piping. It shall be noted that; like window type unit, there is no provision of fresh air intake for split type units.

Packaged/VRF systems are generally available up to 15/20 TR or more capacity depending on manufacturer's design. These systems require arrangements of refrigerant piping, condensate piping and ducting.

Central Air conditioning systems are usually used for large areas, TR may extend to required capacity. System comprises chillers, refrigerant/chilled water and condenser water pumps and piping, Air Handling Units (AHU), Fan Coil Units (FCU)/Cassette units, cooling tower. Location of plant room comprising chillers is usually away from area to be air-conditioned. AHUs are closer and FCUs within conditioned space. Cooling tower is installed in open air preferably near chillers, to restrict length of condenser water piping.

Proper selection and design of system is a job of air conditioning expert where type of use, load conditions, quality, efficiency, economy in installation and running cost are important factors.

6.3 Electrical Aspects of a.c. Systems and Heating

Two main aspects are:

a) required electrical installation, and
b) electrical consumption.

6.3.1 *Electrical Installation*

Electrical Installation shall suite the manufacturer's requirements.

6.3.1.1 *Load*

On broad basis electrical load per TR varies between 1 to 1.5 kW. Under advanced technologies, it may reduce further. Nature of load mainly being inductive involving in-rush of current, shall be considered for selecting size of cable and protections.

6.3.1.2 *Harmonics*

With the increased use of inverters and variable frequency drives harmonic distortion may occur if adequate filters are not designed and provided. Manufacturer's specifications shall be checked for provision of inbuilt filters and necessary additional provision shall be made checking actual requirements depending on site tests.

6.3.1.3 *Window/Split type*

Separate circuit with C type MCB of required ampere capacity generally 16/20/25 A or as per manufacturer's recommendation, depending on TR rating shall be provided for window/split type units. Though most of the units are controlled with remote control, and location of indoor unit sometimes inaccessible, a controlling switch shall be available in accessible position with a power outlet near indoor unit. Generally wiring between indoor unit and outdoor unit is done by the service provider/installing agency. However, efficient earthing shall be ensured at the point of supply outlet.

6.3.1.4 *Packaged type*

Electrical Supply point with adequate size and type cable, earthing and controlling switchgears shall be made available as per manufacturer's requirement. Controlling switchgear shall be provided near the individual

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equipment in accessible position. Rated current capacities shall be adequate. Many times, such locations are in open. Appropriate ingress protection from external influences shall be provided to guard from adverse climatic effects and an arrangement for ease and safety to operating/maintaining personnel.

6.3.1.5 *Central plant*

As per equipment layout of AC system comprising compressors/chillers, chilled water, condenser water pumps, cooling tower, AHUs, FCUs etc., electrical supply arrangement shall be done in consultation with the concerned agency. Cable sizes, types, routes, controlling switchgears and protections shall be as per the guidelines given under Part 1/Section 9 and related clauses from Section 10 to 13 of this part of this code.

6.3.1.6 *Conduits*

Where conduits are used for carrying insulated electrical conductors and when such conduits pass from a non-air-conditioned area into an air-conditioned area or into a fan chamber of duct, a junction box shall be installed or other means shall be adopted to break the continuity of such conduit at the point of entry or just outside, and the conduit should be sealed round the conductors to prevent air being carried from one area into the other through the conduit. This will prevent leakage and inefficiency as well as avoid the risk of condensation of moisture inside the conduits.

6.3.2 *Heating*

In case of air-conditioning plants where re-heating is used, a safety device shall be incorporated in the installation to cut off automatically the source of heating, by means of some device, as soon as the temperature reaches a predetermined high level.

6.3.3 In case of air-conditioning plants where heating by means of an electric heater designed to operate in an air current, a safety device shall be incorporated in the installation to cut off the supply of electricity to the heating device whenever there is failure of the air current in which the heater is required to operate. Serious harm to the plant and sometimes fires may be caused by negligence in this respect.

6.3.4 Air-conditioning and ventilating systems circulating air to more than one floor or fire area shall be provided with dampers designed to close automatically in case of fire and thereby prevent spread of fire or smoke. Such system shall also be provided with automatic controls to stop fans in case of fire, unless arranged to remove smoke from a fire, in which case these shall be designed to remain in operation.

6.3.5 Air-conditioning system serving large places of assembly (over 1 000 persons), large departmental stores or hotels with over 100 rooms in a single block shall be provided with effective means for preventing circulation of smoke through the system in case of a fire in air filters or from other sources drawn into the system even though there is insufficient heat to actuate heat sensitive devices controlling fans or dampers. Such means shall consist of suitable photo-electric or other effective smoke sensitive controls, or may be manually operated control

6.3.6 *Electrical Consumption*

Air conditioning being major guzzler of electricity involving huge running cost, needs precise design and selection of equipment. For human comfort, 24°C temperature is considered as standard as per ASHRAE. However, considering average range of maximum to minimum temperature in Indian tropical region setting upper limits will not affect comfort. Considerable power saving can be achieved with setting the temperature at 1° higher.

6.3.6.1 *Small capacity, room air conditioners*

Based on Energy Efficiency, Bureau of Energy Efficiency (BEE) issues star rating, from 1 star to 5 stars. A unit with 5 stars has maximum energy efficiency. It is denoted by EER (Energy Efficiency Ratio). EER is mentioned as ratio in W/W that is heat removed in watts (3412 BTU = 1 kW/hr) to power used in watts within that hour. For EER, fixed parameters are considered as base. As per recent modification ISEER (Indian Seasonal Energy Efficiency Ratio) is considered, which is more precise as it considers seasonal power consumption with the variation in temperatures in different seasons – summer and winter. Room air- conditioners are available as fixed speed and variable speed with Inverter technology. Efficiency of Inverter type room air conditioners is very good as input power is precisely controlled as per actual requirement.

6.3.6.2 *Medium capacity*

Advanced technology with variable refrigerant flow (VRF) systems give very good results in reducing electricity bills.

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6.3.6.3 *Large capacity*

In major systems having central plant, location of various equipment like compressors/chillers, AHUs, allied piping and ducting design, lengths and cross section aspect ratio (perimeter: cross section ratio) play important role in deciding efficiency of the system. Selection of proper compressor and drives contribute towards power saving.

6.3.6.4 *Heat recovery systems*

These systems help to conserve energy and reduce heating/cooling demands. Scope shall be checked from the experts.

6.3.6.5 *Thermal storage*

Such system utilizes power in off-peak period to create chilled product under low tariff (energy charges) zone of the day. This thermal storage is utilized in peak demand period reducing resultant aggregate demand and give good savings.

7 LIFTS, ESCALATORS AND MOVING WALKS SERVICES

7.1 General

With the trend of horizontal and vertical expanse of buildings; lifts and escalators at places like air ports where there is huge horizontal spread are used increasingly. Horizontal walks are becoming inherent part of the building services. These services require architectural planning and civil work provisions along with electrical work. These points therefore come within the scope of primary planning.

7.2 LIFTS

7.2.1 Design of lifts is done on the basis of anticipated/available/assessed data of human traffic at peak time, number of floors and vertical travel, round trip time and application. These factors decide persons carrying capacity of lift, number of lifts (weight considered per person is 68 kg) and speed. For safety aspects, design requirements, installation, operation, maintenance and inspection requirements IS 14665 series shall be referred.

7.2.2 *Civil Work*

Depending on type, construction of lift requires shaft of RCC construction. As per designed speed and capacity of number of passengers, it requires pit of required depth (below lowermost floor level), overhead (vertical clearance from topmost floor level to bottom of machine room slab), a machine room on top of slab. In case of Machine Room Less (MRL) lift, there is no need of machine room and in case of Capsule Lift, requirement and specifications of shaft may vary or can be eliminated. Door openings (width × height) and landing sill shall be as per IS 17900 (Part 1). All details shall be taken from manufacturer in advance at planning stage. Adequate provisions as per norms shall be made in respect of ventilation and positive pressure.

7.2.3 *Fire Lift*

Provision of fire lift shall be as per the requirements given in National Building Code of India. This lift and related structure shall have rated fire withstand rating and shall perform and sustain desired operation and function during fire/emergency.

7.3 Escalators

Need and provision of escalator is seen usually at public places where service to the quantum of public is to be given. Hence, the installations are seen in cinemas, malls, railway stations, offices with higher occupancy, etc. Civil work infrastructure needs to be provided as per manufacturer's requirements. For safety aspects, design requirements, installation, operation, maintenance and inspection requirements, IS 4591 series shall be referred.

7.4 Moving Walk Ways

Places where walking distance (horizontal) within building is more and time taking, provision of walkways is done. It is usually seen at airports.

7.5 Manufacturers Responsibilities

7.5.1 Reference is drawn to *Lift Act and Rules* made thereunder by respective state governments and IS 14665 series. Manufacturer shall coordinate with architect, civil construction agency and electrical contractor to see all structural, electrical requirements are met and shall construct the lift, escalator, walk-ways complying statutory requirements, and standards, norms.

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7.5.2 Work related to all safeties, control cabling, telephone, alarm, automatic rescue device and battery backup and electrical cabling after point of supply to machine, lift car, protections comes in the purview of lift manufacturer. He shall adhere to all norms.

7.5.3 Testing, commissioning, arranging inspection and permission from concerned authority to operate lift is manufacturer's responsibility. Manufacturer shall handover lift with all documentation, guarantees/warranties, maintenance schedule to the owner. He shall provide information in respect of obligations of owner especially in respect of maintenance of lifts.

7.6 Electrical Aspects of Lifts, Elevators, Walks

7.6.1 *General*

The requirements for main switches and cabling with reference to relevant regulations may be adhered to. The manufacturer should specify, on a schedule, particulars of full load current, starting current, maximum permissible voltage drop, size of switches and other details to suit requirements. For multiple lifts, a diversity factor may be used to determine the cable size and should be stated by the lift manufacturer.

7.6.2 *Electrical Wiring and Apparatus*

7.6.2.1 All electrical supply lines and apparatus forming part of point of supply to be provided to manufacturer for his further work in connection with the lift/escalator/moving walks installation shall be so constructed and shall be so installed, protected, worked and maintained as per relevant sections of this code.

7.6.2.2 All metal casings or metallic coverings containing or protecting any electric supply lines of apparatus shall be efficiently earthed. Earthing system shall conform to provisions of IS 3043 and CEA (Measures Relating to Safety and Electric Supply) Regulations, 2010.

7.6.2.3 All cables and other wiring in connection with the lift installation shall be as per relevant standard.

a) *Power Supply Mains* — The lift sub-circuit from the intake room should be separate from other building service. The separation of cable route and source (circuit breaker/MCCB directly in the respective circuit) shall be made in such a way that failure of the building service feeder does not affect the feeder for the lift. Each lift should be capable of being isolated from the mains supply.

b) For banks of interconnected lifts, a separate sub-circuit is required for the common supervisory system, in order that any car may be shut down without isolating the supervisory control of the remainder.

c) *Lighting* — Machine rooms and all other rooms containing lift equipment should be provided with adequate illumination and with a switch fixed adjacent to the entrance. At least one socket outlet and light point, should be provided at each floor level in the lift shaft including pit.

d) 3 phase power supply cable for machine and 1 phase power supply cable for lighting shall be routed through lift shaft and first terminated in machine room, (when provision of machine is there). 1 phase supply cable shall again be re-routed through shaft for lighting and power supply outlet. No cables, which are not part of lift installation, shall run in the lift well. The lift cables shall run in respective lift wells. Wiring in machine room shall run in rigid metallic trunking. The trunking in machine room floor shall be flushed with the finished floor.

e) Residual current devices shall be of appropriate type and sensitivity. It shall:

   1) have 10 times the maximum leakage current (300 mA maximum) as tripping current and be suitable for frequency converters with a 3-phase supply.

   2) be sensitive for sinusoidal currents up to 1 000 Hz, insensitive for currents more than 1 000 Hz.

      NOTE — These kinds of RCDs are generally classified as 'Type B'.

   3) never be protected with a 30 mA residual current device (RCD). The 30 mA RCD may trip when the lift starts and stall the operation. If the construction-time power supply is for some reason protected with a 30 mA residual current device (RCD), suitably sized isolation transformer needs to be provided.

8 SOUND SYSTEM/AUDIO VIDEO SYSTEM

8.1 Sound System

Sound system is used for public announcement/address, entertainment, alerts, crowd, visitors, vehicle management. It is an important tool in emergency situation/disaster management. It comprises one or more basic components

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from following:

a) Speaker (indoor/outdoor),
b) Amplifier,
c) Mixer,
d) Microphone,
e) Microphone cables, or
f) Speaker cables.

8.2 Conference System (Audio)

Usually installed in meeting halls, it comprises a set of microphones, speakers, controller unit and optional amplifier for external speakers. Microphones/delegate units are installed on meeting table. They have individual on/off control which a person using it is supposed to operate. There is also chairman unit with master control which can disable delegate units speakers, may be integral part or installed separately. Different components of system are interconnected by copper cables of high purity to minimize drop. Microphones are generally looped. For convenience and redundancy microphones may be grouped to form number of loops and connected to controller. For audience, additional separate speakers may be connected through amplifier.

8.3 Audio-Video or Audio-Visual (AV) System

Installation of audio visual system may be done for entertainment, public announcement, board meetings, presentations, video conference/web meeting. Basic components used are speakers, microphones, DVD players, video camera, electronic video screen or video projector and wall/screen. Display units may be single or multiple located at different locations. It may have recording facility.

8.4 Design and Layouts

Design and layouts of system shall be pre-planned with the help of experts. Acoustical requirements if any shall be checked and met with. If the number of the equipment is large, they shall be mounted on racks of suitable dimensions of metal or wood, in such a manner that the controls are within easy reach. The patch cords shall be neatly arranged. For outdoor installations, the line-matching transformers shall be mounted in weather-proof junction boxes. In large open grounds such as an outdoor stadium, care shall be taken to ensure that the sound heard from different loudspeakers do not have any noticeable time lag.

NOTE — Many times requirement of system is not envisaged/considered at initial stage. Under circumstances anticipatory provision for cabling between possible/planned locations of equipment and provision of power outlets shall be made. This helps avoid breakages especially in case of concealed wiring

8.5 Electrical Aspects

8.5.1 *Cabling Material*

Special types of copper cables shielded, braided, tinned, flat, twisted, coaxial, recommended by system designer, suitable for particular task and application with high purity shall be used.

8.5.2 *Installation*

Cables shall be enclosed in separate and independent conduits/trunking for each system or shall be installed 200 mm away from power cables/or as specified by system provider. Crossings shall be done in right angle. Terminations shall be proper and rigid as per recommended method prescribed by equipment manufacturer. The positioning of equipment shall be such that the lengths of the interconnecting cables is kept to the minimum to avoid drops losses in transmission.

8.5.3 *Electric Supply*

Electric supply shall be provided at amplifier/control equipment rack of audio system, through power outlet with efficient earth terminal. Supply shall be stable without voltage fluctuations, UPS/battery based supply may be used considering sensitive electronic equipment. This battery based supply is also necessary where any interruption is not desirable. Use of SPD may be made to prevent equipment damage from possible voltage surge. For video system separate power supply outlets close to display units electronic screen/video projector will be necessary.

8.6 For guidance on selection of equipment of public address system and their installation and maintenance, reference shall be made to IS 1881 and IS 1882.

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9 TELEPHONE SYSTEMS

9.1 General

Intercom system is important private internal communication system forming one of the building services. It may integrate with external public network.

9.2 Design

Requirements shall be assessed at planning stage, with the exchange of information within concerned users and architect/consultant. Design and layouts of equipment showing locations and routes of cabling shall be planned, in advance. It shall form a coordinated activity with construction and other building services.

9.3 Main Components of the System

Main components of the system are:

a) Telephone instrument,
b) Patch cord,
c) Socket/registered jack (RJ series),
d) MDF/junction boxes of required sizes,
e) Krone modules,
f) EPABX exchange,
g) Power supply, and
h) Telephone cables 2-4 pairs, jelly filled armoured/un-armoured cable 10 to 100 pairs.

9.3.1 *EPABX*

Electronic private branch exchanges (EPABX) may be connected to the public exchanges through exchange lines or limited to internal communication. EPABX permit internal communication between the extensions of a system and external communication, for approved branch systems. EPABX is specified with number of incoming lines and outgoing lines of internal communication. For example, 3/8 means exchange having facility to connect three incoming lines from other private or public network and 8 lines of internal network.

9.3.2 *Backbone Cabling*

Generally, the inter-floor/inter-building backbone cabling is included in the scope of main building design. The backbone cabling should accommodate analog voice signal alone or analog and data signals simultaneously, as the case may be. It is the speed of data transmission and bandwidth, which matter most in the design of the communication backbone.

9.4 Exchange of Information

9.4.1 The exact requirement of the subscribers shall be assessed before drawing out the specification of the EPABX system. This means that information on number of subscribers in the building, distribution of the phones in the floors and other areas, nature of traffic etc. are to be collected.

9.4.2 The initial and final requirements of the installations should be ascertained as accurately as possible by prior consultations. Plans shall show:

a) details of the installations proposed;
b) the accommodation and location of the EPABX console, monitor, etc; and
c) the ducts and cable routing required for wiring.

9.5 Design Requirements

9.5.1 The basic architecture and performance requirements of the modern day communication system is microprocessor-based pulse code modulated (PCM)/Time Division Multiplexing (TDM) technology.

9.5.2 The environmental conditions for the EPABX should preferably be controlled so that the room air temperature is maintained between 10°C and 40°C and relative humidity between 50 percent and 95 percent.

9.5.3 Integrated Services Digital Network (ISDN) is commonly required for commercial buildings since it is possible to handle simultaneous calls of different types namely voice, data and images transfer (tele and video

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conferencing) without any loss of data, at a minimum speed of 64 kbps, which can be increased further depending on requirement. EPABX system shall be capable of interfacing with other EPABX system through appropriate protocol.

9.6 Hardware Requirement

9.6.1 *Electronic Private Automatic Branch Exchange*

In EPABX system the individual call stations are connected, each by a twisted pair of wires to the automatic exchange (*see* Fig. 1). This is also the termination for the exchange lines.

9.6.2 *Features*

There are various features available with the present day EPABX with introduction of concerned cards. Features to be incorporated shall be decided depending on functional requirement. Some of the most common features included are abbreviated dialing, recorded announcement system, last number redial, executive override, multi-party conference, call forwarding, direct inward dialing (DID), automatic alarm make-up call, STD barring, group hunting, networking facility.

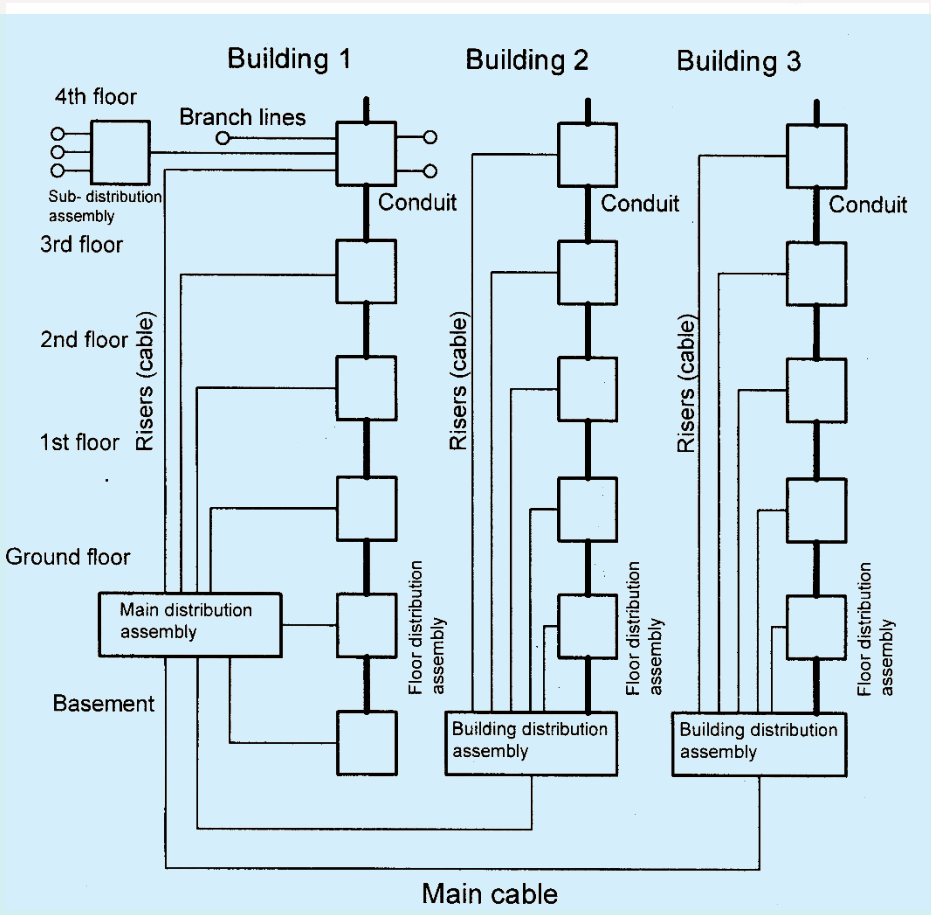


FIG. 1 EXAMPLE OF THE ARRANGEMENT OF A BASIC EPABX SYSTEM IN LARGE BUILDING

9.6.3 *Power Supply*

Depending on the size and type of installation, the telephone system requires for its operation a d.c. power supply of 24 V or 48 V, which is obtained from the power mains through a rectifier. The rectifiers provided with closed-loop control and for small and medium sized systems, are accommodated in the exchange housing. For large systems, rectifiers (controlled) are supplied in separate cabinets.

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9.6.4 *Standby Batteries*

Standby batteries can be provided as an adjunct to the rectifier. These are necessary for important installations such as police stations, fire stations, etc., to cover possible main supply failures.

9.7 Space Requirements

9.7.1 The switching equipment for the telephone systems and small EPABX's takes up little room. Apart from the telephones, only relatively small wall-mounted junction boxes or exchange units are required. The exchanges, furthermore, produce little or no noise, so that they can be accommodated in an office if desired.

9.7.2 For large systems, a separate room should be provided for the exchange equipment, and similarly, for the answering panel. Space should be allowed in planning for additional cabinets or racks, exchange equipment platforms etc. that may be necessitated by future enlargement of the systems. The size of the battery room depends upon the type of power supply equipment used.

9.8 Installation

9.8.1 *Wiring Installation*

9.8.1.1 For wiring within buildings, wire is mainly installed in embedded PVC conduit, or wiring cables with conductors of 0.6 mm or 0.8 mm diameter for surface wiring.

9.8.1.2 For cabling, it is important to maintain a separation of at least 10 mm between the communications wiring and power cables.

9.8.1.3 If conductors belonging to different communications systems run together, for example, telephone wires and loudspeaker wires, or heavily loaded slave clock circuits, there is a risk of mutual interference between them. In such cases it is advisable to use screened cables.

9.8.1.4 In communication cables, the cores are twisted together either in pairs or in star quad formation. For speech transmission to avoid crosstalk either a twisted pair or, in the case of the star quad a pair of opposite cores should be used.

9.8.2 *Ducts, Apertures and Channels*

9.8.2.1 In the course of constructing the shell of the building the appropriate channels and ducts should be formed in the masonry and lead-through apertures provided in walls, ceilings, joists and pillars. Suitable accommodation should be provided for the distribution boards in large communications system (for example, recesses, shafts etc.).

9.8.2.2 For riser cables, the ducts and ceiling apertures for the riser cables should be sufficiently large to permit the later addition of cables or PVC conduits without great expense.

9.8.3 *Conduits*

PVC conduit can be used for the individual sections of conduit networks in residential buildings for the riser conduit from floor to floor, horizontal branches in the floors up to the distribution boxes in the apartments, and between the distribution boxes in the apartments and the flush-type junction boxes.

In addition, at least one extra conduit should be provided from one floor distribution board to the next.

9.8.4 *Wiring in Residential Building*

In residential buildings, a concealed wiring arrangement is most conveniently and economically installed in an adequately dimensioned conduit network. It has been found satisfactory to provide riser conduits or cable ducts and horizontal branch conduits to the apartments, with distribution boxes at the junctions. With a concealed installation of this kind, it is possible at any time to alter the wiring or add to it without inconvenience to the occupier.

9.8.5 *Wiring in Non-residential Buildings*

In office buildings, manufacturing plants, department stores etc. particular importance is attached to flexible arrangement and utilization of the accommodation. To this end, communication wiring can be run in underfloor trunking systems or window-sealed trunking rather than on the walls.

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9.8.6 *Main Distribution Board*

All the lines are collected in the main distribution board. The main distribution board should be located in the same part of the building in the immediate vicinity of the telephone equipment. If the telephone equipment extends over several buildings, each building is connected to the main distribution board by a main cable.

9.8.7 *Floor Distribution Board*

The floor distribution boards should be accommodated close to the stair well. The rising mains are run vertically to the floors.

9.8.8 *Connection of Telephones*

9.8.8.1 At the positions allocated for the telephones, the conduit should be terminated in flush-type boxes. For junction boxes and socket outlets for the connection of telephones, flush-type boxes (switch boxes) to standards are adequate. A maximum of two telephones can be connected to a junction box.

9.8.8.2 In most cases, the telephone is connected permanently to the subscriber's line through a junction box. If it is required to be able to use it in a number of rooms, socket outlets and plugs should be provided. Units for flush and surface mounting are available for both methods of connection.

9.8.9 *Preventive Measures*

Preventive fire precautions (for example, fireproof barriers) should be considered at an early stage of planning.

9.8.10 *Inspection and Testing*

The completed installation shall be inspected and simulation testing shall be performed to ensure that all the designed functions are available as per the standards and norms of specified by the manufacturer.

10 COMPUTER NETWORKING

10.1 General

Computer networking is an inherent part of building service in most of the offices, commercial and industrial establishments. Networking is an independent and specialized subject. Speed of development, advancement and upgradations in this field are very fast. With the increased demand of transmission speed (band width), new products are replacing existing products at a fast pace and rendering them obsolete. The scope under this section do not cover technology, but consider infrastructural provisions to be made in planning, and installation, basically limited to wired networks and its aspects related to building and other building services.

This branch of technology is developing quickly and improved versions are replacing the old ones. A note shall be taken that components mentioned in this section may become obsolete with the availability of new ones in coming times.

10.2 Design and Layout

In networking, different topologies exist which is decided by network designer. Physical network correlates with actual setup of various components. Locations of these components and cabling routes is part of planning, especially when cabling is concealed type, underfloor. Layouts shall be finalized jointly in consultation with network designer. To avoid conflicts between different service providers it shall be mutually agreed by Architect/ MEP consultant and other service providers. Main components of networking are:

a) Information outlets,
b) Network switch(s),
c) Transceiver,
d) Router(s),
e) Patch panels,
f) LIU with adapter pigtails etc.,
g) Rack,
h) Patch cords, cross cords,
j) Cables – STP/UTP category (Cat6, Cat7),
k) Optical fibre, and
l) Connectors.

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10.3 Installation

10.3.1 *Selection of Cables*

Selection of cables shall be as per recommendations of system designer. Cat 5, Cat 5e cables are becoming obsolete with the advancement in technologies. There is continued improvement in capacity of cable to support bandwidth and handle data transmission speed. At present, Cat 6 and Cat 6A cables are widely used which can transmit 1 GBps over 100 m length and Cat7 can transmit 10 GBps over 100m length. To be on safer side, the length shall not exceed 90m. Unshielded Twisted Pair (UTP) cables are most widely used. However, in the locations where electromagnetic interferences are likely to be predominant or where power cables are in close vicinity, Shielded Twisted Pair (STP) shall be preferred. To overcome restriction of length, OFC shall be used. Single mode Fibre optic cables do not have limitation of length. Multimode OFC can support higher speed but may have limitation at length above 500 m.

10.3.2 *Method of Laying*

Depending on location, and number of cables, conduits, trunking and raceways of adequate cross section shall be selected. Clearances from other services as recommended by system designer shall be maintained. Depending on circumstances, provision of raised floors may be necessary in certain areas to facilitate routing of cables. While installing, restriction of bending radii of cables shall be observed.

10.3.3 *Structured Cabling*

In large setups such as data centers, very large number of cables are required to be handled. If cabling is not planned and installed as per protocols, it may lead to mess, create difficulties in maintaining and augmenting. It will also disturb aesthetics. To resolve the issue, preference shall be given to structured cabling over point to point connections. It helps maintain neatness, facilitates movement/shifting, addition and/or modification in existing network in a very convenient and easy way. It saves time as tracing is easier with lesses chances of human error.

10.3.4 *Terminations*

Terminations are done with a connector. This device terminates a segment of cabling or provides a point of entry for networking devices such as computers, hubs, and routers. Connectors can be distinguished according to their physical appearance and mating properties, such as jacks and plugs (male connectors) or sockets and ports (female connectors). There are many types of connectors. Most commonly used connectors in cable networking are RJ 45 (RJ- Registered Jack).

10.4 Testing

Installation shall be tested for desired performance. Network performance test shall be carried out to quantitatively or qualitatively measure the performance of a computer network. A network performance test primarily tests the uplink and downlink speed of a network. It defines how quick and responsive a network is to user/data communication. It is done by uploading and downloading a data object from the network and measuring both upload and download speeds, throughput, successful message delivery rate and more.

10.5 Electrical Aspects

10.5.1 *Network Cabling*

Clearance of 200mm shall be maintained between network cables and electric power cables, if there is no physical segregation. Crossings shall be at right angle.

10.5.2 *Electric Supply*

LAN equipment is sensitive and vulnerable to voltage fluctuations/surges. SPDs shall be installed on the circuits providing electrical supply equipment. Distribution of Electric Supply to all computer networking shall be through UPS with required backup depending on situation. Electrical distribution and layouts shall be so designed that circuits and routes supplying computer system equipment will be distinct from other services.

10.5.3 *Earthing System*

Earthing system is an important aspect of network reliability. It shall be efficient. There shall not be difference in ground potential between supply sources to different equipment, within same network. Earthing, inefficient to dissipate surge properly to earth, may lead to electrical noise, faulty data signals, dropped packets, thus decreasing throughput and overall efficiency of network in data cables in the system. It has been diagnosed that many times, cause of damage to network equipment, such as switches, routers, storage devices, etc., is improper earthing. All

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equipment in the rack shall be properly earthed with paint piercing washers, bonding cords/jumpers and nut-bolts to connect body of equipment to frame of rack and rack to, common bonding earthing bus. High purity copper backbone bus and other spares used for earthing system in network will mitigate risk of failures.

11 SURVEILLANCE/SECURITY SYSTEMS

11.1 Foreword

Surveillance and security systems, as the name suggests, are designed to keep an eye and cover blind spots in building and premises, monitoring authentication and vigil on persons entering and exiting, etc. These systems primarily consist of security cameras and automated access control mechanism.

11.2 CCTV

11.2.1 *Function*

Close Circuit Television (CCTV) has many fold applications. It is important tool of surveillance and can be linked with security system of building like access control, employees monitoring, life safety and evacuation under emergency condition, and can be integrated with BMS for other various aspects. With computer controlled analytics and identification software, it is possible to analyse specific object/identity/action from the video streaming or for forensic application. Depending on need, retention, storage and preservation of recorded data is possible. The preservation may be set for pre-set time period, and quality from which capacity of storage device is decided. CCTV system can be wired or wireless. Scope considered under this section is not going into the details of technology but the factors to be considered in respect of layouts, installation of CCTV system and coordination with other services including electrical aspect.

11.2.2 *Design and Layout*

Design and selection of cameras and equipment comes in purview of system designer/provider. The locations of cameras, equipment and if necessary, control room, shall be marked on drawing, in consultation with architect and other service providers so that conflicts do not arise during installation, functioning is not disturbed and maintenance in future can be attended with ease.

11.2.3 *Components*

Depending on scope/expanse, system may comprise following components for which location, routes need to be decided and marked on drawings:

a) *IP Based CCTV*
   IP Based Network Camera
   CAT6 Cables
   PoE Network Switch
   Network Video Recorder (NVR) with Surveillance HDD/NAS system/Video Servers etc.
   LED Monitors/Display
   Network Rack
   RJ 45 Connectors
   Optical Fiber Cable (OFC)
   Transceiver
   LIU with adaptor pigtails etc.

b) *Analog CCTV*
   CCTV Camera
   3+1/4+1 CCTV Cables
   DVR (Digital Video Recorder with Surveillance HDD
   LED Monitors/Display
   DVR Rack
   BNC Connectors and Power Connectors
   Power Supply

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11.2.4 *Electrical Aspects*

11.2.4.1 *Cabling*

Cabling shall be done by maintaining required clearances from other services and shall run through independent enclosures. Conduits of distinct colour coding may be used for identification. In case of electrical power cables, distance 200 mm shall be maintained, if there is no physical segregation.

11.2.4.2 *Electric supply*

Supply for CCTV system shall be provided through independent circuit. All necessary measures may be considered to maintain supply quality and integrity. Provision of UPS with adequate backup shall be done as a security measure so that recording doesn't get interrupted by malicious act. Electrical supply panels of important nature may be kept under CCTV surveillance.

11.3 Access Control

11.3.1 *Function*

Access Control System makes it possible to control the entry and exit of person in building. It can identify, authenticate, record timings of entry and exit and hence, presence of person in the building. Premises requiring security use different types of access control systems with varied levels of security depending on type of use – residential, commercial, institutional, or places of high security. The data available may be of use for security, administrative purpose, crime investigation, etc.

11.3.2 *Design and Layout*

11.3.2.1 Access point may be decided by building administration/management, security personnel depending on size, expanse and level of security. Access control may comprise biometric, RFID, door controllers with electromagnetic locks and card readers, integrated with CCTV for identification of person, intrusion detection etc. A wired security system is connected by low-voltage wires and a wireless security system may employ tiny radio transmitters which transmits signals to the central control unit. Uninterrupted power supply is an important requirement for these systems.

11.3.2.2 *Emergency considerations*

While designing, most important part of access control system is its operation during emergency, like fire; where fast evacuation is of prime importance. Under the circumstances if the egress is hindered by locked doors, it proves to be fatal. There are many ways and methods through which the behavior of Access control system under fire conditions can be designed. Centralized/individual door access control, power supply to magnetic locks, provision of pull stations near the doors, location of control panel, power supply, access to these points have important role in this regard.

11.3.2.3 *Integration of fire alarm system*

The door access control reader and the electric lock may be wired to the fire alarm in a number of different ways. A system may be designed to drop power to the electric lock or use an IP device that drops power using the network connection or add a power control box that drops power when the fire alarm system detects a fire.

NOTE — It is a prime liability of concerned owners/administrators of building and system provider to make and maintain all necessary provisions for emergency conditions.

11.3.3 *Electrical Aspects*

The system shall be provided with Uninterrupted Power Supply with backup for assessed or mandated time period but not less than 2 h. The power circuits shall be independently controlled with FS grade cables/wires. The wiring used in access control system shall observe all fire related parameters in respect of selection of material and installation method to maintain supply integrity for assessed time period of not less than 2 h.

NOTE — It is important to note that occupants shall be trained to handle Access Control system installed at entrance, and exit doors and shall form a apart of drill.

12 BUILDING MANAGEMENT SYSTEM

12.1 General

Building Management System (BMS), a computer-based automation tool to control/monitor various building services, generally needed in projects having with medium to large expanse. It may be possible to control, operate,

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monitor building services through a central control station integrating various services as given below:

a) Illumination
b) HVAC
c) Security systems
    1) Access control
    2) CCTV
    3) Alarm
    4) Motion detectors
    5) PA system
d) Fire alarm
e) Fire fighting
f) Elevators

12.2 Design

12.2.1 At planning stage, architect in consultation with owner/stake holders shall enlist various services to be incorporated in the building. Further, scope of BMS – single or multi-task shall be agreed upon.

12.2.2 BMS consists of hardware and software programme (usually, configured in a hierarchical manner, can be proprietary or IP based with open standards). Design and integration of different building services shall consider following aspect which are achievable through limited human resources, eliminating possibilities of human error.

12.2.2.1 *Electric supply and energy consumption*

Effective monitoring and targeting of electric supply quality and continuity within internal distribution. Optimising energy consumption with the use of various types of sensors, PLCs, actuators, to allow automatic setback override during unoccupied periods as well as adaptive occupancy scheduling.

12.2.2.2 *Illumination*

Lighting controls programmed to turn on/off, dim by integrating occupancy/motion sensors, photo sensors, timers, on time of day/work time scheduling in system, to reduce unnecessary artificial lighting via motion sensors and as well as by controlling daylight harvesting louvers.

12.2.2.3 *HVAC*

Climate control by monitoring HVAC system to avoid waste, suit precise requirements Indoor Air Quality (IAQ), Demand controlled Ventilation for human comfort and health. For example, controlling mix of fresh air with returned air, by placing sensors in room/duct, monitoring air dampers, chilled/hot water line valves in Constant Air Volume (CAV) or VFDs in Variable Air Volume (VAV) system by adjusting CFM.

12.2.2.4 *Maintenance*

Follow and monitor maintenance schedules for improved equipment/plant reliability, minimal breakdowns/ outages and increased service life.

12.2.2.5 *Water management*

Save water and energy by monitoring water storage through pumping, rainwater harvesting, sewage treatment plant (STP), Water treatment plant, etc.

12.2.2.6 *Emergency/fire situation*

In case of fire, isolating electrical supply other than involving emergency services, automated operation of fire-fighting system by integrating fire alarm, CCTV system. Automated operations in HVAC system like closing of dampers in the ventilation system to control smoke spreading, shut down air handlers, start smoke evacuation fans, and send all the elevators to the ground floor and park them to prevent people from using them.

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12.2.3 Main components of BMS system are:

a) Work station(s);
b) Computer/server;
c) Back-up arrangements;
d) Control units;
e) Various types sensors;
f) Actuators;
g) Cable network, LAN;
h) Required software; and
j) Internet connection.

12.3 Benefits

BMS system benefits in many ways and is recommended in major projects. The main points are given below:

a) Data can be consolidated onto a single system, which helps reporting, managing information, decision-making and record keeping.
b) Comprehensive reporting with functionality for customizable reports delivers greater transparency into system history and promotes compliance.
c) Integrating and managing various building services functionality of which may be interdependent.
d) Control can be achieved from single workstation which allows facility-wide insight and control for better performance.
e) Efficient resource deployment can result in reduced operational costs, empowering operators, simplifying training and decreasing false alarms.
f) Real-time view into facility operations and deep trend analysis provide data-driven insight to optimize your energy management strategies and minimize operational costs, targeting energy efficiency.
g) BMS can help support growth and expansion of the system in the future.
h) With help of information from BMS it is easy to observe maintenance schedules with optimum use of maintenance staff. It helps predictive maintenance and avoid breakdowns.
j) Strategic mobile or desktop control, exceptional alarm management and integrated security solutions helps to see the big picture, helping to speed up response time and mitigate risks for the property, people and business.

12.4 Electrical Aspects

12.4.1 *Energy Conservation*

BMS deals with energy demand management (EDM). It controls waste and reduces electrical energy consumption. It helps to improve and maintain quality of supply and supports energy efficiency.

12.4.2 *Cabling*

Network topology, bus, cables and their type – twisted, shielded, screened/CAT 6/fibre optic and core material of high purity copper shall be as per recommendation of system designer. Length shall be restricted in accordance with cross section, maximum allowable drop to restrict data loss and speed. Separate conduits shall be used with adequate spacing between cabling of other services.

12.4.3 *Electrical Supply*

Electrical Supply to control room shall be through UPS with adequate backup time to suite specific requirement. Use of Fire Survival cables shall be ensured from source of main supply to UPS and for further, distribution to power outlets for related equipment.

12.5 Precautions

Following points shall be considered as precautionary measures:

a) Administrative control shall be well defined with responsibilities;
b) Considering risk of hacking, necessary measures shall be taken to prevent it;

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c) Data shall be backed up. Access rights shall be kept as record;

d) System shall be maintained, critical items shall be identified and checked periodically; and

e) Information/cyber security measures shall be adhered to.

13 FIRE ALARM/DETECTION AND FIGHTING SYSTEMS

13.1 General

Fire-fighting and alarm system is most important building service related to life safety of the occupants in the building This service comes under purview of legal provisions under the Act and Rules notified by respective State Governments. Table 7 under Part 4 of National Building Code categorizes various types of buildings, depending on occupancy and height and prescribes safety provisions for fire prevention and life safety. Provisions of part 4 from NBC has been adopted by most of the states and UTs for mandatory implementation. For details, Part 4 of National Building Code of India 2016 may be referred. The section provides an overview of the systems installed to detect the fire, prevent from spreading and save the lives under fire situation and electrical aspects related to these systems. Fire alarm system and fire-fighting system are interdependent but are based on different engineering aspects.

13.2 Fire Alarm System

13.2.1 The fire alarm includes fire detection and alarm notification. It helps to detect fire at an early stage, send alerts so that appropriate action can be taken to help evacuation of occupants, calling fire-fighting tender, initiating operation of installed fire-fighting system and hence control spread of fire. The integrated PA system help occupants guide to escape routes and mitigate situation of panic. IS 2189 prescribes selection, installation and maintenance of automatic fire detection and alarm system.

13.2.2 *Design and Layout*

13.2.2.1 The system mainly comprises of following components:

a) Detectors — Smoke, heat, beam, multi sensor, flame, spark, ionization, air aspiration, etc.;

b) Hooters;

c) Manual call points;

d) Fire alarm panels — Local/repeater/main;

e) Hooter cum strobes; and

f) Appropriate cable.

13.2.2.2 Design of fire alarm system shall be done by accredited or authorized agency or person. Selection of type of system – addressable and non-addressable, design and layout (number, location, route of cables) shall comply guideline given under IS 2189 which prescribes selection, installation and maintenance of automatic fire detection and alarm system and Part 4 of National Building Code of India 2016.

13.2.2.3 Circuits controlled and powered by fire alarm system may include circuits for control of building systems safety functions like elevator control, shut down, door release, smoke doors, fire doors and damper control, mechanical ventilation/pressurization system. This helps to monitor the fire prevention and life safety operations.

13.2.3 *Electrical Aspects*

13.2.3.1 *Cabling*

Cables shall be of copper conductor with minimum cross-section area of 1.5 mm^2. Depending on requirements, the selection of cable shall be of grade FRLSH/HFFR/FS (Circuit Integrity) complying with the requirements of IS 7098 (Part 1)/IS 17048/IS 17505 (Part 1).

Supply integrity for required time duration shall be assessed based on the evacuation period or as recommended by Chief fire officer. These cables shall be easily identifiable on common treys, raceways etc. The grade of insulation shall not be less than that of other cables running along. The routes of cables shall be planned to avoid adverse impact under emergency situations.

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The equipment and wiring of the fire alarm system shall be independent of any other equipment or wiring and shall preferably be spaced at least 5 cm away from each other. Depending on requirement of mechanical protection and their placement, fire alarm cables may be armored and shielded. Unshielded cables for fire alarm systems shall be used in metallic conduits.

13.2.3.2 *Electric supply*

Electrical supply for fire alarm system shall have 100 percent standby arrangement. There shall be a provision of secondary battery continuously trickle/float charged from ac mains, with facilities for automatic recharging in 8 h sufficiently to supply the maximum alarm load at an adequate voltage for at least 2 h. The capacity of battery shall be such that it is capable of maintaining the maximum alarm load on the system at an adequate voltage for at least 1 h plus the standing load or losses for at least 48 h. Suitable overload protective devices shall be provided to prevent discharging of the batteries through the charging equipment.

13.3 Fire-Fighting

13.3.1 *General*

Fire-fighting system comprises fire extinguishers of various types, water-based system with hydrants, sprinklers, etc. The choice of fire-fighting equipment and their installation details shall be governed by the requirements specified in Part 4 of National Building Code of India 2016 and statutory provisions adopted by local bodies.

13.3.2 *Design and Layout*

13.3.2.1 Depending on rules and regulations, the design and drawings of system showing details of locations of fire-fighting pump room, equipment, routes of piping, storage water tank and pump capacity, type of system, dry, wet risers, down comers, sprinklers shall be approved by Chief fire officer/concerned authority at an early stage as aftermath corrections are difficult to incoporate. Type and capacity of pumps is based on number of hydrants, coverage area, minimum pressure at farthest point, head losses, flow rate of pump (lpm) and prime mover rating of pump(kW). There shall be standby arrangement, may be of diesel engine driven pump, or gen-set to run electrical motor driven pump, in case of power failure.

13.3.2.2 The components of the water based fire-fighting system should be selected in a way such that:

a) The system shall be avaialble with water at the required pressure at all times. Pumps and pressuring systems (for example, jockey pumps, hydro-pneumatic tanks, riding tank, etc) shall be selected accordingly.
b) The capacity of the system shall be such that water can be sprayed on the largest burning object (for example, transformer or oil tank) or the largest contained zone on fire (e.g., warehouse with goods or a library hall so that the fire is confined within the walls of the enclosed space) for a sufficient time to completely extinguish the fire.
c) The piping network shall be so designed that at the pressure is maintained at the farthest end of the pipe network. Also, the flow of water required at every outlet is maintained.
d) Equipment should be so chosen that nuisance operation is avoided.
e) Equipment shall be so chosen that they operate reliably and reliability should be close to 100 percent.
f) Redundancy should be provided to ensure that the system availability is close to 100 percent even in the contingency of loss of electrical power supply required to drive the pumps.

Alternate fire extinguishing systems like clean gas flooding system or foam spray system, if used, should also meet the reliability and availability factor of close to 100 percent.

All systems used should be fail-safe in nature.

13.3.3 *Electrical Aspects*

13.3.3.1 *Electric supply*

Sufficient power shall be available for a fire fighting system and the power source shall be entirely independent of all other equipment in the premises and shall not be interrupted at any time by the main switch controlling supply to the building. An indicator lamp shall continuously glow in a prominent position to indicate status of power in the substation and in the fire-pump room.

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13.3.3.2 *Standby power source*

In case of failure of power from main supply, there shall be provision of Generator set powering fire-fighting system. Generator set shall be of adequate capacity to bear starting load of motors.

13.3.3.3 It is important to note that electric supply and distribution layouts, routes of cables, location of pump room and control panels shall be so designed that under fire situation, supply to the fire-fighting equipment remains uninterrupted.

13.3.3.4 All motors and electrical equipment shall be continuously rated, drip-proof with air inlets and outlets, and protected with meshed wire panels.

13.3.3.5 The starting equipment of the set shall incorporate an ammeter to clearly indicate full load current. It shall not incorporate no-volt trips.

13.3.3.6 Protective measures as defined in IS 1646 shall be applied to fire fighting system..

ANNEX A

(*Clause* 2)

LIST OF INDIAN STANDARDS RELATED TO BUILDING SERVICES

IS No.	*Title*
1881 : 1998	Code of practice for indoor installation of public address systems (*first revision*)
1882 : 1993	Outdoor installation of public address system — Code of practice (*first revision*)
2189 : 2008	Selection, installation and maintenance of automatic fire detection and alarm system — Code of practice (*fourth revision*)
3103 : 1975	Code of practice for industrial ventilation (*first revision*)
3043 : 2018	Code of practice for earthing (*second revision*)
3362 : 1977	Code of practice for natural ventilation of residential buildings (*first revision*)
3646 (Part 1): 1992	Code of practice for interior illumination — Part 1 General requirements and recommendations for welding interiors (*first revision*)
4591 : 1968	Code of practice for installation and maintenance of escalators
7098 (Part 1) : 1988	Specification for crosslinked polyethylene insulated PVC sheathed cables — Part 1 For working voltages up to and including 1 100 volts (*first revision*)
7662 (Part 1) : 1974	Recommendations for orientation of buildings – Part 1 Non-industrial buildings
17048 : 2018	Halogen free flame retardant HFFR cables for working voltages up to and including 1 100 Volts — Specification
17505 (Part 1) : 2021	Specification for Thermosetting Insulated Fire Survival Cables for Fixed Installation having Low Emission of Smoke and Corrosive Gases when Affected by Fire for Working Voltages upto and including 1 100V
14665 series	Electric traction lifts
17900 (Part 1) : 2022	Lifts for the transport of persons and goods — Part 1 Safety rules
SP 7: 2016	National Building Code of India
SP 72 : 2010	National Lighting Code

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SECTION 16 SELECTION OF EQUIPMENT

FOREWORD

Several Indian Standards exist, which cover details of selection, installation, and maintenance of electric power equipment. This Part 1/Section 16 of the Code is formulated in such a manner as to bring out only the essential criteria for selection of equipment, and users of the Code are recommended to make reference to individual product codes for detailed guidelines.

1 SCOPE

This Section of the Code (Part 1/Sec 16) covers general criteria for selection of equipment.

NOTE — This Part 1/Sec 16 shall be read in conjunction with the Indian Standard/Codes on individual equipment.

2 SELECTION OF EQUIPMENT

2.1 Conformity to Indian Standards

Every item of electrical equipment used in the installation shall conform to the relevant Indian Standards, wherever available.

2.2 Characteristics

Every item of electrical equipment selected shall have suitable characteristics appropriate to the values and conditions on which the design of the electrical installation (Part 1/Sec 9) is based and shall, in particular, fulfil the requirements given at **2.2.1** to **2.2.4**.

2.2.1 *Voltage*

Electrical equipment shall be suitable with respect to the maximum steady voltage (rms value for a.c.) likely to be applied, as well as over-voltages likely to occur.

NOTE — For certain equipment, it may be necessary to take account of the lowest voltage likely to occur.

2.2.2 *Current*

All electrical equipment shall be selected with respect to the maximum steady-state current (rms value for a.c.) which it has to carry in normal service, and with respect to the current likely to be carried in abnormal conditions and the period (for example, operating time of protective devices, if any) during which it may be expected to flow.

2.2.3 *Frequency*

If frequency has an influence on the characteristics of electrical equipment, the rated frequency of the equipment shall correspond to the frequency likely to occur in the circuit.

2.2.4 *Load Factor*

All electrical equipment which is to be selected on the basis of its power characteristics, shall be suitable for the duty demanded of the equipment, taking into account the design service conditions.

2.3 Conditions of Installation

All electrical equipment shall be selected so as to withstand safely the stresses and the environmental conditions (*see* Table 1 of Part 1/Sec 8 of this Code), characteristic of its location to which it may be subjected. The general characteristics of building installations are assessed according to the guidelines given in Part 1/Sec 8 of this Code. If, however, an item of equipment does not have by design the properties corresponding to its location, it may be used on condition that adequate additional protection is provided as part of the completed electrical installation.

2.4 Prevention of Harmful Effects

All electrical equipment shall be selected so that it will not cause harmful effects on other equipment or impair the supply during normal service including switching operations. In this context, the factors which may have an influence include:

a) Power factor,

b) Inrush current,

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c) Asymmetrical load,

d) Harmonics, and

e) Transient over-voltages generated by equipment in the installation.

The harmful effects shall also include human, animal and environment safety aspects during transportation, installation, operation, maintenance and disposal at end of life of the equipment. The equipment shall conform to the requirements of ISO 12100. Compliance to Factories Act, 1948 (with amendment 1987), Dangerous Machines (Regulations) Act, 1983, ISO 13849, ISO 13850, ISO 13851, IS 16501, IS 16502 and IS 16503 shall also be made wherever applicable. Other standards as may be notified by BIS shall also be applicable.

2.5 Guidelines on the selection of specific equipment are covered in the relevant Indian Standards. Guidelines on selection of protective devices are given at Part 1/Sec 18 of this Code.

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SECTION 17 ERECTION AND PRE-COMMISSIONING TESTING OF INSTALLATION

FOREWORD

Ensuring that the installation conforms to the predetermined conditions before and after energization, verification is a necessary prerequisite under the statutory provisions. Several aspects/parameters shall be verified and certified for using and energizing the installation.

A general check list of aspects/parameters and tests, neccessary to be carried out are included in this Section. Verification shall be done as per 6 of IS 732. Recommended resistance of conductors is additionally included in Annex B.

In addition to initial testing, 'periodic testing and preventive maintenance checks' are necessary. Recommended maximum intervals between periodic verification, based on building occupancy type as per NBC is provided at annex E. Also, the nature and frequency of such measures depends on the nature of the electrical installation.

1 SCOPE

This section of the code (Part 1/Sec 17) covers general principles of erection of installation and guidelines on initial testing before/during commissioning and shall be used for electrical safety audits.

2 REFERENCES

2.1 The standards listed in Annex A contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

2.2 It must be ensured that all required type test certificates for important equipment like circuit breakers, transformers, switchboards, switchgear and other relevant equipment are checked for their suitability and working.

3 ERECTION

3.1 To ensure erection of safe and quality electrical installation, the work should commence with use of appropriate, appropriate tools, tackles and equipment by qualified and experienced personnel.

3.2 The characteristics of the electrical equipment shall not be impaired in the process of erection.

3.3 Protective (earthing) conductors and neutral conductors shall be identifiable at least at their termination of ends other than those of live conductors through separate colours or other suitable means. These conductors in flexible cords or flexible cables shall be identifiable by different colors or other suitable means throughout their length (*see* 3.6 of Part 1/Sec 4).

3.4 For connections, 'between conductors' and 'between conductors and other electrical equipment', safe and reliable contacts shall be ensured. Continuity resistance testing as per this code should be carried out for assessing the reliability of connections.

3.5 All electrical equipment shall be installed in such a manner that the designed cooling conditions are not impaired and space between individual equipment complements the natural cooling process allowing air to circulate as well as restricting the heat radiation to adjacent equipments.

3.6 All electrical equipment likely to cause high temperatures or electric arcs shall be placed or guarded so as to eliminate the risk of ignition of flammable materials. A proper shielding/barricading should be provided around such equipment/'vicinity containing such equipment' to avoid transfer of excess heat (till flash point) through any possible means. Where the temperature of any exposed parts of electrical equipment is likely to cause injury to persons, these parts shall be so located as to prevent accidental contact therewith. Appropriate personnel with suitable protective gear shall be deployed within such vicinities. In case the work execution is in close vicinity of live electric conductor, the protection gear should be of sufficient capability to avoid any transfer of electricity directly/residually or through leakage to human body. All safety provisions specified in *The Electricity Act,* 2003 and *CEA regulations* must be followed during erection of equipment.

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3.7 Several Indian Standards exist on installation of specific electrical equipment. These shall be adhered to during erection of the installation.

4 INSPECTION AND TESTING

4.1 General Requirements

4.1.1 Before, during and after the completion of new installation, or modification to the existing installation, inspection and testing shall be carried out in accordance with IS 732 and this section of the code, for voltages up to 1 000 V a.c. and 1 500 V d.c. Model forms provided at Annex D shall be used during inspection and testing. The defects shall be rectified before rendering the electrical installation into service.

4.1.2 After performing all requisite pre-commissioning tests for individual equipment as per the relevant standards and guidelines, and subsequently, rendering the installation into service, periodic inspection and testing shall be carried out to maintain the installation in a sound condition. Recommended maximum intervals between periodic verification, based on type of building occupancy as per NBC is provided in annex E.

4.2 Inspection of the Installation

4.2.0 *General*

After completion of wiring, a general inspection shall be carried out by competent personnel to verify that the provisions of this Code have been complied with. This shall verify that all equipment, fittings, accessories, wires and cables, used in the installation are of adequate rating and quality to meet the requirements of the load. General workmanship of the electrical wiring with respect to the layout and finish shall be examined for neatness facilitating easy identification of circuits of the system, adequacy of clearances, soundness of termination with respect to tightness, contact pressure and contact area and natural or arranged similarity in type of material/metal surfaces coupled in contact with each other. Verification of all the protective devices for their rating, range and upward/downward variation in device settings shall be ensured.

4.2.1 *Voltages above 1 kV a.c*

In substation installation, following shall be verified:

a) Characteristics of the equipment (including rated values) for the given operating conditions;
b) Minimum clearances between live parts and between live parts and earth;
c) Power frequency voltage test for switchgear;
d) Voltage test for cables;
e) minimum heights and protective barrier clearances;
f) Visual inspections and/or functional tests of electrical equipment and parts of installation;
g) Functional tests and/or measuring of protective, monitoring, measuring and controlling devices;
h) Inspection of markings, safety signs and safety devices;
j) Correct fire ratings for buildings/enclosures;
k) Emergency exits shall be operational;
m) Adequacy of the earthing system;
n) Suitable fencing shall be available with lockable arrangements;
p) Placement of caution boards, firefighting equipment, operating rods, rubber mats etc, at appropriate locations;
q) Sufficient ventilation and draining arrangements shall be available for indoor substations;
r) All cable trenches shall be provided with nonflammable covers;
s) Equipment for normal operation shall be easily accessible;
t) Equipment shall be duly painted and identifiable with name plates;
u) All construction materials and temporary connections shall be removed;
v) Oil levels, bus bar tightness, transformer tap position, etc, shall be correctly set;
w) Appropriate ingress protection from external influences shall be provided to guard switchgear, panel and equipment, depending upon its location of installation;

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x) Earth bus bars shall be tightly screwed with corrosion free joint surface;

y) Control switch fuses shall be provided at an accessible height from ground;

z) Adequate space shall be available in the transformer for easy topping up of oil, for maintenance pruposes, etc;

aa) Adequate clearances shall be available in the front, rear and sides of the switchboards;

bb) The size and gap in the horngap fuse shall be adequate;

cc) Switch shall operates freely ensuring that all the blades make contact at the same time. The arcing horns contact in advance, and the handles shall be provided with locking arrangements;

dd) Insulators shall be clean and free from cracks;

ee) There shall be no oil leakage from transformer;

ff) Bushings connections to the transformer shall be adequately screwed;

gg) Bushings shall be clean and free from cracks;

hh) Transformer accessories such as breathers, vent pipe, buchholz relay etc, shall be in order;

jj) Connections to Buchholz gas relay in transformers shall be in order;

kk) Oil and winding temperature shall be set as per the specific requirements in transformers;

mm) In case of cable cellars/trenches, adequate arrangements to pump out seepage water shall be ensured.

nn) All incoming and outgoing circuits of panels shall be clearly and indelibly labelled for identifications at both front and rear ends. Also, all entry points below ground level shall be firmly plugged to avoid probable entry of rodents/reptiles/insects and water;

pp) Pads should be provided at suitable locations near each equipment for clamping of temporary earthing arrangement;

qq) No obstructions shall be present in the escape routes causing hinderance;

rr) No protrusions shall be present on any support structure facilitating mounting by any human or animal and thereby, come in close proximity of live parts; and

ss) Risk assessment as per template in IS 16819 (ISO 12100) may be prepared and approved by the competent authority.

4.2.2 *System up to 1 000 V a.c. and 1 500 V d.c.*

4.2.2.1 The electrical installation shall be inspected prior to energizing the installation.

4.2.2.2 The inspection shall ensure that electrical equipment is:

a) In compliance with the safety requirements of the relevant equipment standards;

NOTE — This can be ascertained by examination of the manufacturer's information, marking or certification.

b) Suitably selected and erected as per IS 732 and the provisions of this code, taking into account the manufacturer's instructions; and

c) Not visibly damaged or defective impairing safety.

4.2.2.3 Inspection shall include checking of the following (where relevant):

NOTE — For clause wise compliance of various inspection requirements, refer 6 of IS 732.

a) Method of protection against electric shock;

b) Presence of fire barriers and other precautions against propagation of fire and protection against thermal effects;

c) Selection of conductors for current-carrying capacity;

d) Choice, setting, selectivity and coordination of protective and monitoring devices;

e) Selection, location and installation of suitable overvoltage protective devices (SPD) where specified;

f) Selection, location and installation of suitable isolating and switching devices;

g) Selection of equipment and protective measures appropriate to external influences and mechanical stresses;

h) Identification of neutral and protective conductors;

j) Presence of diagrams, warning notices/signs or similar information;

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k) Identification of circuits, overcurrent protective devices, switches, terminals etc.;

m) Adequacy of termination and connections of cables and conductors;

n) Selection and installation of earthing arrangements, protective conductors and their connections;

p) Accessibility of equipment for convenience of operation, identification and maintenance;

q) Measures against electromagnetic disturbances;

r) Exposed-conductive-parts connected to the earthing arrangement; and

s) Selection and erection of the wiring systems.

4.2.2.3.1 Inspection shall be conducted during the erection of electrical installation for the following:

a) Switchgears, contractors, relays, and all equipments shall be free of packaging material used during transportation;

b) All connections to the earthing system shall be accessible for periodical inspection;

c) Sharp cable bends shall be avoided and cables shall be laid in trenches or alongside the walls and ceilings using suitable support clamps at regular intervals. All power/control cables shall be identifiable, and laid and connected properly using "appropriate termination materials including inhibiting compounds/pastes" to equipment/busbars and shall use appropriate nut bolts/washers/spring washers etc. All control cables should be separated from HT/LT power cables by means of separate raceway/trough/tray at a suitable distance;

d) Suitable linked switch or circuit-breaker or lockable push button shall be provided near the motors/ apparatus for controlling supply to the motor apparatus at an accessible location;

e) Control switchgear shall be provided at an accessible height from ground for controlling supply to overhead travelling crane hoists and overhead bus bar trunking;

f) The metal rails on which the crane travels are electrically continuous, earthed and bonded at both ends;

g) Trailing cables of three cores(with one earthing core) should be used for single phase overhead travelling cranes and portable equipment and six core trailing cables should be used in case of three phase loads, 5th core is used for protective earthing and 6th core for functional earthing;

h) If flexible metallic hose is used for wiring to motors and equipment, full length of wiring shall be enclosed, and the hose shall be secured properly using end coupling;

j) The cables shall not be laid in areas which may damage due to mechanical impact or environmental influence;

k) The screens and armour of the cables shall be connected to earthing system properly;

m) The belts of the belt driven equipment shall be properly guarded;

n) Ammeters and voltmeters shall be tested and calibrated;

p) Relays shall be inspected visually for deposits or dusts or other foreign matter and their operations and accuracies should be checked using suitable primary/secondary injection equipment;

q) Flat washers backed up by spring washers shall be used for making end connections; and

r) Number of wires in a conduit shall conform to provisions of this Code.

4.3 Testing of Installation

4.3.0 *General*

After inspection, the following tests shall be carried out before energizing an installation. The testing shall commence after obtaining permit to work from the person-in-charge/supervisor/team leader and ensuring the all safety provisions are put in place.

NOTE — List of some functional tests are listed under Annex C.

4.3.1 *For system more than 1 kV a.c.*

4.3.1.1 *Verification of specified performances*

Tests should, in general, be carried out on various equipment under installation at appropriate stages of work, to verify performance of the installation. This may include determination of procedure of installation based on stringent technical norms, test methods including confirmation of technical competency of site services, personnel, etc.

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4.3.1.2 *Tests during installation and commissioning*

The user and supplier shall agree on the requirements (methods and acceptance criteria) for tests during installation and commissioning, together with a listing of the testing standards to be applied. This may include functional tests to demonstrate the ability of the equipment to satisfy the operational requirements, such as automatic start-up and shutdown.

The test equipment for demonstration of achievement of design requirements should be agreed between the user and supplier.

The user and supplier shall agree on a schedule of tests for components and systems during the installation and commissioning period. The necessary services to allow the tests to be carried out should be agreed between both the parties.

NOTE — The contractual consequences of the outcome of the tests during installation and commissioning should be stated in the enquiry, as and where felt appropriate.

4.3.1.3 *Trial running*

When agreed between the user and supplier, a trial run shall be performed post all pre-commissioning tests as mutually agreed upon. The purpose of the trial run is to prove the functional capability and assurance of operational safety of the high-voltage installation. During the run, therefore, all significant components should be in operation. The agreement should define under what circumstances a breakdown of a significant component constitutes an interruption of the trial. The user may also define criteria of exceptions for breakdowns of a very short period, for example simply extending the period of the trial by the outage time.

The conditions that have to be met for the successful completion of the trial run should be defined in the enquiry.

NOTE — The contractual consequences of the outcome of the trial run should be stated in the enquiry, as and where appropriate.

4.3.1.4 *Operation and maintenance manual*

Each installation should have an operation manual describing the normal, emergency, and maintenance procedures as well as safety instructions for the operation of the high-voltage electrical installation. For the preparation of manuals and instructions, IEC/IEEE 82079-1 shall apply.

Each installation should have at least three sets of good for construction as well as up-to-date drawings (as built drawings) and operating diagrams “on the operational premises” as well as in “independent safe custody”. These drawings and diagrams should allow operation and maintenance personnel to provide safe and efficient interventions in the installation when need be. Manufacturers of major components of an installation should provide operation and maintenance manuals and test and in-service reports. These documents should be readily available for use when necessary. Emergency routes to the nearest hospital and emergency phone numbers should be displayed in a visible location in the installation.

4.3.1.5 *Measurements of earthing system*

Measurements shall be carried out after construction, where necessary, to verify the adequacy of the design. Measurements may include the earthing system impedance, continuity resistance of the earth return path, prospective touch and step voltages at relevant locations and transferred potential, if appropriate. When measuring touch and step voltages under test conditions, for example, current injection test, two choices are possible. Either measure the prospective touch and step voltages using a high impedance voltmeter or measure the effective touch and step voltages appearing across an appropriate resistance which represents the human body.

4.3.2 *Switchboards*

Switchboards shall be tested in the manner indicated below:

a) All switchboards shall be tested for di-electric test in the manner recommended in IS/IEC 61439-1;
b) All earth connections shall be checked for continuity resistance;
c) The operation of all protective devices shall be tested by means of secondary or primary injection tests;
d) The operation of the circuit-breakers shall be tested from all control stations;
e) Indication/signaling lamps shall be checked for working;
f) The operation of the circuit-breakers shall be tested for all interlock;
g) The closing and opening timings of the circuit breakers shall be tested wherever required for auto transfer schemes;

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h) Contact resistance of main and isolator contacts shall be measured; and

j) The specific gravity of the electrolyte and the voltage of the control battery shall be measured.

4.3.3 *Transformers*

All commissioning tests as listed in IS 10028 (Part 2) shall be carried out.

4.3.4 *Cables*

Cable installations shall be checked as laid down in IS 1255.

4.3.5 *Motors and Other Equipment*

The following tests are made on motor and other equipment:

a) The insulation resistance of each phase winding against the frame and between the windings shall be measured. (Insulation Resistance Tester) of 500 V/1 000 V rating shall be used. Star points should be disconnected. Minimum acceptable value of the insulation resistance varies with the rated power and the rated voltage of the motor.

The following relation may serve as a reasonable guide:

$$R_i = \frac{20 \times E_n}{1000 + 2P}$$

Where,

R_i = insulation resistance in MΩ at 25°C,

E_n = rated phase-to-phase voltage, and

P = rated power kW.

If the resistance is measured at a temperature different from 25°C, the value shall be corrected to 25°C.

b) The insulation resistance as measured at ambient temperature does not always give a reliable value, since moisture might have been absorbed during shipment and storage. When the temperature of such a motor is raised, the insulation resistance will initially drop considerably, even below the acceptable minimum. In case of any doubt under such circumstances, motor winding shall be dried out.

4.3.6 *Energy Meters*

IS 15707 and IS 16444 should be followed in case of energy meters.

4.3.7 *Low Voltage System (up to 1000 V a.c. and 1500 V d.c.)*

4.3.7.1 *General*

The test methods described in **4.3.7** are reference methods only; other method if any, may be followed provided that they give equally reliable and trustworthy results. Measuring instruments and monitoring equipment and methods shall be chosen in accordance with the relevant parts of the IS/IEC 61557 series. If other measuring equipment is used, it shall provide no less a degree of performance and safety. The test and measuring equipment/ instruments should periodically (as specified by relevant standards) be calibrated in authorized test laboratories for their accuracy.

4.3.7.2 Some of the tests specified shall be carried out in live condition. Fault loop impedance tests require power source (for example, transformer/DG) in live condition.

4.3.7.3 The following tests shall be carried out where relevant and should preferably be made in the following sequence:

NOTES

1 Refer IS 732 for more information on methods for measuring the insulation resistance/impedance of floors and walls to earth/protective conductor, measurement of earth electrode resistance etc.

2 The resistance of the wires measured during testing of continuity resistance measurement of conductors shall not exceed the values mentioned in Annex B.

a) Continuity resistance of conductors and verify as per Table 1 in Annex B;

b) insulation resistance;

c) insulation resistance testing to confirm the effectiveness of protection by SELV, PELV or electrical separation;

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d) insulation resistance testing to confirm the effectiveness of floor and wall resistance/impedance;
e) polarity test;
f) testing to confirm effectiveness of automatic disconnection of supply;
g) testing to confirm the effectiveness of additional protection;
h) test of phase sequence;
j) functional tests; and
k) voltage drop.

4.3.7.4 In the event of any test indicating failure to comply, that test and any preceding test, the results of which may have been influenced by the fault indicated, shall be repeated after the fault has been rectified. When testing in a potentially explosive atmosphere appropriate safety precaution in accordance with IS/IEC 60079-17 are necessary.

4.3.7.5 *Portable appliance test (PAT)*

This test is mainly performed in respect of Class I appliances to test earth continuity of appliance from available source at power outlet to avoid risk and ensure safe working. With the help of PAT tester insulation resistance of the appliance can also be checked. Depending on test results it can be decided whether appliance is safe for use. For continuity 0.1 ohm and Insulation resistance of 1 M-ohm and above shall be considered safe.

4.4 Testing of Lightning Protection System of Buildings

4.4.0 *General*

Lightning protection verification shall be done as per IS/IEC 62305. For industrial/commercial and multi storied buildings, suitable lightning protection levels are selected based on risk assessment calculations provided in IS/IEC 62305-2. The effectiveness of any LPS depends on its adoption of design, installation, maintenance, and testing methods explained in IS/IEC 62305-2. Inspections, testing and maintenance shall not be conducted during threat of thunderstorms.

4.4.1 *Application of Inspections*

The objective of the inspections is to ascertain that:

a) the LPS conforms to the design based on IS/IEC 62305,
b) all components of the LPS are in good condition and capable of performing their designed functions, and that there is no corrosion, and
c) any recently added services or constructions are incorporated into the LPS.

4.4.2 *Order of Inspections*

Inspections should be made according to **4.4.1** as follows:

a) during the construction of the structure, in order to check the embedded electrodes;
b) after the installation of the LPS;
c) earthing resistance value for the earth-termination system; and
d) condition of connections, equipotential bonding and fixings.

4.4.3 *Testing*

Inspection and testing of the LPS includes visual inspections and should be completed by the following actions:

a) performing continuity tests, especially, of parts of LPS not visible for inspection;
b) conducting earth resistance tests of the earth-termination system and the results shall be recorded in an LPS inspection report;

NOTE — High-frequency or impulse measurements are possible and useful to determine high frequency or impulse behaviour of the earth-termination system. Such measurements may be performed at the stage of installation of the earthing system to check adequacy between the need and designed earthing system.

c) The resistance to earth of each local earth electrode and where reasonably practical, the resistance to earth of the complete earth-termination system. Each local earth electrode should be measured in isolation with the test joint between the down-conductor and earth electrode in the disconnected position (isolated measurement);

NOTE — For earth networks incorporating both vertical earth rods and a partial or full ring earth electrode, disconnection and testing should be performed at the earth inspection pit. If such inspection is difficult to perform, routine test should be completed by high frequency or impulse tests.

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d) If the resistance to earth of the earth-termination system as a whole exceeds 10 ohm, a check should be made to ascertain that the electrode conforms to 5.4 of IS/IEC 62305. For earth electrodes in rocky soil, the requirements of IS/IEC 62305-3 should be followed. The 10 ohm requirement is not applicable in this case;

e) The results of a visual check of all conductors, bonds and joints or their measured electrical continuity. If the earth-termination system does not conform to these requirements, or checking the requirements is not possible because of a lack of information, the earth-termination system should be improved by installing extra earth electrodes or installing a new earth-termination system in parallel connectivity to existing one; and

f) SPDs should be tested, preferably using the guidelines or equipment provided by the manufacturer.

4.4.4 *Documentation of Inspection*

LPS inspection guides should be prepared containing sufficient information such as the method of LPS installation, the type and condition of the LPS components, test methods used and the records of test data to facilitate LPS Inspections.

The LPS inspection report should be kept together with the LPS design report, maintenance reports and previous inspection reports.

The LPS inspection report should contain the following information:

a) general conditions of air-termination conductors, and other air-termination components;

b) general level of corrosion and the condition of the corrosion protection;

c) security of attachment of the LPS conductors and components;

d) earth resistance measurements of the earth-termination system;

e) any deviation from the requirements of this standard; and

f) documentation of all changes, extension of the LPS and any changes to the structure.

In addition, the LPS construction drawings, design description and test data should be reviewed.

4.5 On completion of laying up of new electrical installation (or modification to an existing installation) a certificate shall be furnished by the appropriate person in the prescribed forms in Annex D, countersigned by the appropriate authority under whose direct supervision the installation was carried out. This certificate can be used by the local electric supply authority (subject to its acceptance) and form a basis for electrical safety audits.

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ANNEX A

(*Clause* 2.1)

LIST OF STANDARDS ON INSTALLATION

IS No./Other Publications	*Title*
732 : 2019	Code of practice for electrical wiring installations Power installations exceeding 1 kV a.c. — Part 1 Common rules
1255 : 1983	Code of practice for installation and maintenance of power cables upto and including 33 kV rating (*second revision*)
10028 (Part 2) : 1981	Code of practice for selection, installation and maintenance of transformers: Part 2 Installation
15707 : 2006	Testing, evaluation, installation and maintenance of a.c. electricity meters — Code of practice
IS/IEC 60079-17 : 2013	Explosive atmospheres – Part 17 Electrical installations inspection and maintenance (*first revision*)
IS/IEC 61439-1 : 2011	Low-Voltage Switchgear and Controlgear Assemblies – Part 1 General Rules
IS/IEC 61557 series	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c.
IS/IEC 62305 series	Protection against lightning
IEC/IEEE 82079-1 : 2019	Preparation of information for use (instructions for use) of products — Part 1 Principles and general requirements

ANNEX B

ESTIMATION OF THE RESISTANCE VALUE LIKELY TO BE OBTAINED DURING CONTINUITY TESTING

(*Clauses* 3.4 *and* 4.3.2)

Table B-1 Specific Conductor Resistance *R* for Copper Wiring at 30°C Dependent on the Nominal Cross-sectional Area *S* for Rough Calculation of Conductor Resistances

Nominal Cross-sectional Area S	Specific Conductor Resistance R at 30°C
mm^2	mΩ/m
1.5	12.5755
2.5	7.5661
4	4.7392
6	3.1491
10	1.8811
16	1.1858
25	0.7525
35	0.5467
50	0.4043
70	0.2817
95	0.2047
120	0.1632
150	0.1341
185	0.1091

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The specific conductor resistance values are related to a conductor temperature of 30°C. For other temperatures Θ the conductor resistances R_Θ can be calculated by the use of the following formula:

$$R_\Theta = R_{30°C}[1 + \alpha(\Theta - 30°C)]$$

Where: Θ is temperature at which desired specific conductor resistance is to be calculated,

α is the temperature coefficient (for copper $\alpha = 0.00393\ K^{-1}$)

Example of calculate SCR of 16 mm² copper conductor @ 40° C the derivative will be:

$$R_{40} = 1.1858[1 + 0.00393(40 - 30)] = 1.2324$$

ANNEX C

(*Clause* 4.3.0)

LIST OF FUNCTIONAL TESTS

C-1 VOLTAGE ABOVE 1 KV AC

a) ***Current Transformer***

1) Physical inspection checks;
2) Terminal marking identification as per schematic diagram;
3) Insulation resistance test;
4) Winding resistance test;
5) Polarity test;
6) Knee point voltage test (for PS class only);
7) Current ratio test;
8) Tan delta and capacitance measurement (applicable for rated voltage above 66 kV);
9) Interposing CT testing (if present);
10) Summation CT testing (if present);
11) Metering circuit checks;
12) Protection circuits checks;
13) Test terminal block link checks;
14) Secondary lead resistance checks (applicable for switch yard only);
15) Burden test/secondary injection test; and
16) Primary injection checks (including core identification checks).

b) ***Potential Transformer/Capacitive Voltage Transformer***

1) Physical inspection checks;
2) Terminal marking identification as per schematic diagram;
3) Insulation resistance test ;
4) Winding resistance test;
5) Polarity test;
6) Voltage ratio test;
7) Tan delta and capacitance measurement (applicable for rated voltage above 66 kV);
8) Metering circuit checks;
9) Protection circuits checks;
10) Primary and secondary PT fuses check;

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11) Test terminal block link checks; and
12) Secondary injection test.

c) ***Circuit Breaker***

1) Physical inspection checks;
2) Breaker internal wiring checks;
3) AC and DC circuit checks;
4) Mechanical and electrical operation (OPEN/CLOSE) checks;
5) Spring charge motor insulation resistance, winding resistance and current checks;
6) Insulation resistance test;
7) Static contact resistance/milli volt drop measurement test;
8) Timing operation test (close, open and close open);
9) Dynamic contact resistance measurement (applicable for 220 kV and above);
10) Coil resistance test;
11) Coil current test;
12) Trip circuit supervision checks;
13) Closing and tripping circuit checks;
14) Anti-pumping checks;
15) Pole discrepancy checks (if applicable);
16) SF6 gas alarm/trip checks (if applicable);
17) Auxiliary contact multiplication circuit checks (feedback/status contact); and
18) Auxiliary contact change over checks (potential free/spare contacts).

d) ***Isolator/Disconnector and Earth Switch***

1) Physical inspection checks;
2) Isolator internal wiring checks;
3) AC and DC circuit checks;
4) Isolator and earth switch motor insulation resistance, winding resistance and current checks;
5) Mechanical and electrical operation (OPEN/CLOSE) checks;
6) Interlock checks between isolator and earth switch both electrical and mechanical (if applicable);
7) Insulation resistance test;
8) Static contact resistance for isolator (earth switch if applicable);
9) Closing and opening circuit checks;
10) Pole discrepancy checks (if applicable);
11) Auxiliary contact multiplication circuit checks (feedback/status contact); and
12) Auxiliary contact change over checks (potential free/spare contacts).

e) ***Surge/Lightning Arrestor***

1) Physical inspection checks;
2) Insulation resistance test;
3) Surge counter operation checks (if applicable);
4) High voltage test (up to 30 kV AC); or
5) Tan Delta, Capacitance and Watt measurement (applicable for rated voltage above 66 kV).

f) ***Protection Relays***

1) Directional over current and earth fault relays;
2) Non-directional over current and earth fault relays;
3) Under voltage and over voltage relays;
4) Residual over voltage or neutral displacement relays;
5) Distance protection relays (line protection relays);

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6) Differential protection relays (transformer, motor, line/cable, busbar, reactor, generator and overall generator);
7) Check synch relay;
8) Automatic voltage regulation relay in RTCC;
9) Reverse power relay;
10) Negative sequence protection relay; and
11) Over and under frequency protection relay:

g) ***Auxiliary Relays***

1) Tripping relay;
2) Lock out relay;
3) Trip circuit supervision relays;
4) Contact multiplication relay;
5) ON/OFF delay timer.

h) ***Busbar/Busduct***

1) Physical inspection checks;
2) Insulation resistance test;
3) Contact resistance/milli volt drop measurement test;
4) High voltage withstand test; and
5) Differential stability checks (if applicable).

j) ***Switchboard Scheme Checking***

1) Inter-panel wiring checks;
2) Bus wiring checks;
3) Insulation resistance checks;
4) AC and DC circuit checks;
5) On load transfer checks;
6) Auto change over scheme checks;
7) Synchronizing scheme checks;
8) Breaker failure and LBB initiation checks (if applicable);
9) Binary input and output checks;
10) Local/remote (DCS/SCADA/BCU) operation checks (if applicable); and
11) Trip matrix checks (if applicable).

k) ***HT Cable***

1) Physical inspection checks;
2) Phase identification checks;
3) Insulation resistance test; and
4) High voltage withstand test.

m) ***Distribution Transformers***

1) Physical inspection checks;
2) OLTC scheme and operation checks (if applicable);
3) Insulation resistance test;
4) Magnetizing current test at all taps;
5) Open circuit/voltage ratio test at all taps;
6) Magnetic balance test at Min, Max and normal tap;
7) Vector group/polarity test at normal tap;
8) Short circuit test at all taps (wherever possible);
9) Winding resistance test at all taps;
10) Polarisation index test at normal tap;

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11) Transformer marshalling box scheme and wiring checks;
12) Testing of accessories (Buchholz relay, OTI, WTI and PRV);
13) Testing of cable (continuity and IR) from accessories to MB; and
14) RTCC operation checks (if applicable).

n) ***Motors/Diesel Generators***

1) Physical inspection checks;
2) Insulation resistance test;
3) Winding resistance test;
4) Neutral side current transformer test (if applicable);
5) High voltage withstand test (if applicable);
6) Differential stability checks (if applicable);
7) Start/stop operation checks at local/remote; and
8) No load/load trial for 4 h.

p) ***Earthing System***

1) Continuity resistance of earthing conductor;
2) Continuity resistance of main bonding conductor;
3) Continuity resistance of supplementary bonding conductor;
4) Earth conductor joint resistance measurement; and
5) Earth electrode resistance measurement (individual and with grid).

ANNEX D

MODEL FORMS FOR REPORTING

(*Clause* 4.1.1 *and* 4.5)

NOTE — For guidance on the application of the rules for initial verification, refer IS 732.

Table D-1 Electrical Installation Verification Report (New or Altered Installation)
(IS — Code of Practice for Electrical Wiring System)

DETAILS OF THE CLIENT	
INSTALLATION ADDRESS	
DESCRIPTION AND EXTENT OF THE INSTALLATION Tick boxes as appropriate Description of installation: Extent of Installation covered by this report: (Use continuation sheet If necessary) see continuation sheet No:	New Installation ☐ Addition to an Existing installation ☐ Alteration to an Existing installation ☐
FOR DESIGN I/We being the person(s) responsible for the design of the electrical Installation (as indicated by my/our signatures below),particulars of which are described above, having exercised reasonable skill and care when carrying out the design hereby DECLARE that the design work for which we have been responsible is to the best of my/our knowledge and belief in accordance with IEC 60364 except for the departures, if any, detailed as follows:	
Details of departures from IEC 60364: (clauses to be inserted)	
The extent of liability of the signatory or the signatories is limited to the work described above as the subject of this report. For the DESIGN of the installation: **(Where there is mutual responsibility for the design) **Signature: ..... Date: ..... Name (IN BLOCK LETTERS)..... Designer No 1** **Signature: ..... Date: ..... Name (IN BLOCK LETTERS)..... Designer No 2****	

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Table D-1 (*Continued*)

FOR CONSTRUCTION

I/We being the person(s) responsible for the construction of the electrical installation (as indicated by my/our signatures below), particulars of which are described above, having exercised reasonable skill and care when carrying out the construction hereby DECLARE that the construction work for which I/we have been responsible is to the best of my/our knowledge and belief in accordance with IEC 60364 except for the departures, if any, detailed as follows:

Details of departures from IEC 60364 (clauses to be inserted):

The extent of liability of the signatory is limited to the work described above as the subject of this report. For CONSTRUCTION of the installation:

Signature: ..... Date: ..... Name (IN BLOCK LETTERS): .....Constructor

FOR INSPECTION & TESTING

I/We being the person(s) responsible for the inspection & testing of the electrical installation (as indicated by my/our signatures below), particulars of which are described above, having exercised reasonable skill and care when carrying out the inspection & testing hereby DECLARE that the work for which I/we have been responsible is to the best of my/our knowledge and belief in accordance with IEC 60364 except for the departures, if any, detailed as follows:

Details of departures from IEC 60364 (clauses to be inserted):

The extent of liability of the signatory is limited to the work described above as the subject of this report. For INSPECTION AND TESTING of the installation:

Signature: ..... Date: ..... Name (IN BLOCKLETTERS): ..... Inspector.

NEXT INSPECTION

I/We the designer(s), recommend that this installation is further inspected and tested after an interval of not more than.....years/months.

PARTICULARS OF SIGNATORIES TO THE ELECTRICAL INSTALLATION VERIFICATI ON REPORT

Designer (No 1)

Name: ..... Company: .....

Address: ..... Postcode: ..... Tel No: .....

..... …….

Designer (No 2) (if applicable)

Name: ..... Company: .....

Address: ..... Postcode: ..... Tel No: .....

..... ……

Constructor

Name: ..... Company: .....

Address: ..... Postcode: ..... Tel No: .....

..... ……

Inspector

Name: ..... Company: .....

Address: ..... Postcode: ..... Tel No: .....

..... …….

SUPPLY CHARACTERISTICS AND EARTHING ARRANGEMENTS - Tick boxes and enter details, as appropriate

Earthing arrangements	**Number and type of live conductors**	**Nature of supply parameters**	**Supply protective device characteristics**
TN-C TN-S TN-C-S TT IT	a.c ☐ d.c ☐ 1-phase, ☐ 2 pole ☐ 2-wire 2-phase, ☐ 3 pole ☐ 3-wire 3-phase. ☐ other 3-wire 3-phase. 4-wire	Nominal voltage. U/U_0 (1) ……...V Nominal frequency,f(1)..Hz Prospective fault current I_{pf} (2)……..kA External loop impedance, Z_e (2)……..Ω (Note: (1) by enquiry, (2) by enquiry calculation or measurement)	Type: Rated current: A
Alternative ☐ Source of supply (to be detailed on Attached schedules)			

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Table D-1 (*Concluded*)

PARTICULARS OF INSTALLATION REFERRED TO IN THE REPORT - Tick boxes and enter details, as appropriate	
Means of Earthing Supplier's Facility Installation	**Maximum demand** Maximum demand (load)……..kVA/A Delete as appropriate
Earth Electrode	**Details of installation earth electrode** (*where applicable*) Type (e.g. rod(s), tape etc)……Electrode resistance to earth……..Ω Location……
Main Protective conductors Earthing conductor: Material……. csa……mm^2 continuity and connection verified ☐ Main protective bonding Conductors: Material……..... csa…….. mm^2 continuity and connection ☐	
Main switch or circuit breaker Type and No. of poles……current rating……A Voltage Rating……V Location……..…….. Fuse rating or setting……A Rated residual operating current $I_{\Delta n}$ = ……mA, and operating time of……..ms(at $I_{\Delta n)}$ (applicable only where an RCD is suitable and used as a main circuit-breaker)	
RECOMMENDATIONS RELATING TO EXISTING INSTALLATION - (in the case of an addition or alteration *see* 61.4.2):	
SCHEDULES The attached schedules are part of this document and this report is valid only when they are attached to it……Schedules of inspections and……..Schedules of test results are attached. (Enter quantities of schedules attached)	

Table D-2 Electrical Installation Conditioning Report (Existing Installation)

ELECTRICAL INSTALLATION CONDITION REPORT (existing installations)
Section A. Details of the client person ordering the report **Name: …….** **Address: ……..** **…….**
Section B. Reason for producing this report. **Date(s) on which inspection and testing was carried out……**
Section C. Details of the installation which is the subject of this report **Occupier: …..……..** **Address: ……..... ☐** **Description of premises (tick as appropriate)** **Domestic ☐ Commercial ☐ Industrial ☐ Other (include brief description)… ☐**…….. **Estimated age of wiring system……..years** **Evidence of additions/alterations Yes No ☐ Not apparent ☐ If yes, estimate age…..years** **Installation records available? Yes No ☐ Date of last inspection……..(date)**
Section D. Extent and limitations of inspection and testing **Extent of the electrical installation covered by this report (see 62.1.4)** **Agreed limitations including the reasons (see 62.1.5)……..** **Agreed with: …….** **Operational limitations including the reasons (see page no……)……** **……..** **The inspection and testing detailed in this report and accompanying schedules have been carried out in accordance with IEC 60364.** **It should be noted that cables concealed within trunking and conduits, under floors and generally within the fabric of the building or underground, have not been inspected unless specifically agreed between the client and inspector prior to the inspection.**

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Table D-2 (*Continued*)

<table>
<tr><td colspan="4">Section E. Summary of the condition of the installation
General condition of the installation (in terms of electrical safety)…….
Overall assessment of the installation in terms of its suitability for continued use
SATISFACTORY/UNSATISFACTORY* (Delete as appropriate)
*An unsatisfactory assessment indicates that dangerous and/or potentially dangerous conditions have been identified.</td></tr>
<tr><td colspan="4">Section F. Recommendations
Where the overall assessment of the suitability of the installation for continued use above is stated as
UNSATISFACTORY, I/we recommend that any observations classified as ‘Danger present’ (Code C1) or ‘Potentially dangerous’ (Code C2) are acted upon as a matter of urgency.
Investigation without delay is recommended for observations identified as ‘Requiring further investigation’.
Observations classified as Improvement recommended (Code C3) should be given due consideration.
Subject to the necessary remedial action being taken, 1/we recommend that the installation is further inspected and tested by……(date)</td></tr>
<tr><td colspan="4">Section G. Declaration
I/We, being the person(s) responsible for the inspection and testing of the electrical installation (as indicated by my/our signatures below), particulars of which are described above, having exercised reasonable skill and care when carrying out the inspection and testing, hereby declare that the information in this report, including the observations and the attached schedules, provides an accurate assessment of the condition of the electrical installation taking into account the stated extent and limitations in section D of this report.</td></tr>
<tr><td colspan="2">INSPECTED AND TESTED BY
Name (Capitals)……
Signature……...
For/on behalf of……
Position……
Address……
Date……..</td><td colspan="2">REPORT AUTHORISED FOR ISSUE BY
Name (Capitals) ……
Signature……
For/on behalf of……
Position……..
Address……..
Date……</td></tr>
<tr><td colspan="4">Section H. Schedule(s)
……. Schedule(s) of inspection and…….. Schedule(s) of test results are attached.
The attached schedule(s) are part of this document and this report is valid only when they are attached to it.</td></tr>
<tr><td colspan="4">Section I. Supply characteristics and earthing arrangements</td></tr>
<tr><td>Earthing arrangements</td><td>Number and type of live conductors</td><td>Nature of supply parameters</td><td>Supply protective device</td></tr>
<tr><td rowspan="5">TN-C

TN-S

TN-C-S

TT

IT</td><td>a.c. ☐ d.c. ☐
1-phase ☐ 2-pole ☐
2-wire
2-phase ☐ 3-pole ☐
3-wire
3-phase ☐ other ☐
3-wire
3-phase ☐ other ☐
4-wire</td><td rowspan="5">Nominal voltage, U/U₀ (1)……..v
Nominal frequency, f (1)…….Hz
Prospective fault current, I_{pf} (2)...kA
External loop impedance, Z_e (2)...Ω
(Note: (1) by enquiry,(2) by enquiry, calculation or measurement)</td><td rowspan="5">Type……
Rated current…..A</td></tr>
<tr><td>Confirmation of supply polarity ☐</td></tr>
<tr><td colspan="4">Alternative source of supply (as detailed an attached schedule)</td></tr>
<tr><td colspan="4">Section J. Particulars of installation referred to in report</td></tr>
</table>

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Table D-2 (*Concluded*)

Means of earthing **Supplier's facility** ☐ **Installation earth electrode** ☐		**Details of installation earth electrode (where applicable)** **Type……** **Location……** **Resistance to earth……Ω**	
Section K. Main protective conductors			
Earthing conductor	**Material**	**Csa……..mm²**	**Connection/continuity verified** ☐
Main protective bonding conductor	**Material**	**Csa……..mm²**	**Connection/continuity verified** ☐
To incoming Water Service	**To incoming gas service**	**To incoming oil service**	**To structural steel**
To lighting protection	**To other incoming Service(s) Specify…….**		
Section L Main switch/switch-fuse/circuit breaker/RCD			
Location…….. **Type) ……..** **No of poles ……**	**Current rating …….A** **Voltage rating……..V**	**If RCD main switch** **Rated residual operating current ($I_{\Delta n}$)…… mA** **Rated time delay ……..ms** **Measured operating time (at ($I_{\Delta n}$)…….ms**	
Section M. Observations **Referring to the attached schedules of inspection and test results, and subject to the limitations specified at the** *Extent and limitations of the inspection and testing section* **No remedial action is required** ☐ **The following observations are made** ☐			
Observation(s) …….. …… …… …… ……	**Classification code** …… …….. …… …… ……	**Further Investigation required (yes/no)** …… …… …… …… …… ……	
One of the following codes, as appropriate, has been allocated to each of the observations made above to indicate to the person (s) responsible for the installation the degree of urgency for remedial action			
C 1 – Danger present. Risk of injury. Immediate action required			
C 2 – Potentially dangerous – urgent remedial action required			
C 3 – Improvement recommended			

D-1 NOTES FOR THE PERSON PRODUCING THE REPORT: (TABLE D-2)

a) This report should only be used for the reporting on the condition of an existing electrical installation.

b) The report, normally comprising at least six pages, should include schedules of both the inspection and the test results. Additional pages may be included, if necessary. The numbering of each page should be indicated along with the total number of pages.

c) The reason for producing this report, such as change of occupancy or landlord's periodic maintenance, should be clearly identified in the section.

d) The maximum prospective fault current (I_{pf}) recorded should be the greater of either the short-circuit current or the earth fault current.

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e) The elements of the installation covered and not covered by the report should be identified in section D (extent and limitations). These aspects should be agreed with the person ordering the report and other interested parties before the inspection and testing is carried out. Any operational limitations, such as inability to gain access to parts of the installation or an item of equipment, should also be recorded in section D.

f) The summary of condition of the installation in terms of safety should be clearly indicated in section E. Observation(s), if any, should be categorized in section M using the coding **C-1** to **C-3** as appropriate. Any observation as **C-1** or **C-2** classification should result in the overall condition of the installation as unsatisfactory.

g) Where an installation has an alternative source of supply a further schedule of supply characteristics and earthing details based upon Section I of this report should be provided.

h) Where an observation requires further investigation due to an apparent deficiency, owing to the extent or limitations of inspection should be clearly identified and indicated in "Further investigation required" within section M.

j) The due date for next electrical installation condition report should be mentioned in Section F. The interval between inspections should take into account the type and usage of the installation and its overall condition.

k) If the space available for observations in Section M is insufficient, additional pages should be provided as necessary.

m) Wherever practicable, items classified as 'Danger present' (C1) should be attended. Where this is not practical, the owner or user should be given written notification as a matter of urgency.

D-2 GUIDANCE FOR RECIPIENTS (Table D-2) (to be appended to the report)

This report is an important and valuable document and should be retained for future reference.

This report form is for reporting on the condition of an existing electrical installation.

a) The purpose of this condition report is to confirm, so far as reasonably practicable, whether or not the electrical installation is in a satisfactory condition for continued service (*see* section E). The report should identify any damage, deterioration, defects and/or conditions which may give rise to danger (*see* section M).

b) The person ordering the report should keep the original report and the inspector should be provided with a duplicate copy.

c) The original report should be retained in a safe place and be made available to any person inspecting or undertaking work on the electrical installation in the future. If the property is vacated, this report will provide the new owner/occupier with details of the condition of the electrical installation at the time the report was issued.

d) Section D (extent and limitations) should identify fully the extent of the installation covered by this report and any limitations on the inspection and testing. The inspector should have agreed these aspects with the person ordering the report and with other interested parties (licensing authority, insurance company, mortgage provider and the like) before the inspection was carried out.

e) Some operational limitations such as inability to gain access to parts of the installation or an item of equipment encountered during the inspection should be noted under Section D.

f) For items classified in Section M as C1 ("Danger present") indicating that using the installation is risky, it is recommended that a competent person shall undertake the necessary remedial work immediately.

g) For items classified in Section M as C2 ("Potentially dangerous") indicating the possibility of using the installation may prove risky, it is recommended that a competent person shall undertake the necessary remedial work as a matter of urgency.

h) Where an observation requires further investigation due to an apparent deficiency, owing to the extent or limitations of inspection should be clearly identified and indicated in "Further investigation required" within section M.

j) For safety reasons, the electrical installation should be re-inspected at appropriate intervals by a competent person and the recommended date for the next inspection should be stated in Section F of the report under 'Recommendations'.

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D-3 MODEL FORMS FOR INSPECTION OF ELECTRICAL INSTALLATIONS

D-3.1 Model Schedule for Items Requiring Inspection for Initial Verification of an Electrical Installation.

All items inspected in order to confirm compliance with the relevant clauses in the IS 732. The list of items is not exhaustive.

D-3.1.1 *Electrical Intake Equipment*

a) Service cable;
b) Service cut-out/fuse;
c) Meter tails – Distributor;
d) Meter tails – Consumer;
e) Metering equipment; and
f) Isolator.

D-3.1.2 *Parallel or Switched Alternative Sources of Supply*

a) Dedicated earthing arrangement independent to that of the public supply;
b) Presence of adequate arrangements where generator to operate in parallel with the public supply system;
c) Correct connection of generator in parallel;
d) Compatibility of characteristics of means of generation;
e) Means to provide automatic disconnection of generator in the event of loss of public supply system or voltage or frequency deviation beyond declared values;
f) Means to prevent connection of generator in the event of loss of public supply system or voltage or frequency deviation beyond declared values; and
g) Means to isolate generator from the public supply system.

D-3.1.3 *Automatic Disconnection of Supply*

Main earthing/bonding arrangements

a) *Presence and adequacy of:*
    1) Distributor's earthing arrangement or installation earth electrode arrangement;
    2) Earthing conductor and connections;
    3) Main protective bonding conductors and connections; and
    4) Earthing/bonding labels at all appropriate locations.
b) *Accessibility of:*
    1) Earthing conductor connections;
    2) All protective bonding connections; and
    3) FELV – requirements satisfied.

D-3.2 Other Methods of Protection

NOTE — Where any of the methods listed below are employed details should be provided on separate pages.

D-3.2.1 *Basic and Fault Protection*

Where used, confirmation that the requirements are satisfied:

a) SELV,
b) PELV,
c) Double insulation, or
d) Reinforced insulation.

D-3.2.2 *Basic Protection*

a) Insulation of live parts,
b) Barriers or enclosures,

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c) Obstacles, or
d) Placing out of reach.

D-3.2.3 *Fault Protection*

a) Non-conducting location – earth-free local equipotential bonding, and
b) Electrical separation.

D-3.2.4 *Additional Protection*

a) RCDs not exceeding 30 mA as specified; and
b) Supplementary bonding.

D-4 SPECIFIC INSPECTION EXAMPLES

As appropriate to the installation

D-4.1 Distribution Equipment

a) Adequacy of working space/accessibility to equipment;
b) Security of fixing;
c) Insulation of live parts not damaged during erection;
d) Adequacy/security of barriers;
e) Suitability of enclosures for IP and fire ratings;
f) Enclosures not damaged during installation;
g) Presence and effectiveness of obstacles;
h) Placing out of reach;
j) Presence of main switch(es), linked where required;
k) Operation of main switch(es) (functional check);
m) Manual operation of circuit-breakers and RCDs to prove functionality;
n) Confirmation that integral test button/switch causes RCD(s) to trip when operated (functional check);
p) RCD(s) provided for fault protection, where specified;
q) RCD(s) provided for additional protection, where specified;
r) Confirmation over-voltage protection (SPDs) provided where specified;
s) Confirmation of indication that SPD is functional;
t) Presence of RCD quarterly test notice at or near the origin;
u) Presence of diagrams, charts or schedules at or near each distribution board, where required; and
w) Presence of non-standard (mixed) cable colour warning notice at or near the appropriate distribution board, where required.

D.4.2 Presence of Alternative Supply Warning Notice at or Near

a) The origin,
b) The meter position, if remote form origin,
c) The distribution board to which the alternative/additional sources are connected,
e) All points of isolation of ALL sources of supply,
f) Presence of next inspection recommendation label,
g) Presence of other required labelling,
h) Selection of protective device(s) and base(s); correct type and rating,
j) Single-pole protective devices in line conductor only,
k) Protection against mechanical damage where cables enter equipment,
m) Protection against electromagnetic effects where cables enter ferromagnetic enclosures, and
n) Confirmation that all conductor connections, including connections to busbars are correctly located in terminals and are tight and secure.

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D-4.3 Circuits

a) Identification of conductors;
b) Cables correctly supported throughout;
c) Examination of cables for signs of mechanical damage during installation;
d) Examination of insulation of live parts, not damaged during erection;
e) Non-sheathed cables protected by enclosure in conduit, ducting or trunking;
f) Suitability of containment systems (including flexible conduit);
g) Correct temperature rating of cable insulation;
h) Cables correctly terminated in enclosures;
j) Adequacy of cables for current-carrying capacity with regard for the type and nature of installation;
k) Adequacy of protective devices: type and fault current rating for fault protection ;
m) Presence and adequacy of circuit protective conductors;
n) Coordination between conductors and overload protective devices;
p) Wiring systems and cable installation methods/practices with regard to the type and nature of installation and external influences; and
q) Cables concealed under floors, above ceilings, in walls adequately protected against damage by contact with fixings.

D-4.4 Provision of Additional Protection by RCDs Having Residual Rated Operating Current ($I\Delta n$) Not Exceeding 30 mA

a) For circuits used to supply mobile equipment not exceeding 32 A rating for use outdoors in all cases;
b) For all socket-outlets of rating 20 A or less provided for use by ordinary persons unless exempt;
c) For cables concealed in walls at a depth of less than 50 mm;
d) Provision of fire barriers, sealing arrangements so as to minimize the spread of fire;
e) Band II cables segregated/separated from Band I cables; and
f) Cables segregated/separated from non-electrical services.

D-4.5 Termination of Cables at Enclosures

a) Connections under no undue strain;
b) No basic insulation of a conductor visible outside enclosure;
c) Connections of live conductors adequately enclosed;
d) Adequately connected at point of entry to enclosure (glands, bushes etc.);
e) Suitability of circuit accessories for external influences;
f) Circuit accessories not damaged during erection;
g) Single-pole devices for switching in line conductor only;
h) Adequacy of connections, including CPCs, within accessories and fixed and stationary equipment; and
j) Presence, operation and correct location of appropriate devices for isolation and switching.

D-5 ISOLATION AND SWITCHING

D-5.1 Isolators

a) Presence and location of appropriate devices;
b) Capable of being secured in the OFF position;
c) Correct operation verified (functional check);
d) The installation, circuit or part thereof that will be isolated is clearly identified by location and/or durable marking; and
e) Warning label posted in situations where live parts cannot be isolated by the operation of a single device.

D-5.2 Switching Off for Mechanical Maintenance

a) Presence of appropriate devices;

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b) Acceptable location – state if local or remote from equipment in question;
c) Capable of being secured in the Off position;
d) Correct operation verified (functional check); and
e) The circuit or part thereof that will be disconnected clearly identified by location and/or durable marking.

D-5.3 Emergency Switching/Stopping

a) Presence and location of appropriate devices;
b) Readily accessible for operation where danger might occur;
c) Correct operation verified (functional check); and
d) The installation, circuit or part thereof that will be disconnected clearly identified by location and/or durable marking.

D-5.4 Functional Switching

a) Presence and location of appropriate devices; and
b) Correct operation verified (functional check).

D-6 CURRENT–USING EQUIPMENT (PERMANENTLY CONNECTED)

a) Suitability of equipment in terms of IP and fire ratings;
b) Enclosure not damaged/deteriorated during installation so as to impair safety;
c) Suitability for the environment and external influences;
d) Security of fixing;
e) Cable entry holes in ceilings above luminaires, sized or sealed so as to restrict the spread of fire;
f) Provision of under-voltage protection, where specified; and
g) Provision of overload protection, where specified.

D-6.1 Recessed Luminaires (Downlighters)

a) Correct type of lamps fitted; and
b) Installed to minimize build-up of heat by use of “fire rated” fittings, insulation displacement box or similar.

D-7 SPECIAL INSTALLATIONS OR LOCATIONS (*SEE* PART 3 OF THIS CODE)

If any special installations or locations are present, list the particular inspections applied.

D-7.1 Model Inspection Schedule of Items Requiring Inspection for an Existing Electrical Installation

A visual inspection should firstly be made of the external condition of all electrical equipment which is not concealed.

Further detailed inspection, including partial dismantling of equipment as required, should be carried out as agreed with the person ordering the work.

The list of items is not exhaustive.

D-7.2 Electrical Intake Equipment

a) Service cable;
b) Service cut-out/fuse;
c) Meter tails – Distributor;
d) Meter tails – Consumer;
e) Metering equipment; and
f) Isolator.

Where inadequacies in distributor’s equipment are encountered, it is recommended that the person ordering the report informs the appropriate authority.

D-7.3 Presence of Adequate Arrangements for Parallel or Switched Alternative Sources

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D-7.4 Automatic Disconnection of Supply

a) Main earthing/bonding arrangements;
b) Presence of distributor's earthing arrangement or presence of installation earth electrode arrangement;
c) Presence and adequacy of earthing conductor;
d) Main protective earthing conductor connections;
e) Accessibility of earthing conductor connections;
f) Presence and adequacy of main protective bonding conductors;
g) Main protective bonding conductor connections;
h) Accessibility of all protective bonding connections;
j) Provision of earthing/bonding labels at all appropriate locations; and
k) FELV.

D-7.5 Other Methods of Protection

Where any of the methods listed below are employed, details should be provided on separate sheets.

D-7.5.1 *Basic and Fault Protection*

a) SELV;
b) PELV;
c) Double insulation; or
d) Reinforced insulation.

D-7.5.2 *Basic Protection*

a) Insulation of live parts;
b) Barriers or enclosures;
c) Obstacles; and
d) Placing out of reach.

D-7.5.3 *Fault Protection*

a) Non-conducting location – earth-free local equipotential bonding; and
b) Electrical separation.

D-7.5.4 *Additional Protection*

a) RCDs 30 mA or less as specified; and
b) Supplementary bonding.

D-7.6 Specific Inspection Examples

D-7.6.1 *Distribution Equipment*

a) Adequacy of working space/accessibility to equipment;
b) Security of fixing;
c) Condition of insulation of live parts;
d) Adequacy/security of barriers;
e) Condition of enclosure(s) in terms of IP and fire ratings;
f) Enclosure not damaged/deteriorated so as to impair safety;
g) Presence and effectiveness of obstacles;
h) Placing out of reach;
j) Presence of main switch(es), linked where required;
k) Operation of main switch(es) (functional check);
m) Manual operation of circuit-breakers and RCDs to prove disconnection;
n) Confirmation that integral test button/switch causes RCD(s) to trip when operated (functional check);
p) RCD(s) provided for fault protection;

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q) RCD(s) provided for additional protection, where required;
r) Confirmation of indication that over-voltage protection (SPDs) is functional, where installed;
s) Presence of RCD quarterly test notice at or near equipment, where required;
t) Presence of diagrams, charts or schedules at or near equipment, where required;
u) Presence of non-standard (mixed) cable colour warning notice at or near equipment, where required;
v) Presence of alternative supply warning notice at or near equipment, where required;
w) Presence of next inspection recommendation label;
y) Presence of other required labelling (please specify);
z) Examination of protective device(s) and base(s); correct type and rating (no signs of unacceptable thermal damage, arcing or overheating);
aa) Single-pole protective devices in line conductor only;
ab) Protection against mechanical damage where cables enter equipment;
ac) Protection against electromagnetic effects where cables enter ferromagnetic enclosures; and
ad) Confirmation that all conductor connections, including connections to busbars are correctly located in terminals and are tight and secure.

D-7.6.2 *Circuits*

a) Identification of conductors;
b) Cables correctly supported throughout;
c) Condition of cables;
d) Condition of insulation of live parts;
e) Non-sheathed cables protected by enclosure in conduit, ducting or trunking;
f) Suitability of containment systems for continued use (including flexible conduit);
g) Cables correctly terminated in enclosures;
h) Examination of cables for signs of unacceptable thermal or mechanical damage/deterioration;
j) Adequacy of cables for current-carrying capacity with regard for the type and nature of installation;
k) Adequacy of protective devices: type and rated current for fault protection;
m) Presence and adequacy of circuit protective conductors;
n) Coordination between conductors and overload protective devices;
p) Wiring systems and cable installation methods/practices with regard to the type and nature of installation and external influences;
q) Where exposed to direct sunlight, cable of a suitable type; and
r) Cables concealed under floors, above ceilings, in walls adequately protected against damage by contact with fixings.

D-7.6.3 *Provision of Additional Protection by RCDs having Residual Rated Operating Current (IΔn) not Exceeding 30 mA*

a) For circuits used to supply mobile equipment not exceeding 32 A rating for use outdoors in all cases;
b) For all socket-outlets of rating 20 A or less provided for use by ordinary persons unless exempt;
c) For cables concealed in walls at a depth of less than 50 mm;
d) Provision of fire barriers, sealing arrangements and protection against thermal effects;
e) Band II cables segregated/separated from Band I cables;
f) Cables segregated/separated from non-electrical services; and
g) Condition of circuit accessories.

D-7.6.4 *Termination of Cables at Enclosures – Identify/Record Numbers and Locations of Items Inspected*

a) Connections under no undue strain;
b) No basic insulation of a conductor visible outside enclosure;
c) Connections of live conductors adequately enclosed;

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d) Adequately connected at point of entry to enclosure (glands, bushes etc.);
e) Suitability of circuit accessories for external influences;
f) Condition of accessories including socket-outlets, switches and joint boxes;
g) Single-pole devices for switching in line conductor only;
h) Adequacy of connections, including CPCs, within accessories and fixed and stationary equipment;
j) Presence, operation and correct location of appropriate devices for isolation and switching;
k) General condition of wiring systems; and
m) Temperature rating of cable insulation.

D-7.7 Isolation and Switching

D-7.7.1 *Isolators*

a) Presence and condition of appropriate devices;
b) Acceptable location – state if local or remote from equipment in question;
c) Capable of being secured in the OFF position;
d) Correct operation verified;
e) Clearly identified by position and/or durable marking; and
f) Warning label posted in situations where live parts cannot be isolated by the operation of a single device.

D-7.7.2 *Switching Off for Mechanical Maintenance*

a) Presence and condition of appropriate devices;
b) Acceptable location – state if local or remote from equipment in question;
c) Capable of being secured in the OFF position;
d) Correct operation verified; and
e) Clearly identified by position and/or durable marking.

D-7.7.3 *Emergency Switching/Stopping*

a) Presence and condition of appropriate devices;
b) Readily accessible for operation where danger might occur;
c) Correct operation verified; and
d) Clearly identified by position and/or durable marking.

D-7.7.4 *Functional Switching*

a) Presence and condition of appropriate devices; and
b) Correct operation verified.

D-7.8 Current–Using Equipment (Permanently Connected)

a) Condition of equipment in terms of IP and fire ratings;
b) Enclosure not damaged/deteriorated so as to impair safety;
c) Suitability for the environment and external influences;
d) Security of fixing;
e) Cable entry holes in ceiling above luminaires, sized or sealed so as to restrict the spread of fire;
f) Condition and provision of under-voltage protection, where required; and
g) Condition and provision of over-load protection, where required.

D-7.9 Recessed Luminaires (Downlighters)

a) Correct type of lamps fitted;
b) Installed to minimise build-up of heat by use of “fire rated” fittings, insulation displacement box or similar;
c) No signs of overheating to surrounding building fabric; and
d) No signs of overheating to conductors/terminations.

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D-8 MODEL SCHEDULE OF CIRCUIT DETAILS AND TEST RESULTS

Distribution board details
Reference.....
Location .....
Zs..... Ω
Ipf..... kA
Correct supply polarity confirmed (✓ or X) ☐

Details of circuits and/or installed equipment vulnerable to testing
.....
.....
.....
.....

Details of test instruments used
(state serial no or other unique identifier)
Continuity .....
Insulation resistance .....
Earth fault loop impedance.....
RCD.....
Earth electrode resistance: .....

Tested by (Capitals) .....

Signature .....Date: .....

Test results

Circuit number	Circuit description	Circuit details: Conductor details: Standard number	Overcurrent: Type	Overcurrent: Rating (A)	Overcurrent: Breaking Capacity (kA)	Installation Reference Method	Cross sectional area (mm²): Live	Cross sectional area (mm²): cpc	Continuity (Ω) [(R1+R2) or {R2}]: (R1+R2)	Insulation Resistance (MΩ): R2	Insulation Resistance (MΩ): L - L	Polarity(✓ or X): L - E	Zs (Ω)	RCD:	RCD: Sensitivity (IΔn)	RCD: Operating time (ms): @ IΔn	RCD: Operating time (ms): @ 5IΔn	Test Button Operation	Remarks (continue on separate sheet if required)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

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ANNEX E

(*Clause* 4.1.2)

Table E-1 Model Schedule of Circuit Details and Test Results

Recommended maximum intervals between periodic verification (in years)			
Category	**Occupancy type as per NBC of India:2016.**(For detailed description, refer NBC: part 4, fire and life safety, table **7**)	Frequency of periodic verification in years (y) based on height(h) of buildings.	
Group A	Residential	<15 (h)	>15 (h)
A1, A2	Lodging and rooming houses, One- or two- private dwelling	10 (y)	NA
A3, A4	Dormitories, Apartment Houses	10 (y)	5 (y)
A5	Hotels	5 (y)	3 (y)
A6	Starred hotels	2 (y)	
Group B	Educational	<15 (h)	>15 (h)
B1, B2	Schools, all other/training institutions	3 (y)	2 (y)
Group C	Institutional	<10 (h)	>10 (h)
C1	Hospitals and sanatoria (IPD/OPD)	2 (y)	
C2	Custodial institutions	5 (y)	3 (y)
C3	Penal and mental institutions	3 (y)	
Group D	Assembly	<10 (h)	>10 (h)
D1 to D6	Theatre/Cinema, accommodation, temporary and other structures, mixed-assembly and mercantile	3 (y)	2 (y)
D7	UG/elevated mass rapid transit system	2 (y)	
Group E	Business	<10 (h)	> 10 (h)
E1 to E5	Offices, laboratories, clinics, libraries, IT parks, telephone exchange, broadcasting and TV stations	3 (y)	2 (y)
Group F	Mercantile	<15 (h)	>15 (h)
F1, F2	Shops, stores	3 (y)	2 (y)
F3	UG shopping centers &service centers in same building	2 (y)	
Group G	Industrial	Any height	
G1	Low hazard	5 (y)	
G2	Moderate hazard	3 (y)	
G3	High hazard	1 (y)	
Group H	Storage, e.g. warehouses, cold storages, truck and marine terminals	1 (y)	
Group J	Hazardous	1	

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SECTION 18 EARTHING

FOREWORD

Earthing provides safety of human beings, livestock and apparatus against earth faults. Any system is characterized by the type of distribution system, which include types of systems of live conductors and types of system earthing. The different types of earthing systems are also covered under this section of the Code.

1 SCOPE

This section of the code (Part 1/Sec 18) covers general requirements associated with earthing in electrical installations. It is based on IS 3043 and IS 732. Specific requirements for earthing in individual installations are covered in respective parts of the Code.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No./Other publications	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
3043 : 2018	Code of practice for earthing (*second revision*)
IS/IEC 62305-3 : 2010	Protection against lightning: Part 3 Physical damage to structures and life hazard

3 GENERAL REMARKS

NOTES

1 Only a.c. systems is considered in this section.

2 For information on functional earthing system, refer 4.5.4.5.5 of IS 732.

3.1 Basic Purpose of Earth Fault Protection

The occurrence of an earth fault in an installation creates two possible hazards:

a) Firstly, voltages appear between exposed conductive parts and extraneous conductive parts, and if these parts are simultaneously accessible, these voltages constitute a shock hazard, this condition is known as indirect contact.

b) Secondly, the fault current that flows in the phase and protective conductors of the circuit feeding the faulty equipment may be of such a magnitude as to cause an excessive temperature rise in those conductors, thereby creating a fire hazard.

3.2 The protective measure known as protective equipotential bonding and automatic disconnection of the supply is intended to provide a high degree of protection against both hazards. The choice of protective device for disconnection is influenced by the type of system of which the installation is a part, because either:

a) the earth fault loop impedance shall be low enough to allow adequate earth fault current flow to cause an overcurrent protective device (*for example*, a fuse or circuit breaker) in the faulty circuit to operate in a sufficiently short time; or

b) where it is not possible to achieve a low enough earth fault loop impedance, disconnection may be initiated by fitting a residual current device (RCD) of 30 mA rating.

3.3 The subject of earthing covers the problems associated with connection of exposed conductive part of installations to the main earthing terminal of that installation and to achieve automatic disconnection of supply before the fault voltage creates a shock hazard. The terms earth and earthing have been used interchangeably in this Code, to denote a low impedance return path of the fault current. The earth is rarely used as a part of return circuit but is mainly used for fixing the voltage of system neutrals.

3.4 Earthing shall be carried out in accordance with the requirements of Central Electricity Authority Regulations and the relevant regulations of the concerned electricity supply authority.

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3.5 In cases where direct earthing may prove harmful rather than providing safety (*for example*, high frequency and mains frequency coreless induction furnaces), relaxation may be obtained from the competent authority.

3.6 All connections shall be proper as it may result in loss of life or serious injury. It is recommended that the value of any earth fault loop impedance shall be such as to conform to the degree of shock protection desired.

3.7 It is recommended that a drawing showing the earthing system be prepared for each installation.

3.8 No addition to the current-carrying system either temporary or permanent, shall be made, which increases the maximum available earth fault current or its duration. It shall be ascertained that the arrangement of earthing system is capable of carrying the new value of earth fault current.

3.9 No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and the live conductors shall be inserted on any supply system. However, this does not include the switches used for controlling a generator or a transformer or a link for test purposes.

3.10 From the point of safety consideration, the objective is not to attain minimum value of the earth resistance but there shall be adequate co-ordination between the obtainable value of the earth fault loop and setting of the protective devices.

3.11 Independent Earthing

An earthing arrangement may be considered electrically independent of another earthing arrangement if a rise/fall of potential with respect to earth in one earthing arrangement does not cause an unacceptable rise/fall of potential in that of other.

4 DESIGN CONSIDERATIONS

4.1 System Earthing

4.1.1 Earthing of system is designed, primarily, to preserve the security of the system by ensuring that the potential on each conductor is restricted to value consistent with the level of applied insulation. It is equally important that earthing should ensure efficient and fast operation of protective gear, in the case of earth faults.

Commonly used system earthing are TN, TT and IT.

First letter denotes the connection between the power system to earth:

a) T = direct connection of one point to earth;
b) I = all live parts isolated from earth, or one point connected to earth through a high impedance.

Second letter denotes the connection of the exposed-conductive-parts of the installation to earth:

a) T = direct electrical connection of exposed-conductive-parts to earth, independently of the earthing of any other point of the power system;
b) N = direct electrical connection of the exposed-conductive-parts to the earthed point of the power system (in a.c. systems, the earthed point of the power system is, usually, the neutral point or if a neutral point is not available, a line conductor).

Subsequent letter(s) (if any) denotes the arrangement of neutral and protective conductors:

a) S = protective function provided by a conductor separate from the neutral conductor or from the earthed line (or in a.c. systems, earthed phase) conductor.
b) C = neutral and protective functions combined in a single conductor (PEN conductor).

NOTES

1 In TN/TT system, safety is achieved by automatic disconnection of supply.

2 IT system ensures continuity of supply during first fault. It is recommended for application such as hospitals, control system, safety supplies, etc. Monitoring of insulation and rectification of first fault, as quick as possible, is essential.

3 TN system – A system having one or more points of the source of energy directly earthed, the exposed conductive-parts (and extraneous conductive parts) of the installation connected to that point by protective conductors.

4 TN-C system – A system in which neutral and protective conductors are combined in a single conductor throughout the system.

5 TN-S system – A system with separate neutral and protective conductor throughout the system.

6 TN-C-S system – A system in which neutral and protective conductors are combined in a single conductor in part of the system.

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7 TT system – A system with one point of the source of energy directly earthed and the exposed conductive-parts (and extraneous conductive parts) of the installation connected to the earth electrodes, electrically independent of the earth electrodes of the source.

8 IT system – A system having no direct connection between live parts and earth and the exposed conductive parts of the electrical installation earthed independently or collectively.

4.1.2 In a TN/TT system, neutral shall be earthed only at one place except in a TN-C-S system with PME. In a TN-C-S system with PME, combined neutral and PE conductor (called as PEN conductor) shall be earthed at the source, at the distribution and at origin of installation. Neutral shall not be earthed downstream the origin of installation.

NOTES

1 Origin of installation is also called as point of commencement of supply.

2 Distribution means the supply points in between the source and origin of installation.

3 In a.c. systems, the earthed point of the power system is usually the neutral point or if a neutral point is not available, it is through line conductor.

4.2 Equipment Earthing

4.2.1 The objective of equipment earthing is to ensure effective operation of the protection system in the event of leakage current through metal which may attain high value causing danger to life or risk of fire.

4.2.2 The earth fault loop impedance should be such that in case of fault, the protection system isolate the faulty circuit.

4.3 Earthing of Installations in Buildings

4.3.1 Disconnection time for earth fault: The maximum allowed disconnection time (t in seconds) during fault derived from IS 3043 are given in Table 1 below. Figure 7 also can be referred.

Table 1 Maximum Allowed Disconnection Times

(*Clause* 4.3.1)

Sl No.	Prospective Touch Voltage	Condition 1 (DRY)			Condition 2 (WET)		
	U_c (V)	Z_1 (Ω)	I (mA)	t (s)	Z_2 (Ω)	I (mA)	t (s)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	50	1725	29	5.000	925	54	0.470
ii)	110	1535	72	0.360	730	151	0.180
iii)	220	1375	160	0.170	575	383	0.035

NOTES

1 Dry or moist locations, dry skin and significant floor resistance.

2 Wet locations, wet skin and low floor resistance.

4.4 Safety by Protective Equipotential Bonding and Automatic Disconnection of the Supply

4.4.1 The protective measure ensure:

a) during an earth fault, the voltages between exposed conductive parts and extraneous conductive parts in the location is minimized; and

b) rapid disconnection of the faulty circuit.

4.4.2 In order to reduce voltage appearing between exposed and extraneous conductive parts, protective equipotential bonding zones are created by connecting exposed and extraneous conductive parts to the Main earth terminal (MET or earth busbar) of the zone.

4.4.3 An installation may consist of number of zones. For instance, when an installation supplies number of buildings, equipotential bonding is necessary in each building so that each constitutes a zone with a reference point to which the exposed conductive parts of the circuits and extraneous conductive parts in that building are connected. Large buildings shall have several zones with in the building

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4.4.4 Rapid disconnection of the circuit subjected to earth fault is met by limiting value of the earth fault loop impedance of each circuit determined by the type and current rating of the protective device such that disconnection occurs before the prospective touch voltage reaches a harmful value.

4.4.5 It is recommended that the maximum sustained voltage developed under fault conditions between exposed metal required to be earthed and the consumer's earth terminal shall not exceed 50 V rms.

4.5 TN System (Earth Fault Loop Impedance is important for Automatic Disconnection of supply during Earth Fault)

4.5.1 The characteristics of the protective devices and the cross-sectional area of conductors shall be chosen such that if a fault of negligible impedance occurs anywhere between a phase conductor and a protective conductor or exposed conductive part, automatic disconnection of the supply occurs within the minimum possible safe time. The time of operation depends on the magnitude of the contact potential. Generally, 65 V may be cleared within 10 s and voltages of the order of 240 V and above shall be cleared instantaneously

This requirement is met if:

$$Z_s \times I_a < U_o$$

Where,

Z_s = fault loop impedance,

I_a = current ensuring the automatic operation of disconnecting device, and

U_o = conventional voltage limits.

4.5.2 In order to provide thermal protection to the protective conductor and considering the requirements of IS 732, automatic disconnection of supply shall take place if the fault loop impedance is

$$Z_s(m) \leq \frac{2}{3} \times \frac{U_o}{I_a}$$

Where,

$Z_s(m)$ = the measured impedance of the fault current loop starting and ending at the point of fault (Ω);

U_o = the line conductor to earthed neutral voltage (V); and

I_a = the current causing the automatic operation of the protective device within the stipulated disconnection time.

4.5.3 Where the measured value of the fault loop impedance exceeds $2 \times U_o / 3 \times I_a$, precise assessment of compliance with IS 732 is recommended.

4.5.4 *Recommended Maximum Earth Fault Loop Impedance Values for MCB's - $Z_s(m)$ (see Table 2)*

Table 2 Maximum Allowed Earth Fault Loop Impedance for MCB's

(*Clause* 4.5.4)

MCB rating in Amps	6	10	16	20	25	32	40	50	63	80	100	125
Z_S in Ω (Type B MCB)	5.11	3.07	1.92	1.53	1.23	0.96	0.77	0.61	0.49	0.38	0.31	0.25
Z_S in Ω (Type C MCB)	2.56	1.53	0.96	0.77	0.61	0.48	0.38	0.31	0.24	0.19	0.15	0.12
Z_S in Ω (Type D MCB)	1.28	0.77	0.48	0.38	0.31	0.24	0.19	0.15	0.12	0.10	0.08	0.06

4.6 TT system (Resistance of earthing system is important for automatic disconnection of supply during earth fault)

All exposed conductive parts collectively protected by the same protective device shall be interconnected by protective conductors with an earth electrode Where several protective devices are used in series, the requirement applies separately to all the exposed conductive parts protected by each device. For compliance with the requirement, the following shall be fulfilled:

$$R_A \times I_a < U_C$$

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Where,

R_A = resistance of the earthed system for exposed conductive parts,

I_a = operating currents of the disconnecting series device or settings of shunt relays, and

U_c = conventional voltage limit (50 V in general case and 32 V in case of relays with time lag).

NOTES

1 Series disconnecting devices or shunt relays (for example, RCCB/ELCB/CBCT and ELR) shall be used for earth fault protection.

2 The maximum allowed residual current of these protective device is 30 mA for human protection and 300 mA for protection against fire due to earth fault.

4.6.1 Maximum earth electrode resistance in TT system protected by RCD's for limiting touch voltage < 50 V (for more information, refer Table 14 and 24.4 of IS 3043) is:

a) 30 mA RCD = 1666 Ω

b) 300 mA RCD = 166 Ω

4.7 IT System

The live parts of IT power system isolated from earth or one point is connected to earth through an impedance. The exposed-conductive-parts of the electrical installation are earthed independently or collectively.

In the event of a single fault to an exposed conductive part or to earth, the fault current is low and automatic disconnection may not take place provided **4.7.1** is fulfilled. In the event of two faults existing simultaneously, provisions shall be taken to prevent risk of harmful pathophysiological effects to person in contact with simultaneously accessible exposed conductive parts.

4.7.1 Exposed conductive parts shall be earthed individually, in groups, or collectively. The following condition shall be fulfilled:

$$R_A \times \Delta I_d \leq 50 \text{ V}$$

Where,

R_A is the sum of the resistance in Ω of the earth electrode and protective conductor for the exposed conductive parts.

I_d is the fault current in A of the first fault of negligible impedance between a line conductor and an exposed conductive part. The value of I_d takes account of leakage currents and the total earthing impedance of the electrical installation.

4.7.2 If IT system is used for continuity of supply, an insulation monitoring device (IMD) shall be provided to indicate the occurrence of a first fault from a live part to exposed conductive parts or to earth. This device shall initiate an audible and/or visual signal which shall continue as long as the fault persists. It is recommended that first fault is eliminated with the shortest delay.

NOTE — For details on IT system, refer 4.2.11.6 of IS 732 and Fig. 6.

4.8 Selection of Devices for Automatic Disconnection of Supply

In general, all circuits are provided with overcurrent protection arrangement. If low earth fault loop impedance causes devices to operate within the specified times (that is, sufficient current flows in earth under fault conditions), such devices may be used for automatic disconnection of supply. If the earth fault loop impedance does not permit the overcurrent protective devices to automatically disconnect the supply under earth through fault conditions, actions shall be taken to reduce impedance by the use of protective multiple earthing system (PME).

4.9 Exposed conductive parts to be earthed are:

a) all metallic parts associated with wiring system (other than current-carrying parts) including cable sheaths and armour, conduit, ducting, trunking, boxes and catenary wires etc.;

b) the exposed metallic parts of all Class I fixed and portable current-using equipment; and

c) the exposed metallic parts of transformers used in the installation other than integral part of equipment.

NOTE — Exposed conductive parts which are not accessible (due to their small dimensions or disposition) by human body (that is, a human body surface not exceeding 50 mm × 50 mm) may not be earthed provided the connection of those parts to a protective conductor cannot readily be made and reliably maintained. *For examples*, screws and nameplate, cable clips and lamp caps etc.

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4.10 Extraneous conductive parts to be earthed are*:*

a) metallic pipes supplying services into the building (*for example*, gas, water etc.);
b) metallic central heating and air-conditioning systems;
c) structural extraneous conductive parts, if accessible in normal use;
d) metallic reinforcements of constructional reinforced concrete to the extent possible; and
e) lighting protection system as per IS/IEC 62305-3.

4.11 Minimum Cross-sectional Areas of Protective Conductors

The cross-sectional area of every protective conductor shall satisfy the requirements for automatic disconnection of supply and shall be capable of withstanding mechanical and thermal stresses caused by the prospective fault current.

NOTE — For sizing of protective conductors, refer 5.4.3 of IS 732.

4.12 Types of Protective Conductors

Protective conductors may consist of one or more of the following:

a) conductors in multicore cables;
b) insulated or bare conductors in a common enclosure with live conductors;
c) fixed installed bare or insulated conductors; and
d) metallic cable sheath, cable screen, cable armour, wirebraid, concentric conductor, metallic conduit, provided that electrical continuity is assured by construction or by suitable connection to ensure protection against mechanical, chemical or electrochemical deterioration.

NOTE — Where overcurrent protective devices are used for protection against electric shock, the protective conductor shall be incorporated in the same wiring system as the live conductors shall be located in proximity.

4.13 Following metal parts are not permitted for use as protective earthing conductors or as protective bonding conductors:

a) metallic water pipes;
b) metallic pipes containing potentially flammable materials such as gases, liquids, powder;
c) constructional parts subject to mechanical stress in normal service;
d) flexible or pliable metal conduits, unless designed for that purpose;
e) flexible metal parts; and
f) support wires; cable trays and cable ladders.

NOTE — Protective conductor may include a protective bonding conductor, a protective earthing conductor or an earthing conductor when used for protection against electric shock.

4.14 Electrical Continuity of Protective Conductors

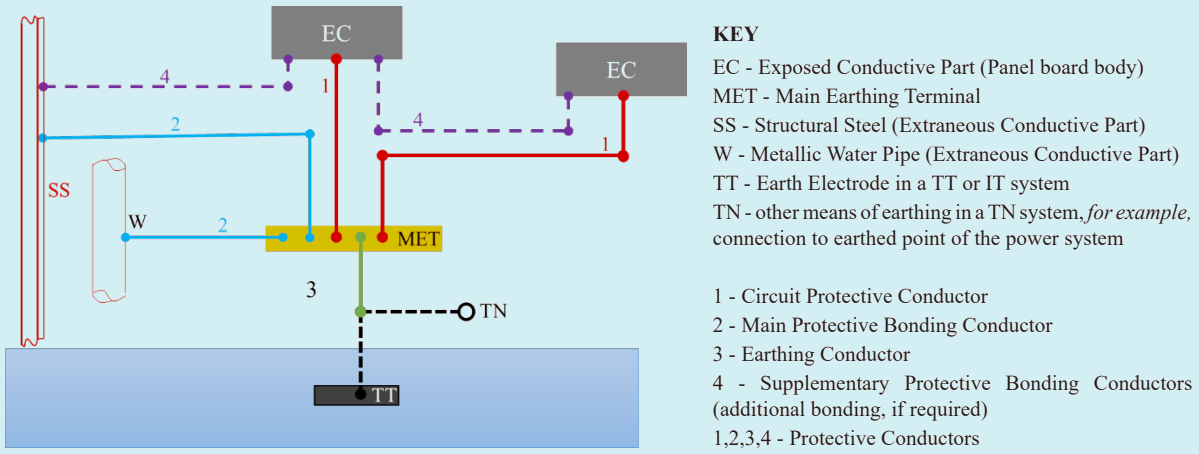
Protective conductors shall be suitably protected against mechanical damage, chemical or electrochemical deterioration, electrodynamic forces and thermodynamic forces. All connections (*for example*, screwed connections, clamp connectors etc.) between protective conductors or between a protective conductor and other equipments shall provide durable electrical continuity and adequate mechanical strength. Screws for connecting protective conductors shall not be used for any other purpose. Joints shall not be soldered.

NOTE — All electrical connections shall have satisfactory thermal capacity and mechanical strength to withstand stresses which may occur in the conductor or in the cable/enclosure with the largest cross-sectional area.

4.15 Protective Equipotential Bonding

Protective equipotential bonding is through connecting extraneous conductive parts in a building to the main earthing terminal of the installation by protective bonding conductors. Where such conductive parts originate outside the building, they shall be bonded near their entry point within the building.

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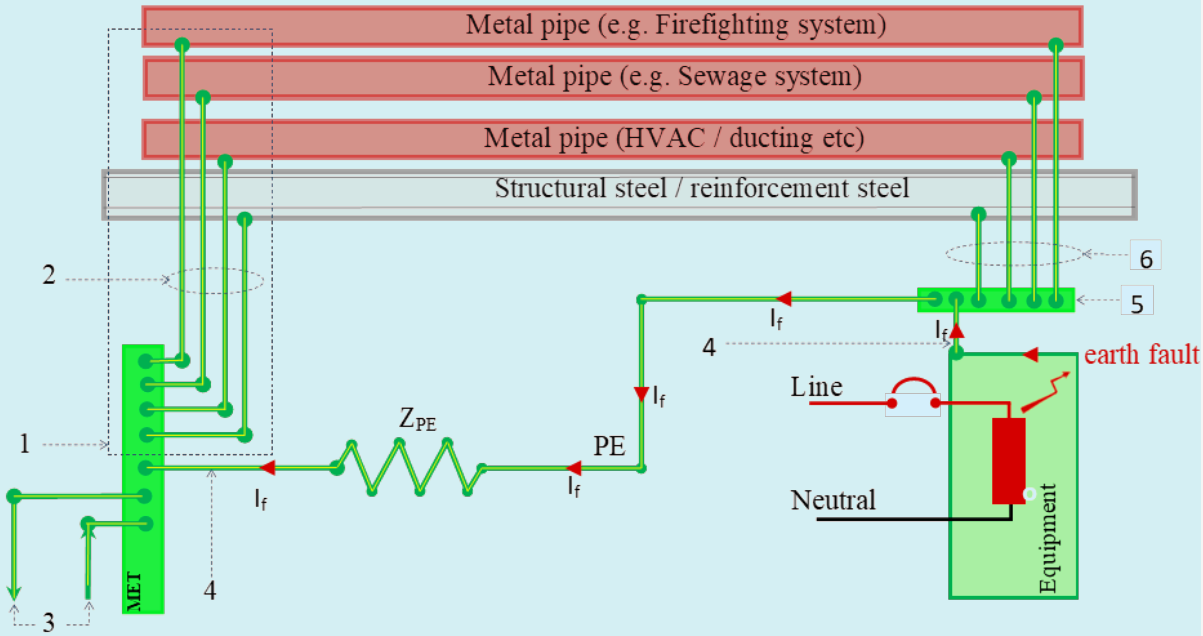


KEY

EC - Exposed Conductive Part (Panel board body)
MET - Main Earthing Terminal
SS - Structural Steel (Extraneous Conductive Part)
W - Metallic Water Pipe (Extraneous Conductive Part)
TT - Earth Electrode in a TT or IT system
TN - other means of earthing in a TN system, *for example,* connection to earthed point of the power system

1 - Circuit Protective Conductor
2 - Main Protective Bonding Conductor
3 - Earthing Conductor
4 - Supplementary Protective Bonding Conductors (additional bonding, if required)
1,2,3,4 - Protective Conductors

FIG. 1 ILLUSTRATION OF EARTHING AND PROTECTIVE CONDUCTORS



1. Main equipotential bonding (connection between MET and extraneous conductive parts).
2. Main equipotential bonding conductor (individual connection, no looping). In case of large number of extraneous conductive parts, an earthing terminal can be located near the extraneous conductive parts for individual connection to these parts and a common connection from this earthing terminal to MET. Suitable indications shall be made to every connection of equipotential bonding conductor to avoid accidental disconnections.
3. Earthing conductor. (Connects MET & earthed point of the source in TN system or MET & earth electrode in case of TT / IT system). One connection from MET is also necessary to LPS (if installed).
4. Protective earthing by Protective Earthing conductor (PE).
5. Supplementary equipotential bonding terminal (SEBT) (to re duce touch voltage <50 V).
6. Supplementary equipotential bonding conductor.

FIG. 2 MAIN AND ADDITIONAL PROTECTIVE EQUIPOTENTIAL BONDING

4.16 Examples of earth electrodes which may be used are:

a) concrete-embedded foundation earth electrode;

NOTE — For more information, see Annex C.

b) soil-embedded foundation earth electrode;

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c) metallic electrode embedded directly in soil vertically or horizontally (*for example*, rods, wires, tapes, pipes or plates etc.);

d) metal sheath and other metal coverings of cables as per requirements;

e) other suitable metallic underground (*for example*, pipes); and

f) welded metal reinforcement of concrete (except pre-stressed concrete) embedded in the earth.

4.17 While selecting the type and embedded depth of an earth electrode, consideration shall be given to prevent mechanical damage and to minimize the effect of soil drying and freezing.

4.18 Consideration shall be take into account the effect of electrolytic corrosion while using different materials in an earthing arrangement. *For example,* for external conductors connected to a concrete-embedded foundation earth electrode, the connection made from hot-dip galvanized steel shall not be embedded in the soil as galvanised steel earth electrodes in soil are subjected to accelerated corrosion when connected with steel in reinforcement.

4.19 The earthing arrangement shall not rely on a metallic pipe used for flammable liquids or gases as the earth electrode and their buried length shall not be considered when dimensioning the earth electrode.

4.20 Earth electrodes shall not be directly immersed in water of a stream, river, pond, lake etc. Protection against electric shock, as stated in 4.2 of IS 732, shall not be adversely affected by any foreseeable change of the earth electrode resistance (*for example*, due to corrosion, drying, freezing etc.).

4.21 The earthing arrangements of the high voltage supply and low-voltage installation shall also comply with 4.5.2 of IS 732.

4.22 The requirements for earthing arrangements are intended to provide a connection to earth which:

a) is reliable and suitable for installation;

b) can carry earth fault currents and protective conductor currents to earth and withstand thermal, thermo-mechanical and electromechanical stresses;

c) is also suitable for functional requirements, if relevant; and

d) is suitable for external influences (*for example*, mechanical stresses, corrosion etc.).

4.23 The connection of various conductors in an earthing arrangement shall be proper. The connection shall be by exothermic welding, pressure connectors, clamps or other suitable mechanical connectors. Mechanical connectors shall be installed in accordance with the manufacturer's instructions. Where a clamp is used, it shall not damage the electrode or the earthing conductor.

5 EARTHING OF INDUSTRIAL AND COMMERCIAL PREMISE

5.1 Earthing system above 230 V should be designed as a PME system with separate protective conductor (TN-S). Protective multiple earthing system shall be implemented to reduce the earth fault loop impedance and to ensure reliable disconnection of supply during an earth fault by the OCPD. In PME system, neutral of the supply transformer and the non-current carrying metal parts in the system are interconnected by the common earth grid, in addition to the separate protective conductor.

5.2 Hence, IS 3043, recommend TN-S system with PME, where the neutral of the source and exposed conductive parts in the installation are solidly connected to the MET and an earthing grid. In this interconnected system, earth fault current is returned to the neutral, through the interconnected system consisting of the PE conductor and earth grid.

5.3 The disposition of the earth electrodes and the extent and size of earth grid depends upon the disposition of plant electrics. The layout shall ensure that earth continuity resistance is within the acceptable range. Depending upon the disposition of the plant electrics, an optimum number of earth electrodes shall be provided as anchorages for the earth grid.

5.4 Protective Earth (PE) conductor shall run in parallel and proximity to line conductors

5.5 The continuity resistance of the earth return path through the earth grid shall be less than one ohm.

5.6 In case of EHT substations, where ground potential may attain very high values (of the order of 5 kV and above) in the event of an earth fault. The earth grid design shall be based on the acceptable limits of the potential gradient, step and touch potential in the substation area.

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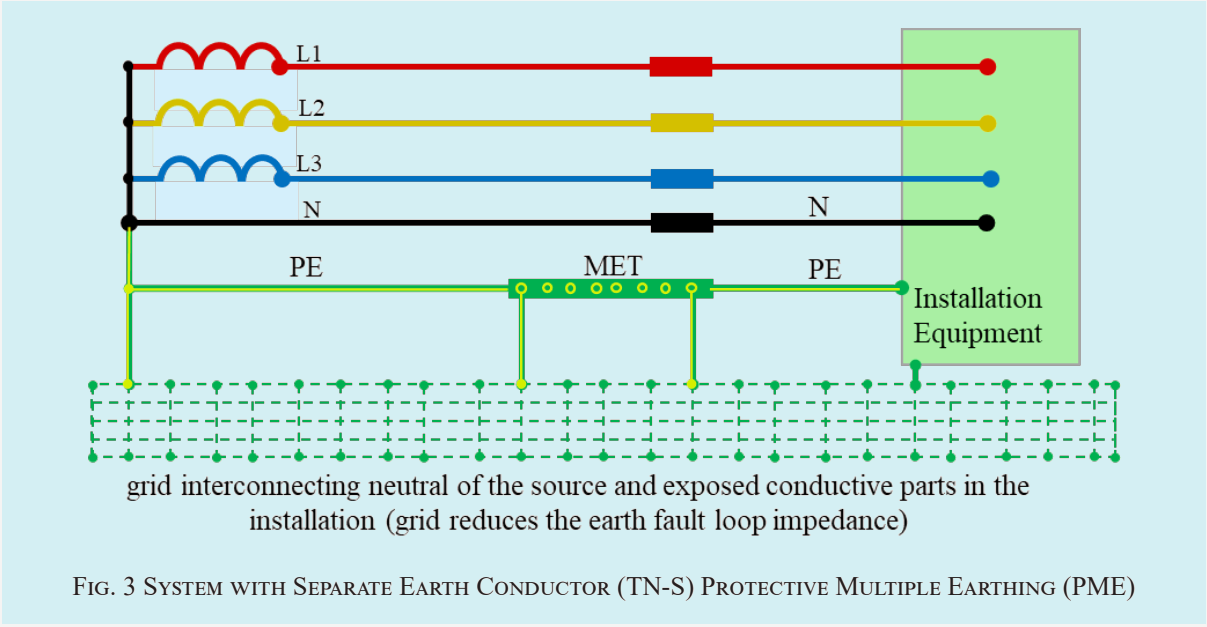


FIG. 3 SYSTEM WITH SEPARATE EARTH CONDUCTOR (TN-S) PROTECTIVE MULTIPLE EARTHING (PME)

6 EARTHING OF LOW VOLTAGE ELECTRIC SUPPLY BY SUPPLIER

6.1 TN-C-S with Protective Multiple Earthing

Commonly used system in low voltage electricity supply system of electricity suppliers is TN-C-S with protective multiple earthed (PME) system (*see* Fig 4). In this system, the neutral and protective conductors of electrical supply undertaking are combined. The PEN conductor referred to as a combined neutral and earth (CNE or PEN) conductor, is earthed at the source and at multiple points. Multiple earthing of the PEN conductor ensures that if the conductor becomes open circuit due to any reason, exposed-conductor parts remain connected to earth. Under such conditions, the supply voltage between the installation line and neutral conductor is substantially reduced.

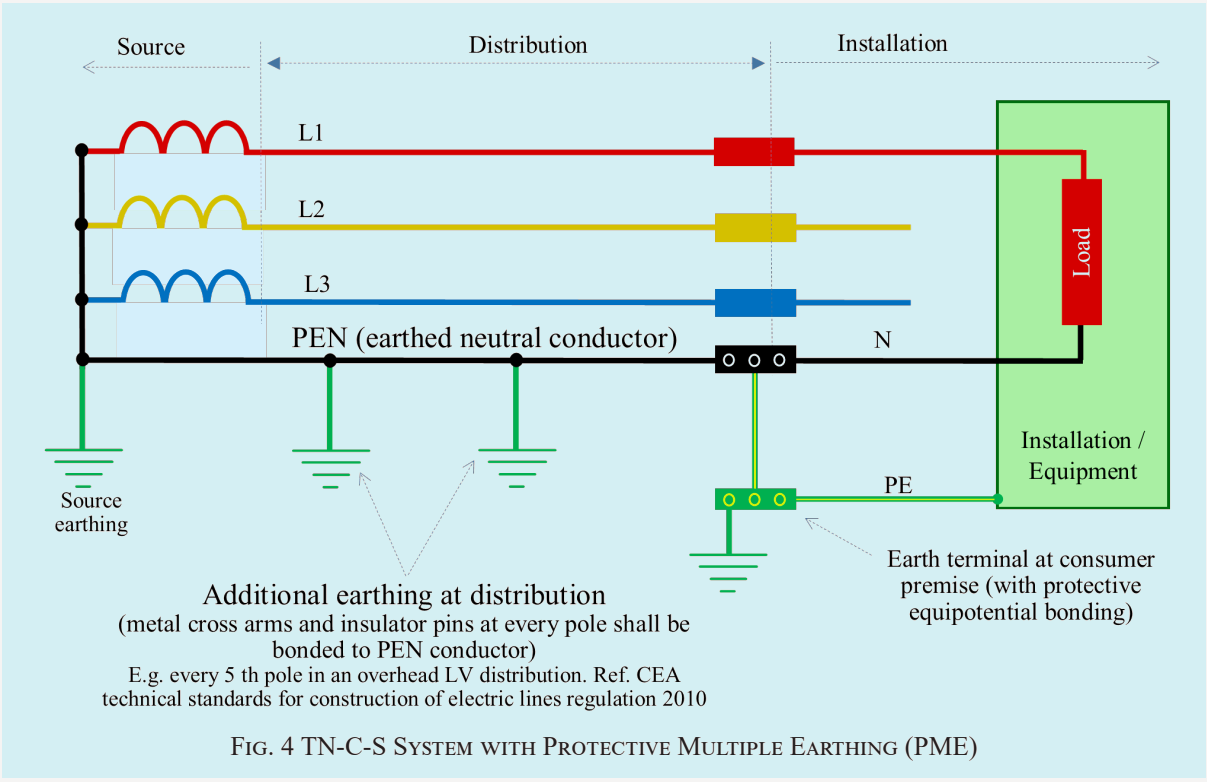


FIG. 4 TN-C-S SYSTEM WITH PROTECTIVE MULTIPLE EARTHING (PME)

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6.2 TT Network

Low voltage electricity supply system of electricity suppliers also uses TT network (*see* Fig. 5). In this system one or more points of the source of energy are directly earthed and the exposed and extraneous conductive parts of the installation are connected to a local earth electrode or electrodes are electrically independent of the source earth. Every consumer installation shall be protected with an RCD of not less than 30 mA for earth fault protection at the origin of installation.

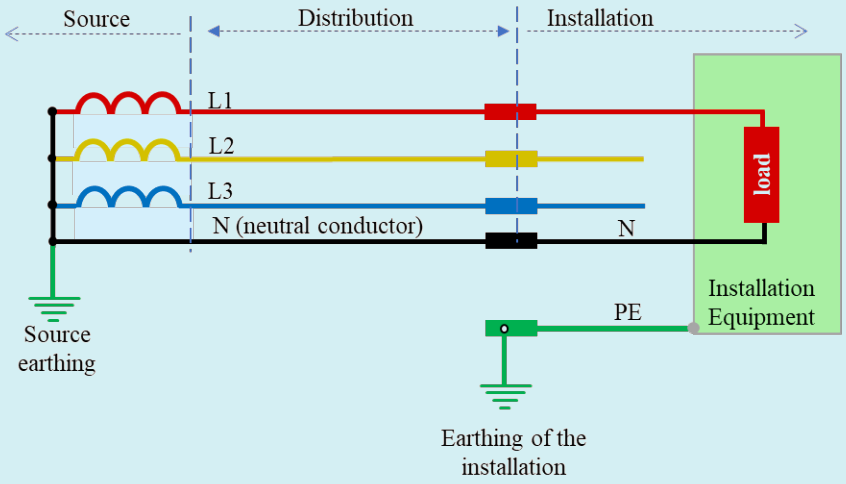


FIG. 5 TT SYSTEM

NOTES

1 In TT system, RCD shall be used for earth fault protection at the origin of installation.

2 Methods to limit the temperory over voltage (power frequency stress voltage) at the consumer premise are explained in Part1/Section 13 of the Code. Suitable measures shall be implemented by the electricty supplier to ensure the maximum allowed temperory over voltages are with in the limits specified in 7.4 and Table 3.

6.3 IT Network

The live parts of IT power system are isolated from earth or one point is connected to earth through an impedance. The exposed-conductive-parts of the electrical installation are earthed independently or collectively.

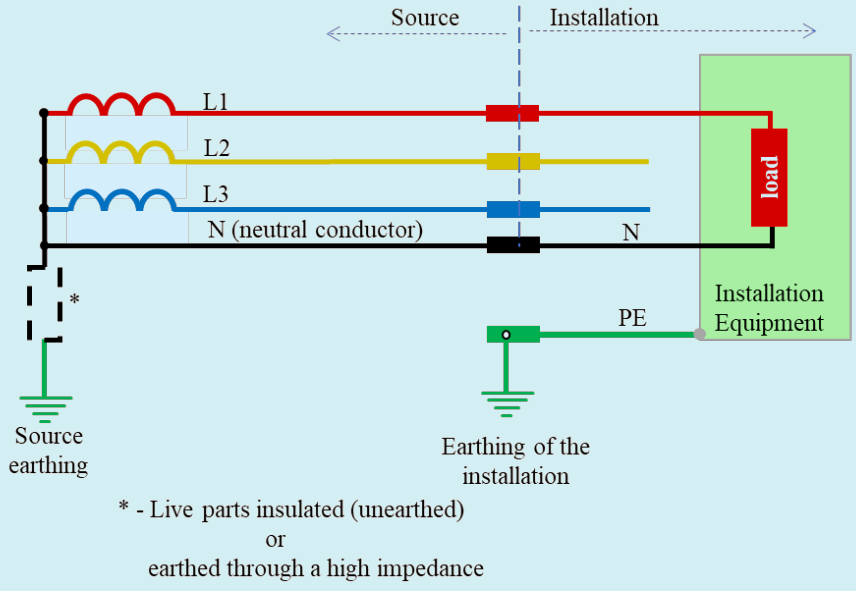


FIG. 6 IT SYSTEM

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7 EARTHING OF SYSTEM EXCEEDING 1 KV

7.1 Design of an earthing system shall take into account the following:

a) data collection (*for example*, earth fault current, fault duration and layout);
b) initial design of the earthing system based on the functional requirements;
c) determine if it is part of a global earthing system;
d) if not part of global earthing system, determine soil characteristics (*for example,* specific soil resistivity of layers);
e) determine the current flowing into earth from the earthing system, based on earth fault current;
f) determine the overall impedance to earth, based on the layout, soil characteristics and parallel earthing systems;
g) determine earth potential rise;
h) determine permissible touch voltage; if the earth potential rise is below the permissible touch voltage and the requirements of Table 3 are fulfilled, the design is adequate;
j) if does not conforms to (h), determine if touch voltages inside and in the vicinity of the earthing system are below the tolerable limits;
k) determine if transferred potentials present a hazard outside or inside the electrical power installation and take suitable actions for mitigation at exposed location; and
m) determine if low-voltage equipment is exposed to excessive stress voltage and take measures for separation of HV and LV earthing systems.

7.2 On fulfilment of criteria as per **7.1**, the design can be refined by repeating the above steps, if necessary. Detailed design is necessary to ensure that all exposed conductive parts, are earthed. Extraneous conductive parts shall be earthed, if appropriate.

NOTE — Flowchart of design process is given in Annex D.

7.3 The structural earth electrode shall be bonded and form part of the earthing system. If earth electrode is not bonded, all safety requirements shall be verfied. Metallic structures with cathodic protection may be separated from the earthing system. Precautions, such as labelling, shall be taken to prevent damage during maintenance work or modifications.

Table 3 Minimum Requirements for Interconnection of Low-voltage and High-voltage Earthing Systems Based on EPR Limits

(*Clause* 7.1 h)

Sl No.	Type of LV System [a,b]	EPR Requirements		
		Touch Voltage	Stress Voltage [c]	
			Fault Duration $t_f < 5$ s	Fault Duration $t_f > 5$ s
(1)	(2)	(3)	(4)	(5)
i)	TT	Not applicable	EPR < 1200 V	EPR < 250 V
ii)	TN	EPR < F . U_{TP} [d e]	EPR < 1200 V	EPR < 250 V

[a] For LV system, *see* IS 732.

[b] For telecommunication equipment, ITU recommendations shall be followed.

[c] Limit may be increased if appropriate LV equipment is installed or EPR may be replaced by local potential differences based on measurements or calculations.

[d] If the PEN or neutral conductor of the low-voltage system is connected to earth only at the HV earthing system, the value of F shall be 1.

[e] UTp is derived from Fig. 7

NOTE — The typical value for *F* is 2. Higher values of *F* may be applied where there are additional connections of the PEN conductor to earth. For certain soil structures, the value of *F* may be up to 5. The touch voltage can exceed 50 percent of the EPR where the top layer has higher resistivity.

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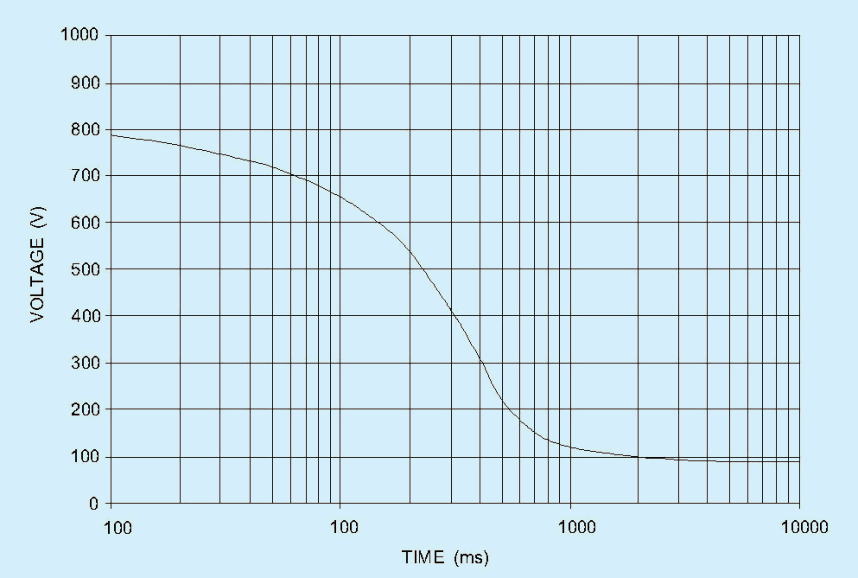


FIG. 7 PERMISSIBLE TOUCH VOLTAGE U_{TP}

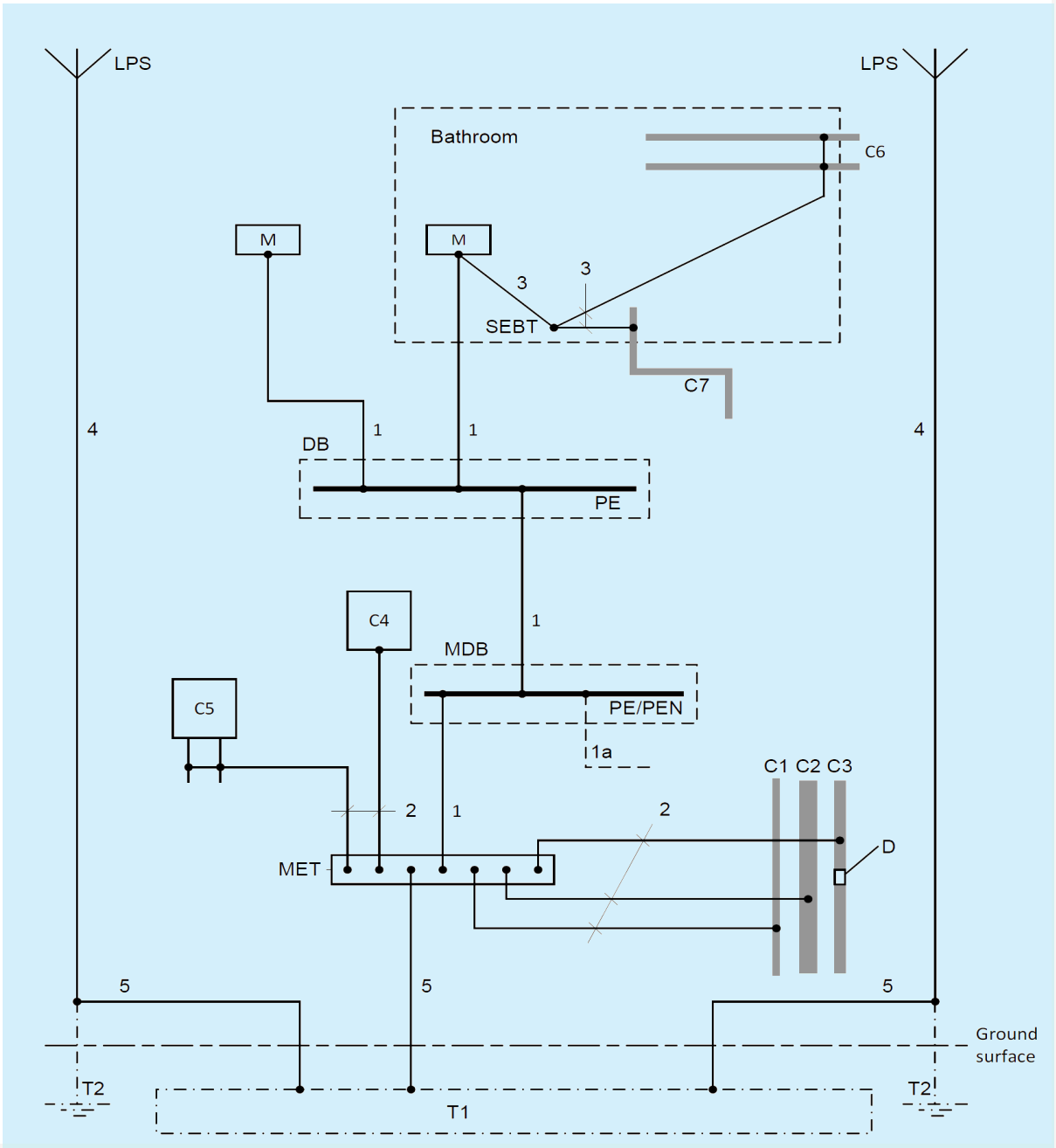
7.4 Protection of low-voltage installations against temporary over-voltages due to earth faults in the high-voltage system and due to faults in the low-voltage system shall be carried out as per **4.5.2** of IS 732.

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ANNEX A

(*Clauses* 3,4.11 *and* 4.23)

EXAMPLE OF EARTHING ARRANGEMENTS AND PROTECTIVE CONDUCTORS



Key

C	Extraneous-Conductive-part
C1	Water pipe, metal from outside
C2	Waste water pipe, metal from outside
C3	Gas pipe with insulating insert, metal from outside
C4	Air-conditioning
C5	Heating system

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C6	Water pipe, metal for example, in a bathroom
C7	Waste water pipe, metal for example, in a room
MDB	Main Distribution Board
DB	Distribution Board
MET	Main Earth Terminal
SEBT	Supplementary Equipotential Bonding terminal
T1	Concrete-embedded foundation earth electrode or soil-embedded foundation earth electrode
T2	Earth electrode for LPS if necessary
LPS	Lightning Protection system (if any)
PE	PE terminal(s) in the distribution board
PE/PEN	PE/PEN terminal(s) in the main distribution board
M	Exposed-conductive part
1	Protective Earthing conductor (PE)
1a	Protective Conductor, or PEN conductor, if any, from supplying network
2	Protective bonding conductor for connection to the main earthing terminal
3	Protective bonding conductor for supplementary bonding
4	Down conductor of a lightning protection system (LPS) if any
5	Earthing conductor

FIG. A-1 EXAMPLES OF EARTHING ARRANGEMENTS FOR FOUNDATION EARTH ELECTRODE, PROTECTIVE CONDUCTORS AND PROTECTIVE BONDING CONDUCTOR

ANNEX B

(*Clause* 5.3)

MINIMUM SIZE OF COMMONLY USED EARTH ELECTRODES, EMBEDDED IN SOIL OR CONCRETE USED TO PREVENT CORROSION AND PROVIDE MECHANICAL STRENGTH

Table B-1 Minimum Size of commonly used Earth Electrodes, embedded in Soil or Concrete used to prevent Corrosion and provide Mechanical Strength

Sl no.	Material and Surface	Shape	Diameter mm	Cross Sectional Area mm^2	Thickness mm	Weight of Coating g/m^2	Thickness of Coating/ Sheating µm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Steel embedded in concrete (bare, hot galvanized or stainless)	Round wire	10				
ii)		Solid tape or strip		75	3		
iii)	Steel hot-dip galvanized[c]	Strip[b] or shaped strip/ plate – solid plate – Lattice plate		90	3	500	63
iv)		Round rod installed vertically	16			350	45
v)		Round wire installed horizontally	10			350	45
vi)		Pipe	25		2	350	45
vii)		Stranded (embedded in concrete)		70			
viii)		Cross profile installed vertically		(290)	3		

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Table B-1 *(Concluded)*

Sl no.	Material and Surface	Shape	Diameter mm	Cross Sectional Area mm^2	Thickness mm	Weight of Coating g/m^2	Thickness of Coating/ Sheating µm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ix)	Steel copper sheathed	Round rod installed vertically	(15)				2000
x)	Steel with electro-deposited copper coating	Round rod installed vertically	14				250[e]
xi)		Round wire installed horizontally	(8)				70
xii)		Strip installed horizontally		90	3		70
xiii)	Stainless Steel[a]	Strip[b] or shaped strip/ plate		90	3		
xiv)		Round rod installed vertically	16				
xv)		Round wire installed horizontally	10				
xvi)		Pipe	25		2		
xvii)	Copper	Strip		50	2		
xviii)		Round wire installed horizontally		(25)[d] 50			
xix)		Round rod installed vertically	(12) 15				
xx)		Stranded wire	1.7 for individual strands of wire	(25)[d] 50			
xxi)		Pipe[e]	20		2		
xxii)		Solid plate			(1.5) 2		
xxiii)		Lattice plate			2		

[a] Chromium ≥16 percent, nickel ≥5 percent, molybdenum ≥2 percent, carbon ≤0.08 percent.

[b] As rolled strip or slit strip with rounded edges.

[c] The coating shall be smooth, continuous and free from flux stains.

[d] The risk of corrosion and mechanical damage is extremely low, 16 mm^2 is recommended.

[e] This thickness is provided to withstand mechanical damage of copper coating during the installation process. It may be reduced to not less than 100 µm where special precautions are taken to avoid mechanical damage of copper during the installation process (for example, drilling holes or special protective tips) as per manufacturer's instruction.

NOTES

1 Specified values are applicable for protection against electric shock and lightning protection. Values specified in bracket are applicable for protection against electric shock only.

2 Bare steel is not recommended in soil due to high corrosion resistance.

3 The behaviour of a galvanized layer on steel in concrete is complex and under certain conditions, can cause damage to the concrete due to its dissimilar properties (also *see* IS 732).

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ANNEX C

(*Clause* 4.16)

ERECTION OF CONCRETE-EMBEDDED FOUNDATION EARTH ELECTRODES

C-1 General

Concrete used for the foundations of buildings, usually, has a large contact area with the soil as well as is conductive. Therefore, bare metal electrodes completely embedded in concrete can be used for earthing purposes, unless the concrete is isolated from the soil by use of a special thermal insulation or other measures. Due to chemical and physical effects, bare or hot-dip galvanized steel and other metals embedded in concrete to a depth of more than 5 cm are highly protected against corrosion, usually, for the service life of the building.

Wherever possible, the conductive effects of the reinforcement of the building may also be taken into consideration. The production of a concrete-embedded foundation earth electrode during the erection of the building may be an economical solution as:

a) it does not necessitate additional excavation works;
b) it is erected at a depth free from negative influences of seasonal weather conditions;
c) it provides a good contact area with soil;
d) it extends over practically all of the building's foundation surface resulting in the minimum earth electrode impedance;
e) it provides an optimal earthing arrangement for lightning protection system purposes; and
f) it can be used as an earth electrode for the electrical installation of the construction site from the start of building construction.

Besides the earthing effect, the concrete-embedded foundation earth electrode provides a means for the main protective bonding.

The following requirements and advice for the erection of a concrete-embedded foundation earth electrode apply.

C-2 OTHER CONSIDERATIONS REGARDING THE USE OF CONCRETE-EMBEDDED FOUNDATION EARTH ELECTRODES

If the building foundation is to be completely protected against water seepage/moisture/loss of heat energy by insulating it using non-conductive materials or if the foundation is to use certain insulating measures against water (*for example*, using plastic sheets of more than 0.5 mm thickness) earthing arrangement using the foundation concrete is non-viable. In such cases, the positive effect of metal reinforcement for protective bonding may be used and for earthing purposes, alternate earthing arrangement shall be used (*for example*, an additional concrete-embedded foundation earth electrode below the isolated foundation, an earthing arrangement around the building, a soil-embedded foundation earth electrode etc.).

C-3 CONSTRUCTION OF CONCRETE-EMBEDDED FOUNDATION EARTH ELECTRODES

C-3.1 For concrete foundations without metal reinforcement, the earth electrodes shall be coordinated with the type and dimensions of the foundation. One or more closed ring(s) or rectangles with dimensions upto 20 m and interconnected are preferred.

C-3.2 To avoid embedding of the electrodes in concrete at less than 5 cm depth, suitable measures to ensure depth above ground shall be used. If strips are used as electrodes, they shall be fixed on edge. If reinforcement is available, the wiring shall be fixed at intervals of not more than 5 m. The connections shall be made by exothermic welding, pressure connectors, clamps or other suitable mechanical connectors. Mechanical connectors shall be installed as per manufacturer's instructions. Where a clamp is used, it shall not damage the electrode or the earthing conductor. Connection devices or fittings depending solely on solder shall not be used independently as it does not reliably provide adequate mechanical strength. The use of keyed joints should be avoided.

C-3.3 The wiring of the concrete-embedded foundation earth electrode shall have, at least, one terminal lug for connection to the electrical system of the building either leaving the concrete inside the building to a suitable connection point (*for example*, to the main earthing terminal) or ending at a special connection clamp embedded in concrete of a wall at its surface. At the point of connection, the terminal lug must be accessible for maintenance and measuring purposes.

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For lightning protection and for buildings with special requirements concerning information technology, more than one terminal lug of the foundation earth electrode, for example, for lightning protection system down-conductors, may be needed.

For connections needed outside the foundation concrete going through the soil, corrosion problems for steel wires need to be taken into account (*see* **C-4**). For such connections, it is recommended that they enter the concrete within the building or outside at a suitable above ground level.

C-3.4 For the minimum cross-sectional area of electrodes including terminal lugs, the values mentioned in Annex B applies. Connections shall be proper (*see* **4.21**).

C-3.5 Metal reinforcement of the foundations of the building may be used as an electrode provided it is adequately connected as per **4.23**. For welded connections, the consent of the person responsible for the structural design and analysis of the construction of the building is required. Connections made by a wrapped iron wire are not suitable for protection purposes, but may be sufficient for EMC purposes and for information technology. Prestressed reinforcement shall not be used as an electrode.

C-3.6 The wiring of the electrodes shall not go over joints between different parts of larger foundations. At such places, suitable malleable connectors should be installed outside the concrete to provide the necessary electrical connections.

C-3.7 Concrete-embedded foundation earth electrodes of single foundations (*for example*, for the construction of large halls) should be connected to other parts of the concrete-embedded foundation earth electrode by using suitable earthing conductors. For embedding such connections in the soil, *see* **C-4**.

C-4 POSSIBLE CORROSION PROBLEMS FOR OTHER EARTHED INSTALLATIONS OUTSIDE CONCRETE-EMBEDDED FOUNDATION EARTH ELECTRODES

Ordinary steel (bare or hot-dip galvanized) embedded in concrete results in an electrochemical potential equal to that of copper embedded in the soil. Consequently, there is a probablity of electrochemical corrosion of other connected earthing arrangements made from steel embedded in the soil near the foundation. This effect is prominent in reinforced foundations of large buildings.

Steel electrode shall not be installed directly from foundation concrete into the soil except for electrodes made from stainless steel. In such cases, suitable measures for prefabricated protection against humidity shall be taken. Hot-dip galvanized covering or protection by painting or other similar materials is not sufficient for such purposes. Also, additional earthing arrangements around and near such buildings shall be made from other than hot-dip galvanized steel so as to provide sufficient service life to the earthing arrangement.

C-5 COMPLETION OF CONCRETE-EMBEDDED FOUNDATION EARTH ELECTRODES

C-5.1 After preparation of electrodes and/or the connected reinforcement, a survey and documented record of the arrangement should be made by a skilled person before pouring in the concrete. The documentation shall contain description, plans and photos and shall form a part of the documentation for the electrical installation (*see* IS 732).

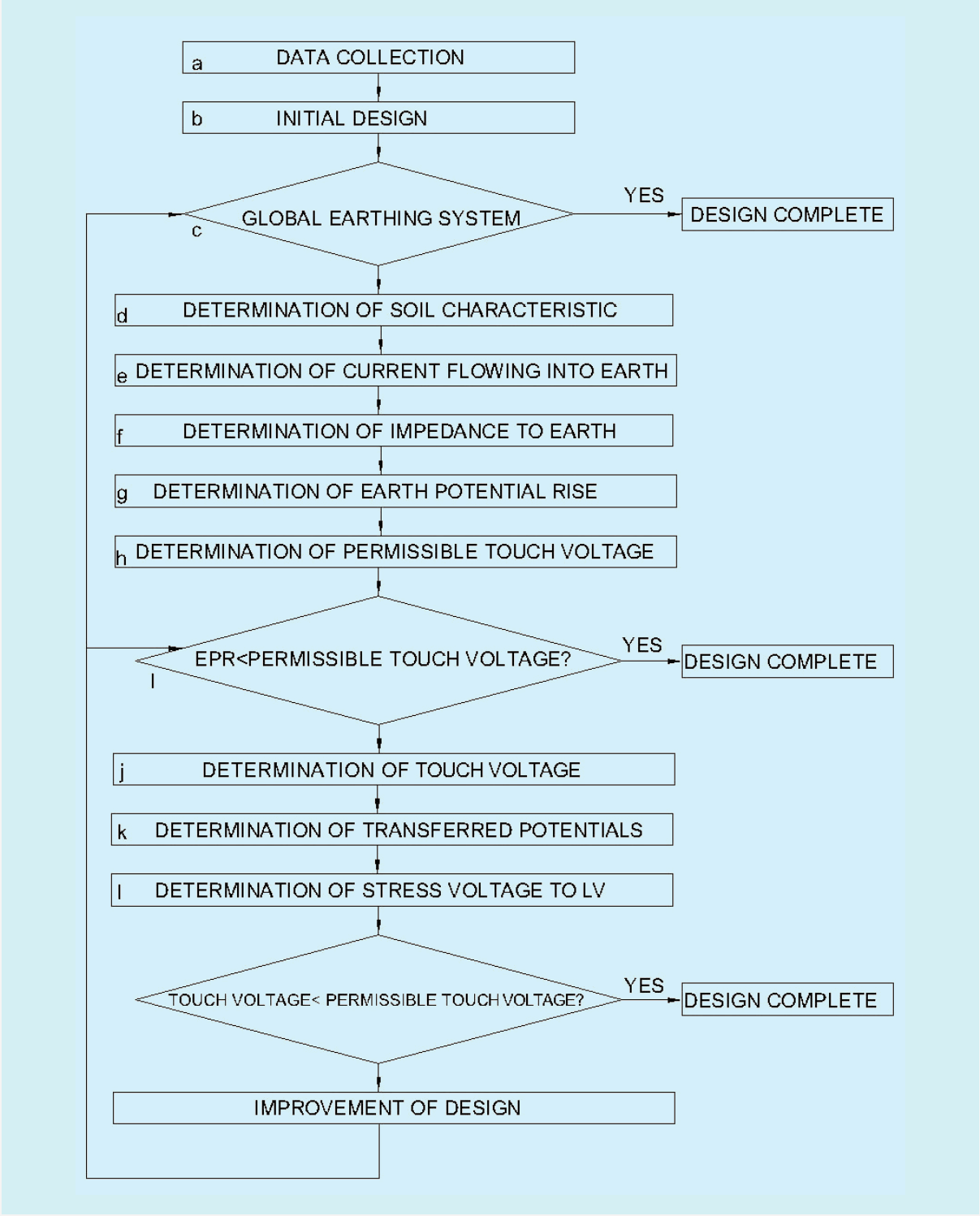
C-5.2 Concrete used for the foundation shall be made from, at least, 240 kg cement per m^3 concrete. The concrete shall have suitable semi-liquid consistency to fill all holes below the electrodes.

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ANNEX D

(*Clause* 7.2)

EARTHING SYSTEM DESIGN FLOW CHART FOR VOLTAGE EXCEEDING 1 kV



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SECTION 19 LIGHTNING PROTECTION

FOREWORD

This section covers the essential design and construction details of lightning protective systems. However, it intends to provide information on the principles and practices in the protection of structures against lightning. Consideration of several other localized conditions such as variations in the architecture, topography of the region, atmospheric conditions, etc shall be taken into account.

Lightning protection of industrial installations categorized as hazardous, require special considerations. These are summarized in Part 7 of the Code.

Assistance has been derived from IS/IEC 62305 standard for "Protection against lightning".

1 SCOPE

1.1 This section of the code (Part 1/Sec 19) covers guidelines on the basic electrical aspects of lightning protective systems for buildings and electrical installation.

1.2 Additional guidelines if any, for specific occupancies from the point of lightning protection are covered in respective sections of the Code.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No.	*Title*
IS/IEC 62305-1 : 2010	Protection against lightning: Part 1 General principles
IS/IEC 62305-2 : 2010	Protection against lightning: Part 2 Risk management
IS/IEC 62305-3 : 2010	Protection against lightning: Part 3 Physical damage to structures and life hazard
IS/IEC 62305-4 : 2010	Protection against lightning: Part 4 Electrical and electronic systems within structures
SP 7 : 2016	National Building Code of India

3 TERMINOLOGY

For the purposes of this section, the following definitions shall apply.

3.1 Air Termination (Lightning Conductor) or Air Termination Network — Those parts of a lightning protective system that are intended to collect the lightning discharges from the atmosphere.

3.2 Bonds — Electrical connection between the lightning protective system and other metal work, and between various portions of the latter.

3.3 Down Conductors — Conductors which connect the air terminations with the earth terminations.

3.4 Earth Terminations or Earth Terminations Network — Those part of the lightning protective system which are intended to distribute the lightning discharges into the general mass of the earth. All parts below the testing point in a down conductor are included in this term.

3.5 Earth Electrodes — Conductor or group of conductors in intimate contact with and providing an electrical connection to earth.

3.6 Fasteners — Devices used to fasten the conductors to the structures.

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3.7 Isoceraunic Level — It is the number of days in a year on which the thunder is heard in the particular region averaged over a number of years.

3.8 Joints — The mechanical and electrical junctions between two or more portions of the lightning protective system or other metal bonded to the system or both.

3.9 Lightning Flash to Earth — Electrical discharge of atmospheric origin between cloud and earth consisting of one or more strokes

3.10 Downward Flash — Lightning flash initiated by a downward leader from cloud to earth (A downward flash consists of a first impulse, which can be followed by subsequent impulses. One or more impulses may be followed by a long stroke).

3.11 Upward Flash — Lightning flash initiated by an upward leader from an earthed structure to cloud (An upward flash consists of a first long stroke with or without multiple superimposed impulses. One or more impulses may be followed by a long stroke).

3.12 Short Stroke — Part of the lightning flash which corresponds to an impulse current (This current has a time T_2 to the half peak value on the tail typically less than 2 ms).

3.13 Long stroke — Part of the lightning flash which corresponds to a continuing current (The duration time T_{LONG} {time from the 10 percent value on the front to the 10 percent value on the tail} of this continuing current is typically more than 2 ms and less than 1 s).

3.14 Lightning Protective System (LPS) — Complete system used to reduce physical damage due to lightning flashes to a structure (It consists of both external and internal lightning protection systems).

3.15 Lightning Equipotential Bonding EB — Bonding to the LPS of separated conductive parts, by direct connections or via surge protective devices, to reduce potential differences caused by lightning current.

3.16 Surge Protective Device SPD — Device intended to limit transient over-voltages and divert surge currents; contains at least one non-linear component

3.17 Metal-clad Building — A building with sides made of or covered with sheet metal.

3.18 Metal-roofed Building — A building with roof made of or covered with sheet metal.

3.19 Side Flash — A spark occurring between nearby metallic objects or between such objects and the lightning protective system or to earth.

3.20 Testing Points — Joints in down conductors or in bonds or in earth conductors connecting earth electrodes, so designed and situated as to enable resistance measurements to be made.

3.21 Zone of Protection — The space within which the lightning conductor is expected to provide protection against a direct lightning stroke.

4 EXCHANGE OF INFORMATION

4.1 The architect should exchange information with the engineer concerned when the building plans are under preparation. The primary objective of such an exchange is to obtain information regarding the architectural features of the structure so that due provision may be made to retain the aesthetic features of the building while planning the location of the lightning conductors and down conductors of the lightning protective system. Information may also be obtained at an early stage regarding other services such as electrical installation, gas and water pipes as well as climatic and soil conditions.

4.2 Scale drawings showing plans and elevations of the structure should be obtained and the nature, size and position of all the metal component parts of the lightning protective system should be indicated on them. In addition, a ground plan should show all the tall objects, such as, buildings, masts, transmission towers, tall trees, etc. within the zone of protection.

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5 CHARACTERISTICS OF LIGHTNING DISCHARGES

5.1 The principal effects of lightning discharge to structure are electrical, thermal and mechanical. These effects are determined by the current which is discharged into the structure. These currents are unidirectional and may vary in amplitude from a few hundred amperes to about 200 kA.

Two basic types of flashes exist:

a) Downward flashes initiated by a downward leader from cloud to earth;

b) Upward flashes initiated by an upward leader from an earthed structure to cloud.

Mostly downward flashes occur in flat territory, and to lower structures, whereas for exposed and/or higher structures upward flashes become dominant. With effective height, the probability of a direct strike to the structure increases (*see* Annex A of IS/IEC 62305-2 : 2010).

A lightning current consists of one or more different strokes:

a) impulses with duration less than 2 ms; and

b) long strokes with duration longer than 2 ms.

Many lightning discharges consist of a single stroke but may also involve a sequence of strokes. A complete lightning discharge may, thus, last a second or even longer. Further differentiation of strokes comes from their polarity (positive or negative) and from their position during the flash (first, subsequent, and superimposed).

5.2 Lightning affecting a structure can cause damage to the structure itself and to its occupants and contents, including failure of internal systems. The damages and failures may also extend to the surroundings of the structure and even involve the local environment. The scale of this extension depends on the characteristics of the structure and on the characteristics of the lightning flash.

5.3 Electrical Effects

The principal electrical effects of a lightning discharge are two-fold.

5.3.1 The lightning current which is discharged to earth through the resistance of the lightning conductor and earth electrode provided for a lightning protective system, produces a resistive voltage drop which momentarily raises the potential of the protective system with respect to the absolute earth potential to a very high value. The lightning current also produces, around the earth electrode, a high voltage gradient which may be dangerous to persons and animals.

5.3.2 The lightning current rises steeply to its crest-value and as a first approximation may be regarded as equivalent to high frequency discharge.

The rate of rise of current in conjunction with the inductance of the discharge path produces an inductive voltage drop which would be added, with due regard to the time relationship, to the resistive (ohmic) voltage drop across the earthing system.

5.4 Thermal Effects

Thermal effects linked with lightning current are relevant to the resistive heating caused by the circulation of an electric current flowing through the resistance of a conductor or into an LPS. Thermal effects are also relevant to the heat generated in the root of the arcs at the attachment point and in all the isolated parts of an LPS involved in arc development (*for example,* spark gaps).

5.5 Mechanical Effects

Mechanical effects caused by the lightning current depend on the amplitude and the duration of the current as well as on the elastic characteristics of the affected mechanical structure. Mechanical effects also depend on the friction forces acting between parts of the LPS in contact with one another, where relevant. Hence, the components of the lightning protection system should, therefore, be provided with adequate mechanical fixings.

6 DAMAGE DUE TO LIGHTNING

6.1 Damage to a Structure

Lightning affecting a structure can cause damage to the structure itself and to its occupants and contents, including failure of internal systems. The damages and failures may also extend to the surroundings of the structure and even involve the local environment. The scale of this extension depends on the characteristics of the structure and on the characteristics of the lightning flash.

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6.1.1 *Effects of Lightning on a Structure*

The main characteristics of structures relevant to lightning effects include:

a) construction (for example, wood, brick, concrete, reinforced concrete, steel frame construction);
b) function (dwelling house, office, farm, theatre, hotel, school, hospital, museum, church, prison, department store, bank, factory, industry plant, sports area);
c) occupants and contents (persons and animals, presence of combustible or non-combustible materials, explosive or non-explosive materials, electrical and electronic systems with low or high withstand voltage);
d) connected lines (power lines, telecommunication lines, pipelines etc.);
e) existing or provided protection measures (protection measures to reduce physical damage and life hazard, protection measures to reduce failure of internal systems); and
f) scale of the extension of danger (structure with difficulty of evacuation or structure where panic may be created, structure dangerous to the surroundings, structure dangerous to the environment).

Table **1** reports the effects of lightning on various types of structures.

Table 1 Effects of Lightning on Typical Structures

(*Clause* 6.1.1)

Sl No.	Type of Structure According to Function and/or Contents	Effects of Lightning
(1)	(2)	(3)
i)	Dwelling-house	a) Puncture of electrical installations, fire and material damage
		b) Damage, normally limited to structures exposed to the point of strike or to the lightning current path
		c) Failure of electrical and electronic equipment and systems installed (for example, TV sets, computers, modems, telephones, etc.)
ii)	Farm building	d) Primary risk of fire and hazardous step voltages as well as material damage
		e) Secondary risk due to loss of electric power and life hazard to livestock due to failure of electronic control of ventilation and food supply systems, etc.
iii)	Theatre Hotel School Department store Sports area	f) Damage to the electrical installations (for example, electric lighting) likely to cause panic g) Failure of fire alarms resulting in delayed fire-fighting measures
iv)	Bank Insurance company Commercial company, etc.	h) As above, along with problems resulting from loss of communication, failure of computers and loss of data
v)	Hospital Nursing home Prison	j) As above, along with problems of people in intensive care, and the difficulties of rescuing immobile people
vi)	Industry	k) Additional effects depending on the contents of factories, ranging from minor to unacceptable damage and loss of production
vii)	Museums and archaeological site Church	m) Loss of irreplaceable cultural heritage
viii)	Telecommunication Power plants	n) Unacceptable loss of services to the public
ix)	Firework factory Munitions works	p) Consequences of fire and explosion to the plant and its surroundings
x)	Chemical plant Refinery Nuclear plant Biochemical laboratories and plants	q) Fire and malfunction of the plant with detrimental consequences to the local and global environment

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6.1.2 *Sources and Types of damage to a Structure*

The lightning current is the source of damage. The following situations shall be taken into account depending on the position of the point of strike relative to the structure considered:

a) S1: flashes to the structure;
b) S2: flashes near the structure;
c) S3: flashes to the lines connected to the structure; and
d) S4: flashes near the lines connected to the structure.

1) *Flashes to the structure can cause:*
   i) immediate mechanical damage, fire and/or explosion due to the hot lightning plasma arc itself, due to the current resulting in ohmic heating of conductors (over-heated conductors), or due to the charge resulting in arc erosion (melted metal);
   ii) fire and/or explosion triggered by sparks caused by overvoltages resulting from resistive and inductive coupling and to passage of part of the lightning currents;
   iii) injury to living beings by electric shock due to step and touch voltages resulting from resistive and inductive coupling; and
   iv) failure or malfunction of internal systems due to LEMP.
2) *Flashes near the structure can cause:*
   i) failure or malfunction of internal systems due to LEMP.
3) *Flashes to a line connected to the structure can cause:*
   i) fire and/or explosion triggered by sparks due to overvoltages and lightning currents transmitted through the connected line;
   ii) injury to living beings by electric shock due to touch voltages inside the structure caused by lightning currents transmitted through the connected line; and
   iii) failure or malfunction of internal systems due to overvoltages appearing on connected lines and transmitted to the structure.
4) *Flashes near a line connected to the structure can cause:*

   failure or malfunction of internal systems due to overvoltages induced on connected lines and transmitted to the structure.

6.1.2.1 As a result, the lightning can cause three basic type of damage:

a) D1: injury to living beings by electric shock;
b) D2: physical damage (fire, explosion, mechanical destruction, chemical release) due to lightning current effects including sparking; and
c) D3: failure of internal systems due to LEMP.

6.2 Types of Loss

Each type of damage relevant to structure to be protected, alone or in combination with others, may produce different consequential loss. The type of loss that may appear depends on the characteristics of the structure itself.

The following types of loss, which may appear as consequence of damages relevant to structure, are considered:

a) L1: loss of human life (including permanent injury);
b) L2: loss of service to the public;
c) L3: loss of cultural heritage; and
d) L4: loss of economic value (structure, its content, and loss of activity).

NOTE — Only utilities such as gas, water, TV, TLC and power supply are considered service to the public.

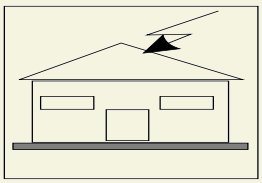
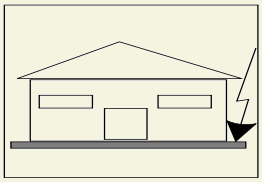
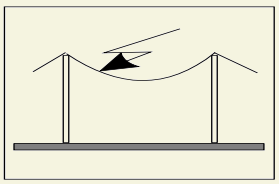
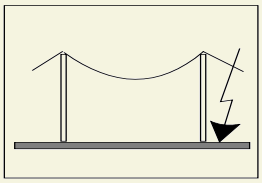
Losses of type L1, L2 and L3 may be considered as loss of social values, whereas a loss of type L4 may be considered as purely an economic loss.

The relationship between source of damage, type of damage and loss is reported in Table 2.

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Table 2 Damage and Loss Relevant to a Structure according to Different Points of Strike of Lightning

(*Clause* 6.2)

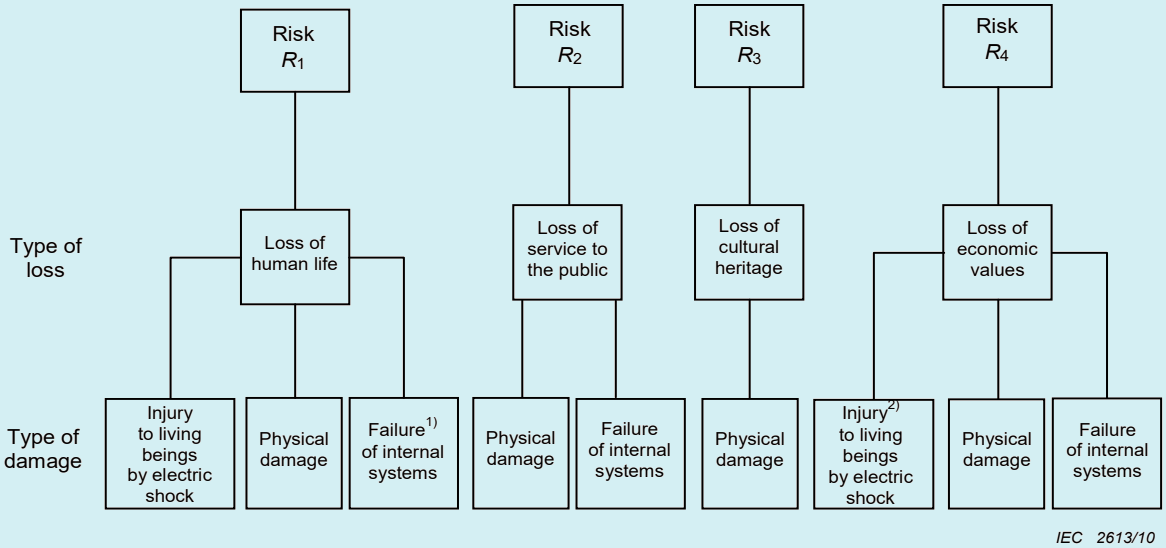
Sl No.	Point of strike		Source of Damage	Type of Damage	Type of Loss
(1)	(2)	(3)	(4)	(5)	(6)
i)	Structure		S1	D1	L1, L4[a]
				D2	L1, L2, L3, L4
				D3	L1[b], L2, L4
ii)	Near a structure		S2	D3	L1[b], L2, L4
iii)	Line connected to the structure		S3	D1	L1, L4[a]
				D2	L1, L2, L3, L4
				D3	L1[b], L2, L4
iv)	Near a line		S4	D3	L1[b], L2, L4

[a] Only for properties where animals may be lost.

[b] Only for structures with risk of explosion and for hospitals or other structures where failure of internal systems immediately endangers human life.

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Types of loss resulting from types of damage and the corresponding risks are reported in Fig. 1.



Key:

1 Only for hospitals or other structures where failure of internal systems immediately endangers human life.

2 Only for properties where animals may be lost.

FIG. 1 TYPES OF LOSS AND CORRESPONDING RISKS RESULTING FROM DIFFERENT TYPES OF DAMAGE

7 DETERMINATION OF THE NEED FOR LIGHTNING PROTECTION

7.1 Need for Lightning Protection: Risk Assessment

The need for the lightning protection of a structure to be protected in order to reduce the loss of social values L1, L2 and L3 shall be evaluated.

In order to evaluate whether or not lightning protection of a structure is needed, a risk assessment in accordance with the procedures contained in IS/IEC 62305-2 shall be made. The following risks shall be taken into account, corresponding to the types of loss reported above:

a) R_1: risk of loss or permanent injury of human life;

b) R_2: risk of loss of services to the public;

c) R_3: risk of loss of cultural heritage.

NOTE — Risk R_4 (risk of loss of economic values) should be assessed whenever the economic justification of lightning protection is considered

Protection against lightning is needed if the risk R (R_1 to R_3) is higher than the tolerable level R_T

$$R > R_T$$

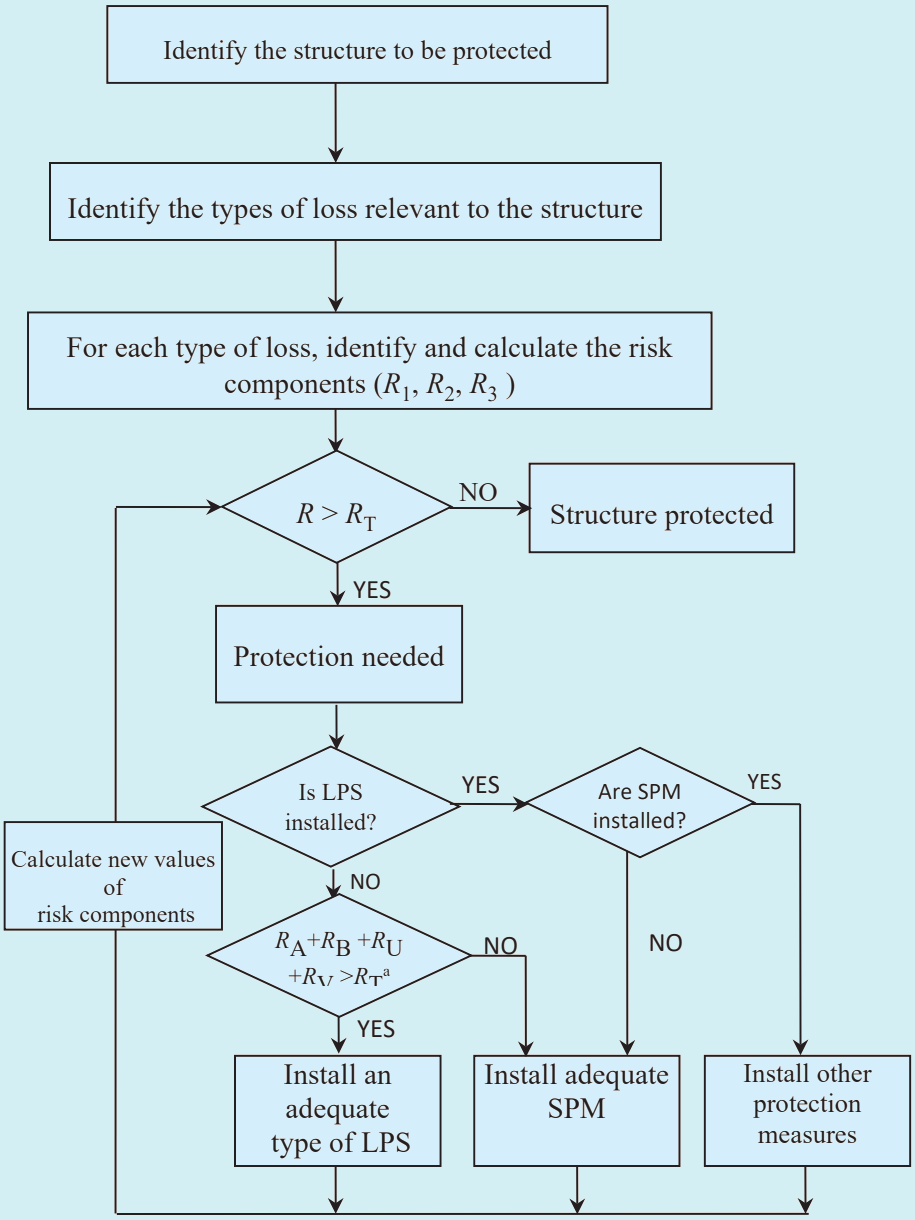
In this case, protection measures shall be adopted in order reduce the risk R (R_1 to R_3) to the tolerable level R_T

$$R \leq R_T$$

If more than one type of loss could appear, the condition $R \leq R_T$ shall be satisfied for each type of loss (L1, L2 and L3).

The values of tolerable risk R_T where lightning could result in the loss of items of social value should be under the responsibility of a competent national body.

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Key:

[a] If $R_A+R_B < R_T$, a complete LPS is not necessary; in this case SPD(s) according to IEC 62305-3 are sufficient.

FIG. 2 PROCEDURE FOR DECIDING THE NEED OF PROTECTION AND FOR SELECTING PROTECTION MEASURES

7.2 Economic Justification of Lightning Protection

Besides the need for lightning protection for the structure to be protected, it may be useful to evaluate the economic benefits of providing protection measures in order to reduce the economic loss L4.

In this case, the risk *R*4 of loss of economic values should be assessed. The assessment of risk *R*4 allows for the evaluation of the cost of the economic loss with and without the adopted protection measures.

Lightning protection is cost effective if the sum of the cost C_{RL} of residual loss in the presence of protection measures and the cost C_{PM} of protection measures is lower than the cost C_L of total loss without protection measures:

$$C_{RL} + C_{PM} < C_L$$

For detailed information on the evaluation of economic justification of lightning protection refer IS/IEC 62305-2.

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8 PROTECTION MEASURES

8.1 General

Protection measures may be adopted in order to reduce the risk according to the type of damage.

8.2 Protection Measures to Reduce Injury of Living Beings by Electric Shock

Possible protection measures include:

a) adequate insulation of exposed conductive parts;
b) equi-potentialization by means of a meshed earthing system;
c) physical restrictions and warning notices; and
d) lightning equipotential bonding (EB).

8.3 Protection Measures to Reduce Physical Damage

Protection is achieved by the lightning protection system (LPS) which includes the following features:

a) air-termination system;
b) down-conductor system;
c) earth-termination system;
d) lightning equipotential bonding (EB); and
e) electrical insulation (and hence separation distance) against the external LPS.

8.4 Protection Measures to Reduce Failure of Electrical and Electronic Systems

The electrical and electronic system protection measures (SPM) include:

a) Earthing and bonding measures;
b) Magnetic shielding;
c) Line routing;
d) Isolating interfaces; and
e) Coordinated SPD system.

These measures may be used alone or in combination.

8.5 Protection Measures Selection

The protection measures listed above together form the overall lightning protection.

Selection of the most suitable protection measures shall be made by the designer of the protection measures and the owner of the structure to be protected according to the type and the amount of each kind of damage, the technical and economic aspects of the different protection measures and the results of risk assessment.

9 CRITERIA FOR PROTECTION OF STRUCTURES

9.1 General

An ideal protection for structures would be to enclose the structure to be protected within an earthed and perfectly conducting continuous shield of adequate thickness and to provide adequate bonding, at the entrance point into the shield, of the lines connected to the structure. This would prevent the penetration of lightning current and related electromagnetic field into the structure to be protected and prevent dangerous thermal and electrodynamic effects of current, as well as dangerous sparkings and overvoltages for internal systems. In practice, it is often neither possible nor cost effective to go to such measures to provide such full protection.

Lack of continuity of the shield and/or its inadequate thickness allows the lightning current to penetrate the shield causing:

a) physical damage and life hazard; and
b) failure of internal systems.

Protection measures, adopted to reduce such damages and relevant consequential loss, shall be designed for the defined set of lightning current parameters against which protection is required (lightning protection level).

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9.2 Lightning Protection Levels (LPL)

The lightning protection levels are categorised into four levels (I to IV). For each LPL, a set of maximum and minimum lightning current parameters is fixed.

NOTES

1 Protection against lightning whose maximum and minimum lightning current parameters exceed those relevant to LPL I needs more efficient measures which should be selected and erected on an individual basis.

2 The probability of occurrence of lightning with minimum or maximum current parameters outside the range of values defined for LPL I is less than 2 percent.

The maximum values of lightning current parameters relevant to LPL I shall not be exceeded, with a probability of 99 percent. The maximum values of lightning current parameters relevant to LPL I are reduced to 75 percent for LPL II and to 50 percent for LPL III and IV. The time parameters are unchanged.

The maximum values of lightning current parameters for the different lightning protection levels are given in Table 3 and are used to design lightning protection components (*for example*, cross-section of conductors, thickness of metal sheets, current capability of SPDs, separation distance against dangerous sparking) and to define test parameters simulating the effects of lightning on such components.

The minimum values of lightning current amplitude for the different LPL are used to derive the rolling sphere radius in order to define the lightning protection zone LPZ 0_B which cannot be reached by direct strike. The minimum values of lightning current parameters together with the related rolling sphere radius are given in Table 4. They are used for positioning of the air-termination system and to define the lightning protection zone LPZ 0_B.

Table 3 Maximum Values of Lightning Parameters According to LPL

(*Clause* 9.2)

Sl No.	First positive impulse			LPL			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Current parameters	**Symbol**	**Unit**	**I**	**II**	**III**	**IV**
i)	**Peak current**	**I**	**kA**	200	150	100	
ii)	**Impulse charge**	Q_{SHORT}	**C**	100	75	50	
iii)	**Specific energy**	***W/R***	**MJ/Ω**	10	5.6	2.5	
iv)	**Time parameters**	**T1/T2**	**µs/µs**	10/350			
	First negative impulse[a]			**LPL**			
	Current parameters	**Symbol**	**Unit**	**I**	**II**	**III**	
v)	**Peak current**	**I**	**kA**	100	75	50	
vi)	**Average steepness**	**di/dt**	**kA/µs**	100	75	50	
vii)	**Time parameters**	**T1/T2**	µs/µs	1/200			
	Subsequent impulse			**LPL**			
	Current parameters	**Symbol**	**Unit**	**I**	**II**	**III**	**IV**
viii)	**Peak current**	***I***	**kA**	50	37.5	25	
ix)	**Average steepness**	**di/dt**	**kA/µs**	200	150	100	
x)	**Time parameters**	**T1/T2**	µs/µs	0.25/100			
	Long stroke			**LPL**			
	Current parameters	**Symbol**	**Unit**	**I**	**II**	**III**	**IV**
xi)	**Long stroke charge**	Q_{LONG}	**C**	200	150	100	
xii)	**Time parameter**	T_{LONG}	**s**	0.5			
	Flash			**LPL**			
	Current parameters	**Symbol**	**Unit**	**I**	**II**	**III**	**IV**
xiii)	**Flash charge**	Q_{FLASH}	**C**	300	225	150	

[a] The use of this current shape concerns only calculations and not testing.

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Table 4 Minimum Values of Lightning Parameters and Related Rolling Sphere Radius Corresponding to LPL

(*Clause* 9.2)

Sl No.	Interception Criteria			LPL		
		Symbol	Unit	II	III	IV
(1)	(2)	(3)	(4)	(6)	(7)	(8)
i)	Minimum peak current	I	kA	5	10	16
ii)	Rolling sphere radius	r	m	30	45	60

9.3 Lightning Protection Zones (LPZ)

Protection measures such as LPS, shielding wires, magnetic shields and SPD determine lightning protection zones (LPZ).

LPZ downstream of the protection measure are characterized by significant reduction of LEMP than that upstream of the LPZ.

With respect to the threat of lightning, the following LPZs are defined (*see* Fig. 3 and Fig. 4):

LPZ 0_A — zone where the threat is due to the direct lightning flash and the full lightning electromagnetic field. The internal systems may be subjected to full or partial lightning surge current;

LPZ 0_B — zone protected against direct lightning flashes but where the threat is the full lightning electromagnetic field. The internal systems may be subjected to partial lightning surge currents;

LPZ 1 — zone where the surge current is limited by current sharing and by isolating interfaces and/or SPDs at the boundary. Spatial shielding may attenuate the lightning electromagnetic field;

LPZ 2, ..., n — zone where the surge current may be further limited by current sharing and by isolating interfaces and/or additional SPDs at the boundary. Additional spatial shielding may be used to further attenuate the lightning electromagnetic field.

NOTE — In general, the higher the number of an individual zone, the lower the electromagnetic environment parameters.

As a general rule for protection, the structure to be protected shall be in an LPZ whose electromagnetic characteristics are compatible with the capability of the structure to withstand stress causing the damage to be reduced (physical damage, failure of electrical and electronic systems due to overvoltages).

9.4 Protection of Structures

9.4.1 *Protection to Reduce Physical Damage and Life Hazard*

The structure to be protected shall be inside an LPZ 0_B or higher. This is achieved by means of a lightning protection system (LPS).

An LPS consists of both external and internal lightning protection systems.

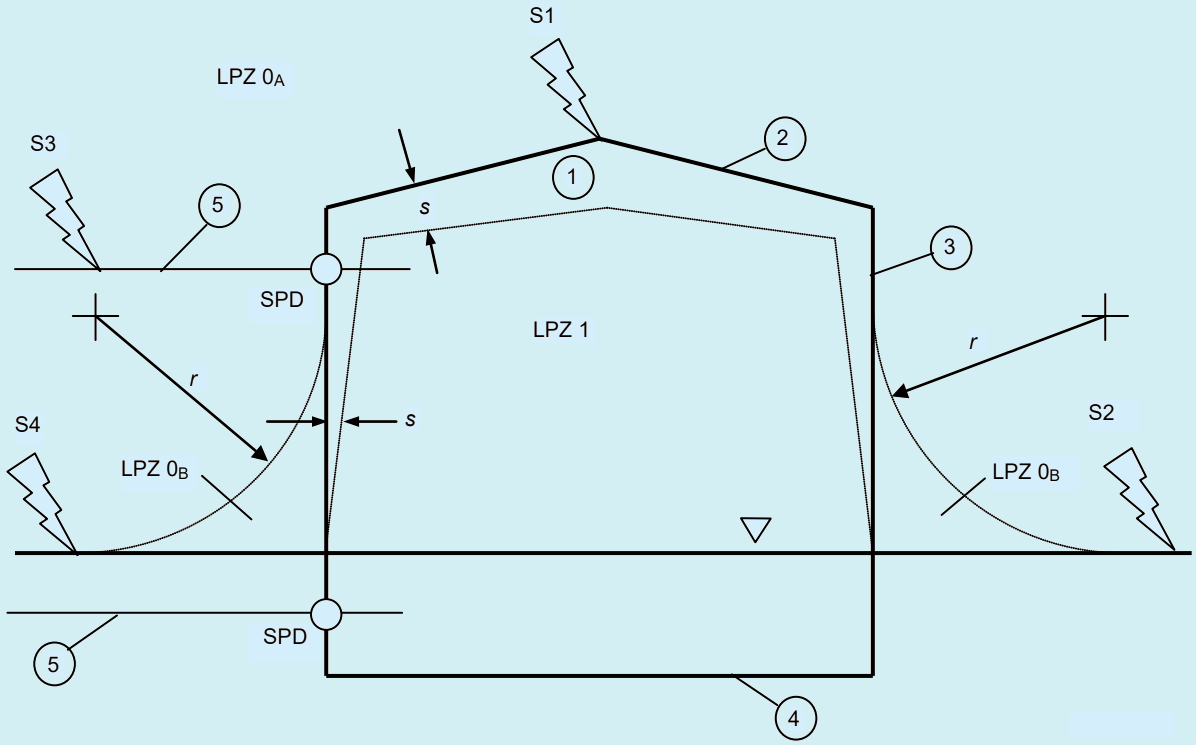
The functions of the external LPS are:

a) to intercept a lightning flash to the structure (with an air-termination system);
b) to conduct the lightning current safely to earth (with a down-conductor system); and
c) to disperse it into the earth (with an earth-termination system).

The function of the internal LPS is to prevent dangerous sparking within the structure, using equipotential bonding or a separation distance, s, (and hence, electrical isolation) between the LPS components and other electrically conducting elements internal to the structure.

Four classes of LPS (I, II, III and IV) are defined as a set of construction rules, based on the corresponding LPL (*see* Table 5). Each set includes level-dependent (*for example*, rolling sphere radius, mesh width etc.) and level-independent (*for example*, cross-sections, materials etc.) construction rules.

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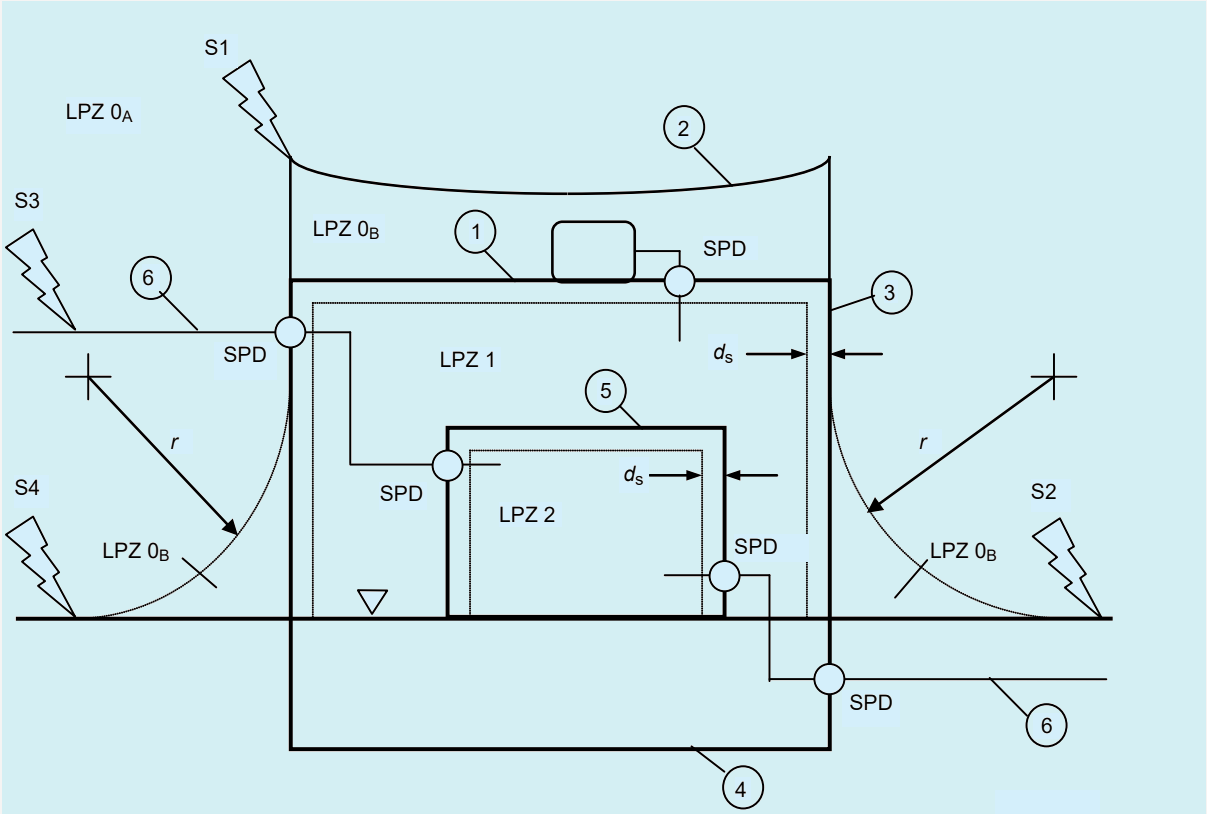


Key:			
1	Structure	S1	flash to the structure
2	air-termination system	S2	flash near to the structure
3	down-conductor system	S3	flash to a line connected to the structure
4	earth-termination system	S4	flash near a line connected to the structure
5	incoming lines	r	rolling sphere radius
		s	separation distance against dangerous sparking

▽ ground level	
◯ lightning equipotential bonding by means of SPD	
LPZ 0A	direct flash, full lightning current
LPZ 0B	no direct flash, partial lightning or induced current
LPZ 1	no direct flash, limited lightning or induced current protected volume inside LPZ 1 must respect separation distance s

FIG. 3 LPZ DEFINED BY AN LPS (IS/IEC 62305-3)

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Key:			
1	**structure (shield of LPZ 1)**	**S1**	**flash to the structure**
2	**air-termination system**	**S2**	**flash near to the structure**
3	**down-conductor system**	**S3**	**flash to a line connected to the structure**
4	**earth-termination system**	**S4**	**flash near a line connected to the structure**
5	**room (shield of LPZ 2)**	**r**	**rolling sphere radius**
6	**lines connected to the structure**	**ds**	**safety distance against too high magnetic field**

▽ **ground level**	
◯ **lightning equipotential bonding by means of SPD**	
LPZ 0A	**direct flash, full lightning current, full magnetic field**
LPZ 0B	**no direct flash, partial lightning or induced current, full magnetic field**
LPZ 1	**no direct flash, limited lightning or induced current, damped magnetic field**
LPZ 2	**no direct flash, induced currents, further damped magnetic field**
	protected volumes inside LPZ 1 and LPZ 2 must respect safety distances d_s

FIG. 4 LPZ DEFINED BY AN SPM (IS/IEC 62305-4)

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Where surface resistivity of the soil outside and of the floor inside the structure is kept low, life hazard due to touch and step voltages is reduced:

a) outside the structure, by insulation of the exposed conductive parts, by equipotentialization of the soil by means of a meshed earthing system, by warning notices and by physical restrictions; and
b) inside the structure, by equipotential bonding of lines at entrance point into the structure.

The LPS shall comply with the requirements of IS/IEC 62305-3.

Table 5 Relation Between Lightning Protection Levels (LPL) and Class of LPS

(*Clause* 9.4.1)

Sl No.	LPL	Class of LPS
(1)	(2)	(3)
i)	I	I
ii)	II	II
iii)	III	III
iv)	IV	IV

9.4.2 *Protection to Reduce the Failure of Internal Systems*

The protection against LEMP to reduce the risk of failure of internal systems shall limit:

a) surges due to lightning flashes to the structure resulting from resistive and inductive coupling;
b) surges due to lightning flashes near the structure resulting from inductive coupling;
c) surges transmitted by lines connected to the structure due to flashes to or near the lines; and
d) magnetic field directly coupling with apparatus.

The system to be protected shall be located inside an LPZ 1 or higher. This is achieved by means of electrical and electronic system protection measures (SPM) consisting of magnetic shields attenuating the inducing magnetic field and/or suitable routing of wiring to reduce the induction loop. Bonding shall be provided at the boundaries of an LPZ for metal parts and systems crossing the boundaries. This bonding may be accomplished by means of bonding conductors or, when necessary, by surge protective devices (SPDs).

The protection measures for any LPZ shall comply with IS/IEC 62305-4.

Effective protection against overvoltages, causing failures of internal systems, may also be achieved by means of isolating interfaces and/or a coordinated SPD system, limiting overvoltages below the rated impulse withstand voltage of the system to be protected.

Isolating interfaces and SPDs shall be selected and installed according to the requirements of IS/IEC 62305-4.

10 MATERIALS AND DIMENSIONS

10.1 Materials

The materials of lightning conductors, down conductors, earth termination network, etc, of the protective system shall be reliably resistant to corrosion or be adequately protected against corrosion. The following materials are recommended:

a) ***Copper*** — When solid or stranded copper wire or flat copper strips are used, it shall be of commercial grade with 98 percent conductivity when annealed and shall conform to relevant Indian Standard.
b) ***Copper-clad Steel or copper coated steel*** — Where copper-clad steel is used, the copper covering shall be permanently and effectively welded to the steel core. The proportion of copper and steel shall be such that the conductance of the material is not less than 30 percent of the conductance of solid copper of the same total cross sectional area.
c) ***Galvanized Steel*** — If there is any difficulty in the use of copper or aluminium, galvanized steel may be used. Where steel is used it shall be thoroughly protected against corrosion by a zinc coating. Galvanized steel may be preferred for some short life installations, such as exhibitions. Copper is preferred to

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galvanized iron where corrosive gases, industrial pollution or salt laden atmospheric conditions are encountered.

d) ***Aluminium*** — Aluminum wire and strips are increasingly used as lightning conductors in view of the fact that aluminum has a conductivity almost 60 percent that of copper. When used, it shall be least 99 percent pure, of sufficient mechanical strength and effectively protected against corrosion.

e) ***Alloys*** — Where alloys of metals are used, they shall be substantially as resistant to corrosion as copper under similar conditions.

Components of lightning protection system shall be manufactured from the materials listed in Table 6 or from other materials with equivalent mechanical, electrical and chemical (corrosion) performance characteristics.

Table 6 LPS Materials and Conditions of Use[a]

(*Clause* 10.1)

Sl No.	Material	Use			Corrosion		
		In open air	In earth	In concrete	Resistance	Increased by	May be Destroyed by Galvanic Coupling with
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Copper	Solid Stranded	Solid Stranded As coating	Solid Stranded As coating	Good in many environments	Sulphur compounds Organic materials	—
ii)	Hot galvanized steel[c,d,e]	Solid Stranded [b]	Solid	Solid Stranded [b]	Acceptable in air, in concrete and in benign soil	High chlorides content	Copper
iii)	Steel with electro-deposited copper	Solid	Solid	Solid	Good in many environments	Sulphur compounds	—
iv)	Stainless steel	Solid stranded	Solid stranded	Solid Stranded	Good in Many Environments	High Chlorides Content	—
v)	Aluminium	Solid stranded	Unsuitable	Unsuitable	Good in atmospheres containing low concentrations of sulphur and chloride	Alkaline solutions	Copper
vi)	Lead [f]	Solid as coating	Solid as coating	Unsuitable	Good in atmosphere with high concentration of sulphates	Acid soils	Copper stainless steel

[a] This table gives general guidance only. In special circumstances, more careful corrosion immunity considerations are required (*see* Annex E of IS/IEC 62305-3)

[b] Stranded conductors are more vulnerable to corrosion than solid conductors. Stranded conductors are also vulnerable where they enter or exit earth/concrete positions. This is the reason why stranded galvanized steel is not recommended in earth.

[c] Galvanized steel may be corroded in clay soil or moist soil.

[d] Galvanized steel in concrete should not extend into the soil due to possible corrosion of the steel just outside the concrete.

[e] Galvanized steel in contact with reinforcement steel in concrete should not be used in coastal areas where there may be salt in the ground water.

[f] Use of lead in the earth is often banned or restricted due to environmental concerns.

10.2 Shapes and Sizes

The recommended shape and minimum sizes of conductors for use above ground and below ground are given in Table 7 and Table 8 respectively.

10.3 Corrosion

Where corrosion due to atmospheric, chemical, electrolytic or other causes is likely to impair any part of the lightning protective system, suitable precautions should be taken to prevent its occurrence. The contact of dissimilar metals is likely to initiate and accelerate corrosion unless the contact surfaces are kept completely dry and protected against the ingress of moisture.

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Table 7 Material, Configuration and Minimum Cross-sectional Area of Air-termination Conductors, Air-termination Rods, Earth Lead-in Rods and Down-conductors

(*Clause* 10.2)

Sl No.	Material	Configuration	Cross Sectional Area (in sq.mm)
(1)	(2)	(3)	(4)
i)	Copper,	Solid tape	50
ii)	Tin plated copper	Solid round[a]	50
iii)		Stranded[a]	50
iv)		Solid round[b]	176
v)	Aluminium	Solid tape	70
vi)		Solid round	50
vii)		Stranded	50
viii)	Aluminium Alloy	Solid tape	50
ix)		Solid round	50
x)		Stranded	50
xi)		Solid round[b]	176
xii)	Copper coated aluminium alloy	Solid round	50
xiii)	Hot dipped galvanized steel	Solid tape	50
xiv)		Solid round	50
xv)		Stranded	50
xvi)		Solid round[b]	176
xvii)	Copper coated steel	Solid round	50
xviii)		Solid tape	50
xix)	Stainless steel	Solid tape[c]	50
xx)		Solid round[c]	50
xxi)		Stranded	50
xxii)		Solid round[b]	176

[a] 50 mm^2 (8 mm diameter) may be reduced to 25 mm^2 in certain applications where mechanical strength is not an essential requirement.Consideration should be given to reducing the spacing between the fasteners.

[b] Applicable for air-termination rods and earth lead-in rods. For air-termination rods where mechanical stress such as wind loading is not critical, a 9.5 mm diameter and 1 m long rod may be used.

[c] If thermal and mechanical considerations are important, then, these values should be increased to 75 mm^2.

Table 8 Material, Configuration and Minimum Dimensions of Earth Electrodes[d]

(*Clause* 10.2)

Sl No.	Material	Configuration	Dimensions		
			Earth Rod Diameter mm	Earth Conductor mm^2	Earth Plate mm
(1)	(2)	(3)	(4)	(5)	(6)
i)	Copper	Stranded		50	
ii)	Tin plated copper	Solid round	15	50	
iii)		Solid tape		50	
iv)		Pipe	20		
v)		Solid plate			500 × 500
vi)		Lattice plate [b]			600 × 600

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Table 8 *(Concluded)*

Sl No.	Material	Configuration	Dimensions		
			Earth Rod Diameter mm	Earth Conductor mm^2	Earth Plate mm
(1)	(2)	(3)	(4)	(5)	(6)
vii)	Hot dipped galvanized steel	Solid round	16	78	
viii)		Pipe	25		
ix)		Solid tape		90	
x)		Solid plate			500 × 500
xi)		Lattice plate [b]			600 × 600
xii)		Profile	[c]		
xiii)	Bare steel[a]	Stranded		70	
xiv)		Solid round		78	
xv)		Solid tape		75	
xvi)	Copper coated steel	Solid round	14	50	
xvii)		Solid tape		90	
xviii)	Stainless steel	Solid round	15	78	
xix)		Solid tape		100	

[a] Shall be embedded in concrete for a minimum depth of 50 mm.

[b] Lattice plate constructed with a minimum total length of the conductor of 4.8 m.

[c] Different profiles are permitted with a cross-section of 290 mm^2 and a minimum thickness of 3 mm, (*for example*, cross profile).

[d] In case of a type B arrangement foundation earthing system, the earth electrode shall be correctly connected at least every 5 m with the reinforcement steel.

10.3.1 Dissimilar metal contacts can exist where a conductor is held by fixing devices or against external metal surfaces. Corrosion can arise, also, where water passing over one metal comes into contact with another. Run-off water from copper, copper alloys and lead can attack aluminum alloys and zinc. The metal of the lightning protective system should be compatible with the metal or metals used externally on the structure over which the system passes or with which it may make contact.

11 DESIGN OF LIGHTNING PROTECTION SYSTEM

11.1 General

Lightning protective systems should be installed with a view to offering technically and economically optimized design with least impedance to the passage of lightning current between air-terminals and earth. The lightning protection system consists of both external and internal lightning protection system. The basic design considerations for lightning protective systems are given in IS/IEC 62305. Lightning protection components shall be tested as per IEC 62561 (all parts).

An external lighting protection system consists of following components (attached to structure or isolated)

a) air terminations;
b) down conductors;
c) joints and bends;
d) testing points;
e) earth terminations;
f) earth electrodes; and
g) fasteners.

On other hand the internal lightning protection is achieved by equipotential bonding or electrical insulation between the parts (maintaining separation distances).

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11.2 Air Terminations

For the purpose of lightning protection, the vertical and horizontal conductors are considered equivalent and the use of pointed air terminations or vertical finials is, therefore, not regarded as essential except when dictated by practical considerations. An air termination may consist of a vertical rod/catenary wires/meshed conductors.

11.2.1 Air termination components installed on a structure shall be located at corners, exposed points and edges (especially on upper level of any facades) in accordance with one or more of the following methods:

a) Protection angle method;
b) Rolling sphere method; and
c) Mesh method.

See Table 9.

11.2.2 Horizontal air terminations should be coursed along contours, such as ridges, parapets and edges of flat roofs, and where necessary, over flat surfaces in such a way as to join each air termination to the rest and should themselves form a closed network.

11.2.3 On structure taller than 60 m, flashed to the side may occur, especially to the point, corners and edges of surface. An air-termination system shall be installed to protect the upper part of tall structures (that is, typically the topmost 20 percent of the height of the structure as far as this part exceeds 60 m in height) and the equipment installed on it. The rules for positioning the air-termination systems on these upper parts of a structure shall meet at least the requirements for LPL IV with emphasis on the location of air-termination devices on corners, edges, and significant protrusions (such as balconies, viewing platforms, etc).

11.2.4 The layout of the network may be designed to suit the shape of the roof and architectural features of the buildings.

11.2.5 The air termination network should cover all salient points of the structure.

11.2.6 All metallic finials, chimneys, ducts, vent pipes, railings, gutters and the like, on or above the main surface of the roof of the structure shall be bonded to, and form part of, the air termination network. If portions of a structure vary considerably in height, any necessary air termination or air termination network of the lower portions should, in addition to their own conductors, be bonded to the down conductors of the taller portions.

11.2.7 All air terminals shall be effectively secured against overturning either by attachment to the object to be protected or by means of substantial braces and fixings which shall be permanently and rigidly attached to the building. The method and nature of the fixings should be simple, solid and permanent, due attention being given to climatic conditions and possible corrosion.

Table 9 Maximum Values of Rolling Sphere Radius, Mesh Size and Protection Angle Corresponding to the Class of LPS

(*Clause* 11.2.1)

Sl No.	Class of LPS	Protection Method		
		Rolling Sphere Radius r	Mesh Size w_m	Protection Angle
		m	m	$\alpha°$
(1)	(2)	(3)	(4)	(5)
i)	I	20	5 × 5	*See* Fig.**5**
ii)	II	30	10 × 10	
iii)	III	45	15 × 15	
iv)	IV	60	20 × 20	

11.3 Down Conductors

The number and spacing of down conductors shall largely depend upon the size and shape of the building and upon class of LPS (lightning protection system). The minimum number of down conductors shall be as per 5.3 of IS/IEC 62305-3 and the distance between the down conductors shall be as per Table 10.

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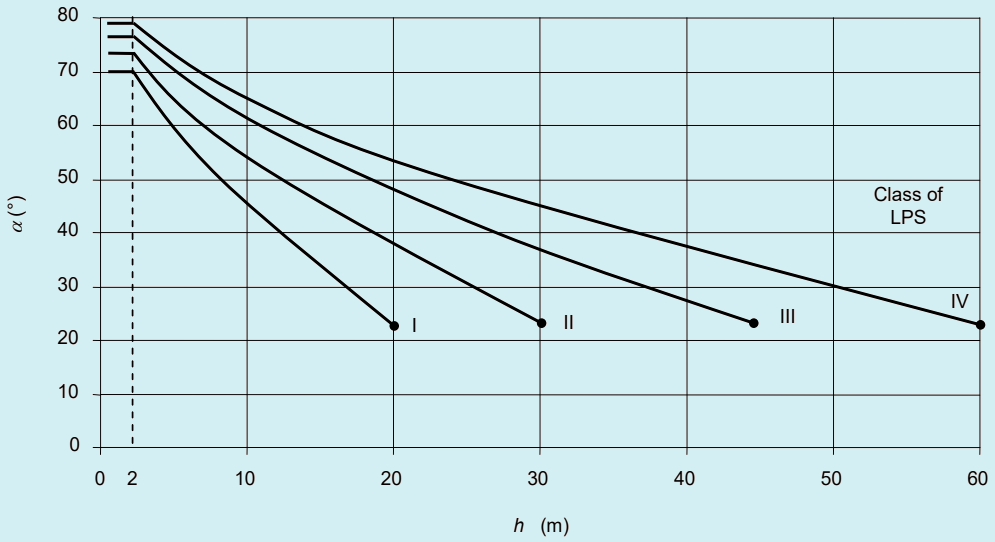


FIG. 5 PROTECTION ANGLE CORRESPONDING TO THE CLASS OF LPS

Table 10 Typical Preferred Values of the Distance between Down-conductors According to the Class of Lightning Protection System (LPS)

(*Clause* 11.3)

Sl No.	Class of LPS	Typical Distances m
(1)	(2)	(3)
i)	I	10
ii)	II	10
iii)	III	15
iv)	IV	20

11.3.1 Down conductors should be distributed round the outside walls of the structure. They shall preferably be run along the corners and other projections, due consideration being given to the location of air terminations and earth terminations. Lift shaft shall not be used for fixing down conductors.

11.3.2 It is very important that the down conductors shall follow the most direct path possible between the air termination and the earth termination, avoiding sharp bends, upturns and kinks. Joints shall as far as possible be avoided in down conductors. The formation of loops on the down conductor shall be avoided or minimum separation distance(s) shall be maintained. Adequate protection may be provided to the conductors against mechanical damage.

11.3.3 Metal pipes leading rainwater from the roof to the ground may be connected to the down conductors but cannot replace them if they do not meet the requirements of IS/IEC 62305-3. Such connections shall have disconnecting joints for testing purposes.

11.3.4 Where the provision of suitable external routes for down conductors is impracticable or inadvisable, as in buildings of cantilever construction, from the first floor upwards, down conductors may be used in an air space provided by a non-metallic non-combustible internal duct. Any covered recess not smaller than 75 mm × 15 mm or any vertical service duct running the full height of the building may be used for this purpose, provided it does not contain an unarmored or non-metal-sheathed cable.

11.3.5 Any extended metal running vertically through the structure should be bonded to the lightning conductor at the top and the bottom unless the clearance are in accordance with IS/IEC-62305 (Part 3) for tall structures.

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11.3.6 Equally spaced down conductors shall be provided in line with IS/IEC 62305. Routing of down conductors (insulated or uninsulated) through electrical and other service shafts are not allowed as it can create fire and explosion during lightning.

11.3.7 In deciding on the routing of the down conductor, its accessibility for inspection, testing and maintenance should be taken into account.

11.4 Joints and Bonds

11.4.1 *Joints*

The lightning protective system shall have as few joints in it as necessary. In the down conductors below ground level these shall be mechanically and electrically effective and shall be so made as to exclude moisture completely. The joints may be clamped, screwed, bolted, crimped, riverted or welded. With overlapping joints the length of the overlap should not be less than 20 mm for all types of conductors. Contact surfaces should first be cleaned and then inhibited from oxidation with a suitable non-corrosive compound. Joints of dissimilar metal should be suitably protected against bimetallic action and corrosion.

a) In general, joints for strips shall be tinned, soldered, welded or brazed and at least double-riveted, welded or brazed. Clamped or bolted joints shall only be used on test points or on bonds to existing metal, but joints shall only be of the clamped or screwed type.

11.4.2 *Bonds*

External metal on or forming part of a structure may have to discharge the full lightning current. Therefore, the bond to the lightning protective system shall have a cross-sectional area not less than that employed for the main conductors. On the other hand, internal metal is not so vulnerable and its associated bonds are, at most, only likely to carry a portion of the total lightning current, apart from their function of equalizing potential. These latter bonds may, therefore, be smaller in cross-sectional area than those used for the main conductors. All the bonds should be suitably protected against corrosion. Bonds shall be as short as possible.

11.5 Testing Points

Each down conductor shall be provided with a testing point in a position convenient for testing but inaccessible for interference. No connection, other than one direct to an earth electrode, shall be made below a testing point. Testing points shall be phosphor bronze, gunmetal, copper or any other suitable material.

11.6 Earth Terminations

Each down conductor shall have an independent earth termination. It should be capable of isolation for testing purposes. In structures where only electrical systems are provided, a type A earthing arrangement may be used, but a Type B earthing arrangement is preferable. In structures with electronic systems, a Type B earthing arrangement is recommended.

11.6.1 Water pipe system should be bonded to the earth termination system if adequate clearance between the two cannot be obtained. They may be effectively bonded, and the bonds should be capable of isolation and testing. The gas pipes, however, should be bonded to the earth termination system.

11.6.2 It is recommended that all earth terminations should be interconnected to a common earthing. Besides equalizing the voltage at various earth terminations, this minimizes any risk of mechanical damage.

11.6.3 A structure standing on bare rock should be equipped with a type B ring earthing. The ring earth conductor encircling the structure shall be embedded inside concrete, preferably installed 1 meter away from the building. Where there is a risk to persons or to valuable equipment, expert advice should be sought.

11.7 Earth Electrodes

Earth electrodes shall be constructed and installed in accordance with 5.4.2 of IS/IEC 62305-3

11.7.1 Earth electrodes shall consist of rods, strips or plates. Metal sheaths of cables shall not be used as earth electrodes.

11.7.2 When rods or pipes are used they should be driven into the ground as close as practicable but outside the circumference of the structure. Long lengths in sections coupled by screwed connectors or socket joints can be built up where necessary to penetrate the substrate of low resistivity.

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11.7.3 When strips are used, these should be buried horizontally at a depth, but not less than 0.5 m deep to avoid damage. The strips should preferably be laid radially in two or more directions from the point of connection to a down conductor. But if this is not possible, they may extend in one direction only.

11.8 Fasteners

Conductors shall be securely attached to the building or other object to be protected by fasteners which shall be substantial in construction, not subject to breakage, and shall be made of stainless steel (Grade 304 or 316). If they are made of any other material suitable precautions should be taken to avoid corrosion.

11.9 Resistance of Earth Termination System

Earth termination system should have a resistance not exceeding 10 ohms to earth. If individual type A earth electrodes are used, and if the recommended length as per IS/IEC 62305 could not be maintained, resistance of each earth electrode shall not exceed 10 ohms.

12 ISOLATION AND BONDING

When a lightning protective system is struck with a lightning discharge, its electrical potential with respect to earth is raised, and unless suitable precautions are taken, the discharge may seek alternative paths to earth by side flashing to other metal in the structure. Side flashing may be avoided by the following two methods:

a) Isolation; and
b) Bonding.

12.1 Isolation

Isolation requires large clearances between the lightning protective system and other metal parts in the structure. The approximate clearance that is, separation distance shall be as per 6.3 of IS/IEC 62305-3.

12.2 Bonding

In structures which contain electrically continuous metal, for example, a roof, wall, floor or covering, this metal, suitably bonded, may be used as part of the lightning protective system, provided the amount and arrangement of the metal render it suitable for use in accordance with **11**.

12.2.1 If a structure is simply a continuous metal frame without external coverings it may not require any air termination or down conductors provided:

a) The electrical continuity between various parts is made durable through brazing, welding, crimping, seaming, screwing or bolting;
b) The thickness of the metal sheet is not less than the value given in Table 11; and
c) It does not consist of any cladding with insulating material.

Table 11 Minimum Thickness of Metal Sheets or Metal Pipes in Air-termination Systems

[*Clause* 12.2.1 a)]

Sl No.	Class of LPS	Material	Thickness[a] t mm	Thickness[b] t' mm
(1)	(2)	(3)	(4)	(5)
i)	I to IV	Lead	–	2.0
ii)		Steel (stainless, galvanized)	4	0.5
iii)		Titanium	4	0.5
iv)		Copper	5	0.5
v)		Aluminium	7	0.65
vi)		Zinc	–	0.7

[a] t prevents puncture.

[b] t' only for metal sheets if it is not important to prevent puncture, hot spot or ignition problems.

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12.2.2 Steel reinforcement in steel reinforced concrete structures confirming to 4.3 of IS/IEC 62305-3 may be used as a natural component of LPS. Such natural components must fulfill requirements of:

a) Down conductors according to 5.3 of IS/IEC 62305-3; and

b) Earth termination networks according to 5.4 of IS/IEC 62305-3.

12.2.3 Where metal exists in a structure as reinforcement which cannot be bonded into a continuous conducting network, and which is not or cannot be equipped with external earthing connections, its presence should be discarded. The danger inseparable from the presence of such metal can be minimized by keeping it entirely isolated from the lightning protective system.

12.2.4 Where the roof structure is wholly or partly covered by metal, care should be taken that such metal is provided with a continuous conducting path to earth.

12.2.5 In any structure, metal which is attached to the outer surface or projects through a wall or a roof and has insufficient clearance from the lightning protective system, and is unsuitable for use as part of it, should preferably be bonded as directly as possible to the lightning protectives system. If the metal has considerable length (*for example*, cables, pipes, gutters, rain-water pipes, stair-ways, etc.) and runs approximately parallel to a down conductor or bond, it should be bonded at each and but not below the test point. If the metal is in discontinuous lengths, each portion should be bonded to the lightning protective system; alternatively, where the clearance permits, the presence of the metal may be disregarded.

12.2.6 Bonding of metal entering or leaving a structure in the form of sheathing or armouring of cable, electric conduit, telephone, steam, compressed air or other services with earth termination system, should be done as per requirement s of IS/IEC 62305. Metal installations, that is, water, gas, heating and air pipes, lift shafts, crane supports etc. shall be bonded together and to the LPS at ground level. Where direct connections with bonding conductors are not allowed, *for example*, catholically protected pipes, Isolating Spark Gaps (ISG) may be used.

12.2.7 Masses of metal in a building, such as bell-frame in a tower, should be bonded to the nearest down conductor by the most direct route available.

12.2.8 Metal cladding or curtain walling having a continuous conducting path in all directions may be used as part of a lightning protective system.

12.2.9 In bonding adjacent metalwork to the lightning protective system careful consideration should be given to the possible effects such bonding would have upon metalwork which may be cathodically protected.

13 PROTECTION OF SPECIAL STRUCTURES

For guidance on design of lightning protection systems for special structures, reference shall be made to IS/IEC 62305 series. Guidance for the appropriate authorities shall also be obtained.

14 INSPECTION AND TESTING

14.1 Inspection

All lightning protective systems shall be examined by a competent engineer after completion, alteration or extensions, in order to verify that they are in accordance with the recommendations of the Code. A routine inspection shall be made at least once a year.

14.2 Testing

14.2.1 On completion of the installation or of any modification, the resistance of each earth termination or section thereof, shall, if possible, be measured and the continuity of all conductors and the efficiency of all bonds and joints shall be verified.

14.2.2 Normally, annual measurement of earth resistance shall be carried out but local circumstances in the light of experience may justify increase or decrease in this interval but it should not be less than once in two years. In the case of structures housing explosives or flammable materials, the interval shall be six months.

14.2.3 Earth resistance shall be measured in accordance with Part 1/Sec 13 of the Code.

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14.2.4 The actual procedure adopted for the test shall be recorded in detail so that future tests may be carried out under similar conditions. The highest value of resistance measured shall be noted as well as the resistance of the soil and details of salting or other soil treatment shall also be recorded.

14.2.5 The record shall also contain particulars of the engineer, contractor or owner responsible for the installation or upkeep or both of the lightning protective system. Details of additions or alterations to the system, and dates of testing together with the test results and reports shall be carefully recorded.

14.3 Deterioration

If the resistance to earth of a lightning protective system or any section of it exceeds the lowest value obtained at the first installation by more than 100 percent, appropriate steps shall be taken to ascertain the causes and to remedy defects, if any.

14.4 Testing Continuity and Efficacy of Conductors and Joints

14.4.1 The ohmic resistance of the lightning protective system complete with air termination, but without the earth connection should be measured and this should be a fraction of an ohm. If it exceeds 0.2 ohm, then there shall be some fault either electrical or mechanical, which shall be inspected and the defect rectified.

14.4.2 For this system is best divided into convenient sections at testing points by suitable joints. A continuous current of about 10 A shall be passed through the portion of the system under test and the resistance verified against its calculated or recorded value. Suitable portable precision testing sets for this purpose should be used.

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SECTION 20 POWER QUALITY

FOREWORD

As the per capita electricity consumption for India has grown from 16 units in 1947, to 884 units in 2012, to, further, 1208 units in March 2020, the aspiration for better quality of life for citizens are soaring high. At the same time facing climate challenges, India is committed for sustainable growth through reduced energy intensity in economy as well as increased utilization of renewable sources of energy in our day-to-day life. By 2030, 2000 units of per capita electricity consumption is expected. As energy access grows, the challenges of safety and sustainability grows too. Power Electronics is increasingly used to give better system performance while at the same time, it is one of the major source of polluting the power quality of supply system. Good quality power along with 24X7 availability will enhance our country's economic well-being.

The power quality is defined as a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy. With recent advances in electrotechnical domain, Power quality has started to play an increasingly important role. As the power providers are shifting to smart grid and smart meters, power quality needs to be standardized with focus on power factor improvement. The power quality can be categorized into two groups, one, addressing the standard for the power quality supplied at the grid level and the other, which deals with the factors that affect the power quality at user level. These factors include harmonics, voltage changes, sags, transients, voltage unbalance, inter harmonics, voltage flicker, voltage notching, DC offset, noise etc. Examining these issues require in-depth details on the power system. In this section of the National Electrical Code of India, we shall examine several aspects of Power factor improvement detailed in the following sub-sections.

Section 20.1 Power quality improvement — pf correction and harmonics control

Section 20.2 Understanding, monitoring and managing Power quality

Section 20.3 Power quality improvement — neutral conductor

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SECTION 20.1 POWER QUALITY IMPROVEMENT — PF CORRECTION AND HARMONICS CONTROL

FOREWORD

The various advantages of maintaining a high power factor of a system reflects on the national economy of a country. The available resources are utilized to its full potential. More useful power is available for transmission and utilization without any additional cost. Moreover, the life of individual apparatus is considerably increased and the energy losses are reduced.

Guidance to the consumers of electrical energy who take supply of low voltage (<=1kV), medium voltage (1kV < U_n <=33kV) and high voltage (33kV < Un <= 150kV) for improvement of power factor at the installation in their premises is provided in this Section. The guidelines provided are intended for installation operating at voltages below 650 V. For higher voltage installations, additional or more specific rules apply.

Assistance has been derived from IS 7752 (Part 1) : 1975 'Guide for the improvement of power factor in consumer installations: Part 1 Low and medium supply voltages'.

1 SCOPE

1.1 This standard (Part 1/Sec 20.1) of the Code covers causes for low power factor and high harmonics, impact of harmonics and guidelines for use of capacitors and filters for improvement in consumer installations.

1.2 Specific guidelines, if any, for individual installation on improvement of power factor are covered in the respective sections of the Code.

2 REFERENCE

The standards listed in below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No./Other Publication	*Title*
7752 (Part 1) : 1975	Guide for the improvement of power factor in consumer installations: Part 1 Low and medium supply voltages
16636 : 2017	Automatic power factor correction (APFC) panels for voltage rating up to and including 1 000 V
IEEE 519-2014	IEEE recommended practice and requirements for harmonic control in electric power systems
17036 : 2018	Distribution system supply voltage quality

3 GENERAL

3.1 Conditions of supply of electricity boards or licensees stipulate the lower limit of power factor which is generally 0.9 (lag/lead) and consumer is obliged to improve and maintain the power factor of his installation to conform to these conditions.

3.1.1 When the tariffs of Electricity Boards and the licensees are based on kVA/kW demand, plus kWH billing with suitable penalty for low power factor and suitable rebate for high power factor or kVA demand plus kVAh billing, improvement in the power factor shall effect savings in the energy bills.

3.2 Power factor is dependent largely on consumers' apparatus and partly on system components, such as transformers, cables, transmission lines, etc. System components have fixed parameters of inductance, capacitance and resistance. The choice of these components to bring up the power factor depends on economics.

3.3 In case of a.c. supply, the total current taken by all items of electrical equipment, except that of incandescent lighting and most forms of resistance heating, are made up of two parts, namely:

a) in-phase component of the current (active or useful current) which is utilized for doing work or producing heat; and

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b) quadrature component of the current (also called 'idle' or 'reactive' current) and used for creating magnetic field in the machinery or apparatus those are inductive in nature. This component is not convertible into useful output.

4 POWER FACTOR

The majority of a.c. electrical machines and equipment draw from the supply an apparent power (kVA) which exceeds the required useful power (kW). This is due to the reactive power (kVAR), which can be either inductive or capacitive, depending on the type of loads catered. The ratio of useful power (kW) to apparent power (kVA) is termed the power factor of the load. The reactive power is indispensable and constitutes an additional demand on the system.

The power factor indicates the portion of the current in the system performing useful work. A power factor of unity (100 percent) denotes 100 percent utilization of the total current for useful work whereas a power factor of 0.70 shows that only 70 percent of the current is performing useful work.

4.1 Principle causes of Lower Power Factor

4.1.1 The following electrical equipment and apparatus have lower power factor:

a) Induction motors of all types, particularly, when they are operated at reduced/light loads;
b) Power transformers and voltage regulators;
c) Arc welders;
d) Induction furnaces and heating coils;
e) Choke coils and magnetic systems; and
f) Fluorescent and discharge lamps, neon signs, etc.

4.1.2 The principal cause of low power factor is due to the reactive power flowing in the circuit. The power factor is also influenced by cable capacitance. The reactive power depends on the inductance and capacitance of the apparatus.

4.2 Effect of Power Factor to Consumer

4.2.1 The disadvantages of low power factor are as follows:

a) Overloading of cables and transformer thus reducing the life of the asset;
b) Decreased/increased line and phase voltage at point of application on account of lagging/leading low power factor;
c) Inefficient operation of plant leading to power and energy loss; and
d) Penal power rates causing economic loss;
e) Wastage of capital due to oversizing of cables/transformers; and
f) Reducing the power flow on transmission line.

4.2.2 The advantages of high power factor are as follows:

a) Reduction in the current leading to reduced loading on conductors and reduced losses;
b) Reduction in power distribution and consumption;
c) Reduced losses in the transformers and cables;
d) Lower loading of transformers, switchgears, cables, etc;
e) Increased capability of the 'power system' (additional load can be met without additional equipment);
f) Improvement in supply voltage conditions and apparatus performance; and
g) Reduction in voltage dips caused by welding and similar equipment.

4.3 Economics of Power Factor Improvement

Static capacitors, also called static condensers, when installed at or near the point of consumption, provide necessary capacitive reactive power, relieve distribution system before the point of its installation from carrying the inductive reactive power to that extent.

The use of the static capacitors is an economical way of improving power factor on account of their comparatively low cost, ease of installation loss maintenance, low losses and the advantage of extension by addition of requisite

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units to meet the load growth. Installation of capacitors also improve the voltage regulation and reduces amperes loading and energy losses in the supply apparatus and lines.

When considering the economics connected with power factor correction, it is most important to remember that any power factor improving equipment, in general, compensate for losses and lower the loadings on supply equipment, that is, cables, transformers, switchgear, generating plant, etc.

The minimum permissible power factor prescribed in the conditions of supply of Electricity Boards or Licensees and the reduction in charges offered in supply tariffs for further improvement of power factor shall, along with other considerations such as reduction of losses etc, determine the kVAR capacity of the capacitors to be installed.

4.4 Conventionally, utility tariff in India have been following two part tariff norms for high consumption consumers. This used to consider maximum demand charge (in kW/kVA units to provide for infrastructure to supply) plus energy charge (in kWh to account for energy consumption). However, in recent times, utilities have started considering to levy tariff only on basis of kVAh since non-linear load concentration has increased rapidly which is impacting the power transfer capabilities. The detailed following cases are as under:

4.4.1 In case of two port tariff with kVA demand and kWh consumption charged, the value of economic improved power factor ($\cos \varphi_2$) may be obtained as follows:

Let the tariff be Rs. *A* per kVA of maximum demand per annum plus Rs. *P* per kWh.

$\cos \varphi_1$ is the initial power factor,

$\cos \varphi_2$ is the improved power factor after installing the capacitors

The economic power factor $\cos \varphi_2$ is obtained from the expression

$$\cos \varphi_2 = \sqrt{1 - \frac{B2}{A2}} \qquad \text{.....(1)}$$

Where

B = total cost of capacitor installation per kVAR per year inclusive of interest, depreciation and maintenance.

NOTE — Refer Appendix A of IS 7752 (Part 1) for the derivation of the formula for economic power factor $\cos \varphi_2$.

5 USE OF CAPACITORS

In order to improve the power factor, the consumer shall install capacitors where the natural power factor of this installation is low.

The average values of the power factor for various types of 3-phase electrical installations as measured by one of major utilities in the country are specified in respective Sections of the Code.

Capacitors for power factor improvement may be arranged as described in IS 7752 (Part 1). The successful operation of power factor improvement depends very largely on the positioning of the capacitor on the system. Ideal conditions are achieved when the highest power factor is maintained under all load conditions.

In poor voltage regulation area, use of synchronous condensers are preferred over conventional capacitors for improving Power Factor.

5.1 Individual Compensation

Wherever possible, the capacitor should be connected directly across the terminals of the low power factor appliance or equipment. This ensures the automatic control through the common switching devices of the apparatus or appliance.

5.2 Group Compensation

In industrial locations, where a large number of small motors or other appliances and machines are installed with periodical operations, it is economical to dispense with individual installation of capacitors. A bank of capacitors may be installed to connect them to the distribution centre of main bus-bars of the group of machines.

5.3 Central Compensation

Capacitors may also be installed at a central point, that is, at the incoming supply or service position. In order to overcome problems of drawing leading currents on light loads, these capacitors may be operated manually or

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automatically, as required. The automatic control is preferred as it eliminates human errors. Automatic operation may be arranged by means of suitable relays in which a contactor controls the capacitors bank and maintains the correct amount of kVAR in the circuit.

Capacitors shall not be connected directly across motor terminals if solid state starters/soft starters are used.

Capacitors shall not be connected directly to motor terminals if variable speed drive is adopted.

Due to high inrush current at the time of switching on, capacitors connected to same bus-bars may discharge instantaneously. This shall be taken care of while providing central compensation with automatic power factor correction relay.

Harmonics (both current and voltage distortion) may reduce life of capacitors.

Switching/controlling devices for capacitors shall have required capacitor switching duty.

5.4 Combined Compensation

Capacitors may be connected directly across the terminals of higher capacity inductive appliances or equipment, in addition to the capacitors with automatic power factor correction relay for central compensation connected at the incoming supply or service position. Impact of capacitor switching transients should also be considered while attempting to connect directly across inductive appliances and equipment.

5.5 The methods of connecting power factor capacitors to supply line and motors are given in Figure 1 and Figure 2 respectively.

6 SELECTION AND INSTALLATION OF CAPACITORS

Capacitor current shall not exceed magnetization current of the motor when directly connected across motor terminals. Chances of resonance and switching transients shall be considered. Energy loss/power consumption of capacitors shall be taken care of. Capacitor banks shall be properly ventilated. Chances of over voltage shall be also be looked into.

Resistors shall be provided across capacitor terminals for discharging.

7 POWER FACTOR IMPROVEMENT AND CAPACITOR RATING

For calculating the size of the capacitor for power factor improvement, reference shall be made to Table 1.

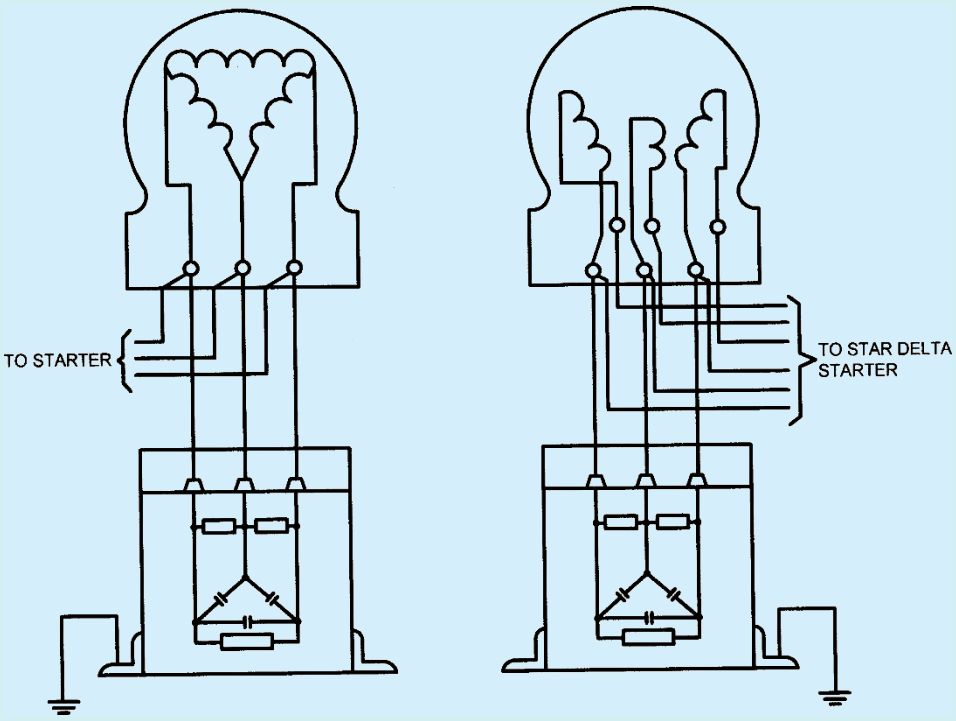


FIG. 1 METHODS OF CONNECTING CAPACITORS TO MOTORS FOR IMPROVEMENT OF POWER FACTOR

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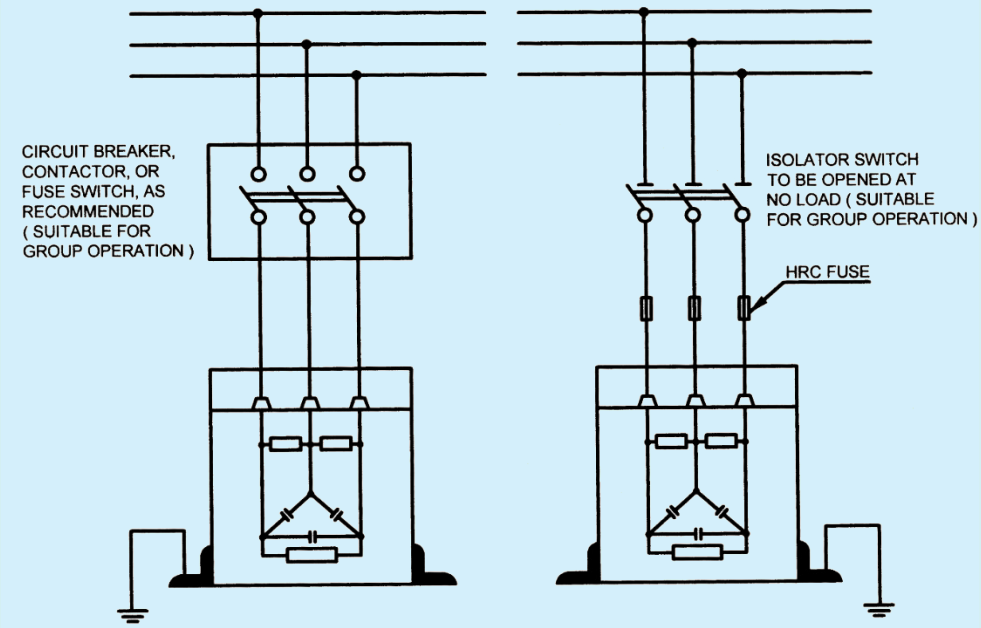


FIG. 2 METHODS OF CONNECTING CAPACITORS TO SUPPLY LINE FOR IMPROVEMENT OF POWER FACTOR

Table 1 Capacitor Sizes for Power Factor Improvement

(*Clause* 7)

Existing Power Factor	Improved Power Factor												
	0.80	0.85	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.00
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Multiplying Factor													
0.40	1.537	1.668	1.805	1.832	1.861	1.895	1.924	1.924	1.998	2.037	2.085	2.146	2.288
0.41	1.474	1.605	1.742	1.769	1.798	1.831	1.860	1.860	1.935	1.973	2.021	2.082	2.225
0.42	1.413	1.544	1.681	1.709	1.738	1.771	1.800	1.800	1.874	1.913	1.961	2.022	2.164
0.43	1.356	1.487	1.624	1.651	1.680	1.713	1.742	1.742	1.816	1.885	1.903	1.964	2.107
0.44	1.290	1.421	1.558	1.585	1.614	1.647	1.677	1.677	1.751	1.790	1.837	1.899	2.041
0.45	1.230	1.360	1.501	1.532	1.561	1.592	1.626	1.626	1.695	1.737	1.784	1.846	1.988
0.46	1.179	1.309	1.446	1.473	1.502	1.533	1.567	1.567	1.636	1.677	1.725	1.786	1.929
0.47	1.130	1.260	1.397	1.425	1.454	1.485	1.519	1.519	1.588	1.629	1.677	1.758	1.881
0.48	1.076	1.206	1.343	1.370	1.400	1.430	1.464	1.464	1.534	1.575	1.623	1.684	1.826
0.49	1.030	1.160	1.297	1.326	1.355	1.386	1.420	1.420	1.489	1.530	1.578	1.639	1.782
0.50	0.982	1.112	1.248	1.276	1.303	1.337	1.369	1.369	1.441	1.481	1.529	1.590	1.732
0.51	0.936	1.066	1.202	1.230	1.257	1.291	1.323	1.323	1.395	1.435	1.483	1.544	1.686
0.52	0.894	1.024	1.160	1.188	1.215	1.249	1.281	1.281	1.353	1.393	1.441	1.502	1.644
0.53	0.850	0.980	1.116	1.144	1.171	1.205	1.237	1.237	1.309	1.349	1.397	1.458	1.600
0.54	0.809	0.939	1.075	1.103	1.130	1.164	1.196	1.196	1.268	1.308	1.356	1.417	1.559
0.55	0.769	0.899	1.035	1.063	1.090	1.124	1.136	1.136	1.228	1.268	1.316	1.377	1.519
0.56	0.730	0.860	0.996	1.024	1.051	1.085	1.117	1.117	1.189	1.229	1.277	1.338	1.480
0.57	0.692	0.822	0.958	0.986	1.013	1.047	1.079	1.079	1.151	1.191	1.239	1.300	1.442
0.58	0.655	0.785	0.921	0.949	0.976	1.010	1.042	1.042	1.114	1.154	1.202	1.263	1.405
0.59	0.618	0.748	0.884	0.912	0.939	0.973	1.005	1.005	1.077	1.117	1.165	1.226	1.368

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Table 1 *(Concluded)*

Existing Power Factor	Improved Power Factor												
	0.80	0.85	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.00
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
0.60	0.584	0.714	0.849	0.878	0.905	0.939	0.971	0.971	1.043	1.1083	1.131	1.192	1.334
0.61	0.549	0.679	0.815	0.843	0.870	0.904	0.936	0.936	1.008	1.048	1.096	1.157	1.299
0.62	0.515	0.645	0.781	0.809	0.836	0.870	0.902	0.902	0.974	1.014	1.062	1.132	1.265
0.63	0.483	0.613	0.749	0.777	0.804	0.838	0.870	0.870	0.942	0.982	1.030	1.091	1.233
0.64	0.450	0.580	0.716	0.744	0.771	0.805	0.837	0.837	0.909	0.949	0.997	1.058	1.200
0.65	0.419	0.549	0.685	0.713	0.740	0.774	0.806	0.806	0.878	0.918	0.966	1.027	1.169
0.66	0.388	0.518	0.654	0.682	0.709	0.743	0.775	0.775	0.847	0.887	0.935	0.996	1.138
0.67	0.358	0.488	0.624	0.652	0.679	0.713	0.745	0.745	0.817	0.857	0.905	0.966	1.108
0.68	0.329	0.459	0.595	0.623	0.650	0.684	0.716	0.716	0.788	0.828	0.876	0.937	1.097
0.69	0.299	0.429	0.565	0.593	0.620	0.654	0.686	0.720	0.758	0.798	0.840	0.907	1.049
0.70	0.270	0.400	0.536	0.564	0.591	0.625	0.657	0.691	0.729	0.769	0.811	0.878	1.020
0.71	0.242	0.372	0.508	0.536	0.563	0.597	0.629	0.663	0.701	0.741	0.785	0.850	0.992
0.72	0.213	0.343	0.479	0.507	0.534	0.568	0.600	0.634	0.672	0.712	0.754	0.821	0.963
0.73	0.186	0.316	0.452	0.480	0.504	0.541	0.573	0.607	0.648	0.685	0.727	0.794	0.936
0.74	0.159	0.289	0.425	0.453	0.480	0.514	0.546	0.580	0.618	0.658	0.700	0.740	0.909
0.75	0.132	0.262	0.398	0.426	0.453	0.487	0.519	0.553	0.591	0.631	0.673	0.713	0.882
0.76	0.105	0.235	0.371	0.399	0.426	0460	0.492	0.526	0.564	0.604	0.652	0.687	0.855
0.77	0.079	0.209	0.345	0.373	0.400	0.434	0.466	0.500	0.538	0.578	0.620	0.661	0.829
0.78	0.053	0.183	0.319	0.347	0.374	0.408	0.440	0.474	0.512	0.552	0.594	0.634	0.803
0.79	0.026	0.156	0.292	0.320	0.347	0.381	0.413	0.447	0.485	0.525	0.567	0.608	0.776
0.80	—	0.130	0.266	0.294	0.321	0.355	0.987	0.421	0.459	0.499	0.541	0.582	0.750
0.81	—	0.104	0.240	0.268	0.295	0.29	0.361	0.395	0.433	0.473	0.515	0.556	0.724
0.82	—	0.078	0.214	0.242	0.269	0.303	0.335	0.369	0.407	0.447	0.489	0.530	0.698
0.83	—	0.052	0.188	0.216	0.243	0.277	0.309	0.343	0.381	0.421	0.463	0.504	0.672
0.84	—	0.026	0.168	0.190	0.217	0.251	0.283	0.317	0.355	0.395	0.437	0.578	0.645
0.85	—	—	0.136	0.164	0.191	0.225	0.257	0.291	0.329	0.396	0.417	0.450	0.620
0.86	—	—	0.109	0.140	0.167	0.198	0.230	0.264	0.301	0.343	0.390	0.424	0.593
0.87	—	—	0.083	0.114	0.141	0.172	0.204	0.238	0.275	0.317	0.364	0.395	0.567
0.88	—	—	0.054	0.085	0.112	0.143	0.175	0.209	0.246	0.288	0.335	0.395	0.538
0.89	—	—	0.028	0.059	0.086	0.117	0.149	0.183	0.230	0.262	0.309	0.369	0.512
0.90	—	—	—	0.031	0.058	0.089	0.121	0.155	0.192	0.234	0.281	0.341	0.484
0.91	—	—	—	—	0.027	0.058	0.090	0.124	0.161	0.203	0.250	0.310	0.453
0.92	—	—	—	—	—	0.027	0.063	0.097	0.134	0.176	0.223	0.283	0.426
0.93	—	—	—	—	—	—	0.032	0.066	0.103	0.145	0.192	0.252	0.395
0.94	—	—	—	—	—	—	—	0.034	0.071	0.113	0.160	0.220	0.363
0.95	—	—	—	—	—	—	—	—	0.037	0.079	0.126	0.186	0.329
0.96	—	—	—	—	—	—	—	—	—	0.042	0.089	0.149	0.292
0.97	—	—	—	—	—	—	—	—	—	—	0.047	0.107	0.250
0.98	—	—	—	—	—	—	—	—	—	—	—	0.060	0.203
0.99	—	—	—	—	—	—	—	—	—	—	—	—	0.143

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7.1 Automatic Power Factor Correction Panels (APFC)

APFC panels are used for automatic power factor correction. These panels have a power factor controller which takes input from a single or multiple current transformer installed on the mains. Based on the requirement, it switches ON/OFF the capacitor bank to maintain the power factor as per the set limit on the controller. Depending on the nature of loads, one can choose the switching device for the capacitor bank. Contactors can be used for slow varying loads whereas Thyristor switching is recommended for fast varying loads or loads sensitive to transient surges.

Another point a user should consider when installing capacitor bank in the system is presence of harmonics in electrical system. Harmonics are caused by the non-linear magnetizing impedances of transformers, reactors, fluorescent lamp ballasts, LEDs, Solar Inverters and EVs, etc. In addition, power electronic devices have become abundant today because of their capabilities for precise process control and energy savings benefits. However, they also bring drawbacks to electrical distribution systems through harmonics.

Harmonic currents caused by nonlinear loads connected to the distribution system flowing through the system impedances distorts the supply voltage. Such loads are increasingly used in all industrial, commercial, and residential installations and their percentage of the total load is growing steadily (*see* Figure 3).

Capacitors are sensitive to harmonic components of the supply voltage due to the fact that capacitive reactance decreases as the frequency increases. It means that a change in relatively small percentage of harmonic voltage can cause a significant current to flow in the capacitor circuit (*see* Figure 4).

The connection of PFC capacitors (without reactors) results in the amplification of harmonic currents at the busbar level, and an increase of the voltage distortion. Capacitors are linear reactive devices, and hence, do not generate harmonics. The installation of capacitors in a power system (in which the impedances are predominantly inductive) can, however, result in total or partial resonance occurring at one of the harmonic frequencies. Because of harmonics, the current I_C circulating through the PFC capacitors is higher as compared to the situation where only the fundamental current I_1 is present. If the natural frequency of the capacitor bank/power-system reactance combination is close to a particular harmonic, then partial resonance will occur, with amplified values of voltage and current at the harmonic frequency concerned. In this particular case, the elevated current will cause overheating of the capacitor, with degradation of the dielectric, which may result in its failure eventually.

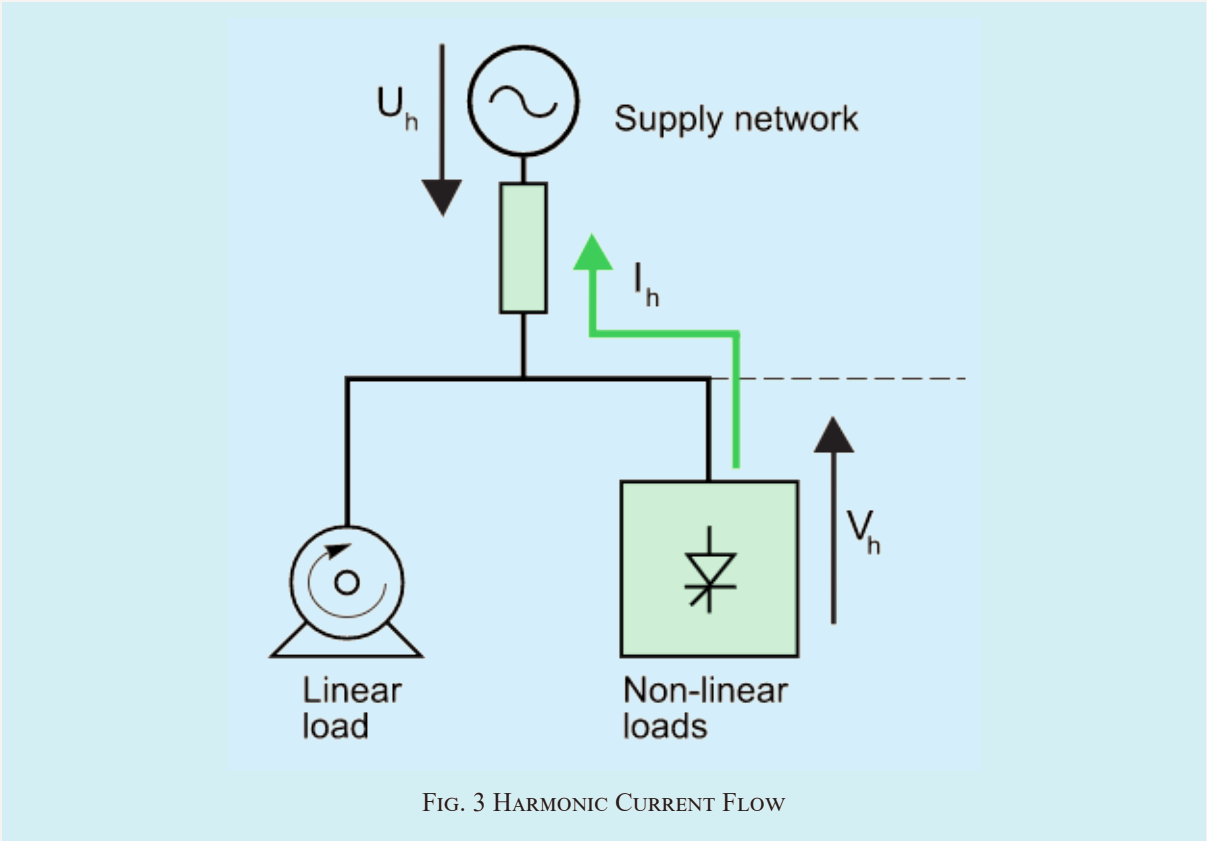


FIG. 3 HARMONIC CURRENT FLOW

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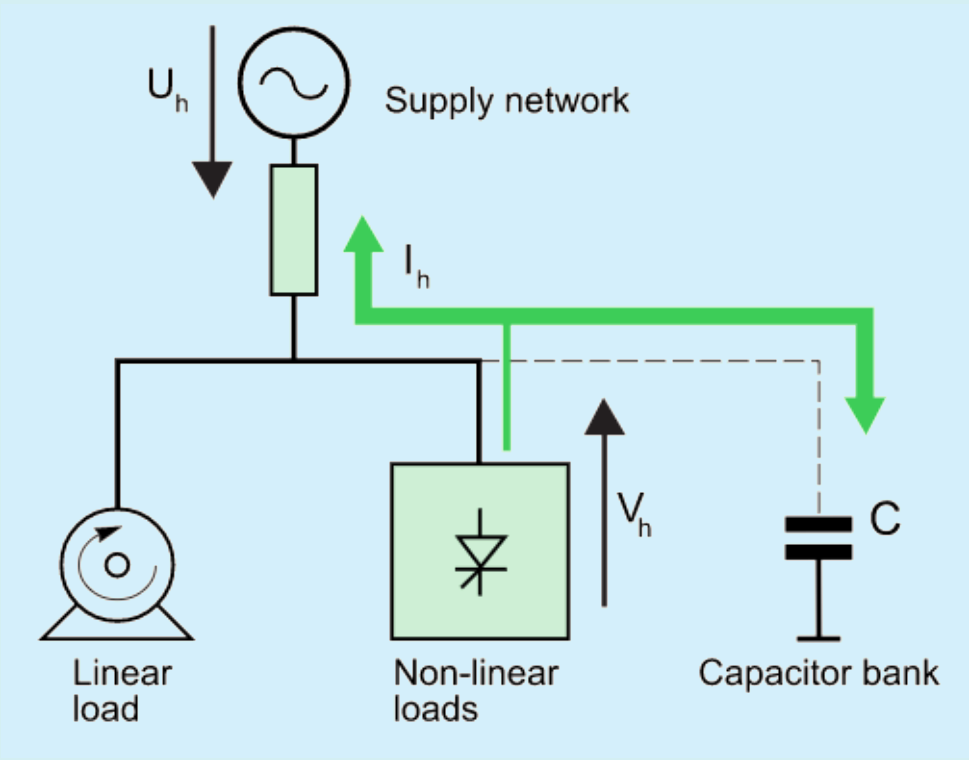


FIG. 4 HARMONIC CURRENT FLOW IN CAPACITOR

The order h_0 of the natural resonant frequency between the system inductance and the capacitor bank is given by:

$$h_0 = \sqrt{(Ssc / Q)} \quad \text{.....(2)}$$

Where,

S_{SC} = the level of system short-circuit power (kVA) at the point of connection of the capacitor;

Q = capacitor bank rating in kVAR; and

h_0 = the order of the natural frequency f_0, that is, $f_0/50$ for a 50 Hz system, or $f_0/60$ for a 60 Hz system.

Possible solution is to use capacitors (heavy duty) with increased current rating if percentage of non-linear load is less than 20 percent (NLL ≤ 20 percent). In order to attenuate the effects of harmonics (significant increase of capacitor current as well as high current and voltage distortion), reactors shall be associated to capacitors. Reactors and capacitors are configured in a series resonant circuit (*see* Figure **5**), tuned so that the series resonant frequency is below the lowest harmonic frequency present in the system. The use of detuned reactors, thus, prevents harmonic resonance problems, avoids the risk of overloading the capacitors and helps reduce voltage harmonic distortion in the network.

The tuning frequency can be expressed by the relative impedance of the reactor (in percent, relative to the capacitor impedance), or by the tuning order, or directly in Hz. The most common values of relative impedance are 5.7, 7 and 14 percent (14 percent is used with high level of 3rd harmonic voltages) (*see* Table 2).

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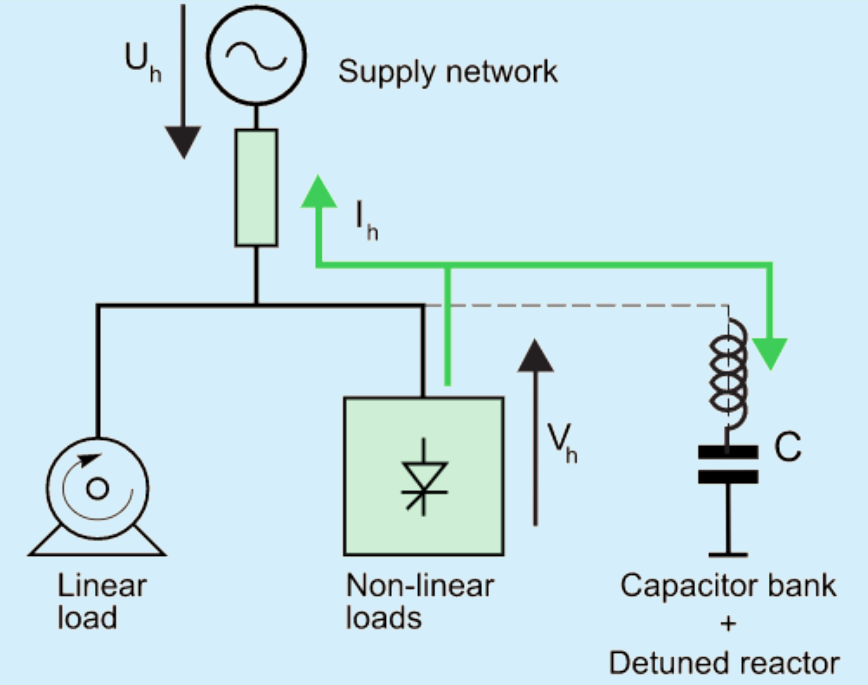


FIG. 5 CAPACITOR WITH DETUNED REACTOR

Table 2 Correspondence between Relative Impedance, Tuning Order and Tuning Frequency

(*Clause* 7.1)

Sl No.	Relative Impedance (percent)	Tuning Order	Tuning Frequency at 50 Hz Hz
(1)	(2)	(3)	(4)
i)	5.7	4.2	210
ii)	7	3.8	190
iii)	14	2.7	135

A significant indicator of harmonic importance is the percentage of non-linear loads NLL, calculated by the formula:

$$NLL\,(percent) = \frac{Power\ of\ non-linear\ loads}{Power\ of\ supply\ transformer} \qquad \text{.....(3)}$$

While choosing capacitors with detuned reactor, care is to be taken to use higher rated voltage for capacitors than the network voltage as shown in the Table 3.

Table 3 Typical Values of Capacitor Rated Voltage

(*Clause* 7.1)

Sl No.	Relative Impedance %	Capacitor Rated Voltage Un V	Network Service Voltage Us, 50 Hz V
(1)	(2)	(3)	(4)
i)	5.7	400	690
ii)	7	480	830
iii)	14	480	830

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IS 16636 on automatic power factor correction panels for voltage rating upto and including 1000 V defines the tests for APFC panels. A completely type tested APFC panel designed, according to this standard, shall guarantee reliable product for the end user.

7.2 Effects of Harmonics

a) Affect operation of sensitive equipment like control and monitoring devices;
b) Distortion of telephone signals;
c) Harmonics cause additional losses (Joule effect) in conductors and equipment;
d) Derating of power sources (generators, transformers and UPSs) leading to over-sizing;
e) Oversizing of conductors on account of the flow of harmonic currents due to skin effect;
f) Reduced service life of equipment; and
g) Nuisance tripping of breakers and installation shutdown.

There are multiple ways to reduce the effect of harmonics by using separate source for non-linear loads, use of reactors, use of transformers with special connections and active harmonic filters (AHF). Among these, active harmonic filter offers a flexible, scalable solution for harmonic mitigation. AHF sense the current by means of CTs mounted on the mains/load. It calculates the harmonic current requirement of the load and produce a harmonic current which will be in phase opposition. This way it will reduce the harmonic current drawn from the utility.

7.3 Harmonic Control Guidelines

IS 17036 : 2018 on Distribution System Supply Voltage Quality is available. Further, Forum of Regulators (FOR) have prescribed Model Regulations on '*Power Quality of Electricity Supply to the Consumers*'. CEA has also notified Technical Standards for Grid Connectivity Regulations with Power Quality benchmark in year 2019. Generally, guidance is obtained from IEEE 519-2014 (Guide for recommended practice and requirement of harmonic control in electrical power systems).

This standard defines the limits of voltage and current harmonics.

The limits in this recommended practice are intended for application at a point of common coupling (PCC) between the system owner or operator and a user, where the PCC is usually taken as the point in the power system closest to the user where the system owner or operator could offer service to another user. Frequently, for service to industrial users (that is, manufacturing plants) *via* a dedicated service transformer, the PCC is at the HV side of the transformer. For commercial users (office parks, shopping malls, etc.) supplied through a common service transformer, the PCC is commonly at the LV side of the service transformer.

It's a shared responsibility of utility and users to maintain the harmonic control. Utility has to maintain Voltage distortion to minimum by adjusting the supply system impedance and users to limit harmonic current to reasonable limits by taking suitable actions.

Harmonic measurements are classified into Short time harmonic measurement (F_{sh}) and Very short time harmonic measurement (F_{vs}), where F represents Voltage or Current rms value.

7.3.1 *Very Short Time Harmonic Measurement*

Very short time harmonic values are assessed over a 3 s interval based on an aggregation of 15 consecutive 12 (10) cycle windows for 60 (50) Hz power systems. Individual frequency components are aggregated based on calculation.

$$F_{n,vs} = \sqrt[2]{\frac{1}{15}\sum_{i=1}^{15} F_{n,i}^2} \qquad \text{.....(4)}$$

Where, F represents voltage (V) or current(I), n represents the harmonic order, and i is a simple counter. The subscript vs is used to denote "very short."

7.3.2 *Short Term Harmonic Measurements*

Short time harmonic values are assessed over a 10 min interval based on an aggregation of 200 consecutive very short time values for a specific frequency component. The 200 values are aggregated based on an rms calculation as shown in Equation (2) where F represents voltage (V) or current (I), n represents the harmonic order, and i is a

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simple counter. The subscript *sh* is used to denote "short." In all cases, *F* represents an rms value.

$$F_{\mathrm{n,sh}} = \sqrt[2]{\frac{1}{200}\sum_{i=1}^{200} F^2_{(n,sh),i}} \qquad \text{.....(5)}$$

Very short and short time harmonic values should be accumulated over periods of one day and one week, respectively. For very short time harmonic measurements, the 99th percentile value (that is, the value that is exceeded for 1 percent of the measurement period) should be calculated for each 24 h period for comparison with the recommended limits. For short time harmonic measurements, the 95th and 99th percentile values (that is, those values that are exceeded for 5 percent and 1 percent of the measurement period) should be calculated for each 7 day period for comparison with the recommended limits in **7.3.2.1** and **7.3.2.2**. These statistics should be used for both voltage and current harmonics with the exception that the 99th percentile short time value is not recommended for use with voltage harmonics.

7.3.2.1 *Recommended harmonic voltage limits*

At the PCC, system owners or operators should limit line-to-neutral voltage harmonics as follows:

a) Daily 99th percentile very short time (3 s) values should be less than 1.5 times the values given in Table 4.

b) Weekly 95th percentile short time (10 min) values should be less than the values given in Table 4.

Table 4 Voltage Distortion Limits

[*Clause* 7.3.2.1 a) and b)]

Sl No.	Bus voltage V at PCC	Individual Harmonic %	Total Harmonic Distortion THD %
(1)	(2)	(3)	(4)
i)	V ≤ 1.0 kV	5.0	8.0
ii)	1 kV < V ≤ 69 kV	3.0	5.0
iii)	69 kV < V ≤ 161 kV	1.5	2.5
iv)	161 kV < V	1.0	1.5[a]

[a] High voltage systems can have up to 2.0 percent THD where the cause is an HVDC terminal whose effect will have attenuated at point in the network where future users may be connected.

7.3.2.2 Recommended current distortion limits for systems nominally rated 120 V through 69 kV.

These limits apply to users connected to systems where the rated voltage at the PCC is 120 V to 69 kV. At the PCC, users should limit their harmonic currents as follows:

a) Daily 99th percentile very short time (3 s) harmonic currents should be less than 2.0 times the values given in Table 5.

b) Weekly 99th percentile short time (10 min) harmonic currents should be less than 1.5 times the values given in Table 5.

c) Weekly 95th percentile short time (10 min) harmonic currents should be less than the values given in Table 5.

Table 5 Current Distortion Limits for Systems Rated 120 V through 69 kV

(*Clause* 7.3.2.2)

Sl No.		Maximum Harmonic Current Distortion (in percent of I_L)					
		Individual Harmonic Order (Odd Harmonics)[a,b]					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	I_{sc}/I_L	3 ≤ h < 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h < 50	TDD
ii)	<20[c]	4.0	2.0	1.5	0.6	0.3	5.0
iii)	20<50	7.0	3.5	2.5	1.0	0.5	8.0

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Table 5 *(Concluded)*

Sl No.	Maximum Harmonic Current Distortion (in percent of I_L) Individual Harmonic Order (Odd Harmonics)[a,b]						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
iv)	50<100	10.0	4.5	4.0	1.5	0.7	12.0
v)	100<1000	12.0	5.5	5.0	2.0	1.0	15.0
vi)	>1000	15.0	7.0	6.0	2.5	1.4	20.0

[a] Even harmonics are limited to 25 percent of the odd harmonic limits above.
[b] Current distortions that result in a d.c. offset; for example, half –wave converters are not allowed.
[c] All power generation equipment is limited to these values of current distortion, regardless of actual I_{Sc}/I_L
where,
I_{sc} – maximum short –circuit current at PCC.
I_L – maximum demand load current fundamental frequency component) at the PCC under normal load operating condition.

7.3.2.3 Recommended current distortion limits for systems nominally rated above 69 kV through 161 kV is specified in Table 6.

Table 6 Current Distortion Limits for Systems rated above 69 kV through 161 kV

(*Clause* 7.3.2.3)

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics) [a, b]						
I_{sc}/I_L	$3 \le h < 11$	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h \le 50$	TDD
<20[c]	2.0	1.0	0.75	0.3	0.15	2.5
20<50	3.5	1.75	1.25	0.5	0.25	4.0
50<100	5.0	2.25	2.0	0.75	0.35	6.0
100<1000	6.0	2.75	2.5	1.0	0.5	7.5
>1000	7.5	3.5	3.0	1.25	0.7	10.0

[a] Even harmonics are limited to 25 percent of the odd harmonic limits above.
[b] Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.
[c] All power generation equipment is limited these values of current distortion, regardless of actual I_{sc}/I_L.
where,
I_{sc} = maximum short-circuit current at PCC.
I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions.

7.3.2.4 Recommended current distortion limits for systems nominally rated above 161 kV is specified in Table 7.

Table 7 Current Distortion Limits for Systems Rated > 161 kV

(*Clause* 7.3.2.4)

Maximum Harmonic Current Distortion in Percent of I_L						
Individual Harmonic Order (Odd Harmonics)[a, b]						
I_{sc}/I_L	$3 \le h < 11$	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h \le 50$	TDD
<25[c]	1.0	0.5	0.38	0.15	0.1	1.5
25<50	2.0	1.0	0.75	0.3	0.15	2.5
≥50	3.0	1.5	1.15	0.45	0.22	3.75

[a] Even harmonics are limited to 25 percent of the odd harmonic limits above.
[b] Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.
[c] All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.
where,
I_{sc} = maximum short-circuit current at PCC.
I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions.

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SECTION 20.2 UNDERSTANDING, MONITORING AND MANAGING POWER QUALITY

FOREWORD

Economic growth of a country is directly influenced by availability and quality of power. The demand for power is not limited to manufacturing sector but extends to all the segments of the society. To remain competitive in the market, the cost of downtime due to power quality issues affecting the profitability of the business must be kept in check.

India's digital market is growing rapidly and with increasing use of power electronics, ratio of non-linear loads to linear loads has increased multifold in last few years.

Non-linear loads introduce harmonics in the supply network. Global standards are addressing the challenge through incorporation of stringent requirements.

1 SCOPE

This section of the Code (Part 1/Sec 20.2) covers power quality improvement of power quality.

2 REFERENCE

The standards listed in below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No./Other Publication	*Title*
IS 14700/IEC 61000 series	Electromagnetic compatibility (EMC)
IEC 62586-2 : 2017	Power quality measurement in power supply systems — Part 2: Functional tests and uncertainty requirements
IEC 62586-2 : 2017	Power quality measurement in power supply systems — Part 2: Functional tests and uncertainty requirements
IEEE 1159 : 2019	IEEE recommended practice for monitoring electric power quality
IEEE 519 : 2014	IEEE recommended practice and requirements for harmonic control in electric power systems
EN 50160 : 1999	Voltage characteristics of electricity supplied by public distribution systems

3 GENERAL

Global and National Standards have evolved over period to provide the users education on power quality and various standards such as IS 17036, IEC 61000, IEEE 1159, IEEE 519 and EN 50160 standards have provided insights on what constitutes power quality as well as methods to manage, monitor and mitigate power quality concerns.

3.1 Understanding Power Quality

3.1.1 The term *power quality* refers to a wide variety of electromagnetic phenomena that characterize the voltage and current at a given time and at a given location in the power system. The increasing application of electronic equipment can cause electromagnetic disturbances and dependence of equipments/appliances sensitivity and performance has heightened the interest in improving the power quality in recent years. This clause includes the additional terminology related to power quality factors. Various power factor related phenomena are shown in Fig. 1.

3.1.1.1 The supply shall provide a power quality complying with the required standards.

3.1.1.2 The equipment shall have ability to withstand the variations in the power quality.

3.1.1.3 The equipment shall not deteriorate the power quality of the nearby installed areas or cause any adverse effects on account of their own behavior.

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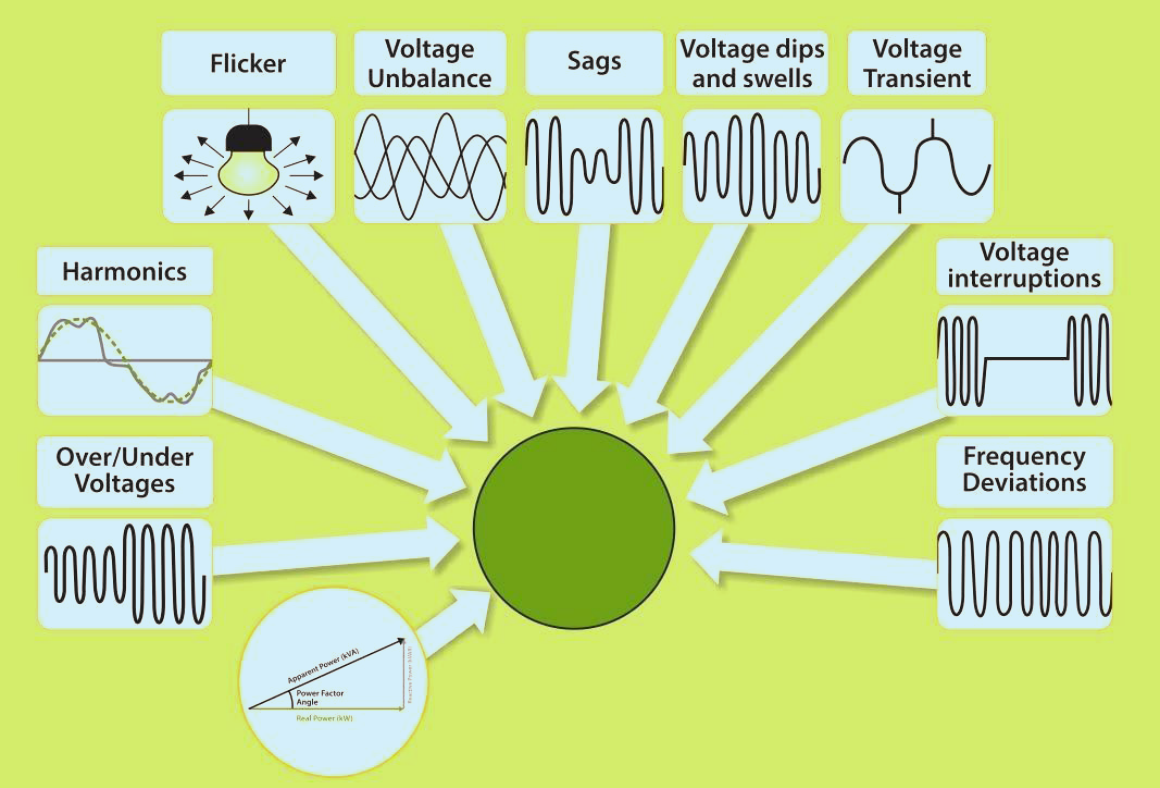


FIG. 1 VARIOUS POWER QUALITY RELATED PHENOMENA

Table 1 provides the categories and typical characteristics of power system electromagnetic phenomena.

Table 1 Categories and Typical Characteristics of Power System Electromagnetic Phenomena

(*Clause* 3.1.2)

Categories	Typical Spectral Content	Typical Duration	Typical Voltage Magnitude
(1)	(2)	(3)	(4)
1.0 Transients			
1.1 Impulsive	–	–	–
1.1.1 Nanosecond	5 ns rise	<50ns	–
1.1.2 Microsecond	1μs rise	50ns – 1ms	–
1.1.3 Millisecond	0.1 ms rise	>1 ms	–
1.2 Oscillatory			
1.2.1 Low frequency	<5 kHz	0.3 – 50 ms	0 – 4 pu
1.2.2 Medium frequency	5 – 500 kHz	20 μs	0 – 8 pu
1.2.3 High frequency	0.5 – 5 MHz	5	0 – 4 pu
2.0 Short –Duration root – means square (rms) variations			
2.1 Instantaneous	–	–	–
2.1.1 Sag	–	0.5 – 30 cycles	0.1 – 0.9 pu
2.1.2 Swell	–	0.5 – 30 cycles	1.1 – 1.8 pu
2.2 Momentary	–	–	–
2.2.1 Interruption	–	0.5 cycles – 3s	<0.1 pu
2.2.2 Sag	–	30 cycles – 3s	0.1 – 0.9 pu

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Table 1 (*Concluded*)

Categories	Typical Spectral Content	Typical Duration	Typical Voltage Magnitude
(1)	(2)	(3)	(4)
2.2.3 Swell	–	30 cycles – 3s	1.1 – 1.4 pu
2.2.4 Voltage imbalance	–	30 cycles – 3s	2 percent – 15 percent
2.3 Temporary	–	–	–
2.3.1 Interruption	–	>3 – 1 min	<0.1 pu
2.3.2 Sag	–	>3 – 1 min	0.1 – 0.9 pu
2.3.3 Swell	–	>3 – 1 min	1.1 – 1.4 pu
2.3.4 Voltage imbalance	–	>3 – 1 min	2 percent – 15 percent
3.0 Long Duration rms Variations			
3.1 Interruption, sustained	–	>1 min	0.0 pu
3.2 Under voltages	–	>1 min	0.8 – 0.9 pu
3.3 Over voltages	–	>1 min	1.1 – 1.2 pu
3.4 Current overload	–	>1 min	–
4.0 Imbalance			
4.1 Voltage	–	steady state	0.5 – 5 percent
4.2 Current	–	steady state	1.0 – 3.0 percent
5.0 Waveform distortion			
5.1 d.c. offset	–	steady state	0 – 0.1 percent
5.2 Harmonics	0 – 9 kHz	steady state	0 – 20 percent
5.3 Interharmonics	0 – 9 kHz	steady state	0 – 2 percent
5.4 Notching	–	steady state	
5.5 Noise	broadband	steady state	0 – 1 percent
6.0 Voltage fluctuation	<25 Hz	Intermittent	0.1 – 7 percent
			0.2 – 2p
7.0 Power frequency variations	–	<10 s	±0.10 Hz

NOTES

1 These terms and categories apply to power quality measurements and shall not be confused with similar terms defined in IEEE Std 1366™ 2012 [B30] and other reliability-related standards.

2 The quantity *pu* refers to *per unit,* which is dimesionless. The quantity 1.0 pu corresponds to 100 percent. The nominal peak value is used as the base value for transients and the nominal rms value is used as the base value for rms variations.

3 Flicker severity index P_{st} as defined in IEC 61000-4-15 : 2010 and IEEE Std 1453™.

3.2 Monitoring Power Quality

3.2.1 *Introduction*

Power quality monitoring is necessary to characterize the electromagnetic phenomena at a particular location in an electrical power circuit. The objective of the monitoring is to diagnose incompatibilities between the electric power source and the load or to evaluate the electrical environment at a particular location to refine modeling techniques or to develop a power quality baseline. Monitoring may also be used to predict future performance of load equipment or requirement of power quality mitigating devices.

The objectives of monitoring power quality for a particular project takes into consideration the choice of monitoring equipment, the method of collecting data, the triggering thresholds needed, the data analysis technique to employ, and the overall level of effort required for the project. The objective may be as simple as verifying steady-state voltage regulation at a service entrance or may be as complex as analyzing the harmonic current flows within a distribution network.

The procedure for defining monitoring objectives differs on the basis of study type (*for example*, when diagnostic monitoring is used to solve shutdown problems with sensitive equipment, the objective may be to capture out-of-tolerance events of certain types). Evaluative or predictive monitoring may require collection of several voltage and current parameters in order to characterize the existing level of power quality.

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Measurement of electromagnetic phenomena includes both time and frequency domain conducted parameters as listed above, which may take the form of overvoltages, undervoltages, interruptions, sags and swells, transients, phase imbalance, frequency deviations and harmonic distortion.

3.2.2 *Need for Monitoring Power Quality*

The prime reason to address the challenges in quality of power is economic, particularly, for critical process loads adversely affected by electromagnetic disturbances. Effects due to poor power quality can cause malfunctioning, process disruption, breakdown, anomalies/damages etc. to equipment and process. Since power disruptions affect efficiency and productivity, availability of quality power and quick restoration of power interruption is crucial for economic growth.

3.2.2.1 *Equipment tolerances and effects of disturbances on equipment*

The limits of tolerance of equipment shall be considered for power quality monitoring (*for example*, a specific variable frequency drive (VFD) may be sensitive to an overvoltage or undervoltage condition, but there may be significant variations in response by VFDs manufactured by different manufacturers to the same phenomena). Power quality monitoring should attempt to optimize the characteristic of individual process equipment by aligning power quality monitoring results with reported equipment problems. This characterization of individual loads helps to identify the equipment requiring protection as well as indicate the level of protection required.

3.2.2.2 *Equipment types*

There may be wide range of responses as well there may be similar response by various equipments (*of different make/model*) when subjected to specific operating conditions. In view of same, it is recommended to consider grouping of equipment types based on their immunity and response to power quality disturbances.

3.2.2.3 *Effect on equipment by phenomena type*

The effects of various categories of electromagnetic phenomena as mentioned in **3.1** on the operation of equipment is as under:

3.2.2.3.1 *Transients*

Transient overvoltages, caused by lightning or switching operations, can result in degradation or dielectric failure in all classes of equipment such as transformers, rotating machinery, capacitors, cables, CTs and PTs and switchgear, semiconductor devices, VFDs and other electronic equipment and their power supply components. Impulsive transients can pass through inter-winding capacitance and appear on the low side of the transformer. Repetitive application of lower magnitude transients causes slow degradation leading to decreased mean time between failures and eventual breakdown. (*see* Fig. 2).

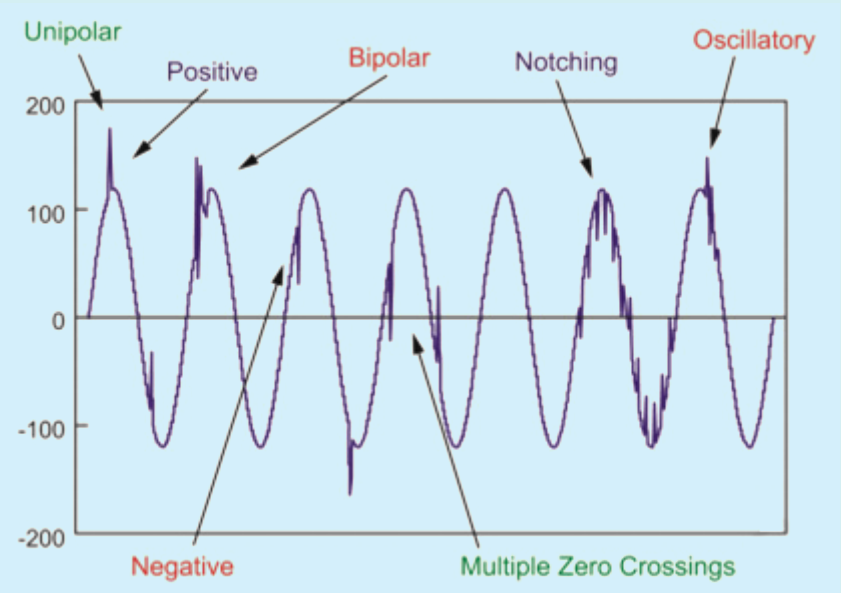


FIG. 2 GRAPHIC ILLUSTRATION OF VARIOUS TRANSIENT CHARACTERISTICS

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3.2.2.3.2 *Short-duration rms variations*

The effect of short duration rms variations such as power interruptions, sags, swells etc. may cause equipment shutdown leading to complete process shutdown. The repair of faulty equipment and restoration of operation may result in loss of considerable amount to time and money.

However, power quality monitoring is imperative as it is difficult to identify the cause of disruption. Equipments with advanced features may provide the diagnostic tool or "trip codes" to identify the fault which may be incorrect at times. Under the category of short-duration rms variations, the effect of interruptions, sags and swells are different on various classes of equipment. Monitoring of power quality parameters help in determining the energy requirements, duty cycle, voltage boost etc. to properly size mitigation devices.

Instantaneous interruptions affect electronic and lighting equipments and may cause malfunctioning or shutdown.

Sags, are most common in occurrence, may cause process disruptions. Often, the sag is sensed by electronic process controllers equipped with fault-detection circuitry that initiates shutdown of less-sensitive loads. Additionally, many control power systems and emergency stop circuits use hard-wired relay logic and contactors that may be highly sensitive to sags. A power quality monitor will be able to correctly capture the intensity of the sag in terms of its duration and magnitude. With the proper analysis of the data and its source, it helps in identifying the right mitigation approach.

Swells result in increase in voltage applied to equipment above its nominal rating and thus, may cause failure of the components depending on its magnitude and frequency of occurrence. Electronic devices including VFDs, computers, and electronic controllers etc. may show immediate failure modes during these conditions. Transformers, cables, busses, switchgear, CTs, PTs and rotating machinery may suffer reduced equipment life over time. A temporary increase in voltage of protective relays may result in unwanted operations of some relays and may not affect others. Frequent voltage swells on a capacitor bank can cause the individual cans to bulge while output is increased from the bank. The visible light output from some lighting devices may be increased during a temporary swell. Clamping type surge protective devices (*for example*, varistors, silicon avalanche diodes) may be destroyed by swells exceeding their maximum continuous operating voltage rating.

3.2.2.3.3 *Long-duration rms variations*

Long-duration rms variations in supply voltage, that is, lasting longer than 1 min, can cause serious concerns to load equipments. These variations are in the form of sustained or long duration interruptions, undervoltages or overvoltages and can occur due to tripped breakers, blown fuses, overloaded feeders, incorrect tap settings on transformers, malfunctioning regulators or controls, blown fuses on capacitor banks, and capacitor banks in service during light load conditions, among many others.

While a sustained interruption, almost, always may cause equipment shutdown, except those protected by UPSs, standby generators or energy storage systems; sustained undervoltages for more than 1 minute may cause malfunctioning of load equipment. Motor controllers can drop out during undervoltage conditions. The dropout voltage of motor controllers is, typically, at 70 percent to 80 percent of nominal voltage. Long-duration undervoltage increases heating loss in motors due to increased currents drawn by the motors. Speed variations are possible for induction machinery due to loss of torque. Electronic devices such as computers and electronic controllers may stop operating. Undervoltage conditions on capacitor banks result in a reduction of reactive power output of the bank. The visible light output from some lighting devices may be reduced during undervoltage conditions.

Similar to swells (under short duration rms variations), overvoltages lasting more than one minute are equally dangerous to electronic devices which may experience immediate failure. Sustained or repetitive overvoltage on transformers, cable, bus, switchgear, CTs, PTs, and rotating machinery can result in loss of equipment life due to insulation degradation. A sign of frequent overvoltage conditions on a capacitor bank is bulging of individual cans.

3.2.2.3.4 *Voltage imbalance/unbalance*

Voltage imbalance from the utility side, typically, remains well within 2 percent limits. More commonly, it emerges in individual customer load buses due to phase load imbalances, especially where large (individual or multiple) single phase loads are used. Even for capacitors banks, fuses blown in one or two phases of a three phase-capacitor bank can cause imbalance in voltage. Under such cases, overheating of customer motors and transformers can readily occur if the imbalance is not addressed. Phase current imbalance of three-phase induction motors varies almost as the cube of the voltage imbalance applied to the motor terminals. According to NEMA MG-1-2006 [B35], a 3.5 percent voltage imbalance can result in 25 percent additional heating in both U-frame and T-frame motors.

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3.2.2.3.5 *Waveform distortion*

Harmonic current injection into the electricity supply system from customer loads cause harmonic voltage distortion to appear on the power system supply voltage. Effects of harmonics and their mitigation strategies are discussed in Part 20/Sec 1 of this code.

3.2.2.3.6 *Voltage fluctuations*

Fluctuations in the supply voltage are, most often, manifested as nuisance variations in light output from lighting sources (hence, the associated term, lamp flicker). A sudden voltage decrease of less than 0.5 percent can cause a noticeable reduction in light output. Similarly, new age LED lighting installations are also significantly affected due to rapid voltage fluctuations and are highly susceptible due to the dv/dt variations. The failure rates of such LEDs and the resulting costs, over the period of time would be more than the cost of a power quality monitoring before undertaking a big LED retrofit project in a plant or any such premises (*see* Fig. 3 and Fig. 4).

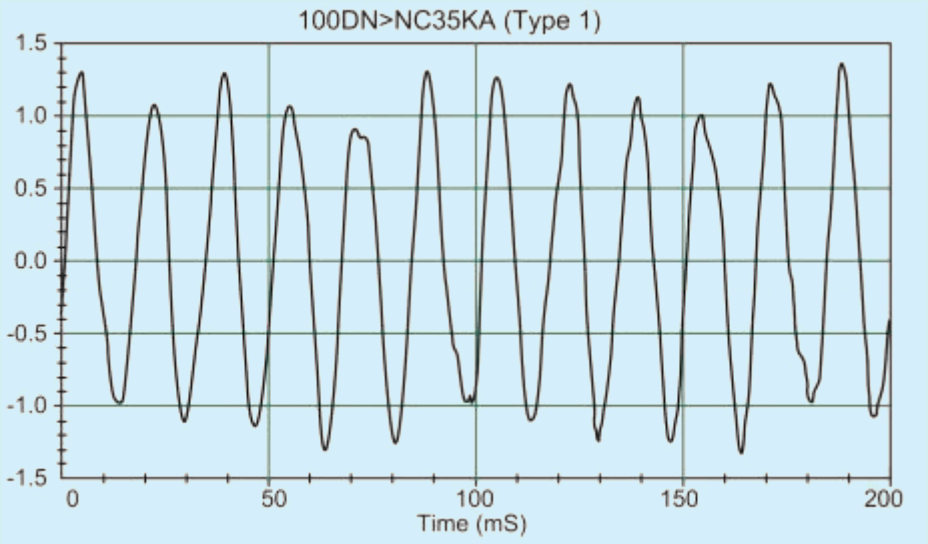


FIG. 3 EXAMPLE OF VOLTAGE FLUCTUATIONS CAUSED BY ARC FURNACE OPERATION

3.2.2.3.7 *Power frequency variations*

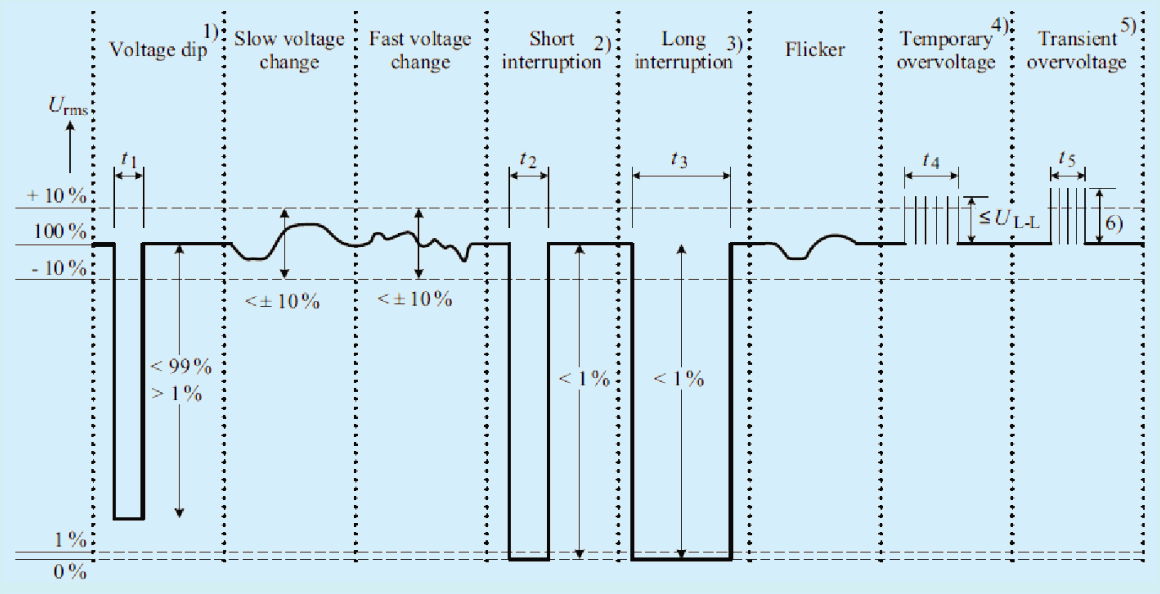
In general, utilities maintain stringent control measures for prevention of variations in the power system frequency. Slight variations in frequency on an electric system can cause severe damage to generator and turbine shafts due to the subsequent large torques developed. In addition, cascading system separations can result with even slight deviations in frequency since electric systems are highly interconnected and operate in synchronism. Frequency variations are more common on customer-owned generation equipment systems when operating in an islanded mode. For example, if there was a sudden shedding of load, the generator may overspeed momentarily and cause a frequency increase on small systems operating independently of large grid power provider sources.

Frequency synchronization errors can, sometimes, occur on a customer feeder that serves large rectifier loads. These loads may cause voltage notching severe enough to register extra zero crossing events on electronic loads, that are counted as zero crossings of the a.c. voltage while obtaining frequency. While these events are recorded as frequency errors by electronic controllers, the fundamental frequency does not change. Tripping, often, occurs due to such errors. Although there are not actual frequency errors, as observed by the controllers.

3.2.3 *Measuring Instruments for Power Quality Monitoring*

Instruments used to monitor electromagnetic phenomena can range from a simple analog voltmeter to a sophisticated multiple-site and permanently installed power quality monitoring system. Selection and use of the correct type of monitoring system requires the user to understand the capabilities and limitations of the instrument, its responses to power system variations and the specific objectives of the analysis.

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1) 10 msec ≤ t_1 < 1 min

2) 0.3 sec < t_2 ≤ 3 min for automatic reclosures in 110-kV overhead systems (special case of a voltage dip)

3) t_3 > 3 min (Long interruptions are not a characteristic quantity of the voltage quality. They are a characteristic of the supply reliability)

4) sec ≤ t_4 < 1 min

5) 1 µsec < t_5 ≤ msec

6) Max. 6 kV at the LV level

FIG. 4 SUMMARY OF VARIOUS VOLTAGE QUALITY RELATED EVENTS WITH RESPECT TO THEIR MAGNITUDE AND DURATION

Instrument features required are dependent on the monitoring location and objectives. For example, if the power quality at the service entrance is being assessed, the emphasis may be on trends of long-term steady-state conditions and on determining if power quality disturbances originated from the electric power provider or from within the facility itself. The level of detail required (rms voltage stripcharts or high-speed waveform captures) is indicated by the type of phenomena likely to be causing problems.

The type of monitor to be employed is based on the need to monitor. In general, portable/handheld monitors are used to troubleshoot problems in facilities or electric distribution system in the reactive approach, although they can also be used for shorter term compliance monitoring. Permanently installed units are used for monitoring longer term system performance and reliability as well as providing data and/or alarms when power-quality-related problems occur. Permanently installed monitors include dedicated power quality monitors, revenue meters with power quality functionality, statistical survey/compliance monitors, and system protection relays with some power quality functionality. Some mitigation equipments also provide limited power quality information, such as in a UPS, surge suppression system, and distributed generation equipment etc. The data can also be integrated into customer-owned, enterprise-level process control software to correlate variations in the quality of the supply to the quality of the process.

3.2.3.1 *Parameters to be measured*

Voltage and current are two primary measurements for power quality phenomena. The data can be utilized to compute number of desired parameters, the most basic of which is the true rms value for each cycle. A sample list of additional parameters that can be derived from these two primary parameters is listed in Table 2.

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Table 2 Parameters that can be Determined from Acquired Voltage and Current Data

(*Clause* 3.2.3.1)

NSI transformer derating factor	Interharmonics rms current	True power factor
Arithmetic sum power factor	Interharmonics rms voltage	Unsigned harmonic power
Arithmetic sum displacement power factor	Current – time product	Vector sum displacement factor
Arithmetic sum voltage – amperes	Negative sequence current	Vector sum power factor
Current crest factor	Negative sequence voltage	Vector sum volt – amperes
Current THD	Net current	Voltage crest factor
Current THD (rms)	Positive sequence current	Voltage THD
Current total Interharmonics distortion (TID)	Positive sequence voltage	Voltage THD (rms)
Current (TID) rms	Residual current	Voltage TID
Current imbalance	RMS current	Voltage TID (rms)
Displacement power factor	RMS current individual harmonics	Voltage telephone interference factor (TIF)
Frequency	RMS harmonics current (total)	Voltage TIF (rms)
Fund frequency arthmetic sum volt – amperes	RMS voltage	Voltage imbalance
Fund frequency vector sum volt – amperes	RMS voltage individual harmonics	watt hours
Harmonic power (sum)	Total fund frequency reactive power	Zero sequence current
IEEE 519 current TDD	Transformer k factor	Zero sequence voltage

3.2.4 *Effective Power Quality Monitoring and Application Techniques*

After establishing the need for power quality, understanding the monitoring objectives, the instruments and logging parameters required to meet the objectives, the section provides a recommended practice to follow for a typical power quality survey. This list of parameters to be considered as follows:

a) Safety;
b) Monitoring location;
c) Equipment connection;
d) Measurement thresholds; and
e) Installation time frame.

3.2.4.1 *Safety*

The manner in which a power quality monitor is attached to the circuit under evaluation may impact areas other than the accuracy of the data being captured. It is imperative that the connection of the sensing leads (for current/voltage) be made in a way such that it does not jeopardize the safety of site personnel as well as the integrity of existing connections. While most hook-ups are temporary in nature and may not utilize the same practices as for permanent installations, the provisions of this code, statutory regulations and local state enforcement codes/regulations should not be compromised.

Due to the requirement of real time analysis for power quality monitoring objectives, live equipment connection may be unavoidable. Generally, such cases are to avoid continuous process or equipment disruption. This requirement underscores the absolute need for safety considerations during the installation and removal of any power quality monitoring equipment. Accordingly, general safety considerations such as arc flash exposure levels, protective devices upstream of the monitoring location, source of the circuit being monitored shall be known to the installer for taking adequate precautions as necessary. Secure placement of the equipment and protection of all live parts shall be taken care of.

3.2.4.2 *Monitoring location*

The location to install the power quality monitor is dependent on the objective of the survey. It is also important to have knowledge of the entire electrical environment prior to connecting a monitoring device through a single-line diagram of the electrical circuit being monitored. Knowledge of different information such as multiple source feeders, standby sources of power, neighbouring plants play a vital role in determining the monitoring location.

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If the monitoring objective is to diagnose an equipment performance problem, then the monitor should be placed as close to the load as possible.

If the monitoring objective is to investigate the overall quality of a facility, then the monitor should be placed on the secondary of the main service entrance transformer, which is usually 600 V class service equipment. The monitor records the quality of power supplied to the facility as well as the effect of major loads within the facility. The monitor may, then, be moved downstream in the electric distribution system to record the power quality on individual feeders.

If harmonics are of concern, the monitor should be placed at the affected equipment or filter locations to measure harmonic currents and distorted voltage. Capacitor banks that are affecting harmonics or magnifying switching transients can also be investigated by connecting a monitor at the capacitor bank (*see* Fig. 5).

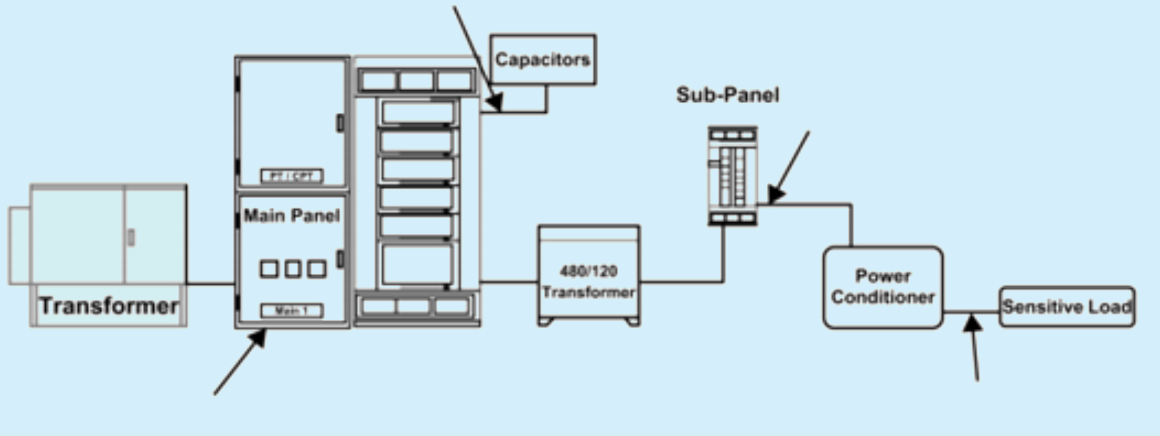


FIG. 5 SUGGESTED MONITORING LOCATIONS ON TYPICAL LOW VOLTAGE SYSTEM
(ARROWS POINT TO SUGGESTED LOCATION OF PROBES)

Keeping in view the multitude of power quality monitoring objectives, usage of multiple monitors simultaneously at more than one location within a facility helps to narrow the cause at much faster rate. For example, for monitoring performance of sensitive electronic loads such as computers and VFDs, monitor shall be placed as close to these equipment as possible. At the same time, to quickly identify the source of disturbance, *see* Table 3 for monitoring upstream of the circuit.

Table 3 Suggested Monitoring Locations

(*Clause* 3.2.4.2)

Equipment Concern	Recommended Monitoring Location
Specific piece of equipment exhibits problems related to power quality	At the equipment, connection to the facility's electrical system (that is, circuit breaker)
All equipment connected to distribution system within a facility exhibits problems to power quality	At the branch connection to the facility's electrical system (that is, motor control center)
Entire facility exhibits problem related to power quality	Secondary of the transformer serving the facility (*see* note)
NOTE — The primary of same transformer may be monitored by electric service provider.	

To monitor the distortion levels with respect to harmonics as per IEEE 519 : 2014, the monitoring location should be at the point of common coupling.

Usage of appropriate PT and CTs is important while connecting the power quality monitors. Table 4 provides a summary of available types and their applicability for use in various monitoring locations.

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Table 4 Recommendations for Types of CTs and PTs to use with Power Quality Monitors

(*Clause* 3.2.4.2)

Monitoring	Voltage Transducer	Current Transducer
Substation	Metering PT's voltage dividers bushing taps	Metering CT's Relaying CT's
Overhead feeder	Metering PT's	Metering CT's
Underground feeder	Metering PT's Voltage divider	Metering CT's
Service entrance	Direct connection	Metering CT's Clamp – on CT's
In facility	Direct connection	Clamp – on CT's

3.2.4.3 *Equipment connection*

Monitoring objectives may be compromised by making inappropriate connection to the electrical system. During power measurement on a circuit, it is important to be aware of the polarity of each current connection and to verify that the voltage and current connections are made to the proper phase (*i.e.* phase A voltage shall be in phase with phase A current).

Types of circuit configurations shall also to be considered while connecting the monitor such as three Phase star, three phase delta and other configurations.

Connection leads play a crucial role in ensuring correct voltage and current data is collected. Hence, adequate care shall be taken while making the connections.

3.2.4.4 *Measurement thresholds*

Suggested threshold settings for power quality monitors are given in Table 5.

Table 5 Suggested Threshold Settings for Power Quality Monitors

(*Clause* 3.2.4.4)

		Suggested Thresholds for Phase Voltages	
Sl No.	PQ Events	Thresholds	Remarks
(1)	(2)	(3)	(4)
i)	Sag	0.9 pu	– 10 percent of nominal supply voltage
ii)	Swell	1.1 pu	– 10 percent of nominal supply voltage
iii)	Transient	2 × Vphase	approx 2 × nominal phase-neutral voltage
iv)	Noise	1 percent × Vphase	approx 0.01 × nominal phase-neutral voltage
v)	Harmonics	5 percent THD	Voltage distortion level at which loads may be affected
vi)	Frequency	± 0.1 Hz	–
vii)	Phase imbalance	2 percent	Voltage imbalance greater than 2 percent can affect equipment

The following steps shall be taken to determine monitor thresholds:

a) Determining the monitoring objectives;
b) Monitoring in scope mode (if available) to observe steady-state waveform fluctuations. Set monitor thresholds just above these values;
c) Letting the monitor run with these sensitive thresholds until it captures about 20 events or for 30 minutes, whichever occurs first. This provides a record of background fluctuations. It may be noted that background voltage fluctuations, even though below equipment susceptibility levels, may have a cumulative degrading effect on the load equipment; and
d) Reset the monitor thresholds above the fluctuations recorded using the sensitive threshold settings. If time permits, repeat the process until no more than one event is recorded in a 30 min period (unless there is an unusually high level of real activity).

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3.2.4.5 *Installation time frame*

The installation time frame refers to the monitoring period or duration and the time during which monitoring has occurred. Data collection at the appropriate time and for the appropriate duration is necessary to properly diagnose power quality events.

The monitoring period is a direct function of the monitoring objective.

Usually, the monitoring period attempts to capture a complete cycle, that is for a period at which the power usage pattern becomes repetitive. However, for seasonal problems, the monitoring period might be for months.

Generally, there can be three types of scenarios requiring different monitoring periods.

3.2.4.5.1 *Baseline power monitoring*

The purpose of the monitoring is to document the power profile at a specific site or location. Primary information obtained is steady-state and transient extremes. Other parameters such as frequency or RFI noise may also be of specific interest. Baseline monitoring is primarily used, prior to installing equipment, to verify power specification compliance. The recommended monitoring period is defined as a complete working cycle (power period). In all cases, the information obtained is a snap shot of the power quality profile. As the environment changes, repeating the measurements is recommended. The updated (new) site profile should be compared to the original. Site profiles may be seasonally dependent as well.

3.2.4.5.2 *Problem solution monitoring*

Locating a power problem that causes a specific equipment/load malfunction can take a few days upto weeks. This type of activity is intended to find the specific power disturbance that creates the problem and document its repeatability. Once the problem is identified, corrective action is implemented. After implementation of corrective action, power monitoring is conducted to check the effectiveness of the solution and to verify for adequacy.

Plant personnel shall be instructed to keep a log of equipment malfunctions, including time of occurrence, equipment affected, trip codes, operating mode of equipment, and other pertinent information. Correlating this information with power quality monitoring results is invaluable for locating sensitive equipment and resolving the problems.

3.2.4.5.3 *Power supply monitoring*

This type of monitoring helps in understanding the change in overall power quality picture as a result of major changes in the environment. Power studies are conducted for long periods of time, usually a few years, at multiple locations.

3.2.5 *Interpreting Power Monitoring Results*

Troubleshooting and solving power-related problems may involve a number of complexities. Some issues can be resolved by carefully examining the load while others may be by verifying correct wiring and grounding practices. Some concerns may require involvement of power provider and others may require the use of power monitoring equipment. Power problem shall take into account all the related parameters.

All of the efforts to obtain information prove meaningful provided the investigator has knowledge and skill to find a solution from the available data. Interpreting a power monitor's output is perhaps the most critical part of the process of power monitoring. Given the limits and variety of practical field tools and tremendous range of distribution system and load characteristics, interpretation is dependent on the experience and skill of the investigator.

A number of steps such as interpreting data summaries including measurement validations and summary preparation. Critical data extraction includes determining the critical events from multiple disturbances and event reality checks and interpreting the critical events using any one or multiple signature analysis, steady state waveshape analysis as well as waveshape disturbance analysis, high frequency analysis, harmonic analysis, pattern recognition etc. *See* Table 6.

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Table 6 Reference Chart for Problem Analysis

(*Clause* 3.2.5)

Typical Problems	Disturbance Type	Possible Causes
Overheated neutral	Steady – state	Shared neutrals
Intermittent lockup		Improper or inadequate wiring
Frequency deviations		High source impendence
Voltage imbalance		Silicon – controlled rectifier
Current imbalance		(SCR) rectifiers
		Notching
		Harmonics
		Current Imbalance
		Capacitor banks
		Single – phase load
		SCR/rectifier
		Voltage imbalance
Interruption		Utility faults
Garbled data		Inrush current
Random increases in harmonic levels		Bonding and grounding
		Inadequate wiring
		Capacitor bank
		SCR/rectifier load
Intermitted lockup	Sag/Swell	Source voltage variations
Lights flicker		Inrush current
Garbled data		Inadequate wiring
Component failure	Impulses	Lightning
Dielectric breakdown lockup	EMI/RF1	Load Switching
Garbled data		Capacitor switching
Wavy CRTs		Static discharge
		Hand – held radios
		Loose wiring/arching
Overheated transformers	Harmonics	Electronic loads
Voltage distortion		SCR/rectifier load
Current distortion		Bandwidth of source impedance
Overheated		Voltage imbalance
Garbled		
Lockup		
Problems occur at the same time	All	Timed loads
Problem occur at regular intervals		Cyclical loads
SPS and/or automatic transfer switch does not work	Discontinuities	Switching to alternate sources
Excessive frequency shift		No synchronized power switching
		Differences in source impedance

3.3 Power Quality Management

Management of power quality involves building upon the various analyses, summaries that are available through power quality monitoring and understanding the impact of power quality phenomena on various equipment and then, taking an informed decisions on, further, managing and improving power quality. The approach for power quality management can be seen in Fig. 6.

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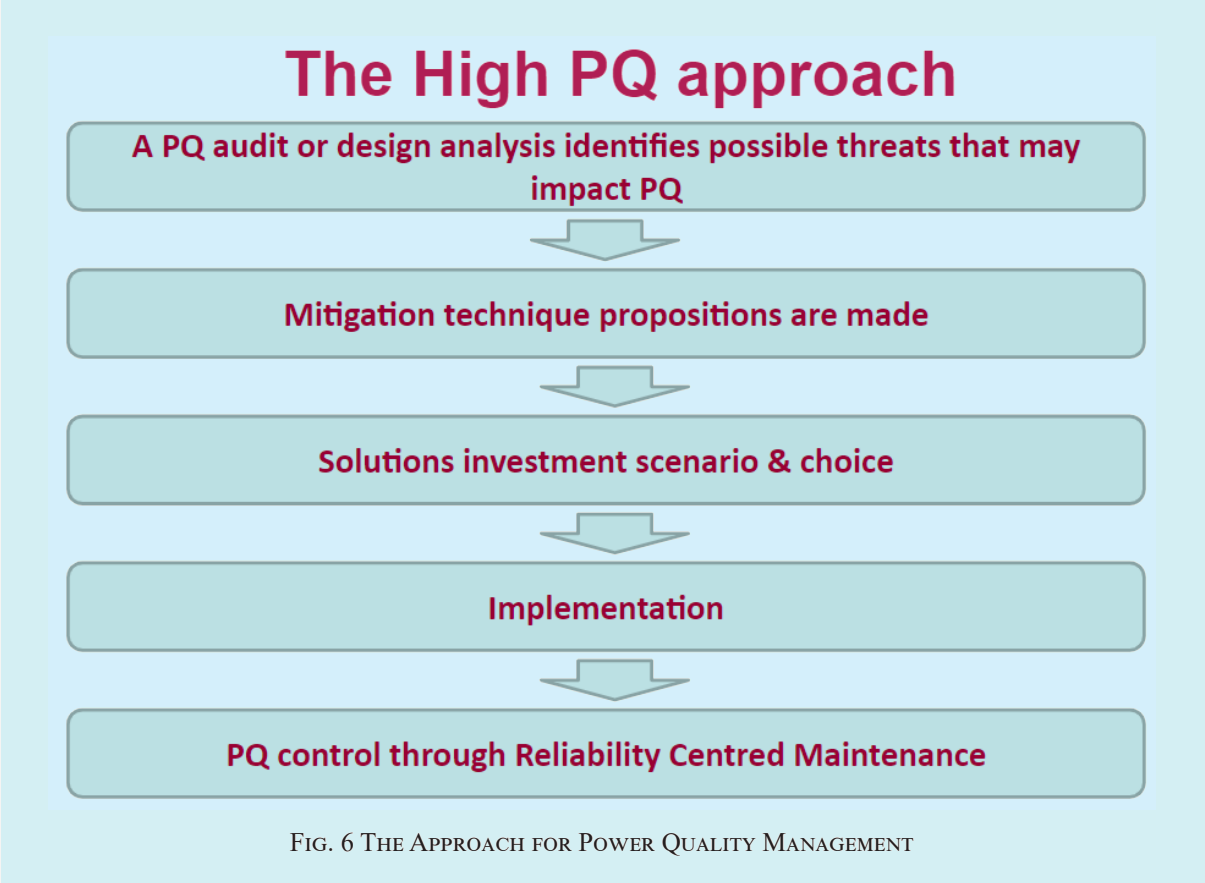


FIG. 6 THE APPROACH FOR POWER QUALITY MANAGEMENT

Depending on the power quality monitoring objectives (as discussed in **3.2**) such as addressing the critical equipment performance issues, establishing a baseline for future performance predictions or other objectives as outlined earlier, the next step is to take corrective actions based on the findings and its interpretations. Table 7 and Table 8 provide a glimpse of the typical counter measures and mitigation methods that may be employed in response to most prevalent power quality phenomena. However, the list is not exhaustive list and care shall be taken to understand the characterization of power quality phenomena with respect to its spectral content, duration and magnitude for applying the right mitigation methods.

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Table 7 Most Common PQ Countermeasures and Mitigation Solutions

(*Clause* 3.3)

PQ Phenomena	Specific PQ issue	Typical Causes	Suggested Counter Measures
Transients	Impulsive	Lightning strike, transformer energization, capacitor switching	Reduce the magnitude and incidence of switching transients; Reduce the lightning surges entering the customer facility; Install surge/lightning arrestors and/or isolation transformers.
	Oscillatory	Line or Capacitor or load switching	
Short duration voltage variation	Sag and swell	Ferro resonant transformers, single line-to-ground faults	Reduce the incidence rate, amount of variation or the duration of RMS variations; Install dynamic voltage restorers, constant voltage transformers, PWM, Autotransformers
	Interruption	Temporary (self-clearing) faults	
Long duration voltage variation	Under voltage	Switching on loads, capacitor de-energization	Reducing the load changes, reducing the source impedance, or decoupling the load from lighting circuits.
	Over voltage	Switching off loads, capacitor energization	
	Sustained interruptions	Faults	Limit the incidence rate and duration of sustained interruption
Voltage Imbalance		Single phase loads, Single phasing condition	Improve voltage regulation and load balancing
Waveform distortion	Harmonics	Adjustable speed drives and other non-linear loads	Use active or passive filters to reduce harmonic voltage distortion, neutral upsizing, transformer based solutions
	Notching	Power electronic converters	Observe proper routing of conductors, Retrofit drives that incorporate Silicon Controlled Rectifiers (SCRs) and diodes
	DC Offset	Geo-magnetic disturbance, half wave rectification	Use d.c link chokes
Voltage Flicker		Arc furnace, arc lamps	Dynamic compensation (Static VAR Compensator)

Table 8 Common Voltage Sag Mitigation Solutions and their Characteristics

(*Clause* 3.3)

	Size	Purchase cost	Maintenance	Efficiency	Reaction time	Voltage	Current	Reactive power	Technology Maturity
Flywheel	=	–	–	–	=	+	+	+	+
Static UPS	+	=	–	–	+	+	+	+	+
DVR – 1	+	+	+	=	=	=	=	+	=
DVR – 2, 200 percent load	–	+	+	=	=	+	=	=	=
DVR – 2, 400 percent load	–	+	+	=	=	+	=	=	=
Statcom - SMES	–	=	–	–	–	=	=	+	–
Shunt Connected SM	+	–	–	=	=	+	+	+	–
Transformerless Series injector	+	=	+	=	=	=	=	=	+

NOTE – The harmonic currents are reduced by creating a low impedance path through the SM.

Efficiency
+: Losses < 0.55 percent of Srated
=: losses 0.5-2 percent of Srated
-: losses > 2 percent of Srated

Size
-: only > 1 MW
=: only > 100 kW
+: only <100kW

Harmonics, reactive Power
=: no influence
+: positive influence

Purchase Cost
-: > 250 €/kVA
=: 150 – 250 €/kVA
+: <150 €/kVA

Reaction time
+: reaction or activation transient < 1 ms
=: transient 1-5 ms
-: transient > 5 ms

Maintenance
-: annual maintenance required
+: no annual maintenance required

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Power quality is a dynamic reflection of operative system and should be continuously monitored and managed for ensuring energy efficient drives in various aspects of industrial, commercial and domestic environments. A high power quality approach indicated is ideal for adoption in best managing the challenges posed by new age non-linear loads in operation. The solution approach should be more system oriented rather than component oriented and should start from setting the fundamentals of electrical system to be placed right from the beginning (*see* Fig. 7).

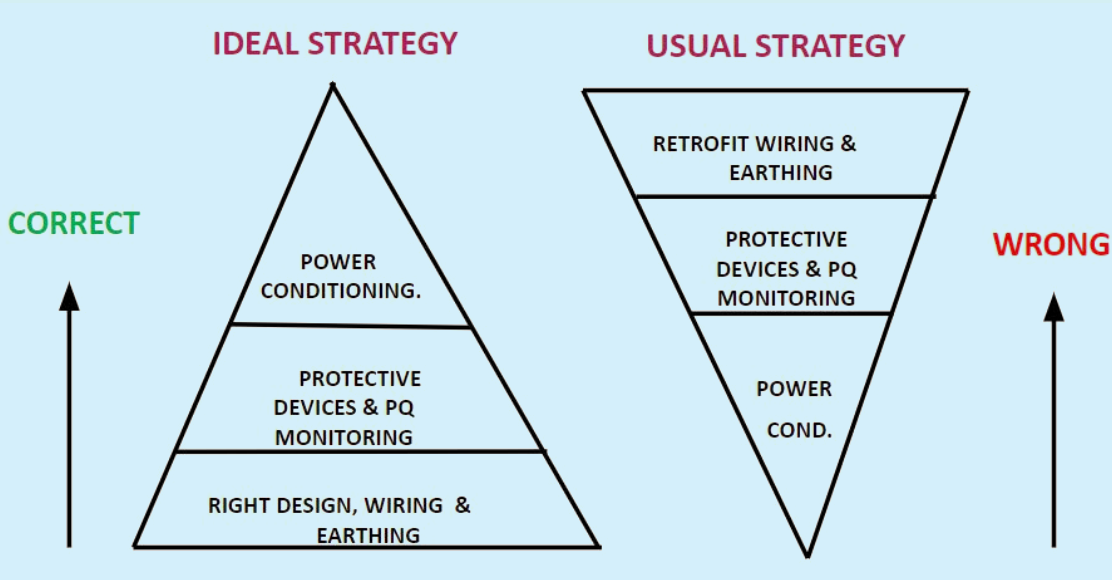


FIG. 7 STRATEGY FOR POWER QUALITY MITIGATION

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SECTION 20.3
POWER QUALITY IMPROVEMENT — NEUTRAL CONDUCTOR

FOREWORD

As more number of electronic devices are connected to our power systems, more the concept of "quality" of the power becomes important. "Quality" can be defined in numerous ways. Stable voltages and undistorted waveforms are two desirable characteristics in power systems. Grounding affects voltage stability, and more importantly, is critical to personal safety. Neutral conductors connect all of the non-current carrying parts of the electrical system, or any metallic parts in the vicinity of the electrical system together. The neutral conductor allows all equipment to have the same reference voltage. This helps facilitation of operation of various equipment operation and helps prevent the flow of unintended currents on connections.

1 SCOPE

This section of the Code (Part 1/Sec 20.3) covers neutral conductor for power quality improvement.

2 THE NEUTRAL

2.1 The Neutral — A live and Unique Conductor

Although the neutral conductor is a live conductor, current should not be allowed to circulate in it. There has been renewed interest in the neutral conductor with proliferation of electronic loads, the circulation of harmonic currents and the risk of overloads. Within this context, the aim of this document is to describe the current situation regarding typical and recommended installation rules with respect to breaking, protecting and dimensioning the neutral conductor.

2.2 The Neutral — A live Conductor in Electrical Distribution

2.2.1 *General System for Electrical Distribution*

The most common system for low-voltage electrical distribution is the three-phase type system with distributed neutral. This arrangement enables both three-phase loads not connected to neutral (*for example*, motors) and single-phase common loads to be supplied with power at the same time. The most common voltage levels used in India are 415 V phase-to-phase and 240 V phase-to neutral (*see* Fig. 1). The supply transformer secondary is, therefore, generally connected in a star or even a zigzag configuration. Relevant regulations stipulate that when not used as a protective earth conductor (PEN, in which case its color should be green/yellow), the neutral conductor should be black in color.

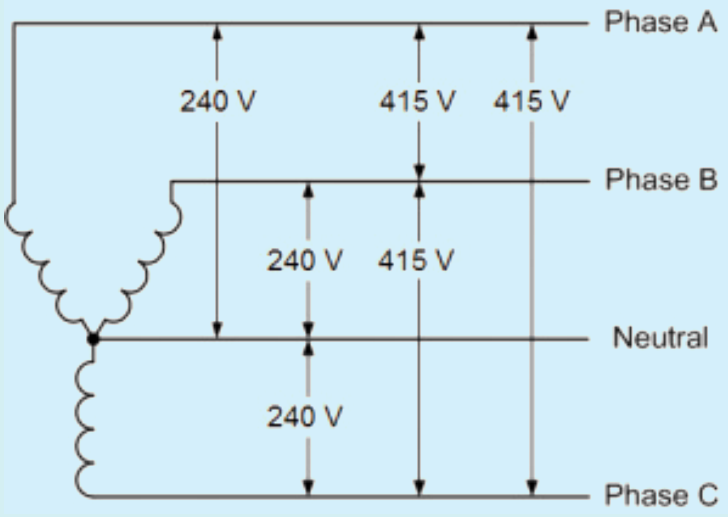


FIG. 1 3-PHASE 4-WIRE CONFIGURATION

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2.3 Neutral, but Not Passive

The neutral conductor has specific features in relation to other electrical distribution conductors:

a) It plays specific role in earthing systems;
b) It is, generally, possible and recommended to earth the neutral;
c) It can be used as a protective earth conductor;
d) The neutral conductor is a live conductor;
e) It provides single-phase loads with power;
f) It supports the circulation of unbalanced currents;
g) It supports the circulation of third harmonic and triplen currents from non-linear loads;
h) It provides path for fault currents flow (such as insulation faults, overloads, short-circuits etc.);
j) When it is used as a protective earth conductor, capacitive leakage currents flow through the neutral;
k) A certain number of precautions must be taken when designing an electrical installation;
m) Specific regulations must be observed when dimensioning and protecting the neutral conductor;
n) The continuity of the neutral conductor is imperative when it is used as a protective earth; and
p) The neutral conductor must be disconnected if its voltage in relation to earth increases to a dangerous level.

3 CROSS SECTION AND PROTECTION OF THE NEUTRAL CONDUCTOR

The cross-section area (c.s.a) and the protection of the neutral conductor, apart from its current-carrying requirement, depend on several factors, namely:

a) the type of earthing system such as TT, TN, etc.;
b) the harmonic currents; and
c) the method of protection against indirect contact hazards.

3.1 Cross Section Area

Where the neutral conductor carries current without a corresponding reduction in load of the line conductors, the neutral conductor shall be taken into account in ascertaining the current-carrying capacity of the circuit. Such currents may be caused by a significant triple harmonic current in three-phase circuits. If the harmonic content is greater than 15 percent of the fundamental line current, the neutral conductor size shall not be smaller than that of the line conductors. Thermal effects due to the presence of third harmonic or multiples of 3rd harmonic and the corresponding reduction factors for higher harmonic currents are given in Annex V of IS 732.

3.2 Protection

Overload detection shall be provided for the neutral conductor in a multi-phase circuit where the harmonic content of the line currents is such that the current in the neutral conductor is expected to exceed the current carrying capacity of that conductor. The overload detection shall be compatible with the nature of the current through the neutral and shall cause the disconnection of the line conductors but not necessarily the neutral conductor.

NOTE — For more information, refer 4.4.2.3 of IS 732.

The color of the neutral conductor is black. PEN conductor, when insulated, shall be marked by one of the following methods:

a) Green-and-yellow throughout its length with, in addition, black markings at the terminations; or
b) Black throughout its length with, in addition, green-and-yellow markings at the terminations.

4 SIZING THE NEUTRAL CONDUCTOR

4.1 Influence of the Type of Earthing System

4.1.1 *TT and TN-S System*

a) Single-phase circuits or those of c.s.a.— 16 mm^2 (copper) or 25 mm^2 (aluminium) — the c.s.a. of the neutral conductor must be equal to that of the phases.
b) Three-phase circuits of c.s.a. > 16 mm^2 copper or 25 mm^2 aluminium — the c.s.a. of the neutral may be chosen to be:
    1) Equal to that of the phase conductors; or

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2) Smaller, if:

i) The current likely to flow through the neutral in normal conditions is less than the permitted value Iz. The influence of triplen (1) harmonics must be given particular consideration; or

ii) The neutral conductor is protected against short-circuit, in accordance with the following:

The size of the neutral conductor is at least equal to 16 mm^2 in copper or 25 mm^2 in aluminium.

4.1.2 *TN-C System*

The same conditions apply in theory as those mentioned above, but in practice, the neutral conductor must not be open-circuited under any circumstances since it constitutes a PE as well as a neutral conductor.

NOTES

1 It is recommended that TN-C systems should not be maintained in existing buildings containing, or likely to contain, significant amounts of information technology equipment.

2 TN-C-systems shall not be used in newly constructed buildings containing, or likely to contain, significant amounts of information technology equipment.

4.1.3 *IT System*

In general, it is not recommended to distribute the neutral conductor, that is, a three-phase three-wire system is preferred. When a 3-phase 4-wire installation is necessary, the conditions described above for TT and TN-S system are applicable.

4.2 Influence of Harmonic Currents

4.2.1 *Effects of Triplen Harmonics*

Harmonics are generated by the non-linear loads of the installation (such as computers, florescent lighting, LED lighting, rectifiers, power electronic choppers) and can produce high currents in the neutral. In particular, triplen harmonics of the three phases have a tendency to cumulate in the neutral as:

a) Fundamental currents are out-of-phase by 2π/3 so that their sum is zero; and

b) On the other hand, triplen harmonics of the three Phases are always positioned in the same manner with respect to their own fundamental and are in phase with each other (*see* Fig. 2).

Load factor of neutral conductor as a function of percentage of 3rd harmonics is shown in Fig. 3.

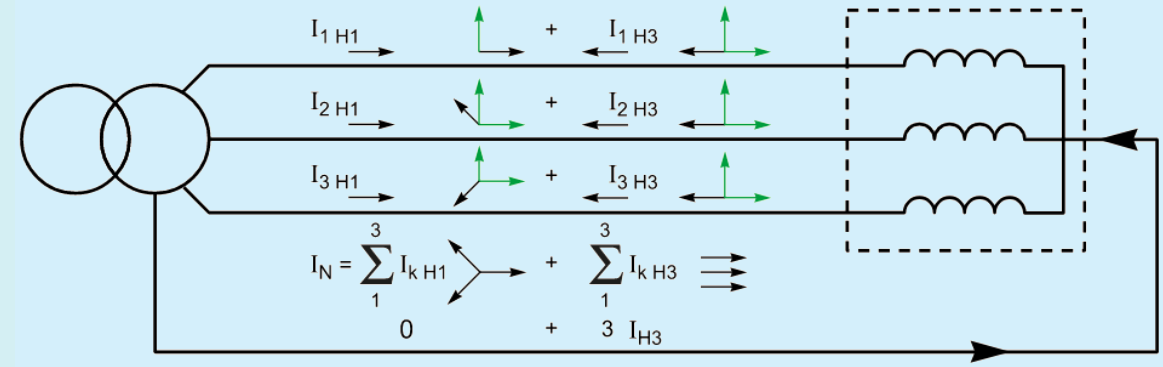


FIG. 2 EFFECTS OF TRPLEN HARMONICS

4.3 Reduction Factors for Harmonic Currents in Four-core and Five-core Cables with Four Cores Carrying Current

The basic calculation of a cable concerns cables with three loaded conductors only considering there is no current in the neutral conductor. Because of the third harmonic current and triplen harmonics, current flows in the neutral as well. As a result, this neutral current creates heat for other three phase conductors and therefore, a reduction factor for phase conductors is necessary (*see* Table 1). Reduction factors, applied to the current-carrying capacity of a cable with three loaded conductors, give the current-carrying capacity of a cable with four loaded conductors, where the current in the fourth conductor is due to harmonics. The reduction factors also take the heating effect of the harmonic current in the phase conductors into account.

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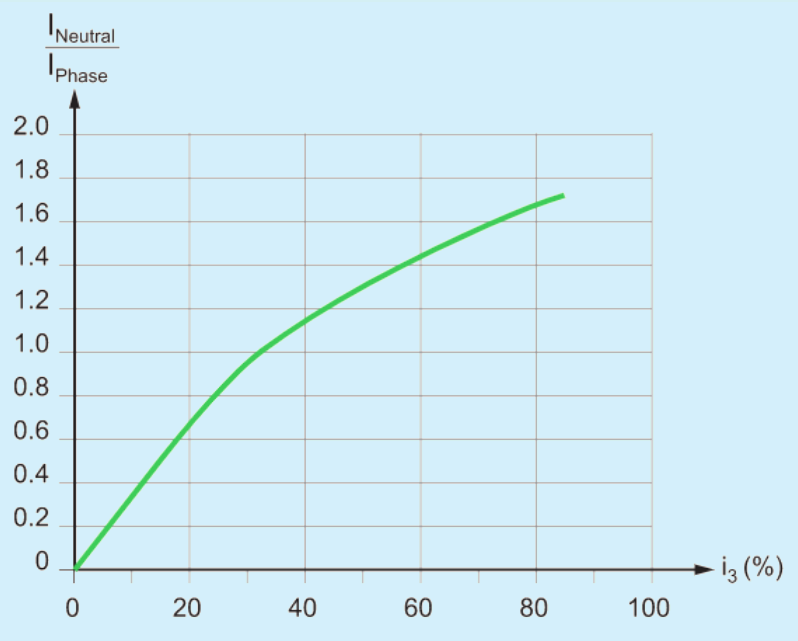


FIG. 3 LOAD FACTOR OF NEUTRAL CONDUCTOR AS A FUNCTION OF PERCENTAGE OF 3_{RD} HARMONICS

a) Where the neutral current is expected to be higher than the phase current, then, the cable size should be selected based on the neutral current;

b) Where the cable size selection is based on a neutral current which is not significantly higher than the phase current, it is necessary to reduce the tabulated current carrying capacity for three loaded conductors;

c) If the neutral current is more than 135 percent of the phase current and the cable size is selected on the basis of the neutral current, then, the three phase conductors will not be fully loaded. The reduction in heat generated by the phase conductors offsets the heat generated by the neutral conductor to the extent that it is not necessary to apply any reduction factor to the current carrying capacity for three loaded conductors; and

d) To protect cables, the fuse or circuit breaker has to be sized taking into account the greatest of the values of the line currents (phase or neutral). However, there are special devices that allow the use of c.s.a. of the phase conductors smaller than the c.s.a. of the neutral conductor resulting in economic operations.

Table 1 Reduction factors for Harmonic Currents in Four Core and Five Core Cables

(*As per* IS 732)

Sl No.	Third Harmonic Content of Line Current (Percent)	Reduction Factor	
		Size Selection is Based Line on Current	Size Selection is Based on Neutral Current
(1)	(2)	(3)	(4)
i)	0-15	1.80	–
ii)	15-33	0.86	–
iii)	33-45	–	0.86
iv)	> 45	–	1.0

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Examples:

Consider a three-phase circuit with a design load of 37 A to be installed using four core PVC insulated cable clipped to a wall. A 6 mm^2 cable with copper conductors has a current-carrying capacity of 40 A and hence, is suitable if harmonics are not present in the circuit.

a) If 20 percent third harmonic is present, then a reduction factor of 0.86 as per Table 1 is applied and the design load becomes: 37/0.86 = 43 A. For this load, a 10 mm^2 cable is necessary. In this case, the use of a special protective device would allow the use of 6 mm^2 cable for the phases and 10 mm^2 cable for the neutral.

b) If 40 percent third harmonic is present, the cable size selection is based on the neutral current which is: 37 × 0.4 × 3 = 44.4 A and a reduction factor of 0.86 is applied, leading to a design load of: 44.4/0.86 = 51.6 A. For this load, a 10 mm^2 cable is suitable.

c) If 50 percent third harmonic is present, the cable size is selected on the basis of the neutral current, which is: 37 × 0.5 × 3 = 55.5 A. In this case, the rating factor is 1 and 16 mm^2 cable is required.

5 PROTECTION OF THE NEUTRAL CONDUCTOR

5.1 Protection Against Overload

If the neutral conductor is correctly sized (including the harmonics effect), no specific additional protection of the neutral conductor is required as it is protected by the protection employed for phase conductors. However, if the c.s.a. (cross section area, mm^2) of the neutral conductor is lower than the phase c.s.a, a neutral overload protection must be installed as specified in **3.1**.

5.2 Protection against Short-Circuit

If the c.s.a. of the neutral conductor is lower than the c.s.a. of the phase conductor, the neutral conductor must be protected against short-circuit. If the c.s.a. of the neutral conductor is equal or greater than the c.s.a. of the phase conductor, no additional specific protection of the neutral conductor is required as it is protected by the protection employed for phase protection.

6 BREAKING OF THE NEUTRAL CONDUCTOR

The requirement to break the neutral conductor is related to the protection against indirect contact and over current. Refer 4.2 and 4.4.1 of IS 732.

6.1 In TN-C System

The neutral conductor shall not be open-circuited under any circumstance as since it acts both as PE (Protective Earthing Conductor) and neutral conductor.

Protective (PE) conductors provide the bonding connection between all exposed and extraneous conductive parts of an installation to create the main equipotential bonding system. These conductors conduct fault current due to insulation failure (between a phase conductor and an exposed conductive part) to the earthed neutral of the source. PE conductors are connected to the main earthing terminal of the installation. The main earthing terminal is connected to the earthing electrode by the earthing conductor. PE conductors must be:

a) Insulated and coloured yellow and green (stripes); and

b) Protected against mechanical and chemical damage.

In IT and TN-earthed system, it is strongly recommended that PE conductors should be installed in close proximity (that is, in the same conduits, on the same cable tray, etc.) as the live cables of the related circuit. This arrangement ensures the minimum possible inductive reactance in the earth-fault current carrying circuit.

6.2 In TT, TN-S and IT System

6.2.1 In TN-S systems, the neutral conductor may not be isolated or switched.

6.2.2 In TT and IT system, in the event of a fault, the circuit breaker opens all poles, including the neutral pole, due to is omni-polar property. The action can only be achieved with help of fuses in an indirect way, in which the operation of one or more fuses triggers a mechanical trip-out of all poles of an associated series-connected load-break switches.

7 ISOLATION OF THE NEUTRAL CONDUCTOR

It is a good practice to provide all circuit with the means for isolation.

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SECTION 21 ENERGY EFFICIENCY ASPECT

FOREWORD

Efficient use of energy acquires added significance as energy saved is energy generated.

The optimization of electrical energy usage can be facilitated by appropriate design and installation considerations. An electrical installation can provide the required level of service and safety for the lowest electrical consumption. This is considered by designers as a general requirement of their design procedures in order to establish the best use of electrical energy. In addition to the many parameters taken into account in the design of electrical installations, more importance is nowadays focused on reducing losses within the system and its use. The design of the whole installation therefore takes into account inputs from users, suppliers and utilities.

This section of NEC covers existing electrical installations in buildings, in addition to new installations. It is in the refurbishment of existing buildings that significant overall improvements in energy efficiency can be achieved.

The optimization of the use of electricity is based on energy efficiency management which is based on the price of electricity, electrical consumption and real-time adaptation. Efficiency is checked by measurement during the whole life of the electrical installation. This helps identify opportunities for any improvements and corrections. Improvements and corrections may be implemented through major investment or by an incremental method. The aim is to provide a design for an efficient electrical installation which allows an energy management process to suit the user's needs, and in accordance with an acceptable investment.

The *Energy Conservation Act*, 2001, also emphasizes the need of energy conservation.

Energy efficiency improvement measures consider the following:

a) both the consumption (kWh) and the price of electricity;

b) technology; and

c) environmental impact.

1 SCOPE

This section of the Code (Part 1/Sec 21) covers the aspects to be considered for energy efficient design, selection of energy efficient equipment to reduce energy consumption, guidance on conducting or carrying out energy audit, energy efficiency assessment of an electrical installation for minimizing energy losses, optimizing energy use, and maintaining efficient performance.

Confirmation to IS 16996 (Low voltage electrical installation – Energy efficiency) shall be considered as primary requirement to comply this section.

2 REFERENCES

The standards listed in below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No./Other Publication	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
12615 : 2018	Line operated three phase a.c. motors (IE CODE) "Efficiency classes and performance specification"
16996 : 2018	Low-voltage electrical installations — Energy efficiency
NBC 2016	National Building Code (NBC) of India 2016
ECBC : 2017	Energy Conservation Building Code 2017
IEC 60287-3-2	Electric cables — Calculation of the current rating — Part 3-2: Sections on operating conditions — Economic optimization of power cable size
IEC 61557-12 : 2018	Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC — Equipment for testing, measuring or monitoring of protective measures — Part 12: Power metering and monitoring devices (PMD)

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3 TERMINOLOGY

3.1 Load Energy Profile — Figure representing the energy consumption (Y-axis) within a period of time (X-axis) based on measurements for a mesh or a group of meshes (for example, hourly consumption of energy for a period of a week).

3.2 Power Demand Profile — Figure representing the power demand (Y-axis) for a given integration period within a period of time (X-axis) based on measurements for a mesh or a group of meshes.

3.3 Electrical Energy Efficiency (EEE) — System approach for optimizing the efficiency of electricity usage.

3.4 Mesh — One or more circuits of the electrical installation for one or more zones including one or more services supplying a group of electrical equipment for the purpose of electrical energy efficiency.

3.5 Active Electrical Energy Efficiency Measure — Operational measure, either manually or automatically controlled, for optimizing the energy efficiency of the electrical installation (*for example*, Thermostat control, occupancy lighting control, building optimization control systems).

3.6 Passive Electrical Energy Efficiency Measure — Measure for optimizing the energy efficiency of the electrical installation by selection and erection of electrical equipment other than control equipment (*for example*, Selection and location of transformer, cross section of cables, routing of wiring system, sub-division of circuits).

3.7 Electrical Installation Efficiency Class — Defined level of energy efficiency for an electrical installation.

3.8 Driving Parameter — External factors that affect energy efficiency (*for example*, Regulation, environmental conditions, occupancy, energy prices and management requirements, mode of operation, duty cycle, load curves, state, operating, parameters, indoor temperature, lighting levels, production volume).

3.9 Bary Centre Method — Procedure to optimize the position of energy source(s) and loads in consideration of energy efficiency.

3.10 EE Assessment — Process to determine the electrical installation efficiency class of an installation.

3.11 Electrical Energy Management System (EEMS) — System monitoring, operating, controlling and managing energy resources and loads of the installations.

3.12 Load Shedding — Method(s) of optimizing demand by controlling the electrical loads for variable periods of time.

3.13 Demand Response — Changes in electric usage by end-user customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.

3.14 User Interface — Means that allow the user to monitor and/or control the electrical installation, locally or remotely (*for example*, visual or audible signal, local display, remote display, push button).

3.15 Measurement — Process of obtaining value(s) that can be attributed to a quantity.

3.16 Monitoring — Continuing procedure for the collection and assessment of pertinent information, including measurements, for the purpose of identifying deviations and determining the effectiveness of the plans and procedures.

3.17 Power Metering and Monitoring Device (PMD) — Combination in one or more devices of several functional modules dedicated to metering and monitoring electrical parameters in energy distribution systems or electrical installations, used for applications such as energy efficiency, power monitoring and network performance.

4 GENERAL

Energy efficiency aims at eliminating wastage of energy and minimizing losses. The major factors to be considered in this regard include system design, selection of equipment, operation and maintenance practices, capacity utilization factors, etc. Improving efficiency typically costs less than the energy tariffs. To standardize and benchmark the level of efficiency of various electrical and other energy consuming equipment, the Bureau of Energy Efficiency was instituted in March 2002. Wherever available, the standards and labelling/rating standards for various equipment proposed by Bureau of Energy Efficiency shall be followed while selecting equipment, with

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a preference for higher efficiency equipment to the extent possible. Provisions of the *Energy Conservation Act*, 2001 should also be considered, where applicable.

Also, along with energy efficient designing and selection of equipment, active energy efficiency becomes an important factor as it is not only related to energy saving devices and equipment installed, but also to ensure that these devices and equipment use only the energy required. It is this aspect of monitoring and controlling that is critical for achieving the maximum efficiency. It is the management of energy use through measurement, monitoring and control that effects sustainable energy efficiency.

IS 16696 provides requirements, measures and recommendations for the design, erection and verification of all types of low-voltage electrical installation including local production and storage of energy for optimizing the overall efficient use of electricity. This standard is applicable to the electrical installation of a building or system and is not applicable on products.

4.1 Fundamental Principles

4.1.1 *Safety of the Electrical Installation*

The requirements and recommendations of this part of shall not impair requirements included in IS 732.

4.1.2 *Availability of Electrical Energy and User Decision*

Energy efficiency management shall not reduce electrical availability and/or services or operation below the level desired by the user.

The electrical installation shall have provisions for overriding the energy efficiency management settings according to the user's decision (*for example,* if someone is ill, the user can decide to heat the room to a higher temperature, even during peak consumption or if a company receives an urgent delivery order, there can be a need for the workshop to operate at an unexpected hour).

4.1.3 *Design Principles*

The design principles take into account the following aspects:

a) load energy profile (active and reactive energy);
b) availability of local generation (PV, wind turbine, generator, etc.) and storage;
c) reduction of energy losses in the electrical installation;
d) the arrangement of the circuits with regard to energy efficiency (meshes, *see* **7.4**);
e) the customer's power use distribution over time; and
f) the tariff structure offered by the supplier of the electrical energy.

Maintaining the quality of service and the performance of the electrical installation.

In order to verify the achievement of electrical energy efficiency measures, an overall energy efficiency assessment should be made.

4.2 Energy efficiency Assessment for Electrical Installations

4.2.1 *General*

Assessment of installations shall be performed according to Annex B of IS 16996. This assessment shall be made, preferably, by measurement. It may be also achieved by calculation.

The frequency of periodic inspection of an installation shall be determined on the basis of type of installation and equipment, its use and operation, the frequency and quality of maintenance, factors liable to influence energy efficiency and the external influences. The results and recommendations of the previous report, if any, shall be also taken into account.

The maximum interval for follow-up assessment is recommended to not exceed:

a) five years for commercial; and
b) three years for industrial infrastructure.

4.2.2 *Action Plan following an assessment*

On assessment as per Annex B of IS 16996, if new installation is of lower installation efficiency class than required, the identified variances shall be corrected taking into account the local regulations. In case of periodic assessment, if the electrical installation is of lower installation efficiency class than required, an action plan shall be prepared to achieve desired efficiency class.

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5 DESIGNING NEW INSTALLATIONS

5.1 General

While designing an electrical installation, the following shall be taken into account:

a) load energy profile (active and reactive energy);
b) minimization of energy losses in the electrical installation by means of:
   1) optimal location of the transformers, local production and switchboard (barycentre),
   2) location of HV/LV substation,
   3) reduction of losses in wiring; and
c) local production and storage.

5.2 Determination of Load Energy Profile

The prospective load energy profile within the installation shall be determined. Synthetic profiles (typical load energy curves) from loads or load groups may be used from similar applications. If measurements or synthetic profiles are not available, the main loads (based on equipment rating) including expected duration of operation should be identified. This consumption could then be summed to create a load energy profile.

5.3 Determination of the Transformer and Switchboard Location with the Barycentre Method

Account shall be taken of the building's use, construction and space availability for the best position to be obtained, but this should be determined in consultation with the buildings designers and owners prior to construction. To keep the wiring losses to a minimum, the main distribution transformers and switchboards shall be located, taking into consideration the building constraints, in such a way as to keep distances to main loads to a minimum. The methods used for determining the position can be used to determine the optimal available site for the distribution equipment and transformers.

The barycentre method is an iterative approach that can be used to determine

a) whether the load distribution is uniform, or of localized type,
b) whether the loads or other equipment should be relocated, and
c) the total load barycentre location.

See examples of calculations in Annex A in IS 16996.

5.4 HV/LV Substation

5.4.1 *General*

To find the optimal solution for the transformer, the following shall be considered:

a) optimum number and location of HV/LV substations;
b) working point of the transformer;
c) efficiency of the transformer; and
d) load energy profile.

5.4.2 *Optimum Number and Location of HV/LV Substations*

Depending on several criteria, such as the required power, the building surface area and the load distribution, the number of HV/LV substations and the distribution layout will have an influence on the lengths and cross-sectional areas of conductors. If the barycentre is located in one building side, it is advised to choose one substation close to this barycentre; or if the barycentre is located in the middle of the building layout, it may not be possible to locate the HV/LV substation near the load centre. In such cases, it is recommended to split the electrical distribution into several HV/LV substations located close to their respective barycentres. This facilitates the optimization of LV conductor lengths and sizes.

5.4.3 Other considerations during design are:

a) Working point of the transformer and efficiency of the transformer;
b) Efficiency of local production and local storage;

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c) Losses in the wiring:
   1) Voltage drop,
   2) Cross-sectional areas of conductors,
   3) Power factor correction, and
   4) Reduction of the effects of harmonic currents.

Following clauses from IS 16996 shall be considered while designing and maintaining an energy efficient installation:

a) Determination of the zones, usages and meshes (*see* 7 of IS 16996);
b) Energy efficiency and load management system (*see* 8 of IS 16996);
c) Maintenance and enhancement of the performance of the installation (*see* 9 of IS 16996); and
d) Parameters for implementation of efficiency measures (*see* 9 of IS 16996).

6 EQUIPMENT SELECTION

The main criterion for equipment selection, from energy efficiency point of view, is that the energy loss is minimized without reducing the desired output. In other words, the operating efficiency should be high. Proper sizing of equipment is essential to ensure optimum utilization of energy. It is also necessary to avoid over rating or under rating the equipment. It should be ensured that operating power factor of equipment is high. Most commonly encountered equipment in electrical systems are mentioned below.

6.1 Motors

Motors should be energy efficient motors, conforming to IS 12615 (IE2 class or higher), especially, for applications that operate more than 3 000 h per year. In cases where motors are often running below nominal conditions, variable speed drives should be installed for controlling motors. This is particularly the case where motors are used in flow systems and where the power needed from motor depends on its speed. Use of variable speed drives brings substantial energy saving wherever different flow conditions/speeds are encountered, especially, in the process industry. Use of variable speed drives is a highly efficient means of achieving flow control etc. as compared to throttling of valves, dampers etc. or the use of stepped pulleys. Motors with higher operating power factor shall be considered during selection as this results in lower current and consequently lower losses.

6.2 Transformers

While procuring transformers, normal loading shall be indicated to optimize transformer efficiency to be maximum at projected load and for minimizing losses under normal operating conditions. Losses should be accounted while selecting equipment, by the method of loss capitalization or specifying the minimum acceptable value for maximum efficiency.

6.3 Cables Equipment

Optimizing cable route/length can best reduce cable losses. Though the losses can also be reduced by over sizing the conductors, this is not recommended due to the practical problems encountered with termination of over-sized cables.

6.4 Lighting

An efficient lighting system can substantially reduce the energy consumption. The selection criteria for lighting shall include, among other factors, light sources of higher luminous efficacy, such as LED. Street lighting and other tasks, where colour rendering properties of light are not of significance, can be achieved more efficiently using sodium vapour lamps compared to mercury vapour lamps. The use of incandescent lamps should be avoided. Newer technologies such as building automation systems for optimizing power consumption through natural lighting, reduction in HVAC load demand using films or glazing with high visible light transmittance and low heat transfer, lights controlled by sensors which get activated by movement/human presence, etc., which can significantly optimize the use of electrical energy, should be used.

The design of the electrical lighting system is also important for lighting system efficiency. The electrical lighting system should be designed using an ambient-task-accent lighting design approach, using indirect ambient lighting and direct task and accent lighting. Recommended values of illuminance should be in accordance with the *National Building Code of India*, 2016, (Part 8, Section 1, Sub-section 4: Lighting; and Table 4: Recommended Values of

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Illuminance). Lighting and controls should be designed and installed in accordance with the *Energy Conservation Building Code* (Chapter 6: Lighting and Controls).

The selection criteria for luminaires should include minimum harmonic distortion, maintenance of power factor higher than 0.9, and compatibility with dimming systems. Low loss electronic ballasts should be employed, where feasible, after taking care that the harmonic distortion is within permissible limits.

7 ENERGY AUDIT

An energy audit covers the verification, monitoring and analysis of the energy use, including submission of a technical report containing recommendations for improving energy efficiency, cost benefit analysis and an action plan to reduce energy consumption. The purpose of an energy audit broadly includes:

a) Reviewing the level of energy consumption;
b) Creating a data base;
c) Identifying energy conservation potential;
d) Preparation of norms/guidelines for implementation of energy conservation measures; and
e) Recommending the use of energy efficient appliances and of adapted control strategies.

Regarding energy audit, *Energy Conservation Act*, 2001 has been enacted and the regulations issued under the said act shall be complied with. Accordingly, designated consumers, as notified from time to time, shall get the energy audit carried out through an accredited energy auditor/firms and implement techno-economic viable recommendations/measures. Every designated consumer shall appoint or designate a certified energy manager, whose responsibility shall be to assist the designated consumer in complying with the energy consumption norms and standards and other mandatory provisions.

The recently updated version of the energy conservation building code formulated by the Bureau of Energy Efficiency and prescribed by the Central Government shall be implemented for new buildings having connected load of 100 kW and above or contract demand of 120 kVA and above, after notification by the respective State Governments.

8 ENERGY EFFICIENCY ASSESSMENT OF ELECTRICAL INSTALLATIONS

8.1 Voltage Drop

In the absence of any consideration like start-up time for motors, equipment with high inrush current, and temporary conditions, such as voltage transients and voltage variation due to abnormal operation, the voltage drop between the origin of the consumer's installation and the equipment should be as mentioned in the following Table:

Type of Installation	Lighting	Other Uses
A – Low-voltage installation supplied directly from a low-voltage network	3 percent	5 percent
B – Low-voltage installation supplied from a private network	6 percent	8 percent

NOTE — It is recommended that the voltage drop in the terminal circuits should not be greater than the values indicated for type A installation.

Where the main lines of the installations are more than 100 m long, the voltage drop may be increased by 0.005 percent per meter of line beyond 100 m, but not exceeding 0.5 percent (refer IS 732).

8.2 Cross-sectional Area of Conductors

Increasing the cross-sectional area of the conductor reduces the power loss. This decision shall be made by assessing the savings within a time scale against the additional cost due to over-sizing. For cables, the size shall be determined considering the cost of losses that will occur during the working life of the cable against the initial cost of the cable. A calculation method for the same can be referred from IEC 60287-3-2.

8.3 Power Factor Correction

Power factor correction will lead to reduction of reactive energy consumption, which will improve electrical energy efficiency since maximum electrical energy will be transformed in active energy. It will also reduce thermal losses in wiring systems, particularly in the low-voltage public distribution system. Power factor correction will

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also reduce the losses in the power to be transmitted in the transmission and distribution networks and in the customers' networks and installations. Capacitor bank can be used to improve the power factor.

There shall be a provision for a permanent power factor measurement at the main incomer. The acceptable levels of power factor shall be at least 0.9 for medium and large commercial buildings and 0.95 for industries.

8.4 Reducing the Effects of Harmonic Currents

Harmonic disturbances not only stress equipment due to overheating, but also generate additional power losses through the wiring system. Therefore, the measurement of Total Harmonic Distortion (THD) at the installation level and at the current-using-equipment level for harmonics is necessary and recommended. Appropriate measurement for inter-harmonic should also be performed.

The energy meter at the incomer shall be capable of capturing and reporting the harmonic disturbances. The maximum levels acceptable for THD at installation level should be 5 percent for all types of facilities, whether commercial buildings or industries.

Active harmonic filters shall be installed at the loads if the THD level is found to be exceeding the maximum acceptable limits. Increasing the cross-section area of the conductor can also reduce the harmonics in the system.

8.5 Adapting a Methodology to Minimize Electrical Installation Energy Losses

The Barycenter method or a similar methodology shall be adapted to minimize the energy losses in the electrical installation. The objective of this method is to install transformer and switchboard at a location based on relative weighting due to the energy consumption of the loads, so that the distance to a higher energy consumption load is lower than the distance to a lower energy consumption load. This method not only improves the energy performance of the installation, but also reduces the cost of installation by reducing the length of the cables.

8.6 Arrangement and Measurement of the Electrical Circuits to Enhance Energy Efficiency

Identification of the energy end use for a particular circuit or mesh or zone is needed to enable accurate measurement and analysis of its energy consumption. Different end uses can be lighting, HVAC, motors, other specific processes, etc. Similarly, a zone can represent a surface area in m^2 or a location where electricity or energy is used, for example, a workshop, a building floor, etc. A mesh is a circuit or a group of circuits identified with respective energy using equipment, it determines one or several uses in one or more zones. When similar equipments are operating or several different equipment are operating at the same time, it's beneficial to keep all of them under one circuit, it makes the system more economical and efficient as a particular mesh can be monitored and controlled as a single unit.

An end use or mesh or zone which accounts for 10 percent or more of the total energy consumption of the facility shall be measured continuously or shall have a permanently installed energy use measurement provision.

9 OPTIMIZE ENERGY USE — INSTALLATION OF ENERGY METERS/POWER MONITORING DEVICES AND ENERGY MONITORING SYSTEM

Installation of energy meters or power monitoring devices (PMD) and an energy monitoring system can provide guidance on optimizing the energy use, considering the loads and end user requirements. The energy consumption of a facility can be reduced by 5 percent only through energy metering and monitoring and by simply understanding the energy end use.

9.1 Energy Meters or Power Monitoring Devices (PMD)

The energy meters or power monitoring devices (PMD) installed should be digital and at least the main meter at the incomer level shall be capable of two-way communication, from the demand as well as the supply side. Adequate energy metering and monitoring infrastructure shall be installed to help monitor operational energy use and costs and to enable continuous energy performance improvement. Digital energy meters should be installed for the following:

a) Utility grid points,
b) Captive generator sets, and
c) On-site renewable energy system (if installed/operational).

The energy meters installed at the incomer level shall have high accuracy, high sampling rates and advanced capabilities to measure power quality parameters that is., harmonics, sags, swells, voltage interruptions, etc.

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The electrical distribution shall be designed with adequate load segregation to facilitate cost-effective sub-metering according to the end uses and functional areas; and documenting the same through clear single line diagrams. Separate sub meters shall be installed for all energy end uses and functional areas in the facility that individually account for 10 percent or more of the total energy consumption. These end uses may be:

1) HVAC including cooling towers, chillers, pumps, AHUs (Air Handling Units), FCUs (Fan Coil Units), and distributed units for split or window ACs where applicable;
2) Lighting; and
3) Other industry specific processes.

At a minimum, the sub-metering infrastructure should facilitate the aggregation of energy use. All energy meters installed shall have the capability to communicate energy data for monitoring.

9.2 Energy Monitoring System

Energy monitoring systems that can display the following parameters shall be installed with two-way communicable smart energy meters or power monitoring devices (PMD):

a) Hourly energy demand and use,
b) Energy breakdown and mix and energy consumption patterns,
c) Demand side power quality analysis,
d) Energy consumption by process, department, building, floor, etc.,
e) Comparison of actual energy use with targets or historical trends and benchmark energy KPIs, and
f) Reporting on sustainability projects with display of energy efficiency ratings.

The energy monitoring system should have the ability to utilize near-real-time or time-of-use pricing through integration of smart meters with the monitoring and control system. The system should be capable of supporting predictive demand for better demand management and proactive demand control.

The following measurements are recommended to effectively monitor energy performance and to improve energy efficiency:

Electrical Quantities to Measure	*Symbol*	*Benefits of Measurement*
Active energy	E_a	Monitor energy and manage costs more closely, by zone and/or usage.
Reactive energy	E_r	Monitor energy and manage costs more closely, by zone and/or usage.
		Monitor the operation of reactive loads for example, motors, transformers, capacitors.
Power, power demand	P	Better control the demand in order to optimize the supply contract.
Power Factor	PF, cosφ	Optimize power factor to avoid penalties.
Load profiles (energy consumption)	LP	Optimize the supply contract
Voltage and current harmonics	THD_u THD_i	Detect non-positive-sequence harmonics causing excessive energy losses in motors or transformers.
Frequent deviations of voltage	U	Detect devices frequently operating outside their specified range and over consuming energy.
Voltage unbalance	U_{nb}	Detect non-positive-sequence components causing excessive energy losses in motors.

NOTE — One intent of Energy Efficiency is to optimize the supply contract and to avoid penalties

Refer *National Building Code (NBC) of India* and IEC 61557-12.

9.3 Use of Building Management Systems

Building Management Systems (BMS) provide for management of building energy consumption up to 30 percent by modulating the operation to the demand based on occupancy, weather, etc. It is recommended that several

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applications (lighting control, HVAC control, presence management) are integrated in the BMS so that control strategy can be optimized holistically and not focused on one application only.

10 MAINTAINING EFFICIENT PERFORMANCE

Adopting a life-cycle cost methodology can help in maintaining efficient performance of the facility which includes energy efficient design, selection and installation of high efficiency equipment, optimizing through energy monitoring and automation, and finally, identifying new energy efficiency measures through energy audits, to strive for continuous improvement.

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SECTION 22 SAFETY IN ELECTRICAL WORKS

FOREWORD

Safety procedures and practices are essential and mandatory in electrical works. Basic approach to electrical work from the point of view of eliminating electrical hazards and ensuring safety shall be a priority.

It is essential that safety shall be preached, practiced and monitored at all times from designing stage to, further, during installation, use, operation and maintenance. The safety instructions shall be implemented as and when required.

The guidelines and recommendations from the point of view of safety mentioned in this section are, therefore, for the use of designers; persons involved in use, installation, operation, maintenance, electrical safety audits and also, for the employers/owners of electrical installation.

NOTE — A person who is owner, occupier within the meanings defined under the act and regulations is responsible and legally bound to maintain electrical installation in safe condition.

Employer shall implement safe work practices, establish procedures accordingly and maintain documentation. Employees shall follow the practices and procedures laid down while working on electrical installations.

1 SCOPE

1.1 This section of the Code (Part 1/Sec 22) covers statutory and administrative controls for implementation of safety, guidelines on safety procedures and practices to be observed for safeguarding property and persons working on/with/in vicinity of Electrical Installation from the point of view of risks associated with the activities such as installing, testing, commissioning, verifying, operating, using, maintaining, dismantling etc. and also, for persons whose exposure to electrical installation is not intentional or involving part of their work/activity.

1.2 Observance of safety is broadly divided into following stages and tasks of electrical work:

a) Design and layout;
b) Installation;
c) Working-on;
d) Testing and commissioning/energizing;
e) Maintenance; and
f) Temporary electrical installation.

1.3 Electrical hazards and mitigation is divided into three parts:

a) Electrical shock hazard;
b) Electrical fire hazard; and
c) Electrical arc flash hazard.

2 REFERENCES

2.1 Statutory provisions as per *Electricity Act*, *2003*

a) Central Electricity Authority (measures relating to Safety and Electric Supply) Regulations, 2010 as and when amended.
b) Central Electricity Authority (Technical Standards for Construction of Electric Plants and Electric Lines) Regulations 2010; as and when amended.
c) Central Electricity Authority (Safety requirements for construction, operation, maintenance of Electric Plants and Electric Lines) Regulations, 2011.

2.2 The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

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IS No.	*Title*
732 : 2019	Code of practice for electrical wiring installations
2551 : 1982	Specification for danger notice plates
3034 :1993	Fire safety of industrial buildings: Generating and Distributing stations
5216 (Part 1) : 1982	Recommendations on safety procedures and practices in electrical work — Part 1 General
5216 (Part 2) : 1982	Recommendations on safety procedures and practices in electrical work — Part 2 Lifesaving techniques
8923 : 1978	Warning symbol for dangerous voltages
IS 14700-3-3 : 2018/ IEC 61000-3-3 : 2017	Electromagnetic compatibility (EMC) — Part 3 Limits — Section 3 limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply system, for equipment with rated current 16 A per phase and not subjected to conditional connection (*second revision*)
13503 : 2013	Classification of insulating liquids
16081 : 2013	Specification for unused synthetic organic esters for electrical purpose
IS 16242 (Part 1) : 2014/ IEC 62040-1 : 2013	Uninterruptible power systems (UPS) — Part 1 General and safety requirements for UPS
IS 16504 (Part 1) : 2019/ IEC 60204-1 : 2016	Safety of machinery — Electrical equipment of machines: Part 1 General requirements (*first revision*)
IS 16504 (Part 11) : 2020/ IEC 60204-11 : 2020	Safety of machinery — Electrical equipment of machines – Part 11 Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV
16659 : 2017	Specification for unused natural esters for transformer and similar electrical equipment
IS/IEC 62305 : 2010	Lightning protection
IEC 60331 series of standard	Test for electric cable under fire condition — Circuit integrity
IEC 61482-1 : 2019	Live working — Protective clothing against the thermal hazards of an electric arc — Part 1: Test methods
IEC 61482-2 : 2018	Live working — Protective clothing against thermal hazards of an electric arc — Part 2: Requirements
IEC 61936-1 : 2014	Power installation exceeding 1 kV — Part 1 Common rules
SP 31 : 1986	Method of Artificial Respiration
IEEE 1584 : 2018	Guide for arc flash hazard calculations
NFPA 70E 2018	Standard for Electrical safety in Workplace

3 TERMINOLOGY

Definition of the terms used in this section are given below:

3.1 Accessible — Not obstructed/guarded by locked doors, readily approachable/capable of being physically reached quickly without use of any appliance or special effort for operation.

3.2 Apparatus — Electrical apparatus and includes all machines, fittings, accessories and appliances in which conductors are used.

3.3 Approach Limit — A limited approach boundary at a distance from exposed energized electric part from which electric shock hazard exist.

3.4 Appropriate Government — Central Government or State Government having respective jurisdiction as mentioned under section 2 of *Electricity Act*, 2003.

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3.5 Approved — Permitted by an authority having jurisdiction.

3.6 Arc Flash — Release of energy caused by an electric arc**,** intensity of which is called arc rating.

3.7 Arc Flash Boundary — An approach limit of a person from arc source at which incident energy equals 1.2 cal/cm^2 or 5 joules/cm^2 for 1 s, (exposure to such energy may cause second degree burns).

3.8 ATPV — Arc thermal protection value (in respect of protective clothing/garments measured, in kJ/m^2 or cal/cm^2)

3.9 Bare — Not covered with insulating material.

3.10 Branch Circuit — A circuit between final circuit breaker protecting the circuit and outlets.

3.11 CEA — Central electricity authority, an authority constituted under sub section (1) of section 70, of *Electricity Act*, 2003 having jurisdiction to make regulations as per section 177 of the Act.

3.12 CEA Safety Regulations — Central electricity authority (measures relating to safety and electric supply) regulations, 2010 as and when amended, as per section 53 of the *Electricity Act*, 2003.

3.13 Conductor — Any wire, cable, bar, tube, rail, plate used for conducting electricity and so arranged as to be electrically connected to system.

3.14 Designated Person — A person having certificate of competency or work permit issued by an appropriate government to carryout work on electrical lines and apparatus under Regulation 3 of CEA Safety Regulations and authorised by the owner of the installation as per Regulation 3 of CEA Safety Regulations.

3.15 Earth Electrode — A conductor or group of conductors in intimate contact with and providing an electrical connection to earth.

NOTE — The word 'ground'/'grounding' used in place of 'earth'/'earthing' has same meaning, purpose, objective in that regard.

3.16 Earth Fault — An un-intentional electrical connection between live or un-grounded electrical current carrying conductor and normally non-current carrying conductor, metal enclosure/equipment having connectivity to earth.

3.17 Electrical Inspector — An authority having jurisdiction under section 162 of *Electricity Act,* 2003 and powers conferred thereunder.

3.18 Electrical Safety — Identifying hazards associated with the working on electrical installation, use of electrical energy and taking precautions to reduce the risk associated with those hazards.

3.19 Enclosed — A case, housing of apparatus or fence or wall surrounding the installation to prevent person from unintentionally contacting energized parts.

3.20 Enclosure — Surrounded by case, housing, fence or wall that prevents person from unintentionally contacting energised parts and to protect the equipment from physical damage.

3.21 Energise — Connecting to electric supply source and commission/charge.

3.22 Equipment — Any item used for such purposes as generation, conversion, transmission, storage, distribution or utilization of electrical energy, such as machines, transformers, apparatus, measuring instruments, protective devices, equipment for wiring systems, appliances.

3.23 Exposed — In respect of unguarded conductor or circuit parts capable of being inadvertently touched or approached nearer than a safe distance.

3.24 Extraneous Conductive Part — A conductive part liable to introduce potential (generally earth potential) and not forming part of electrical installation.

3.25 Fault Current — A current resulting from fault, which flows through an abnormal unintended path, resulting from insulation failure or bridging of insulation, where impedance between live conductor(s) and exposed extraneous conductive parts at fault position is considered negligible.

3.26 Guarded — Covered, shielded, fenced or protected by means of suitable casings, barrier, rails, metal screen to avoid the possibility of dangerous contact.

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3.27 Guarding — (in respect of overhead line) an arrangement provided on overhead electric line to earth the snapped live bare conductor(s) to ensure them rendering dead and also prevent it from becoming accessible from ground.

3.28 Incident Energy — Amount of thermal energy measured in cal/cm^2, or J/cm^2/kJ/m^2 impressed on surface, generated at the instance of electric arc.

3.29 Limited Approach — An approach limit at a distance from an exposed energised electrical conductor within which shock hazard exists.

3.30 Notified Voltage — A voltage notified by appropriate government for the purpose of self-certification.

3.31 Outlet — A point on wiring system from which current is taken to supply electrical equipment for its utilization.

3.32 PPE — Personal Protective equipment for the protection of persons from electrical hazard while working on live electrical installations or work within restricted boundary.

3.33 RCD — A mechanical switching device or association of devices intended to cause the opening of the contacts when the residual current attains a given value under specified conditions, intended for protection against electrical shock or over heating due to earth leakage.

3.34 Restricted Approach — A boundary at a distance from exposed energised electric part within which there could be electric shock hazard due to electric arc flash, and beyond which entry is restricted.

3.35 Risk Assessment — Process which identifies chances of injury or damage to health by estimating its potential severity which help of framing protective measures.

3.36 Safety Working Clearance — Minimum clearance to be maintained in air between live part of equipment on one hand and earth or other piece of equipment or conductor on which it is necessary to carryout work on other hand.

3.37 Shock Hazard — A possibility of current passing through body causing injury or damage to health.

3.38 Sock Hood — A personal protective equipment covering neck and head excluding facial area of eyes and nose.

3.39 Working Distance — Distance between a person's face, chest or other body parts and prospective arc source.

4 DESIGNS AND LAYOUT

For any electrical work, appropriate design and layout forms foundation of safety. After energization of installation, it is difficult and, sometimes, impossible to correct the defects in basic design. Therefore, it is important to consider following guidelines with respect to design of an electrical installation considering aspects of safety.

4.1 Every electrical installation up to 1 000 V a.c. and 1 500 V d.c. shall be designed, erected and tested as per the provisions of IS 732.

4.2 Safety aspects affecting design are integrated under following parameters:

a) geographical location;
b) the type of installation based on its utility, namely, domestic dwellings; other structures, buildings, spaces for commercial, industrial, administrative usages; transmission/distribution systems;
c) persons occupying/working in that area;
d) expected level of knowledge and responsibility of person in regard with probable risk/hazard involving out of electrical installation which they are exposed to;
e) layouts allowing sufficient space/safety clearance to allow access, operation and maintenance;
f) civil construction suitable for installation of equipment, along with sufficient reinforcement/arrangement for venting pressures as per necessity and, also, giving consideration to anticipated future expansion/ requirements;
g) design of electrical panels/distribution/apparatus and outage for maintenance; and
h) sustainability.

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The safety aspects under these various parameter affecting design shall have relevance to available BIS, IEC standards and shall be in accordance with CEA Safety Regulations, related provisions from Central Electricity Authority (Technical Standards for Construction of Electric Plants and Electric Lines) Regulations; as and when amended.

4.3 All electric supply lines and apparatus shall be of sufficient mechanical strength for duty cycle required to be performed under environmental conditions of installation and shall so be constructed and installed.

4.4 Design shall be based on calculations made with respect to load, fault levels, touch and step potentials, earthing, loop impedance etc. It shall be available, especially, for all major installations and shall form part of documentation to be maintained and updated as record and kept readily avaialble as and when required by the authority.

4.5 All electrical equipment shall be installed above mean sea level and important part of installation shall be above maximum flood level.

4.6 Material to be used for electrical installation shall to specifications as per Indian Standards or IEC standards (*where relevant Indian Standards are not available*). These shall be suitable for use under respective climatic conditions as well as corrosive environment. Accordingly, it shall also be of such grade, fire rating, quality, treated/coated to prevent deterioration and sustain under respective indoor/outdoor/concealed in concrete/underground/wet locations.

4.7 Under hazardous zones, equipment and apparatus shall comply with the requirements of flameproof, dust tight, totally enclosed or any other suitable type of electrical fittings as per relevant Standard. And, civil construction shall be sustainable to withstand blasts as per risk hazard assessment.

4.8 In order to withstand fire situation, wires/cables shall be fire resistant having proper class FR (Flame Retardant)/ FRLSH (Flame Retardant Low Smoke Halogen)/HFFR (Halogen Free Flame Retardant), FS (Fire. Survival)[1]. Design of electrical installation shall recommend proper type and class of wire considering following properties of wire:

a) non propagation of fire – self-extinguishing;
b) low generation of smoke – opaque, impairing visibility and suffocation during fire;
c) no or zero toxic fumes/smoke-due to burning of insulation directly affecting respiration and endangering life;
d) formation of acids after coming into contact with water causing adverse effects on metal structures including steel embedded in concrete; and
e) withstand high temperature for the required time period[2] and retain integrity of supply to serve emergencies/ critical services.

NOTES

1 FS cable, depending on voltage level, shall meet the test requirements depending on environment. These cables shall be as per IS 17505 (Part 1) to maintain circuit integrity and survive under fire conditions categorized on the basis of withstand temperature from 650 °C to 950 °C, time ranging from 15 min to 180 min and also, withstand mechanical shock, water jet.

2 The time period, *for example*, may be the expected time required for beginning of rescue operation, followed by evacuation and completion.

3 Use of FS cables shall be made where electric supply integrity is important, *for example*, cabling related to PA system, emergency lighting and luminous signs of escape routes, Fire Alarm system, operation of Fire Fighting, Sprinkler system, control cabling of protective devices; and may also include installations with high importance involving security, assets, occupancy. While considering use of FS cable, correlated fire risk hazard shall also be considered.

4.9 In order to prevent generation of heat above permissible limit within conduits, trunking, raceways, the number and size of conductors and enclosures shall be designed in accordance with the standard as mentioned in section for ‘wiring installations’.

NOTE — Adequate space factor (space within enclosure, remaining free after drawing wires) is important in this regard which also facilitates drawing and withdrawing of wires without damaging the insulation.

4.10 Following controls of requisite capacity to carry and break the current shall be placed after the commencement of supply such that they are readily accessible and are easily operatable to completely isolate the supply to installation.

a) a linked switch with fuse or circuit breaker on consumer side for voltage not exceeding 650 V.
b) a linked switch with fuse or circuit breaker on consumer side for voltage exceeding 650 V and up to 33 kV having combined installed transformer or apparatus capacity up to 1 000 kVA supplied at or up to 11 kV and 2 500 kVA at voltage above 11 kV and up to 33 kV.

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c) a circuit breaker on consumer side for voltage exceeding 33 kV having combined installed transformer capacity above 1 000 kVA supplied at voltage up to 11 kV and above 2500 kVA for voltages exceeding 11kV and up to 33kV.

d) a circuit breaker on consumer side for voltage above 33kV.

e) In case of transformers, circuit breaker on the primary side shall be provided. However, for capacity below 1 000 kVA, a linked switch with fuse (suitable to carry full load current and break only magnetizing current) may be allowed. On secondary side, circuit breaker shall be provided.

4.11 Supply for motor/s, apparatus shall be controlled by suitable linked switch with appropriate fuse rating/circuit breaker or an emergency tripping device with manual reset placed such that it is readily accessible and easily operatable.

4.12 All switchboard/electrical panel shall comply with following:

a) a clear space of at least 1m in width shall be provided in front of switchboard. Switchgears and control panels shall be provided with insulating floors or mats conforming to IS 15652;

b) In case of attachments or bare connections at the back of the switchboard, the space behind the switchboard shall either be less than 20 cm or more than 75 cm in width measured from farthest protruding part of any attachment or conductor;

c) If the space behind the switch board exceeds 75cm, passageway from either end of the switch board clear to a height of 1.8 m shall be provided;

d) Switchgears on control panels shall be marked with identification and its intended functions on front and rear side of panel board. Danger notice as per IS 2551 shall be displayed conspicuously;

e) There shall be adequate illumination within all the panel rooms to maintain clear visibility. Under National Lighting Code, various factors to be considered for calculation of level of illumination have been mentioned. Generally, it shall be 300 lux in the task area and 200 lux.

f) In case of dusty environment, the panel shall be adequately protected from dust by fabricating and constructing electrical panels with appropriate ingress protection class. If required, electrical panel room may be kept under positive pressure of clean air or through any other effective means.

g) Under corrosive, humid and hot conditions, additional precautionary measure shall be taken to suitably place the panels such as in air-conditioned rooms.

NOTE — For more details. IS/IEC 61439 series shall be referred.

4.13 Adequate precautions shall be taken to ensure that live parts are not exposed to cause danger within the working distance of a person working on the live wires. In case of bare conductor, these shall be inaccessible and shall be provided with protective switchgear at accessible position for rendering them dead. While designing layout of installation, safe working clearances shall be maintained as per the Table 1 and Table 2.

NOTE — For more details, IS/IEC 61439 series may be referred.

Table 1 Safety Working Clearances as per Schedule VII of CEA Regulations 2010

(*Clause* 4.13)

Highest System Voltage kV (a.c.)	Safety Working Clearance m
12	2.6
36	2.8
72.5	3.1
145	3.7
245	4.3
420	6.4
800	10.3

NOTE — For altitude above 1 000 m and up to 3 000 m, a correction factor of 1.25 percent shall be applied per 100 m increase of altitude.

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Table 2 Minimum Safety Working Clearances in Substation to be maintained as per Schedule VIII of CEA Regulations 2010

(*Clause* 4.13)

DC Voltage	Pole to Earth Distance	Ground Clearance
kV	m	m
100	1.17	4.55
200	1.80	5.65
300	2.45	6.75
400	3.04	8.00
500	3.65	9.00
600	3.98	10.10
800	5.30	11.20

NOTES

1 Above clearances are for bare conductor or live parts of any equipment installed within outdoor sub-station and are not for overhead line.

2 The ground clearances mentioned are not for equipment installed within fenced area/building where access is restricted.

3 The pole to Earth clearances are for conductor structured electrode configuration using gap factor, k = 1.35.

4.14 In case of high-rise buildings (building with height above 15 m from surrounding ground), an isolating device with fuses or a circuit breaker shall be provided at the supply point of building at a conspicuous position and at height of not more than 1.7 m above ground in order to completely isolate the supply within the building, in case of emergency.

NOTE — It is recommended that 'complete' isolation of supply within building shall not mean isolation of supply to emergency services where supply integrity impacts the evacuation operation, Fire Lift, Fire Fighting service, illumination of escape route/sign boards, public announcement system. Such services shall either be provided with alternate supply arrangement or circuits of these emergency services shall be bifurcated from the switch controlling supply to the building

The vertical ducts/corridors provided for power cables shall not be used for any other service and there shall be fire barrier at each floor crossing/wing of building.

4.15 All non-current carrying metal parts shall be connected with earthing system to maintain them at earth potential and to avoid development of dangerous contact potentials. For installations not exceeding 650 V, earthing system shall be so designed to have equipotential bonding which is capable of carrying prospective earth fault current without exceeding allowable temperature limits as per relevant Standards.

Size of Earth conductor and number of earth electrodes shall be selected such that earth fault loop impedance shall be sufficiently low to operate protective devices in due time.

NOTE — In TT system, earth electrodes such as pipes, rods, plates etc. capable to limit earth resistance to sufficiently low value are necessary for dissipation of high fault current to ground at the origin of installation.

It shall be mechanically strong, withstand corrosion and retain electrical continuity during the life of installation.

4.16 The supply of electricity to all electrical installations of 2 kW and above shall be controlled by a residual current device(RCD) with rated residual operating current not exceeding 30 milliamps for providing protection against electric shock. One common RCD at supply point with rated residual operating current of 300 milliamps shall be provided for all installations having load more than 10 kW for protection against fire due to leakage current. It shall disconnect the supply on the occurrence of earth fault or leakage of current. To maintain supply redundancy, RCDs may be provided atn incoming side of each phase in three phase distribution board. In case, it is not possible to achieve a low earth fault loop impedance, disconnection may be initiated by fitting an RCD of 30 mA rating as specified in IS 732.

NOTES

1 The use of RCD with rated residual current not exceeding 30 mA shall be treated as additional protection in the event of failure of basic protection.

2 As per the CEA regulations, RCDs are mandated for electrical installations above 2 kW and 10 kW. However, it is recommended that RCDs shall be provided to connected load as per 4.2.11.3.3, 4.2.15, 4.3.2.3.9 of IS 732.

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4.17 The layout of an electrical installation above 650 V shall be so designed such that access and operation of all live conductors and apparatus are by designated personnel. Table 3 prescribes safe working distances.

Table 3 Safe Working Distances as per Schedule III of CEA Regulations 2010

(*Clause* 4.17)

Voltage	Safe Working Distance
kV	M
11	0.61
33	0.71
66	0.91
110	1.02
132	1.07
220	1.52
400	2.13

4.18 Electricity Supplier's installation such as apparatus and equipment for metering for supply above 650V, shall be in separate building or in a locked weatherproof and fireproof enclosure for independent access at any time. If there is any difficulty in providing separate building, segregation shall be provided between supplier's and consumer's installation.

4.19 Layout of all installation shall be such as to maintain safety clearances for electrical apparatus as per the relevant Indian standard. This ensures that sufficient space is available for easy operation and maintenance without any hazard to the operating and maintenance personnel working near the equipment.

4.20 Electrical equipment requiring natural air circulation and depending on convection principles for cooling, shall be provided with adequate ventilation. Air flow shall not be prevented by any wall or adjacent equipment. Under dust and corrosive environment, refer guidelines at **4.12 d)**.

4.21 Suitable provision shall be made such that the circuit at lower voltage is guarded against danger of accidently charging above its normal voltage.

4.22 Sub-station or switching station with an apparatus containing more than 2 000 litres of oil shall not be located at basement where proper oil draining arrangement cannot be provided.

4.23 Provision of baffle wall of four hours fire rating shall be made between:

a) apparatus containing more than 2000 litres of oil; and
b) between single phase transformer banks/ICTs.

4.24 Provision of oil soak pit shall be made and in case of more than 9 000 litre of oil in any one tank, provision of draining oil shall be made to prevent spread of fire resulting from ignition of oil. Adequate arrangement for fire extinguishing shall be ensured.

4.25 To mitigate the risk of fire likely to be initiated in transformer filled with mineral oil ('O' class insulating liquid), use of 'K' class insulating liquid classified under IS 13503 having fire point above 300°C shall be done. Following alternates have added advantage of non-toxicity and environment friendly as under:

a) Synthetic organic esters as per IS 16081/IEC 61099, specifications conforming to Transformer esters Type – T1.
b) Natural esters as per IS 16659/IEC 62770.

NOTES

1 IS 16659 /IEC 62770 does not recommend the use of Natural Esters in equipments exposed to atmosphere owing to its susceptibility to oxidation leading to formation of sludge. Hence, its use shall be restricted to non-breathing (sealed) Transformers only. It shall not be used for breathing transformers (transformers having breather).

2 Synthetic Esters as per IS 16081 /IEC 61099 may be used both for sealed as well as breathing transformers.

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4.26 Within residential or commercial buildings, dry type transformer shall be used.

NOTE — The condition mentioned in **4.25** above is as per CEA Reg. 44 (2) (vii) (e). State Government has powers to deviate the provisions of CEA Regulations. If permitted by respective State Government, liquid filled transformer with insulating liquids as mentioned under **4.24** may be used in place of dry type transformer**.**

4.27 At the locations which are sensitive, where risk and potential of damages/losses due to fire are likely to be high, transformers with K class insulating liquid having required fire related parameters in respect of flash point, fire point, low heat value, etc; shall be used.

4.28 Transformers of capacity 10MVA or above, or containing oil above 2 000 l shall be provided with fire-fighting system as per IS 3034 or with Nitrogen Injection Fire protection system, as directed by Electrical Inspector.

This is applicable if K class insulating liquid is not used.

4.29 Under conditions where sub-station or switching station can not be installed on ground floor, such installations shall not be placed below the first basement. There shall not be seepage or leakage of water. If required, adequate automatic dewatering system shall be provided.

4.30 Entrance doors of the sub-stations and/or switching stations located at basement, shall have 2 h fire rating. Opening of the door shall be outside. A curb/sill of suitable height shall be provided to prevent flow of oil outside the room. Surrounding walls shall be lined with fire bricks.

4.31 Cables under such conditions shall be FRLS and sealing shall be done along the routes at all floor levels. Cable trenches inside substation or switching station be filled with sand, pebbles or covered with non-inflammable material slabs.

4.32 All buildings shall have lightning protection installed as per IS/IEC 62305-3 based on the risk assessment specified in IS/IEC 62305-2. All apparatus up to 1 000 V a.c. and 1500 V d.c. shall have Surge Protection Device's, conforming to IS 16463 series, installed based on the zonal concept of IS/IEC62305-4 or IS 732. Down conductors shall not be routed through enclosed shafts or ducts. Apparatus above 1000 V a.c. shall also be protected against switching surges as per IEC 60099 series.

4.33 Power distribution shall be designed in sections such that it isolates the required section/part of electrical installation under maintenance or repair.

4.34 Interlocking shall be provided under following conditions:

a) in case of isolators and controlling circuit breakers such that the isolators cannot be operate unless the corresponding breaker is in open position;
b) in case of earthing switch, it cannot close unless the corresponding isolator is in open position;
c) the circuit breakers of two or more power supplies cannot switch ON, where they are not intended to be operated in parallel;
d) all gates/doors providing access to live parts cannot open unless live parts are made de-energized through proper discharging and earthing is ensured; and
e) where two or more generators operate in parallel and neutral switching is adopted, generator breaker cannot be closed unless one of neutral is connected to the earthing system.

4.35 Adequate protections shall be provided to automatically disconnect supply under abnormal conditions as under:

a) over-current protection to disconnect the supply in coordination with the designed withstand capacity of equipment, cable etc. within time;
b) earth fault or earth leakage protection to disconnect the supply if fault current exceeds the limits;
c) alarm and tripping where oil/winding temperature limit exceeds;
d) differential protection against incipient faults;
e) protection against overvoltage; and
f) protection against leakages/shock.

NOTE — Selection of circuit protection for over-current, short-circuit current and other characteristics shall consider total impedance of respective circuit. There shall be coordination with the protective devices to clear fault without excessive damage to the electrical component of circuit, assuming fault between two or more conductors or between circuit conductor and ground conductor/metal enclosure.

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4.36 All industrial and commercial installations shall be provided with TN-S earthing system and an earth matt as per IS 3043 to:

a) limit touch and step potential to tolerable values;

b) limit earth potential rise to tolerable values so as to prevent danger due to transfer potential through earth, earth wires, cable sheath, fences, pipe lines, etc.;

c) maintain fault loop impedance value such that operation of protective device is effective; and

d) all non-current carrying metal parts associated with the electrical installation, cable armouring, are effectively connected to earthing system.

4.37 In case of star connected system with earth neutral or delta connected system with artificial neutral:

a) the neutral point of every generator and transformer shall be connected to earthing system as per IS 3043. In case of multi-source system, neutral switching may be resorted for limiting neutral current circulation; and

b) In case of installations above 33kV, system neutral earthing and protective frame earthing may be integrated to limit step and touch potential within permissible value.

4.38 Fire Protection arrangements shall be provided as per norms prescribed in NBC/relevant standards and CEA Regulations. In case, where inflammable material including gases and chemicals are produced, handled or stored, electrical installation, equipment and apparatus shall comply with flameproof and dust free equipment and totally enclosed fittings depending on hazardous zones as per relevant standards.

4.39 In case of overhead lines, all conductors shall have minimum breaking strength 350 kg. There shall not be more than one joint in a span and the joint shall have electrical conductivity as per relevant Standard.

4.40 Design considerations for load, permissible stresses and factor of safety for structures and conductors of overhead lines shall be as per relevant standards and CEA Reg 57, whichever is more stringent.

4.41 Ground clearances of lowest overhead line conductor shall not be less than that mentioned in Table 4 and Table 5.

Table 4 Minimum Ground Clearance of AC OH line as per CEA Reg. 58

(*Clause* 4.41)

OH line System Voltage	Clearance across the street	Clearance along the street	Clearance at other places
kV	m	m	m
Less than 0.65	5.8	5.5	4.6[a]
Above 0.65 and up to 11	6.1	5.8	4.6[a]
Above 11 and up to 33	6.1	5.8	5.2

[a] In case of insulated service line clearance may be 4.0 m.

NOTES — For lines exceeding 33kV add 0.3m for every 33kV or part thereof.

Table 5 Minimum Ground Clearance of DC OH line as per CEA Reg. 58

(*Clause* 4.41)

DC Voltage in kV	Ground Clearance of OH line
	m
100	6.1
200	7.3
300	8.5
400	9.4
500	10.6
600	11.8
800	13.9

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4.42 Clearances of overhead line conductor from permanent or temporary building/structure, shall not be less than that mentioned in Table 6 and Table 7.

Table 6 Minimum Clearance of AC OH line from building as per CEA Regulation 61(2)

(*Clause* 4.42)

Particulars of OH Line (AC)	Horizontal Clearance m	Vertical Clearance in m
Up to 650V	1.2	2.5
Above 650V and up to 11kV	1.2	3.7
Above 11kV and up to 33kV	2.0	3.7

NOTES

1 Horizontal clearance shall be measured when the line/conductor is at maximum deflection.

2 Line shall not be constructed/cross over any building. The vertical clearance mentioned shall be observed only in case of existing situation for a temporary period till the line is removed. The conductor under such conditions shall be adequately insulated and attached with bare earthed bearer conductor having breaking strength 350 kg and supported at suitable intervals.

3 Vertical clearance shall be considered with maximum sag of conductor.

4 For line with voltages above 33kV add 0.3 m for every 33kV or part thereof.

5 Where minimum clearances between building and the overhead line having voltage less than 650V are not maintainable, such spans shall be replaced with Aerial Bunch Cable with a prior approval and as per the recommendations of Electrical Inspector.

Table 7 Minimum Clearance of DC OH Line from Building as per CEA Regulation 61(4)

(*Clause* 4.42)

DC Line Voltage	Vertical Clearance m	Horizontal Clearance m
100 kV	4.6	2.9
200 kV	5.8	4.1
300 kV	7.0	5.3
400 kV	7.9	6.2
500 kV	9.1	7.4
600 kV	10.3	8.6
800 kV	12.4	10.7

NOTES

1 Horizontal clearance shall be measured when the line is at maximum deflection.

2 Line shall not be constructed/cross over any building. The vertical clearance mentioned in above table shall be observed only in case of existing situation for a temporary period till the line is removed. The conductor under such conditions shall be adequately insulated and attached with bare earthed bearer conductor having breaking strength 350 kg and supported at suitable intervals.

3 Vertical clearance shall be considered with maximum sag of conductor.

4.43 Maximum span of overhead lines shall not exceed the minimum limits specified in Table 7. For 66kV and above, cables/conductors and as under Reg.96 for lines below 66kV of CEA Regulations in regard of Technical Standards for Electric Plants and Lines.

4.44 At places. where conductors at different voltage potential are erected on same supports, adequate provision shall be made to maintain required clearances and guard the conductor at lower voltage potential being charged above its normal working voltage by adopting suitable methods of construction.

4.45 Before commencement of any construction activity of any building/structure or storage near/under/over existing electrical line (overhead or underground) or construction of any electrical line (overhead or underground)

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in vicinity of existing building/structure, whether temporary or permanent, CEA Reg. 63 shall be strictly adhered to.

4.46 While laying underground cables, required depths depending on the location, protocols of maintaining clearances between other underground utility services as well as demarking of the routes shall be adhered. Also, system shall be planned taking into consideration the future requirements.

4.47 Utility companies shall carry out work of laying/erecting lines under intimation and in coordination with the local bodies. The updated drawings, GPS mapping of underground lines with sections showing depth shall be maintained and made available to authority, local body and public on demand.

5 STATUTORY CONTROLS FOR IMPLEMENTATION OF SAFETY

Statutory provisions for ensuring safety are mandatory and thereby, recommends conformance to relevant BIS/IEC standards. In case of any inconsistency with CEA regulations, provisions of regulations shall prevail. This section states eligibility criteria for persons to work on/execute works of Electrical Installations and with prior permission from the authorities, to commence upon the supply of newly constructed Electrical Installation or re-commence the electrical supply after disconnection for 6 months or more.

5.1 The safety regulations made under the *Electricity Act,* prohibits person to undertake electrical work of installation, additions, alterations, repairs except such replacement of lamps, fans, fuses, switches, domestic appliances/fittings of voltage not exceeding 250V; unless the person holds license of an Electrical Contractor; within the meaning and mandate of CEA Regulations 2010.

5.2 No person can operate or carryout the duties incidental to generation, transmission, conversion, distribution, or use of electricity and work on electrical lines, apparatus unless he has been designated in that behalf.

5.3 No person shall be designated unless he is having certificate of competency or holding permit issued, recognised by the government, and his name is recorded in the register by the concerned.

5.4 Engineers, supervisors and technicians working on electric plants, operation and maintenance of transmission and distribution system shall possess qualifications and shall have undergone the training prescribed under CEA Regulations.

5.5 Under following cases before energising electrical installation where statutory permission is obligatory as per CEA Regulations 2010 (amended to date), with any deviation if so allowed by state government*, same shall be complied with:

a) Reg. 43 – inspection and permission from Electrical Inspector to energise installation above notified voltage, or from Chartered Electrical Safety Engineer for voltages up to notified voltage;
b) Reg. 32 – inspection and permission from Electrical Inspector to energise installation of generating unit above certain capacity as decided by state government;
c) Reg. 36 – inspection and permission from Electrical Inspector to commence Electrical supply for building above 15 m height having connected load and voltage above certain limit as decided by state government; and
d) Reg. 121(1) for EV charging infrastructure, if provided in the building and premises.

NOTE — In case of installations belonging to or under control of central government, the authority shall be treated as central government instead of state government.

5.6 Designation of qualified Electrical Safety Officer is mandatory for generation, transmission and distribution companies and also, for a registered factory with more than 250 kW electric load, for continuous monitoring of electrical safety, interpretation of rules, regulations and ensuring compliance.

6 ADMINISTRATIVE CONTROLS TO IMPLEMENT SAFETY AT WORK PLACES

Setting norms, documenting, monitoring, creating awareness, scheduling trainings, creating and maintaining records, maintaining inventory of safety and personal protection related equipment are parts of safety management which can be achieved by administrative controls. This section gives guidelines to implement safety through administrative controls.

6.1 At work places, the employer/owner of electrical installation shall document and implement electrical safety programme which shall include:

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a) carrying out initial inspection before installation is brought in use, to verify newly installed electrical equipment/system complies relevant standards;

b) scheduling protective/preventive and routine maintenance norms, its periodicity, following manufacturer's recommendations in this regard and laying down procedures for monitoring including routine inspection;

c) laying down procedure to be adopted while working on electrical installation for various tasks by assessing electrical hazards of shock/arc flash which may arise due to particular task; work environment and/or Human Error;

d) identifying PPE based on risk assessment and evaluation of potential of electrical hazard related to task;

e) creating awareness amongst the persons working on, by explaining them the exposure to the potential of electrical hazard and its aftermath effects related to task, before they undertake or which they may have to undertake;

f) creating self-discipline amongst persons working on to use PPE before undertaking any task depending on the potential of electrical hazard to which they may be exposed to;

g) making provision of the team with required number of qualified and experienced persons to handle the task;

h) keeping required safety tools as per requirements of work/task; maintaining such tools in good condition and replacing after expiry of their useful life and keeping their records;

j) keeping provision of PPEs related to the task and potential hazards; maintaining such PPE in good condition and replacing them in due time before expiry and keeping their records;

k) keeping provision of testing instruments complying to standards, making them available as and when necessary and keeping their record;

m) keeping provision of lock out/tag out devices, making them available as and when necessary and keeping their record;

n) assigning duty/fixing responsibility for monitoring compulsory use of PPE by the persons involved in work task;

p) scheduling periodical verification/inspection, not exceeding 3 years where there is no change (additions/ alteration/modification) in the existing installation and verifying that the procedures laid down while undertaking any related work, are updated and followed strictly with necessary documentation;

NOTES

1 Period of inspection shall be reduced depending on hazard, factors of external influences, *for example*., corrosive environment.

2 For periodical verifications refer Part1/Sec 17.

q) maintaining updated list of designated persons authorized to undertake tasks depending on their qualification, training and experience; duly signed by the authorizing authority and authorised persons as a token of mutual understanding; and

r) assigning the duties Electrical Safety Officer for checking the performance.

NOTES

1 It is important to designate eligible person with required skills and experience for the task assignment. It shall be informed that error, overlooking, connivance may endanger his or colleagues' life and his responsibilities.

2 It is mandatory to designate Electrical Safety officer for generation, transmission, distribution and electric supply companies and factories within the meaning of Factory Act, having electrical connected load more than 250 kW to monitor provisions of Electrical Safety Regulations.

s) In case of persons employed on contract basis, they shall be informed of all possible hazards and shall be asked to follow safety related policies under the supervision of qualified person;

t) maintaining updated records and keeping them ready as and when required by the authority, in respect of electrical design comprising drawings, calculation sheets, equipment manufacturer's manuals/ instructions, inspection and safety verification reports, routine and other test reports; and

u) keeping adequate financial provisions/budget to attend maintenance needs pointed out by technical team so that delay in attending does not lead to a possible disaster.

6.2 The employer/owner of electrical installation shall undertake training programmes for electrical safety and survival training based on IS/IEC standards comprising of class room, on field simulations, case studies models. For the persons working on and exposed to electrical hazards training shall include:

a) to handle the authorized work/task as per the list of designated persons;

b) permit to work system, sequence/procedures to be followed, lock out/tag out programme and its significance, knowledge about lockout/tag out devices and their installation, duties and responsibilities involved;

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c) reading and understanding single line diagram, knowledge about construction, safe operation of authorized equipment/system, care to be taken while switching on/off supply;

d) possible electrical hazards that might be present or arise with respect to particular equipment/system and ways to avoid them;

e) procedures and techniques to handle emergency while in operation/during work;

f) use of appropriate tools, insulating, shielding/PPE required in various tasks as per the policies and procedures laid down;

g) knowledge to check, select and use appropriate tools, PPE, testing equipment relevant and in sound condition to perform specific duty;

h) knowledge about limited and restricted approach boundary/distances and precautions to be taken accordingly:

j) awareness to unqualified persons regarding possible exposure to the electrical hazard;

k) response/survival procedure, in case of emergency, due to shock/contact release;

m) Initial few minutes are critical for the person suffering from electrical shock. Immediate treatment after contact release is life-saving. Hence, training of quick and appropriate First aid treatment comprising correct positioning of victim, preliminary checks of consciousness, pulse, breathing, and further, decision to provide cardio pulmonary resuscitation (CPR), use of automated external defibrillator (AED), shall be provided;

NOTE — Since persons responsible for initial responding to medical emergency are not likely to be medical professionals, the training shall be conducted by a qualified person with medical background only. Incorrect positioning, decision/method to give CPR/AED may turn out to be dangerous. Particularly for such emergency, frequency of such training shall, therefore, be more and as suggested by certifying body.

n) scheduling refresher courses at intervals not exceeding 3 years where time period is not mentioned specifically; such courses shall include information about relevant updated IS/IEC standards and new/ modern technologies;

p) re-training of safety related practices shall be taken up as and when required, such as in case of revision of applicable standard; non-compliance with safety policy/practices which are rare in usage; and

q) training programme shall be documented mentioning all course details, attendees, and dates.

6.3 The employer/owner of electrical installation shall ensure that the safety audits as per IS 732 are carried out at regular intervals and electrical engineers are aware of the safety requirements as per the latest IS/IEC standards.

7 INSTALLATION

The guidelines under this section specifies the safety and precautionary measures to be taken during new installation work or installation undergoing major modification/augmentation to be used after work completion. The supervision/strict vigil during the specified work along with special attentions to hidden work is important.

7.1 Electrical work shall be undertaken with the statutory safety requirements and the guidelines, recommendations given under this section. Work and workmanship shall follow relevant standards, codes and approved method of constructions.

7.2 Work shall be executed as per the approved drawing and design. Any deviation which may arise due to actual worksite conditions shall be approved from concerned authority. Record of such occurrences be maintained for future reference.

7.3 Proper planning of electrical work shall be carried out in coordination with works of other utilities, to ensure that no safety issues occur due to lack of coordination within different agencies working on the project.

7.4 With respect to new and major works/projects, a bar chart showing integration of all detailed activities of different works shall be prepared and followed for safer working environment and coordinated activities.

7.5 To maintain physical clearances from the other services, norms shall be strictly followed. Approach boundaries and arc flash boundaries shall be marked in front of panel boards/equipment/apparatus.

7.6 In case of existing overhead or underground line on work site, necessary compliance as per CEA Reg. 63, shall be checked to maintain required mandatory clearances and prior approvals shall be taken before commencement of work.

7.7 In case of difference between actual site conditions and drawing or discrepancy in drawing, such cases shall be immediately brought to the notice and resolved by concerned design providers.

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7.8 Work must be executed strictly under supervision of the competent licensed person with the responsibility to ensure compliance with all standards, norms and statutory provisions. He shall ensure that workmen use appropriate tools, tackles and safety devices while working. He shall supervise proper integration and coordination with other work activities to avoid unsafe condition for the persons working on site.

7.9 Site layouts of electrical distribution and circuit diagrams shall be displayed at main and other major electrical panel board. All control switchgears shall be properly marked. Stand-by arrangement which is not connected to the supply whether apparatus or cable shall be identifiable with proper marking. Instructions to be followed during emergency shall be marked in conspicuous location.

7.10 All electrical panel boards, switchgears shall be provided with 'DANGER' sign as per IS 2551 shown in sample figure below:

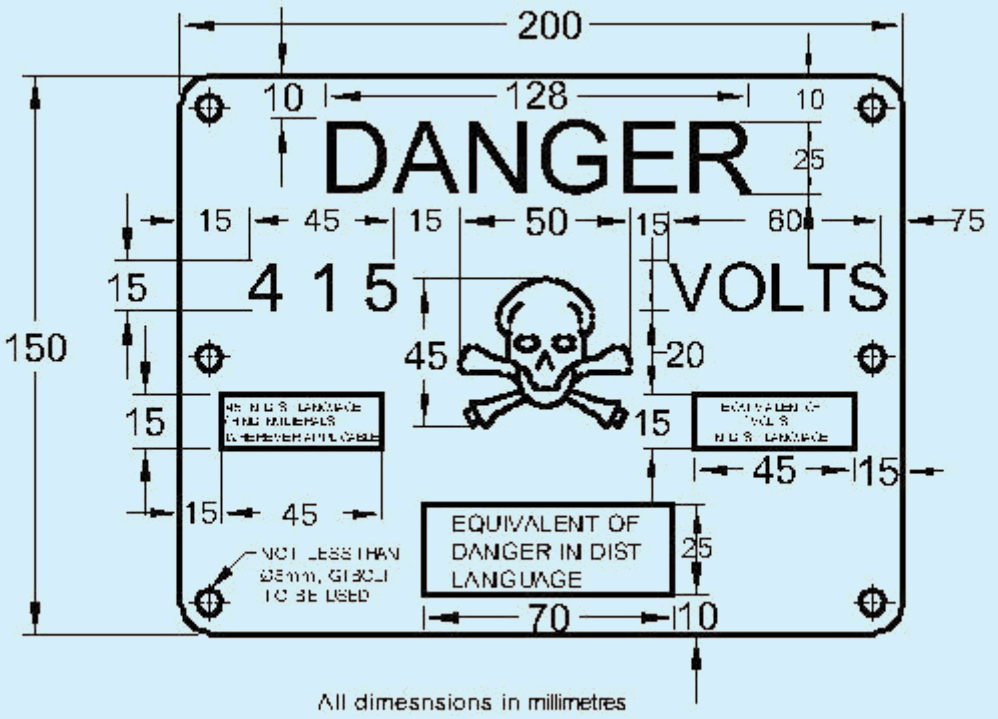


FIG. 1 DANGER SIGN BOARD

NOTE — Such signs may create psychological effect and automatically alarms people about the impending danger.

7.11 For availing and using electrical supply for construction purpose, safety instructions mentioned in **13** shall be followed.

7.12 Before energising any installation for testing and commissioning, adequate precautions shall be taken as mentioned in **11**and CEA Reg. 45.

8 WORKING ON ELECTRICAL INSTALLATIONS

This section provides guidelines for the works such as nature of routine, predictive, preventive and break down maintenance, and modification of the existing electrical installations in use. Following points give general guidelines for establishing safe working conditions.

8.1 Before commencement of work, adequate precaution shall be taken to ensure that lines and apparatus to be worked upon are isolated from all sources of supply, discharged, dead, earthed and short-circuited. Measures shall be taken against the accidental/inadvertent energizing of the mains and apparatus and also, of the line/conductor/ apparatus in close vicinity of working area.

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8.2 Competent and experienced personnel authorized to perform the particular task as per statutory requirements complying the provisions mentioned in **4**, shall work or assist the work on live mains and apparatus.

8.3 Depending on task and required skill of operation, maintenance persons working on the tash shall be trained as per **6.2**. He shall be able to read and understand single line diagram, identify main and alternative sources of electrical supply, interlocks, back-feeds, standby arrangement etc.

8.4 In case of work in electric plant, transmission or distribution system, the authorized person working on the task shall be trained as per schedule I/II of CEA Regulations.

8.5 Under unavoidable conditions, when it is required to work on live electrical installation, personnel shall be provided with appropriate tools in good condition, protective and safety devices such as gloves, rubber shoes, suitable to withstand respective voltage level; safety belts, ladders, platforms etc., to secure position while working as well as based on assessed risk, PPE complying with the requirements in **14** and schedule III of CEA regulations 2010.

8.6 Personnel shall not undertake work/task without appropriate tools, tackles and PPE. Also, they shall not perform work for which they are not designated/authorized.

8.7 Person supervising the work shall confirm that the workmen are using appropriate tools and PPE as per **8.5**.

8.8 Warning boards/tags shall be attached on or placed adjacent to the live apparatus and at the limits of the zone where work is to be carried out.

8.9 While the work is ongoing, approach boundaries shall be strictly monitored for person working on the task and people in vicinity.

8.10 In event of connection of dead circuits to live mains, connection to the live mains shall be secured in the end and for all circuits, phase sequence shall be checked to ensure that correct phases are connected before switching on the supply.

8.11 Designated persons shall be competent to apply the safety instructions as per IS 5216(Part 2), the chart for resuscitation of person suffering from electric shock and shall be available to attend emergency during the task.

8.12 Care shall be taken while carrying/moving ladders or any material or tools from one place to another such that the flashover distance/vertical clearance from overhead line is well maintained and no material is stored/stacked below overhead line.

8.13 Before making trenches for cables, adequate care shall be taken to check existing cable route markers. In absence of cable route markers, information shall be gathered from the concerned utility/local body about existence of any underground cables to avoid damaged and flashover due to hitting of digging tool which may lead to an accident. Digging of soil within ten meters of 132kV and above tower shall not be done without written permission from the owner of tower.

ADDITIONAL INSTRUCTIONS FOR WORKING ON INSTALLATIONS OF VOLTAGES 650V AND ABOVE

8.14 All mains and apparatus shall be regarded as live and handled accordingly.

8.15 No person other than authorized shall work within the minimum safe working distance from the exposed live mains and apparatus. The minimum working distance shall be as per Table 3 and **4.17**.. Exposed live equipment in the vicinity shall be cordoned off to avoid hindrance to movement of the maintenance personnel.

8.16 Authorized persons shall be thoroughly conversant with the complete power distribution system/network. Such person shall know location of disconnecting devices, sources of electrical energy, sources of stored energy and possible hazards associated with the task.

8.17 Before commencement of major work, complete plan shall be prepared in advance for the working personnel. They shall be briefed about task, possible hazards, arrangements to handle emergency, safety plan, responsibilities, sequence of operation, time schedule etc. Permit to Work (*see* **8**) shall be taken, locking-out/tagging-out (*see* **9**) protocol shall be followed.

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8.18 No authorized person shall work on electrical installation unless it is rendered dead unless permit to work is issued and instructions are received from supervisor confirming that the mains is rendered dead.

8.19 The electrical circuits shall be de-energized by designated persons, by disconnecting switches, isolating links, unbolting connections or racking out breakers. Where possible, the isolation should be visibly checked. The re-closure of isolating devices by unauthorised persons shall be prevented by adequate means by following lock-out/tag-out system.

8.20 The operations of rendering the circuit dead shall be carried out by short circuiting and earthing all phases at both ends/sides of the point of working location. This arrangement shall be of adequate capacity to carry any short circuit current for time to operate protective device. This work shall be done under the instructions and supervision of the person-in-charge of maintenance/team leader.

8.21 Authorized persons working on and/or in vicinity of live lines shall be aware of and observe restricted approach boundary/limited approach boundary (*see* **14**) and take adequate care.

9 PERMIT TO WORK

To establish safe working condition, following guidelines shall be followed to authorize permit to work to trained personnel :

9.1 Work on and/or in close proximity to electrically charged major installations shall be authorized to trained personnel only under ‘permit-to-work’ system.

9.2 The person in-charge shall issue permit-to-work certificate to authorize the trained personnel or supervisor/leader of team to perform the task by rendering the part of installation dead for safe working.

9.3 In case, multiple teams are carrying out different tasks on the same line or apparatus, a permit-to-work shall be issued by the person-charge to the supervisors/leaders of all teams.

9.4 In emergency situations where it is necessary to start the work without delay, actions taken shall be reported to person In-charge. During such instances, it shall be ensured that one person is always present at switching locations and there is adequate mechanical locking arrangement till the work completion.

9.5 The circuit opening devices shall be locked in open position (*see* locking out/tagging out under **9**) before working on the mains and commencing of apparatus.

9.6 On successful completion of work, locking devices shall be removed by a competent person. Earthing and short-circuiting shall be removed till the work in under progress. The authorized personnel or supervisor/leader of the team/maintenance staff shall return the permit to the issuing authority who shall, then, cancel it.

9.7 In all cases, the issue and return of permits shall be recorded. The permits shall be issued for work adjacent to live electrical mains or apparatus, if so required.

9.8 A model form of permit-to-work certificate is given in IS 5216 (Part1).

NOTES

1 The permit is prepared in duplicate by the person-in- charge of operation on the basis of message duly logged from the person-in-charge of the work.

2 The original permit will be issued to the person-in-charge of work and the duplicate shall be retained in the permit book. For further work allocation, tokens may be issued to the workers authorizing them individually to carry out the prescribed work.

3 On completion of the work, original shall be returned to the issuing officer duly discharged for cancellation.

9.9 Permit books are important records and all sheets in the permit books shall be serially numbered. No page should be detached or used for any other except *bonafide* work. If any sheet is detached, a dated and initiated statement shall, then and there, be recorded in the book by the person responsible.

9.10 Permit books shall be kept only by the person-in-charge of operation maintaining record of the receipts and issues made by him.

10 LOCKOUT/TAGOUT SYSTEM

For the safety of persons working on electrical installation for maintenance, repairs and allied work where de-energising of electrical supply for that particular section is a must, this procedure shall be in coordination with and shall be a part of ‘permit to work’. Under this, it is ensured that the part/section/conductor/circuit of the

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electrical installation either single or in multiple, where the work(s) is to be carried out are disconnected from electrical source, and are locked, tagged, relieved of stored energy from springs/capacitors mechanism secured to prevent from re-energising and tested before the work begins.

10.1 It is necessary to prepare proper system and sequence of operation for implementation of lock out/tag out system through the following:

a) availability of current single line diagram in detail, showing flow of electrical energy from its original source, alternative source/back feeds, interlocks, couplers etc;
b) tags, signs, labels, identifying points and locations in line with the single line diagram;
c) estimating time required for the task. If work/task is to be continued for more than one shift, making appropriate arrangements for handing over responsibilities to the personnel/team taking over task in the next shift by providing them status of current work, balance work etc. Role of person in-charge is important as he plans and ensures execution of the work.
d) arrangement for power-interrupted shall be through physical means/break and not through de-energizing by circuit interlocking from all available sources of electrical energy;
e) test facility to verify disconnection of supply with proper instruments ;
f) knowledge about possibility of induced energy;
g) notifying all concerned about the sequence/order of work before implementation;
h) de-energizing by designated person;
j) as far as possible, visual confirmation of opening of contact blades;
m) locking out, further, operation on control-gears and confirming, tagging with work under progress, names and contact details of the persons involved in the task; and
n) installation of grounding device on phase conductors rated for required fault duty.

10.2 Restoration of electric supply after completion of work:

a) person in charge shall verify the execution of work for its completeness and desired quality;
b) removal of all tools and tackles used for the work along with spares and other material;
c) notify all concerned for clearing the area beyond approach boundary to re-enrgize the electrical installation;
d) removal of shorting links and grounding devices deployed for the task;
e) performing necessary tests to confirm the satisfactory completion of work ;
f) removal of lockout/tagout devices;
g) notifying all concerned supply regarding restoration of electric supply; and
h) After restoration of electric supply, observing the operations for its functioning for some time before vacating the place.

11 TESTING, COMMISSIONING/CHARGING/ENERGISING AND HANDING OVER ELECTRICAL INSTALLATION

Pre-commissioning check points and safety precautions are given under Part1/Sec 17. It is important to follow the guidelines before putting the installation in regular use.

11.1 Before commissioning or charging any electrical installation, it shall be ensured that all pre-commissioning tests are conducted as per Part1/Section 17 on site and the obtained results are documented.

11.2 Certificates of satisfactory routine tests from manufacturer and under certain cases type and acceptance test from accredited laboratory, wherever necessary, shall be available. Documentation of such test report/certificates, duly signed by competent person, shall be preserved as records.

11.3 In case of charging the installation on completion of work and after returning the permit, removal of the earthing and short-circuiting devices shall be carried out in the reverse order to that adopted while de-energizing. The conductor shall not be touched after the earthing device is removed.

11.4 Settings of all relays, protection devices shall be done properly with respect to designed load, fault current, correlated short circuit withstand capacity, tripping time with desired coordination. Simulations shall be performed for testing and certificate from the appropriate person, agency; mentioning all details and schedule of settings, and the documents shall be preserved as record.

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11.5 In case of cables above 650V, 'high pot' testing shall be carried out before charging. After testing, care shall be taken to discharge cable properly owing to the dielectric absorption, particularly prominent in DC voltage testing.

11.6 Inspection shall be carried out, and there shall no objectionable points/remarks in the Inspection Reports (refer schedule IV, Forms I/II/III from CEA Safety Regulations 2010). Any statutory permission/approval if required under CEA safety regulations 2010 (*see* **5.5**) shall be complied with before testing/energising the installation.

11.7 Electricity supplier shall observe obligations as per CEA Reg. 16 (Earth terminal at consumer's premises), Reg. 31 (testing of consumer's installation) and Reg. 33 (Precautions against leakage before connection) before release of supply.

11.8 No person shall apply test voltage to any mains unless he is authorized, has fulfilled conditions of permit-to-work and has notified all persons working on the mains of the proposed application of test voltage. If any part which becomes alive, the person-in-charge of the test shall take due precautions to ensure that the exposed live portion does not constitute danger to any person and limited approach boundary is protected. It should also be ensured before the application of test voltage, that no other permit-to-work has been issued for working on these mains/lines.

11.9 Post commissioning check sheets and as-built/record drawings of completed work shall be prepared showing all details like layout, distribution diagrams, capacities of switchgears, their protections, cables etc. This shall form part of documentation to be preserved and handed over to the care taker. This record shall be readily available for persons maintaining electrical installation and for presenting to concerned authorities, whenever, called for.

12 MAINTENANCE OF ELECTRICAL INSTALLATION

For assuring continuous safety, observing and complying with the schedules of maintenance is plays an important role. Owner of electrical installation shall be responsible to maintain the installation safe. Routine, preventive and predictive maintenance ensures keeping installation safe, avoid break-down maintenance; mitigate hazards like electric shock, electric arc flash and electrical fires which may result into loss of human life and loss of livestock in thousands, apart from loss and damages to property. This section covers guidelines on the aspect of safety related to electrical maintenance:

12.1 All maintenance activities in a low voltage installation shall be followed by the necessary tests as recommended in 6 of IS 732: 2019.

12.2 Maintenance can be broadly categorized into three types:

a) routine maintenance; which is of general nature, period and frequency of which shall be decided based on actual use, work conditions, site environment;

b) preventive maintenance; which shall cover protections, useful and safe working life of apparatus, equipment, component of system and recommended replacement in due time after expiry of that period; and

c) predictive maintenance; which is to be attended as and when abnormality indicative of future breakdown hazardous condition is noticed in visual inspection or in the routine tests.

12.3 Maintenance schedules of routine and preventive shall be prepared depending on installation. To assess conditions of installation, observations in periodical inspections comprising visual check and routine tests shall be recorded in standard forms/checklists. The defects noticed shall be attended on priority wise depending on the hazard.

12.4 Maintenance schedule in respect of electrical equipment/apparatus shall be followed as per the recommendations of manufacturer and relevant code of practice.

NOTE — Delays and connivance in attending defects due to lack of financial provision or otherwise, often leads to possible disaster. Under these circumstances, if it is seen that operation/function of such component of system/apparatus is risky, adequate alternative shall be chosen and use of same shall be curbed by keeping it isolated.

12.5 As per provision under Reg. 30 of CEA Safety Regulations, installation shall be certified/inspected by chartered electrical safety engineer or an electrical inspector as per the mandate of state government, depending on notified voltage level.

NOTES

1 Under CEA Safety Regulations for Inspection Reports, Forms I/II/III have been specified under schedule IV of the regulations, depending on voltage level.

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2 Installations in domestic dwellings and small commercial establishments, shall be inspected, at least, once in five years. It is recommended that inspections in industrial and large commercial establishments, public entertainment places shall be done annually.

12.6 Installations where designation of electrical safety officer is necessary as per 4.6, it shall be his responsibility to interpret and comply statutory safety provisions, monitor the maintenance activities including periodical inspections of installation, arrange for inspection/testing at least once in year and to, further, check compliance against defects noticed/identified.

12.7 In case of supplier's installation within the premises of consumer, supplier of electricity shall maintain the installation in safe condition up to the point of commencement of supply.

NOTE — As per the definition given under Reg. 16 of CEA Safety Regulations 'point of commencement of supply' shall mean the point at the incoming terminal of switchgear installed by consumer (immediate after energy meter).

12.8 Maintaining resistance value of the earthing system/equipotential bonding, considering loop impedance within permissible limits shall be a priority. To check and assess disconnection of supply with in the stipulated time, earth fault loop impedance test shall be taken at least once in a year. If vertical earth electrodes (such as rods/pipes/plates) are provided, resistance of these electrodes shall be tested. Continuity of earth conductor shall be checked and maintained intact. Connections at earth terminal shall be cleaned and tightened. Under the corrosive atmosphere, these points are of more importance.

12.9 Illumination level required for operation and maintenance of apparatus, equipment, system shall be maintained as per standards. Any depreciation in lux level, if noticed, shall be reinstated.

12.10 During visual inspection, surface wiring and cable work shall be checked to ensure that it is rigid and intact. There shall not be any loose wiring or open joints. Insulation shall be checked for damages, and reasons causing such damages, *for example,* due to contact with sharp edges, heat, rodents etc shall be adequately addressed. Necessary preventive action shall be taken.

12.11 All electrical panels shall be checked for ingress protection. Door gaskets shall be replaced wherever necessary. Smooth mechanical operation of panels like door opening/closing, racking in and out, locking system shall be ensured. Identification marking of all switchgears and circuits shall be adequate. Insulating mats, marking of approach boundaries (*see* Fig. 2) shall be intact in place.

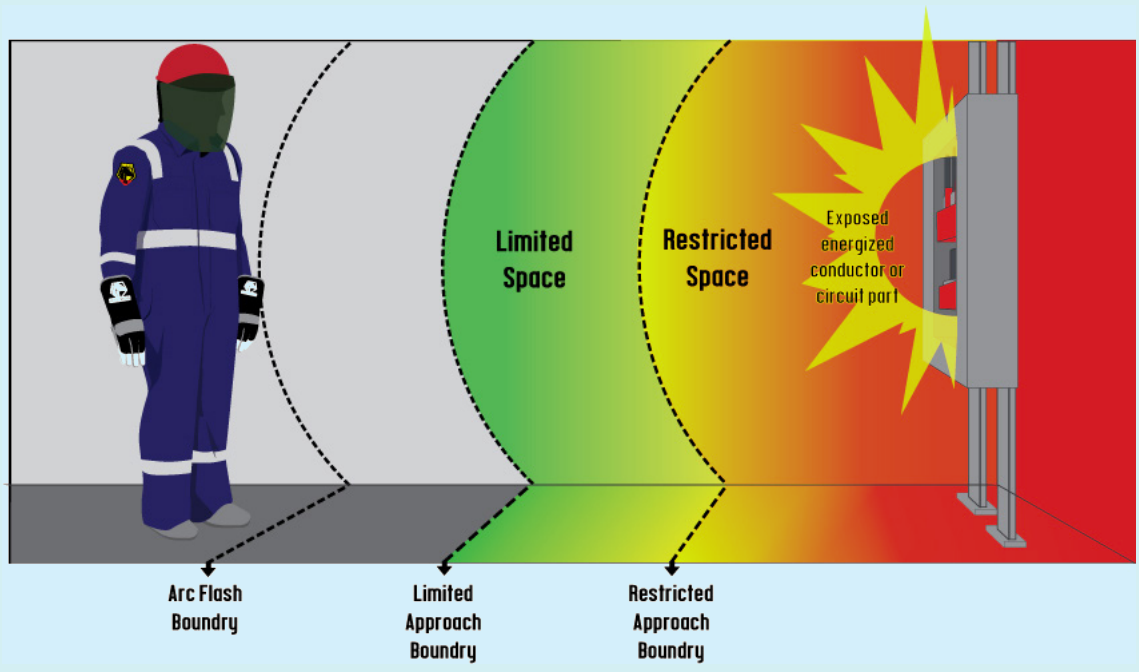


FIG. 2 APPROACH BOUNDARIES

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12.12 It shall be ensured that covers of switchgears, DBs, fuse cut out boxes etc are in place and door of electrical panels are closed/locked to avoid exposure to live parts.

12.**13** Points of terminations, joints, loose contacts, corrosion and heating are common cause of electrical trouble. Such points shall be cleaned and tightened. Wherever necessary, use of bimetallic lugs shall be made. Continuity of conductors testing as specified in 6.2.3.2 of IS 732 shall be conducted in all final circuits. In case of major installations, hot spots in electrical panels/system shall be checked by thermal camera, and needful action be taken, if required.

12.14 All protective devices shall be calibrated tested and its proper coordination shall be verified, at least, once in two years or as and when found necessary. Changes, if required, in settings shall be made. Such records shall be preserved.

12.15 Tests related to harmonics shall be conducted, especially, where non-linear loads exist. Corrective action to mitigate effects and bring the values within permissible limit as per IEEE 519 shall be taken immediately.

12.16 Electric panel/switchgear room, meter room, ducts for electrical cables shall be for specific use only and always be maintained clean, no encroachment shall be allowed within, and easy access to same shall be maintained without any obstacles on its way.

12.17 Raceways installed below ground/false flooring shall be maintained clean and free from entry of rodents, water or other things which may cause damages to the cables.

12.18 Locations where access is restricted, it shall be checked that appropriate system to prevent entry of un authorised persons is in place and is in proper condition.

12.19 Wherever sub-stations, panel rooms are located in basement, seepages/leakages and working of de-watering system and its automation shall be checked periodically and particularly, in rainy season. Necessary action shall be taken, if not found in order.

12.20 Necessary precaution for oil filled transformers shall be taken in respect of its insulating properties, moisture content, oxidation and sludge, acidity, DDF, DGA, leakages if any and oil level shall be maintained.

12.21 Overhead lines shall be maintained and checked periodically for permissible sag, allowable joints, guarding arrangement, interference of trees, creepers, construction of unauthorised structures/storage below endangering clearances, encroachment on way, interference of other overhead services of LV systems, such as that of cables of TVs, internet, telephones using overhead line structures/crossing electric lines with unsafe clearances etc.

12.22 Condition of poles shall be checked, especially, metal tubular poles which are susceptible to corrosion which are prone to corrosion at the bottom, often due to missing pole caps leading to accumulation of water within.

12.23 Earthing of poles/OH line structures and other accessories shall be checked and tested. Counterpoise earthing shall be at required depth and unexposed.

12.24 Necessary repainting with anti-corrosive paint shall be done to protect overhead line poles/structures, as per necessity.

12.25 Required fencing/entry barriers for distribution transformer centres, switching stations, sub stations existing, especially, in public places shall be well maintained.

12.26 Operation of required and mandatory fire protection devices and systems shall be checked. Class of fire extinguishers shall be verified and refilled in due time. Fire drill shall be conducted as per schedule and record shall be preserved. Periodical training sessions of operating staff shall be conducted to handle the situation in case of fire emergency.

12.27 In case of maintenance of underground cable work after locating the fault and attending it by jointing, record shall be maintained along with geographical location and date of attending the fault.

12.28 Due to civil work, any change in the required minimum depth of cable shall be corrected/adequate preventive measures be taken.

12.29 Checking of strain relief arrangement of cables for not causing any load on terminals shall be ensured.

12.30 Special care for street feeder boxes shall be taken to keep the doors closed and locked. Earthing shall be intact with proper termination.

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12.31 It shall be checked that all tools, tackles and PPE are kept in place, well maintained and in safe usable condition and sufficient in number. Visual checks and tests shall be carried out for confirmation. Storage place and arrangement shall be appropriated so as not to cause damage.

12.32 Batteries shall be maintained and shall be checked for swelling as per the schedule. Under normal conditions, batteries shall be replaced before expiry of recommended useful life. Battery rooms shall be kept clean and well ventilated.

13 TEMPORARY ELECTRICAL INSTALLATIONS

Temporary electrical installations are vulnerable to electrical accidents and fire. Following additional care for temporary electrical installation shall be ensured:

13.1 Temporary installation at construction sites:

a) Wiring of temporary electrical installation shall be erected in such a way to protect it from possible mechanical damage due to construction activity.

b) Panel Boards and apparatus shall be installed in such a way to protect them from water used at constructions sites.

c) Electrical panels installed in open spaces shall be protected from rain, dust and other adverse climatic conditions. Double insulated panels with higher degree of ingress protection (e.g. IP65/66) are preferred.

d) At power outlet point, earth leakage protection shall be provided.

e) Cables of apparatus and portable electrical tools shall be double insulated and shall be provided with earth core. Extension of wires/cables shall be with proper electrical accessories

13.2 Temporary electrical installation at sheds used the purpose of exhibition, function, ceremonies etc.:

a) At such places, DG Set is source of supply in general. The installation of generator for temporary purposes, adequate care shall be taken to ensure that earthing connections for neutral and body are firmly secured. Balanced load shall be applied and neutral current shall be kept to minimum. In case of multiple supply sources, care shall be taken to prevent back feeding. Capacitor banks may be judiciously used to limit excess current due to inductive load due to tube lights with conventional ballasts etc.

b) To prevent fire hazard, light sources shall be installed/erected at distance from cloth shed/curtains.

c) For such installations, mains shall be located at higher level. There shall be proper separation between phases and neutral. The wires shall not be bunched it shall not touch directly to any metal part/structure/ cloth laden wooden supports; without adequate insulation base.

d) Utmost care shall be taken to ensure that tappings taken from mains wire to provide electric supply for light, fan or any power outlets are covered with proper insulation.

e) In open spaces, wind may cause swinging of wires and may cause loose wires to come in contact with sharp edged metal parts leading to insulation damage. This can endanger the human life and special care shall be taken to address the issue.

NOTE — For further details, refer Part 5/Sec 2 of this code.

14 ELECTRICAL HAZARDS INVOLVING USE/OPERATION AND WORKING ON ELECTRICAL INSTALLATION

There have been incidences of electrical accidents victimizing domestic users, working personnel and persons in nearby areas. Based on risk assessment, three types of hazards emphasizing the need of safe conditions for usage/ operation/work and adoption of safety precautions to be adopted are:

a) Electrical shock (**14.1** to **14.4**);

b) Electric arc flash (**14.5 to 14.13**); and

c) Electric fire (**14.14 to 14.26**).

14.1 Electric Shock Hazard

Electric shock is physiological effect resulting from electric current through human or animal body. If current exceeding 30 mA passes near the heart of human body and is not interrupted within very short time, it could turn out to be dangerous. The burns caused by path of current passing through body may be less superficial but can be deep and penetrating and can be very complex and serious in nature. To avoid such instances, it is, therefore, important that hazardous live electrical parts shall not be accessible and under fault condition, accessible conductive parts not forming part of any electric circuit, shall not turn out to be hazardous.

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14.2 Shock risk hazard assessment shall comprise following points:

a) system voltage level;
b) possibility of shock and its potential;
c) condition of installation;
d) protections provided;
e) persons handling the task;
f) persons not related with the task but are present in vicinity (approach boundaries*); and
g) requirement of PPE.

NOTE* — Approach Boundaries may be referred from NFPA 70E 2018, Table 130.4(D)(a) and (b).

14.3 Protections required can be categorised in two parts as under:

a) Basic protection; and
b) Protection under fault condition.

14.3.1 Basic protection shall comprise adopting measures for prevention of direct contact with a conductor which is normally live and shall include:

a) basic insulation, (of hazardous live parts);
b) barriers (an arrangement which prevents access from any usual direction against direct contact with live part);
c) enclosures, (an arrangement surrounding hazardous internal live parts of an equipment to prevent access);
d) marking of approach boundaries; and
e) use of PPE.

NOTE — The recommended design aspects with respect to clearances maintenances and safe working distances are mentioned under **4.12, 4.13, 4.17** and **4.19**. These precautions are applicable in general and shall, especially, be observed for workplaces and public places.

14.3.2 Protection under fault condition arising due to indirect contact, failure of basic insulation and/or accidental contact with live electric part which shall comprise:

a) automatic disconnection of power supply to the circuit/equipment in which fault has occurred within restricted time, and limiting of prospective touch potential between exposed conductive parts of installation and other extraneous conductive parts. This safety measure is called as protective equipotential bonding and automatic disconnection of supply. Protective device shall be selected taking in to account the characteristics of fault current and fault loop impedance of that particular circuit/equipment/section.
b) In case, leakage current exceeds the threshold safe limit, automatic disconnection of supply by means of RCD as per IS 12640 (Part 1). Selection of RCD shall be made judiciously depending on applicability, characteristics of residual current which correlates with type of load – linear or non-linear (refer **4.16**. In case of TNC-S system, RCD will work as an additional protection against electrical shock).
c) precise designing, installation and maintenance of protective earthing *viz.* resistance of protective conductors and joint resistances, earth fault loop continuity to ensure operation of circuit protective device to disconnect the supply in the event of a fault and limit the rise in potential of any exposed conductive parts during the fault more than 50 V a.c. is necessary.
d) provisions to eliminate hazards arising out of transfer of potential, earth potential rise during the fault in sub-stations/lightning strike by strict observation of restricted entry zones, carpeting the probable affecting area with layer of stone metal to reduce step/touch potential and continuous maintenance of earthing system comprising of earth mat to keep earth grid impedance sufficiently below the designed value.
e) Protective equipotential bonding required to minimise any potential difference between exposed conductive parts and extraneous conductive parts during a fault;

NOTES

1 Extraneous conductive part shall be judiciously identified, else could turn out to be hazardous. Generally, it is accessible and in contact with general mass of earth, for example, metal pipelines in building, its resistance between conductive part and MET is low enough to limit dangerous touch voltage to human beings.

2 Also, check provisions under Reg. 41(vii) (x) of CEA safety Regulations.

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14.4 For domestic dwellings, care shall be taken while positioning of power outlets by keeping them out of reach of children, using shuttered sockets, and properly locating the distribution boxes with doors/covers, appliances/ gadgets/equipment with class II insulation, conforming to related Indian Standards, provided with heavily insulated cords, plug tops with earth pin, efficient earthing system etc. It shall be important to mitigate chances of occurrences of hazards by observing these points considering limited knowledge level of the domestic users.

14.5 Arc Flash Hazard

Arc flash is rapid release of energy in the form of hot plasma, metal vapours of arcing electrodes, ionised gases forming conductive path between phases, neutral or earth through a dielectric medium/air, creating severe thermal effect, intense light, UV emissions, volumetric expansion/blast with creation of toxic gases, shrapnel/splinters and high sound waves, causing most serious effects on persons around and collateral damages to the assets. It could be difficult to predict direction of arc flash due to magnetic field created by short circuit current and hence, resulting movements of arc plasma. Arc may track path through body from surface of body to earth in case of HV systems.

14.6 Quantifying the hazard of arc flash events in the form of radiation, convection, metal splash, and plasma jets during handling energized electrical equipment and steps to mitigate at different levels are, therefore, important.

14.7 Arc flash risk assessment shall be carried out from the point of view of possibility of occurrence, potential severity of injury, damage to health and collateral damages to system/assets.

14.8 Important factors to assess likelihood of hazard are work task, state of installation, condition of maintenance, visible deterioration, loose contacts, overheating, history of arcing, and any incident reported in that connection; protections provided, for example, against over current and operating time, other devices to mitigate arc energy.

NOTE — Possibility of occurrence also relates to the work task to be performed. Reference may be taken from Table 130.5 (C) of NFPA 70E 2018 ‘Possibilities of occurrence of Arc Flash Incident’ depending on various work tasks

14.9 Severity of arc flash hazard depends on incident energy which is proportional to the magnitude of fault current, arc clearing time, and distance from the arc electrode, which further results in irreversible damages to skin/body due to burns of various degrees, damages ears/hearing eyes/optical system and mental trauma.

NOTE — Methodology for calculating incident energy can be referred from latest version of IEEE 1584 on Guide for Performing Arc Flash Hazard Calculations. This will help determine incident energy potential and arc flash boundary.

14.10 The arc flash hazard shall be handled at three levels as under:

a) eliminate chances of occurrence (*see* **14.11**);
b) mitigate hazard/incident energy (*see* **14.12**); and
c) use of PPE (*see* **14.13**).

14.11 Following factors shall be taken care of towards eliminating chances of arc flash hazard:

a) de-energise the section of installation before taking up work in hand with care as mentioned in **8** and **9**;
b) strict observance and monitoring of maintenance schedules, all protective equipment shall be kept in safe and reliable working condition;
c) adequate measures shall be taken to restrict entry of rodents, reptiles by continuous checking of condition of ingress protection during maintenance and needful actionshall be taken to keep the equipment vermin proof;
d) Tools shall be adequately attended while working and after work completion in the work area. Removal of tools after work completion shall be ensured as tools inside the enclosure/near exposed conductive parts can causes flashovers;
e) usage of precise protections with fast tripping time;

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f) marking/labelling he equipment and observing precautions for restricted approach boundary, limited approach boundary arc flash boundary; necessary PPE as per the classification when working on live network. *See* sample below:

WARNING		
2	**ARC FLASH AND SHOCK HAZARD APPROPRIATE PPE REQUIRED**	**2**
ARC FLASH PPE LEVEL 2 Working Distance ≥ 45 cm_ Arc Rating of PPE 8 cal/cm^2 min. Arc Flash Boundary 1.8 m	**TASK REQUIRING PPE** 1. Work on energised conductor/circuit 2. Removing covers/opening doors 3. Racking in/out	
SHOCK PROTECTION – 415 V AC	Insulating glove: class O	
Limited Approach Boundary ---------- 1.0 m Restricted Approach Boundary ---------- 0.3 m		
CAUTION	Only designated persons to work Follow all safety procedures Use proper PPE	
Location	Panel details	

FIG.3 LABELING RISK HAZARD AND PPE

NOTES

1 Routine operation within Limited Approach Boundary may be allowed when the installation and its maintenance is carried out in conformation with the safety norms and guidelines of the equipment manufacturer with certification wherever required.

2 Approach Boundaries may be referred from Table 130.4(D) (a) and (b) of NFPA 70 E 2018.

3 References for Arc Flash Boundaries may be taken from Table 130.7(C)(15)(a) and (b) of NFPA 70 E 2018.

g) Work shall be undertaken only in sufficient light or unobstructed view of work area and adequate clearances.

h) In case of circuit disconnection by current limiting protective device, it shall not be manually re-energised unless it is confirmed that disconnection was on account of overloading and not due to fault. Repetitive reclosing of switching devices without confirmation of clearing fault may turn out to be dangerous.

14.12 Mitigation of Arc Flash Hazard

Under the circumstances, where working on/in vicinity of live installation is unavaoidable, following points shall be taken into consideration toward mitigation of arc flash hazard:

a) Working on energised installation within restricted boundary shall be permitted with proper documentation* and only under emergency situations where alternative arrangement does not exist and when de-energising is likely to cause/impose increased risk like interruption of life support, emergency alarm systems, ventilation systems and where task to be handled is not possible under de-energised state.

NOTE

1 Documentation shall state the reason for working on energised installation, clear indication of task to be handled with anticipated time period, task risk assessment based on incident energy; approach boundaries and actual working distance; PPE depending on risk assessment, provisions to restrict entry of unauthorised person within approach boundaries; to approve the person authorising and supervising such work and job completion report.

2 Documentation is not necessary for works carried out outside the restricted boundary for the task like visual inspection, thermography etc.

b) depending on risk assessment switchgears and enclosures shall conform IEC 62271-200 qualifying arc test and IAC classification (internal arc classified).

c) over current protections shall have shortest possible operating time, thereby, reducing the arcing time which leads to reduction in the PPE level requirements and limits both direct and collateral damage to equipment.

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d) to reduce fault levels, fault limiting device, precise fuses to limit let through fault current, circuit breakers with adjustable trip settings to allow shaping of device tripping curve in accordance with the arc flash level may be considered.

e) use of Arc eliminators/ultra-fast Earth Switching may be considered.

f) use of Optical Relays, triggering operation with the flash of light associated with the arc flash.

g) remote operation of switches outside the arc flash boundary reduces hazard as incident energy level drops off exponentially with increase in working distance.

NOTE — Many flashover incidences occur while racking-in or racking-out of the equipment. Controlling such operation remotely through distant operating switches, push buttons, HMI screens or over networking through SCADA system etc., are effective for handling hazard.

14.13 Protective Clothing/PPE

Level 1 and Level 2 measures mentioned in **14.12** are initial steps towards mitigating danger of electrical hazards. However, when risk associated with the hazard is not adequately brought under control, use of protective clothing or PPE is inevitable while working under restricted boundary and within arc flash boundary as per classification depending on risk assessment.

14.13.1 PPE provides thermal resistance and limit incident energy of arc flash to the non-dangerous degree without exceeding threshold to second degree burns as per the Stoll curve. Appropriate selection of PPE shall be based on risk assessment and potential exposure to incident energy.

NOTE — Stoll curve shows human tissue tolerance to heat to predict onset of second-degree burn injury.

14.13.2 Product may be evaluated depending on needs, estimated incident energy and accordingly, appropriate level of clothing, garments, sock-hood/face sheets/visor, gloves having arc thermal resistance, flame retardant behaviour shall be selected.

14.13.3 *Protective Clothing* – All parts of a garment (upper and lower body) including the fabric, stitching material and other assemblies shall have arc thermal resistance and flame retardant behaviour. There shall not be exposed metal parts/accessories on clothing.

14.13.4 Care shall be taken to check the characteristics of the worn clothing (including under garments) and its coverage over all parts body is within arc flash limit. Fabric shall not cause injury or aggravate risk to person wearing it as it has tendency to burn to extent depending on the material.

14.13.5 When exposed to arcing, characteristics shall be checked for catching flames, burning cease time, break-open/hole formation, melting, charring, shrinking, dripping, embrittlement, debris formation and limiting the Incident Energy to non-dangerous degree. It shall pass the test as per IEC 61482-1-1 (for open arc)/IEC 61482-1-2 (Box test) depending on the type of exposure for assessing respective characteristics of protective clothing, PPE.

NOTE — Under open Arc, heat is transferred is in all directions and specimen is mainly exposed to heat radiation. In box test, heat transfer is focussed and specimen, in addition to radiation; is exposed to convection as well as metal splash. Therefore, selection of test criterion shall be specific.

14.13.6 The product to be evaluated for thermal resistance as per IEC 61482-1-1 and be assigned ATPV (or break open) value and heat attenuation Factor or as per IEC 61482-1-2 and categorised under class 1 or class 2, shall be tested in accordance with IS 15758 (Part 4)/ISO 15025 (Protective clothing- protection against flame- Method of test for limited flame spread) and classified according to ISO 14116 (protective clothing- protection against heat and flame. Limited flame spread materials, material assemblies and clothing) in respect with restricted flaming period and further spread.

14.13.7 In line with test procedures as mentioned above, products complying with the IEC 61482-2 shall be appropriately selected depending on classification/type of exposure and risk assessment.

14.13.8 Hazard risk classification as per IEC 61482-1-1 and 61482-1-2 is based on type of exposure as below:

a) With respect to open arc hazard, the assessed ATPV/Break Open value of 4 cal/cm^2 (167.5 kJ/m^2) shall be a baseline of arc thermal resistance for protective clothing/PPE.

b) With respect to arc in limited volume/enclosed box, the product tested and classified as Table 8 shall be chosen for the assessed risk.

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Table 8 Classification as per IEC 61482-1-2

(*Clause* 14.13.8)

Class 1 (basic protection) Test level - 158 kJ	ATPV 4 cal/cm^2 (16.75 J/cm^2) to 24 cal/cm^2 (99.78 J/cm^2)
Class 2 (increased protection) Test level - 318 kJ	ATPV > 24 cal/cm^2 (99.78 J/cm^2)

NOTE — Under NFPA 70E 2018, Arc Flash PPE are classified in to 4 categories; 1, 2, 3, and 4 ranging from 4 cal/cm^2 to 40 cal/cm^2. Table 130.7(C)(15)(a) and (b) specifies Arc Flash PPE categories for various types of equipment with respect to voltage level, fault current, clearing time, working distance for a.c. and d.c. respectively. Table 130.7(C)(15)(c) recommends Arc rated clothing and PPE as per Arc Flash category. References from these tables may be taken for selecting clothing and PPE.

14.13.9 PPE Product shall be marked with:

a) name of manufacturer;
b) production details, for example, batch No., date of manufacture and expiry;
c) conformity with relevant Indian Standard;
d) arc rating and applicability/classification/category; and
e) instructions for users regarding care, maintenance and usable life.

14.13.10 Depending on assessed values of arc energy, arc rated clothing alone does not assure full protection on direct exposure to incident energy. Most severely affected parts of body during arc flash incidence are hands, forearms, head and neck. Therefore, selection of following PPE, tested and certified as per standards, shall be made to limit transmitted incident energy below the limits with reference to stoll curve:

a) Arc rated flash suit;
b) Arc rated flash suit hood/face mask/sock hood/balaclava;
c) Arc rated gloves;
d) Safety glasses/goggles;
e) Hearing protection for ear canals;
f) Leather footwear; and
g) Hard hat liner.

14.14 Electric Fire Hazard

Electrical short circuit/flashover is major cause of fire. Overhead conductor line faults/snapping; failures in transformers, lightning result in fire. Fires result in huge loss of assets, properties and irreversible damages to health and loss of life. It is, therefore, important to look and act on this issue seriously.

NOTES

1 Automatic disconnection of supply within the time specified in IS 732 or IS 3043 providing adequate protection against thermal effects and fire, to an extent.

2 In order to ensure safety in LV system, tests prescribed in this Part1/Section 17 shall be carried out during erection and commissioning and on periodical basis.

14.15 Protection against Fire caused by Electrical Equipment

Persons, livestock and property shall be protected against damage or injury caused by heat or fire generated or propagated in electrical installations by following the requirements of this standard and the instructions by equipment manufacturers. The heat generated by electrical equipment shall not cause danger or harmful effects to adjacent fixed material or to material which may likely be in proximity to such equipments. Electrical equipment shall not present a fire hazard to adjacent materials.

NOTE — Damage, injury or ignition may be caused by effects, such as:

a) heat accumulation, heat radiation, and hot elements;
b) reduction of the safe functioning of electrical equipment, for example, protective devices such as protective switchgear, thermostats, temperature limiters, seals of cable penetrations and wiring systems;
c) overcurrent;

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d) insulation faults and/or arcs causing interference;

e) harmonic currents;

f) lightning strikes;

g) over-voltages; and

h) inappropriate selection or erection of equipment.

14.16 In fire triangle, heat is one of the three components. Faults/defects in electrical installation can cause generation of heat and failure of insulation, further, leading to sparking/arcing. The second component, fuel, can be in any form such as interiors, papers, drapery etc. The two components on combining with the third component, oxygen which is easily available, initiates fire.

14.17 Cause(s) leading to fire in buildings are:

a) initial faulty design such as undersized cross section of wires with respect to load characteristics, short circuit withstand capacity or subsequent overloading beyond the rated capacity resulting into heating of conductors and gradually, deteriorating insulation followed by break down at some point;

NOTE — Accidental damage to insulation, usually, becomes known and can be repaired but gradual deterioration of insulation remain unnoticed and hence, is dangerous.

b) inadequate size of earth conductor, lesser than the capacity required to carry prospective fault current safely to earth till protective device operates, resulting into heating, damaging the earth conductor/melting the insulation (if earth wire is insulated) as well as nearby wire's insulation;

c) poor workmanship such as incorrect method of construction/installation, number of wires and their enclosures (conduits/trunkings) not correlated to maintain adequate space factor resulting into overcrowded wires within enclosures etc;

d) use of sub-standard material, defective workmanship while installation, damage to insulation while drawing wires through conduits;

e) defaults in maintenance schedules and extended use of components after their service life;

f) additions and alteration carried out by unqualified person;

g) inadequate load distribution and faulty circuits design;

h) over rating of MCBs/MCCBs/fuses with respect to safe current carrying capacity of wires or underrating of short circuit withstand capacity;

j) improper terminations and loose contacts;

k) missing covers, open doors of DBs/panels leading to entry of vermins;

m) inadequate ventilation;

n) outlived batteries of UPS;

p) heat dissipating luminaries or their ancillaries, for example, halogen/incandescent lamps, control gear boxes, drivers of LED lights etc in close contact with wooden material, drapery etc;

q) development of faults in equipment, for example, failure of thermostat in heating equipment, bursting of capacitor of air-conditioning unit etc;

r) prolonged/continuous use of equipment not designed for continuous rating; and

s) accumulation of trash, use of space near electrical panels as store-room etc.

14.18 Causes leading to fireout of flashovers on electrical lines and equipment:

For causes leading to arc flash, reference may be taken from arc flash hazard (*see* **14.8**).

14.19 Cause(s) of fire due to overhead lines are summarised as under:

a) snapping of conductors due to improper stringing/defective joints or exceeding limit of allowable joints in OH conductor;

b) no provision of Guarding, leading to snapping/snapped live conductor coming in contact with the flammable material stored below or with crops (usually, dry at the time of harvesting);

c) inadequate spans leading to sag and lower vertical clearances than required;

d) growth of trees below electrical lines or branches of adjacent trees interfering OH lines; and

e) inadequate setting of relays and rating of respective CTs in sub-station, leading to non-tripping or delayed tripping of lines.

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14.20 Transformer Fires

Transformer fires differ from fires caused due to short circuit in wiring installations. An added component, transformer oil (usually mineral oil) within equipment, works as fuel. On occurrence of fault within transformer, partial discharge occurs. It affects the dielectric properties of insulating material and oil. As a result, arc is generated leading to formation of hot vapours composed of hydrocarbon gases and pressure rise (can result into tank rupture). In case, hot vapours come in contact with the oxygen in atmosphere, fire/explosion takes place.

14.21 Factors leading to and aggravating transformer fire risk are:

a) Contamination and oxidation of oil, and sludge formation leading to degradation of oil, resulting in loss of insulating properties;

b) ageing leading to degradation of oil and insulating material;

c) partial discharge and generation of hot spots in windings;

d) overloading resulting into acceleration of ageing process due to heating and leading to deterioration of oil and insulating material;

e) inadequate ventilation affecting dissipation of heat leading to fast ageing of oil and insulating material;

f) failure in regular maintenance of transformer, carrying out routine tests for checking, watching and acting upon to keep all parameters within permissible limits (*see* **12.19**);

g) failure in complying with safety regulations related to oil (*see* **4.22**, **4.23**, **4.24**); and

h) transformer bushing failure.

14.22 Lightning may also lead to fire in buildings and electrical sub-stations, if

a) adequate protection as applicable and specified in IS/IEC 62305, Reg. of 44(3) and 74 CEA Safety Regulations are not available;

b) system is not designed properly;

c) installation methods and procedures/provisions of Lightning protection system are not followed strictly; and

d) earth resistance is not maintained below the required limit.

14.23 General guidelines/measures to avoid aggravation/mitigate chances of fire:

a) Correct initial design is foundation of safety and reference may be taken from the provisions mentioned in **4** (*see* **4.8**, **4.9**, **4.16**). Therefore, electrical design of new project shall be precise and validated.

NOTE — In IS 732, RCD of 300 milliamps is recommended to prevent fire due to leakage current in the building.

b) In case of existing installations, subsequent remedial action with respect to design may be difficult but shall not be avoided. For location vulnerable to fire, warning notice indicating hazard risk shall be displayed for extra attention and vigilance.

c) Strict observation and monitoring of scheduled tests and maintenance eliminate critical issues endangering safety and occurrences of fire (*see* maintenance of electrical installation under **12**)

d) As per norms, adequate provisions related to fire fighting and detection, routine fire audit and further compliance mitigate chances of fire, control aggravation and limit devastation (*see* **4.7, 4.38**).

14.24 Additional/specific guidelines for prevention and remedial measures to avoid aggravation/mitigate chances of fire in buildings:

a) use of FR/FRLSH/HFFR/FS cables (*see* **4.8**);

b) Overloading shall be prevented by replacing wires of suitable higher size, through diverting load on other circuits having spare capacity, installation of additional circuits or reducing load on over-loaded circuits;

c) undersized earth conductor shall be replaced with adequate size or additional conductor of same material and size may be installed. Earthing shall periodically checked;

d) to maintain space factor in wire enclosures, if required, number of wires in a particular enclosure may be reduced and reinstalled in separate additional conduit/trunking;

e) to avoid damage to wire insulation during installation, bushes shall be used at ends of conduits while drawing wires and burr at the end of metal conduits shall be removed;

f) over current protective devices of higher ratings and/or not having variable setting to suit requirement shall be replaced with precise rating/setting facility in correlation with safe limit of current carrying capacity of wire. This shall be assessed periodically (*see* **4.35**);

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g) installation shall be checked periodically, and lose contacts or any sign of heating shall be attended (*see* **12.13**);

h) batteries of standby power supply arrangement shall be kept under surveillance (*see* **12.32**);

j) all heat dissipating luminaries shall be installed such that there is sufficient space/ventilation for heat dissipation, and are not installed on or in proximity to such material prone to fire;

k) equipment shall comply with relevant standards and shall be suitable for required duty cycle. They shall maintained periodically, fault defects shall attended immediately and shall be discarded/disposed after completion of their useful life.

m) spaces surrounding electrical panels/switchgears/DBs shall always be kept clean and material prone to catching fire shall not be stored in vicinity;

n) all works of additions/alteration/modification, subsequent to original installation, shall be performed carefully after studying the installed system and shall be carried out by competent person (*see* **5.1**); and

p) provision of fireman's switch shall be ensured in high-rise buildings (*see* **4.13**).

14.25 Additional guidelines for prevention and remedial measures to avoid aggravation/mitigate chances of fire arising out of arc flash:

a) Reference may be taken from arc flash hazard (*see* **14.10**); and

b) care shall be taken to keep space clean and free of any fire prone storage material within arc flash boundary.

14.26 In addition, **8.7** gives categorical approach in two parts:

a) Precaution to fire victim:
   1) space separation from origin of fire;
   2) flame propagation prevention through:
      i) physical layout of sub-station;
      ii) liquid containment;
      iii) fire barriers; and
      iv) extinguishing system.

b) Precaution to fire origin:
   1) electrical protection;
   2) thermal protection;
   3) pressure protection; and
   4) fire resistant material.

14.26.1 To save human life and restrict hazard potential so as to minimize loss, damages and devastation shall be first priority. This can be achieved through:

a) provision of space for separation from origin of fire;

b) prevention of flame propagation by proper designing of layouts so as to restrict fire in limited area and eliminate chances of spread of fire;

c) Compliance of statutory requirements related to containment of oil, with respect to location, doors with fire rating, oil draining arrangement, oil spillage restriction by curbing/silling, oil soak pit, fire rated baffle walls, etc. (Refer Reg. 44 (2) (vi), (vii), (x) of CEA safety regulations) (also *see* **4.22**, **4.23, 4.24**).

   NOTES

   1 In transformer fire cases, it shall be noted that mineral oil used in transformer is major risk factor raising hazard potential and its severity. Hence, oil protection measures are important.

   2 Compliance to above mentioned safety points may involve civil construction, therefore, may be considered and executed accordingly.

d) As per Reg. 27 of CEA safety regulations, fire buckets with clean dry sand, provision of gas masks, extinguishers, adequate fire fighting system complying with IS 3034, nitrogen injection system/deluge sprinkler/water mist system shall be provided, maintained and operated by trained personnel.

14.26.2 To prohibit the occurrence of fire at origin, following measures shall be taken:

a) Carrying out scheduled tests to assess the condition of oil and bushings as Table 9. Depending on test results, needful action shall be taken.

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Table 9 Routine Tests for Transformer Oil, Bushings and Parameters to be Tracked During Maintenance

[*Clause* 14.26.2 a)]

Sl No	Oil Test	Results/Indication
(1)	(2)	(3)
i)	DGA (dissolved gas analysis)	H_2 – Partial discharge C_2H_4 – Thermal fault in oil CO – Thermal fault in cellulose C_2H_2 – Arcing
ii)	PD (Partial discharge)	Ageing
iii)	BDV (Break down voltage)	Insulation property
iv)	T/F Bushings/Cable test	Results/indications
v)	Tan delta (dissipation factor)	Dissipation and health of bushings

14.26.3 Protections to prevent fire at various stages as shown in Table 10 shall be provided, maintained and periodically checked to prevent fire. Reference may be taken from Reg. 45 (2) of CEA safety Regulations (*see* **4.35**).

Table 10 Protections to be checked and maintained for Operability to Prevent Fire at Stage 1 and Stage 2

(*Clause* 14.26.3)

Sl No.	Protection	Preventive Stage
(1)	(2)	(3)
i)	Over-current	Stage 1
ii)	Short-circuit	Stage 1
iii)	Earth-fault	Stage 1
iv)	Magnetic oil gauge (MOG)	Stage 1
v)	REF (restricted earth fault relay)	Stage 1
vi)	Thermal relay (oil temperature, winding temperature)	Stage 1
vii)	Differential protection	Stage 1
viii)	Oil surge relay	Stage 2
ix)	Pressure relief valve	Stage 2
x)	Buchholz relay	Stage 2
xi)	Explosion vent	Stage 2

14.26.4 Leakage of oil, loss of oil level from conservator, abnormal temperature on thermometer etc provide visual indications of ensuing fault/danger and hence, shall be attended on top priority with corrective measures. Schedule of filtration and replacement of silica gel from breather shall be maintained. Transformer oil shall be replaced if does not conforms to relevant Indian Standards requirements.

14.26.5 Oil type transformer shall not be installed within residential or commercial building (*see* **4.26**).

14.26.6 'K' class oil with flash point above 250°C and fire point above 300°C may be opted in place of mineral oil with flash point 140°C (*see* **4.24**) and to further mitigate the risk of fire, K3 class oil (property of heat value less than 32 kJ) may be considered. (*see* **4.27**)

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15 ACTIONS TO BE TAKEN IN CASE OF AN ELECTRICAL ACCIDENT

Electrical accidents are unfortunate events. Under such emergency, quick rescure actions and correct decision making are important which can save lives and reduce extent of damages to property. Following points cover actions to be taken under such circumstances:

15.1 Electrical Supply of the respective circuit shall be immediately switched off. In case of return supply or non-confirmation of de-energized power supply, person suffering from electrical shock shall be removed with proper non-conducting tackles only. Under such conditions, power supply shall not be switched on before investigation is complete and defects, if any, are eliminated to avoid recurrence.

NOTE — It shall be noted here that electrical circuitry of critical and emergency services rescuing arrangement, fire fighting, PA system, surveillance, illumination of escape routes shall be distinct such that when main supply is disconnected under electrical hazard, these emergency services can continue to function. If required to save the victim, electric supply of critical and emergency services can be disconnected and can, subsequently, be restored after rescuing the victim.

15.2 Person suffering from electrical shock shall be safely moved away and positioned properly. Breathing, pulse, consciousness of the person shall be checked. Depending on the condition, action to resuscitate shall be taken on top priority by trained persons till the medical help arrives.

NOTE — Training sessions for handling situation to treat the person suffering from electrical shock shall be regularly conducted under the guidance from the experts. Immediate action of manual or artificial resuscitating is lifesaving, if conducted in proper way. Hence, periodical training is required.

15.3 It is obligatory to inform Electrical Inspector within 24 h of occurrence of incident. For proper investigation of accident, site shall be maintained as it was at the time of an accident.

15.4 In house scrutiny shall be carried out. Causes leading to accident shall be identified, noted and informed to all concerned. Group discussions shall be carried out to increase awareness towards safety. Corrective action shall be taken.

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NATIONAL ELECTRICAL CODE OF INDIA

PART 2 ELECTRICAL INSTALLATIONS IN STAND-BY GENERATING STATIONS AND CAPTIVE SUBSTATIONS

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PART 2 ELECTRICAL INSTALLATIONS IN STAND-BY GENERATING STATIONS AND CAPTIVE SUBSTATIONS

FOREWORD

This Part 2 of the National Electrical Code of India is primarily intended to cover the requirements relating to stand-by generating stations and captive substations. Standby generating sets are generally the standby power supply source and play an important role in preserving property and lives in emergencies. Captive sub stations are intended for serving an individual occupancy. The general provisions relating to such installations are common and are detailed elaborately in this part of the code.

Generating stations covered by this Part 2 are the stand-by or emergency supply and captive substations normally housed in or around the building in question. This Code does not include the switching stations and other large generating plants that come solely under the preview of the relevant electric supply authorities even though to some extent the requirements stipulated herein could also be applicable to them.

Specific requirements if any, for generating and switching substations for individual buildings that might vary depending on the nature of the occupancy or the size of the building are enumerated in the respective sections of the Code.

In the formulation of this Code, note has been taken of the requirements stipulated in installation Codes of individual equipment as well as the fire-safety Codes for generating stations and substations. It is generally not feasible to draw very strict guidelines for the design and layout for such installations owing to the complexity of the needs of building installations and hence only the essential safety considerations are listed out for compliance. It is essential to take recourse to the assistance of local authorities for further details.

Specific requirements pertaining to stand-by generating stations and captive substations for multistoried buildings are covered in Part 3/Section 22 of this Code.

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SECTION 1 ELECTRICAL INSTALLATION OF STAND-BY GENERATING STATIONS

FOREWORD

This section of National Electrical Code of India (Part 2/Sec 1) is intended to cover requirements relating to the Installation of Generating Set(s) primarily used as a standby source of electrical supply. To ensure optimum performance, installation of generating sets also require specialised engineering knowledge and experience in relation with prime mover. The electrical supply from standby generating sets is of prime importance for the life safety and emergency services in all types of buildings having different utilities and especially in multi-storeyed buildings. It is also used in IT centres, industries with continuous process to minimise economic losses, avoid equipment damage due to supply interruptions. Installation of generating sets requires compliances of norms of Central Pollution Control Board related to Environmental aspects and CEA Regulations related to Safety.

1 SCOPE

This section of the code (Part 2/Sec 1) provides guidelines in respect of electrical design, selection, along with installation, testing, commissioning, maintenance and statutory compliances in respect of standby generating sets, meant to supply power during the period of supply interruption of primary source, or during the emergency, having individual capacity up to and including 2000 kVA. The scope also includes considerations in respect of the prime mover usually RIC (Reciprocating Internal Combustion) engine which is an integral part of generating set.

The guidelines mentioned hereunder are general for typical installations. Specific requirements may vary depending on application and situation. Under such circumstances, OEM shall be consulted.

2 REFERENCES

2.1 Statutory Requirements

a) *Environment Protection Act,* 1986 Sec 6 and 25;

b) *Environment (Protection) Rules,* 1986;

c) Central Pollution Control Board (CPCB) Guidelines; (to be read with State Pollution Control Board deviations if any);

d) *CEA (Measures related to Safety and Electric Supply) Regulations,* 2010; and

e) *Petroleum* and Explosives Safety Organization (PESO), for fuel storage.

2.2 References

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO No.	*Title*
IS/ISO 8528	Reciprocating internal combustion engine driven alternating current generating sets:
(Part 1) : 2005	Application rating and performance.
(Part 2) : 2005	Engines
(Part 3) : 2005	Alternating current generators for generating sets
(Part 4) : 2005	Control-gear and switchgear
(Part 5) : 2005	Generating sets
(Part 6) : 2005	Test methods
(Part 7) : 1994	Technical declaration for specifications and design
(Part 8) : 2016	Requirements and tests for low power generating sets

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IS/IEC/ISO No.	*Title*
(Part 9) : 1995	Measurement and evaluation of mechanical vibrations
(Part 10) : 1998	Measurement of airborne noise by the enveloping surface method
(Part 12) : 1997	Emergency power supply to safety devices
10000 (Part 4) : 1980	Methods of test for internal combustion engines: Part 4 Declaration of power, efficiency, fuel consumption and lubricating oil consumption
3043 : 2018	Code of practice for earthing

3 TERMINOLOGY

For the purpose of this part, the definitions given (Part 1/Sec 2) of this Code shall apply.

4 GENERAL CHARACTERISTICS

Generating set consists of a prime mover, RIC (Reciprocating Internal Combustion) engine which produces mechanical energy which is converted to electrical energy by generator coupled to engine, control gear and switchgear and auxiliaries.

4.1 Prime Mover

Prime mover characteristics are considered by its fuel, fuel consumption, exhaust, noise, speed, mass, dimensions, surge capacity, maintenance requirements etc.

4.2 Generator

Generator characteristics are considered by output voltage behaviour during normal steady operation and fluctuating/variable load, power factor, short circuit behaviour, efficiency, parallel operation behaviour, maintenance, etc.

4.3 Controlling, Switching

Controlling, switching, operation, monitoring and protecting the set under condition of fault are main characteristics of control gear and switchgear.

4.4 Auxiliaries

Characteristics of auxiliaries are to provide essential service for smooth, proper and safe functioning. It comprises starting system, air intake and exhaust system, cooling system, lubricating system, fuel system, auxiliary electrical power supply, etc.

4.5 Start-up Time/Changeover Time

There may be certain time lag in changeover from one power source to another. This elapse of time is important consideration especially for safety services which may require certain provisions to be made in system. The automatic supply changeover classified as given in the Table 1.

Table 1 Classification of Automatic Supply System in Accordance with Maximum Changeover Time

(Refer IEC 60364-5-56)

(*Clause* 4.5)

Class	Changeover time in Seconds	Remarks
A	Nil	No-break
B	Within 0.15 s	Very short break
C	Within 0.5 s	Short break
D	Within 5 s	Average break
E	Within 15 s	Medium break
F	More than 15 s	Long break

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4.6 Performance Classes

Gen-set are classified in to 4 types; G1, G2, G3 and G4; depending on performance with respect to voltage and frequency. G1 type is considered suitable for general purpose lighting load, G2 suitable to operate with public utility electric power system, G3 where equipment requires precise level of stability in respect of voltage, frequency and waveform, for example telecommunication and thyristor-controlled loads and G4 where precision is required at exceptionally high level, for load like data centres, computer systems.

5 SELECTION

5.1 Purpose/Functions/Duty Classification

It is recommended to provide all requirements, parameters, details of generator load along with its characteristics, run time etc., to the manufacturer or his authorised representative/dealer/service provider to decide specifications suiting the requirements. If there are no specific declarations stated by the customer, then declarations stated by manufacturer should be taken as basis of requirements and parameters (*see* 4 Technical declarations and Annex A, B, C under IS/ISO 8528-7)

5.1.1 *Classification*

IS/ISO8528-1 classifies Gen-sets comprising reciprocating internal combustion engines (RIC) in to three types depending on purpose, function or application to use as emergency standby power (ESP), prime rated power (PRP), limited time power (LTP), continuous operating power (COP).

5.1.2 *Emergency Standby Power (ESP)*

The IS/ISO 8528-1 standard defines standby power as the maximum power available from the generator set to energize a variable electric load profile, where it has been determined that the total annual runtime doesn't exceed 200 h of operation. In addition, the average* load factor over a 24 h period shall not exceed 70 percent of ESP unless otherwise approved by the generator set manufacturer:

$$*P = \frac{P_1t_1 + P_2t_2 + P_3t_3 + \ldots. + P_nt_n}{t_1 + t_2 + t_3 + \ldots\ldots + t_n}$$

where,

P = Average power

P_1, P_2, P_3 ….. = power drawn during time period t_1, t_2, t_3 respectively. (power less than 30 percent, shall be considered as 30 percent)

t_1, t_2, t_3 ….. run time in hours (stop period shall not be counted)

$t_1 + t_2 + t_3 + \ldots\ldots + t_n = 24$ h

Actual average power output shall be less than permissible average power output.

NOTES:

1 PRP or Prime rated power is applicable when using electric power from Gen-sets in lieu or in addition to commercially purchased power to supply variable loads without restriction of hours per year but with limitation of average 70 percent load factor within 24 h, and maintenance intervals.

2 LTP is for constant load or base load application for total period not exceeding 500 h/year. Some manufacturers provide PRP Gen-sets without restriction of 70 percent load in 24 h for application at data centres.

3 COP continuous operating power is maximum power the Gen-set is capable of delivering continuously whilst supplying constant electrical load, for unlimited hours per year with maintenance intervals.

5.1.3 *Emergency Power Supply to Safety Devices*

Specific guidelines are given under IS/ISO 8528-12, when the standby power supply from Gen-set is to be used as emergency power supply to safety devices, which includes critical services requiring supply integrity for life safety.

5.2 Rating

Ratings correspond to maximum allowable loading conditions depending on duty classification. For example, a manufacturer may specify multiple ratings for same Gen-set, for example, a rating of 2 000 kVA for ESP application shall be taken as 1 825 kVA for PRP application and 1 600 kVA for COP application. It can be seen that there is inverse relationship between the generator set rating and allowable runtime as runtime directly relates with engine life and mean time between overhaul.

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5.3 Overloading

Generally overloading of 10 percent within period of 12 h is considered while deciding capacity. However, for Gen-sets classified under standby category, overloading capacity is not mandated. Hence manufacturer shall be consulted in this regard.

5.4 Power Factor

Unless otherwise specified by manufacturer, or custom requirement, generator power factor is 0.8. Unity power factor in respect of single-phase generator may be available depending on manufacturer.

In respect of any specific requirement in regard with the power factor; lagging/leading/unity manufacturer may be consulted.

5.5 Capacity Design/Sizing of Gen-set

Determining correct capacity of Gen-set is a critical task requiring expertise. Wrong design may lead to number of problems. Under sizing will lead to overheating, high running time than recommended, frequent issues of maintenance and repairs involving direct and indirect cost, unexpected system failures and undesired outages, endangering critical services during emergency relating to life safety, decreased service life etc. Over design will lead to inefficient working, fuel loss, but slightly higher capacity is always desirable to take care of unpredictable conditions.

It shall be noted that generators are expected to run at minimum 30 percent load to run at proper temperature and properly burn the fuel.

5.5.1 *Classify Electrical Load*

Enlist the equipment/system to be connected on Gen-set. Sort out load depending on critical importance and characteristics as:

a) Critical load related to life safety as a mandatory requirement;

b) Non-critical but essential services load; and

c) Depending on characteristics.

5.5.2 *Assess Load Requirement*

Work out starting and running load in respect of each equipment. Resistive load will be same at starting and running. Motive Inductive Load will have higher starting current hence will require higher starting power. In respect of motors with DOL starter they will draw higher current (6 to 7 times of F.L) compared to star-delta starter (2 to 3 times of F.L.) and star delta starter will draw higher current than soft starter (1.2 to 1.5 times of F.L. current). Typically motor with DOL starter may require Generator having 3 times the rating of motor, which may vary depending on surge capacity/maximum allowable voltage dip. Single motor running or multiple motor running, simultaneous starting or differed starting time/sequence of loading also affect capacity design.

5.5.3 *Non-linear Loads*

Check non-linear load creating harmonic distortion and measures adopted to compensate. Assess possible harmonic distortion which generator will require to bear. De-rating or resizing in respect of alternator with higher rating without change in prime mover may be necessary.

5.5.4 *Voltage and Frequency Regulation*

Requirements in respect of steady state and transient electrical frequency shall be considered. Also, nature of electrical load current waveform imposed on generator may affect output voltage waveform and steady state voltage accuracy affecting performance. (*see* **4.6** under this section).

NOTE — Buyer shall compare his calculation sheet, requirements, parameters given to manufacturer with that of he is providing. It is binding on the manufacturer to provide certain details on the Rating Plate. (*see* 14 under IS/ISO 8528-5) Points to be agreed mutually shall be confirmed (*see* 4 Technical declarations under IS/ISO 8528-7). Any difference if noticed shall be resolved across the table. All documentation shall be maintained as record.

5.5.5 *Unbalanced Loads*

Consideration of unbalanced load is also important in deciding capacity of generator. It is recommended to maintain the unbalance within 10 percent. But in spite of adequate precautions, it may not be possible to keep the load balanced throughout the daily load cycle, seasonal variations, varying loads depending on occupancy, unpredicted emergencies. Proper study of load pattern will be necessary to achieve the requirement.

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5.5.6 *Capacity Combination – Parallel Operation*

Using single generator of total required capacity or using more than one generator and operating them in parallel or sectionalising the load and use independently for specific requirement of that time shall be decided considering following factors specific to respective site, situation, and use:

a) Available space;
b) Actual requirement of load(s) to be supplied and the time;
c) Ease and emergency of operation;
d) Environmental aspects related to emission and noise;
e) Run time hours and fuel consumption;
f) Redundancy;
g) Maintenance;
h) Capital cost;
j) Achieving minimum 30 percent load criteria;
k) Future/phase-wise augmentation; and
m) Characteristics/suitability of generators for parallel operation.

5.6 Environmental Aspects

Ministry of Environment and Forest, Government of India, have set up norms in respect of Noise and Emission limits. Central and State Pollution Control Boards are nodal agencies in respect of implementation.

5.6.1 *Noise pollution – Acoustic Enclosures*

Under CPCB norms it has been made mandatory to maintain noise limit 75 dB* at 1 m from enclosure or surface. For OEM it is mandatory provide Diesel Generating Set with integral acoustic enclosure for capacity up to 800 kW/1000 kVA (*see* also IS/ISO 8528-10).

NOTE — Above condition does not apply to DG set manufactured before 1st Jan 2005. Such generators shall be provided with acoustic enclosure/room having specifications as mentioned under the CPCB guidelines. A mandate has been issued on 25th Feb 2015 by the National Green Tribunal in respect of phasing out old generators which shall be referred for needful action.

5.6.2 *Emission Control*

CPCB Emission norms have been set up under three categories; generating sets up to 19 kW, above 19 kW and up to 75 kW, above 75 kW and up to 800 kW. It shall be noted that owner shall be vigilant to comply required the norms and hence upkeep due maintenance. In respect of Diesel Gen-Sets exceeding 800 kW notified *Environment (Protection) Rules*, 2002 as amended up to date may be referred.

5.6.3 *Operating Conditions*

For determining rated output Gen-sets are tested at standard atmospheric pressure, temperature and relative humidity. Depending on geographical condition performance may differ. It is therefore recommended to share details of location with the OEM to assess de-rating.

6 LOCATION, SITE-PREPARATION AND, INSTALLATION

6.1 Selection of Site and Location

Following factors shall be considered while selecting site/location of generating set:

a) Acoustics provisions; built in canopy/separate room;
b) Chances of resonance and echo;
c) Ventilation;
d) Distance of gen-set from building;
e) Stack height;
f) Aspects related to pollution, dust, humidity;

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* Noise limit mentioned is in respect of diesel gen-set. In respect of petrol/kerosene or Natural Gas/LPG driven gen-set limit is 86 dB.

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NOTE — As far as possible location shall be away from cement or stone dust, cotton fibres, furnace producing acidic fumes etc. OEM shall be consulted in respect of above issues. Under dusty, polluted environment there are chances of getting the radiator clogged. Here OEM may recommend heavy duty air cleaner or heat exchanger cooled system. In coastal regions where humidity is high alternator may require anti-condensation system.

g) Load centre;

h) Location of sub-station/point of supply; and

j) Location from the point of view of safety to sustain operation during emergency.

NOTE — It is likely that point under (f), (g), (h) may suggest different locations. However, the Gen-set is providing standby supply to emergency services, point No. (h) shall be given prime importance.

6.2 Drawing

Prior to commencement of work a detailed drawing showing site, location from nearby structures access ways for transportation, foundation details, placement of related equipment, exhaust piping, electrical panel and electrical single line diagrams showing specifications and details of equipment, cabling, etc. shall be prepared. In case of any chances of conflict between other works, mutual consent shall be taken.

NOTE — Electrical Inspectorate may require user/owner to get prior approval for drawing.

6.3 Installation

While installing conditions mentioned under **6.3.1** to **6.3.5** below shall be considered.

6.3.1 *Indoor/Outdoor/Rooftop*

At planning stage, it is necessary to decide location so that necessary arrangements can be done related to Architectural, Structural, Civil Work requirements. Future additions, augmentation shall also be considered. Required clearances around and in between gen-sets shall be as per OEM's recommendations so that operation and serviceability of generating set shall be easy. If installation is within room, door sizes shall be of adequate size considering size of removable/replaceable parts. Necessary provisions in respect with cables, Fuel lines, breather vent, coolant/lube-oil drain, coolant, storage of consumables, spares shall be considered.

NOTES:

1 Where Gen set is meant to provide supply to critical services for which supply integrity is important, location shall be so chosen that in case of emergency like fire, functioning of the Gen-set will not get affected. This location may be at safe place away from building.

2 In case of roof top Gen-sets, OEM shall be informed in advance and the recommended pre-installation check list shall be followed.

6.3.2 *Foundation*

For foundation design requirements of OEM shall be followed. Generally, M20 grade CC foundation is suitable to sustain static and dynamic load, however design and depth of foundation may vary depending on safe bearing capacity of soil. Anti-Vibration mounting (AVM) pads shall be used to compensate dynamic loading if required. Length and breadth shall be 150 to 300 mm more than the base rail/outer dimensions of acoustic canopy. Height from ground level shall not be less than 150 mm. Required curing time shall be allowed for foundation to set. Surface shall be flat to the accuracy of + 0.5 percent.

NOTE — Improper foundation may lead to alignment and vibration problems resulting into premature failure of Gen-set components and service life.

6.3.3 *Orientation*

Orientation of generating set shall be such that natural wind flow shall not be obstructed. Ideally direction of wind shall be such that it shall enter from alternator end and exit from radiator end. In case it is not possible to maintain, barriers may be provided in consultation with OEM. It shall be seen that hot air is not re-circulated.

6.3.4 *Ventilation*

To maintain parameters related to permissible temperature rise within limit, adequate cross ventilation is important. Orientation as mentioned under **6.3.3**, will help achieve the requirement in respect of ventilation. If OEM recommends additional forced measures, same shall be provided. Generally maximum allowable temperature rise within room/enclosure shall not be more than 10°C above ambient up to 40°C and 5°C above ambient if it exceeds 40°C or as specified by OEM. Improper ventilation may affect fuel efficiency, performance, rubber components, exhaust, alternator winding. Under adverse conditions, it may be possible to consider de-rating of the set.

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6.3.5 *Fuel*

6.3.5.1 *Diesel*

In case diesel engines, fuel tanks where they are not part of factory assembled unit, following points shall be considered:

a) Supply and return line allowable pressure, segregation, length;

NOTE — Higher pressure may lead to low power, late stopping, engine die down

b) Level of fuel tank above/below with respect to engine and fuel pump;

c) Minimum requirement of fuel by gravity if any, in respect of Gen-sets with AMF panels;

d) Arrangements shall be done for condensate drain, breather, fill neck to allow expansion;

e) Capacity; shall be to suffice requirement for continuous use for the assessed critical period but shall not exceed norms mentioned under petroleum rules; and

f) Galvanised tank, piping shall not be used for diesel.

Separate storage arrangement for fuel refilling may be done depending on need and nearby availability. Storage of fuel above 1 000 *l* requires approval from the authority. This arrangement should comply with applicable Petroleum Rules.

NOTES:

1 Diesel consumption

Fuel efficiency is an important factor for considering running cost. It is measured at 50 percent, 75 percent and 100 percent loading. Specific fuel consumption is measured in gm/bhp/hour or l/hr. Specific gravity of Diesel is 0.845 as per ISO 3046. It is always desirable to have optimal fuel consumption over broad range of loading. All manufacturers provide fuel consumption charts. It shall be noted that actual consumption may vary depending on ventilation, observance of maintenance schedule, percentage loading, and occasional overloading.

2 Diesel shall comply specifications as per IS 1460.

3 In case of Fuel Tank of Gen-sets on roof top, Specific Rules mandatory as per Local Fire Authority and Petroleum Rules shall be followed in respect of placement and capacity.

6.3.5.2 *Gas*

Depending on availability of natural gas it can be a good option considering environmental aspects. OEM recommendations shall be referred in respect of installation of various components such as shut-off valves, regulators, carburettor, filter etc; of fuel supply system.

NOTE — Before commissioning pre-installation check from the manufacturer shall be done in which specific requirements in respect of Gas fuel shall be to the satisfaction.

6.4 Batteries

Heavy duty batteries may be 12 V/24 V of required Ah rating depending on the capacity of Gen-set, connectivity to control circuitry, model of respective manufacturer. Batteries shall be suitable to operate under respective ambient temperature. Connections shall be made with the class 5 copper cables of 35/50/70 mm^2 or as per required size and type to restrict voltage drop within 8 percent of nominal battery voltage during cranking. Generally, 1.25 m length is considered. But depending on length to restrict voltage drop size may be increased. Ensure polarity before making connections. Use adequate lugs. Protocols in respect of initial and routine charging shall be followed. For AMF applications static battery charger working on mains supply may be necessary to keep batteries charged at all the times, to respond mains failure instantly. Location of batteries shall be at cool place and on stands.

6.5 Stack/Exhaust

6.5.1 *Back Pressure*

Design of exhaust system shall be such that it will exert minimum back pressure and not exceed the values (mm of Hg) recommended by OEM for respective model of diesel engine. Depending on required stack height (*see* **4.4.7.4**), depending on length provision of long bends, expansion, additional bellows shall be made.

6.5.2 *Crossing*

Crossing of exhaust pipe through enclosure/wall to outside shall be done with adequate provisions to sustain expansion/contraction.

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6.5.3 *Stack Height*

Gen-sets located in close vicinity of building shall be provided with stack height as per following formula.

$$H = h + 0.2 \times \sqrt{\text{kVA of Gen-set}}$$

Where

H = height of exhaust stack; and

h = height of building.

Above formula is applicable for Gen-sets up to 800 kW/1 000 kVA

In case of Gen-sets above 800 kW minimum stack height irrespective of adjacent building shall maximum out of following:

a) 30 m;

b) 6 m above the building where generator set is to be installed; and

c) 14 $Q^{0.3}$ where Q = Total SO_2 emission from the plant in kg/h.

6.5.4 *Exhaust Piping*

Exhaust piping may be done in class B MS pipe. Galvanised pipes shall not be used. Adequate lagging and cladding shall be done to exhaust piping inside enclosure/room to avoid heat dissipation within. It is important that there should not be any leakage inside enclosure which may affect winding of alternator due to deposition of carbon. Depending on design, length and height of exhaust piping, provisions shall be made for, long bends, expansion by 13 mm for every 3 m above 5 m of Gen-set, additional bellows, and support system to sustain the structure. It is recommended that jointing shall be done with bolted flanges.

6.5.5 *Silencer*

Location of silencer shall be considered from the point of view of back pressure imposed on system and the attenuation of sound. Proper alignment of silencer shall be checked with respect to expansion bellow. For preferred silencer location OEMs recommendations shall be followed.

NOTES:

1 It had been a practice to use residential silencer to attenuate noise. However, since pollution control norms have come in to existence there is no specific purpose to mention 'Residential Silencer'

2 Depending on hazard classification applicable to the area where Gen-set is to be installed, provision of Spark Arrestors may be made as per recommendations by concerned authority.

6.6 Cooling System — Air/Water

6.6.1 *Air-Cooled Engines*

Air cooling system has limitation of capacity. Its manufacturing is done by some manufacturers in lower capacity. Care in respect of water and coolant related matter does not arise in respect of air-cooled engines. However efficiency compared to water cooled engine may be less especially in summer.

6.6.2 *Water/Liquid Cooled Engines*

In case of water-cooled engines, water used shall bear the required properties in respect of hardness, *p*H values, chlorides, TDS, sulphates etc; which may cause scaling, overheating, corrosion. In case water quality is not satisfactory, need of water softening plant shall be checked with OEM. Use of coolants shall be made as per the recommendations. System as whole shall satisfy requirements in respect of inlet temperature, allowable temperature rise, pressure, water piping, valves, fittings and connections etc. It shall be checked that path of air-flow en route radiator is not obstructed.

6.7 Electrical Installation

6.7.1 *Cable Installation*

Adequate provisions shall be kept for installation of cables so that it shall remain free from mechanical damages and thermal effects.

6.7.2 *Cable Size and Type*

Usually full load current in respect of single-phase generator is considered to be 4.5 × kVA rating and in case of three phase generator 1.4 × kVA.

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Size and type of power cables between alternator and control panel and changeover arrangements to mains shall be decided in consideration with Part 1 Section 9 and requirements of supply integrity. Factors like overload, surge and de-rating depending on situation shall be considered.

NOTES:

1 Recommendations of OEM shall also be considered in respect of size of cable and in case of any difference higher size shall be used.

2 It is recommended that for Gen-sets of lower rating preference shall be given to copper cables.

6.7.3 *Control Cabling*

For control cabling use 10/12 core 2.5 mm^2 copper cable. Suitable increase in size shall be done if length exceeds 5 m

6.7.4 *Terminations*

Connections shall be firm, there shall be adequate contact area so that connecting nut bolts shall not form a path of load current and heat is not generated at the terminals. Use of proper lugs and cable glands shall be made for terminations. It shall be checked that self-weight of cable does not exert pressure on the terminals, proper support/ clamping shall be provided if necessary. Colour code shall be watched in respect with phase sequence. Bending shall be restricted to allowable radii.

6.7.5 *Control Panel*

Control panel is integrated part of Gen-set providing operation facilities, controls, protection for prime mover and generator, indications/alarms. Depending on requirement operation of control panel may be manual, semi-automatic or fully automatic.

6.7.5.1 *User interface*

Control panel of Gen-set performs various functions to protect engine and alternator apart from start/stop. Status of various parameters, alarming conditions in respect of temperature, lube oil pressure, coolant level, battery, voltage, current etc. is displayed. Protections against overload, short-circuit are provided. Alarms and tripping arrangement is provided. Auto Transfer facility in case of mains failure with proper interlocking to avoid back-feeding are available, arrangement of data retrieval can also be made available. Depending on capacity of Gen-set and the manufacturer there could be a variation and added sophistication. Reference may be taken from IEC 61850.

NOTE — In case of auto transfer for neutral single pole contactor shall not be used. There shall be a simultaneous transfer of neutral pole along with phase(s). It is therefore recommended to provide 2-pole contactor in case of single phase and 4-pole contactor in case of three phase Gen-sets.

6.7.5.2 *Mandatory protections*

For generator having capacity 100 kVA and above earth fault protection shall be provided. And generator having capacity 1 000 kVA and above differential protection or restricted earth fault protection shall be provided.

6.7.5.3 *Over current protecting device*

A 4-pole circuit breaker (not MCCB) shall be used for connecting the main switchboard. For generator sets below 250 kW output (maximum), 4-pole MCCB with external release and motorized closing functions can be used. If parallel operation with mains supply is not envisaged, suitable interlock should be provided to ensure that the main supply circuit breaker is closed only when the generator circuit breaker is open and vice-versa.

6.7.5.4 *Reverse power flow*

Possibility of reverse power flow shall be checked and provision of appropriate protection shall be made.

6.8 Parallel Operation

Paralleling requires that the incoming generating set be synchronised which may be achieved manually or automatically. Synchronising involves voltage and frequency adjustment to bring incoming machine into synchronism and in phase with existing system.

6.8.1 *Manual Operation*

Manual operation requires skill and experience. Switching-in has to be carried out accurately. Multiple lamps shall be used to produce rotary light showing state of synchronization. Required controls are generator circuit breaker, contactor/load switch, voltage and frequency adjusting devices, synchronising lamps, zero voltmeter/ synchroscope, reverse power protection and instrumentation comprising double frequency meter, double voltmeter, active load sharing control, reactive and active power meter, etc.

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6.8.2 *Automatic Operation*

Required controls and instrumentation necessary for parallel operation are; remote operated generating set circuit breaker having corresponding short closing time, voltage and frequency adjusting devices, automatic load sharing control, reverse power protection, automatic synchronizer and selection switch MANUAL/AUTO and instrumentation as mentioned under manual operation.

6.9 Earthing Arrangement

6.9.1 *Earthing of Genset*

Earthing design, type and method of earthing a Gen-Set installation and its arrangement shall conform to 29 of IS 3043 and 4.5.4.4.6 of IS 732.

6.9.2 *Earth Connections*

If AVM pads with rubber or any insulating material are provided between engine-alternator and base frame, earthing shall be provided distinctly to all non-current carrying metal parts.

6.9.3 *Earthing for Parallel Operation of Generators*

When generators operate in parallel to avoid problem associated with circulating current in neutral, arrangement shall be made as per IS732 or with interlocked isolating devices such that neutral of only one generator shall be connected to earth at one time Or suitable relay shall be provided in neutral conductor to sense the current and switch the neutral contactor when the current in neutral exceeds the limit.

7 TESTING AND COMMISSIONING

It is recommended to strictly perform stage-wise pre-commissioning checks from the manufacturer or his authorised representative.

7.1 Statutory Requirement

Depending on capacity of Gen-Set as notified by appropriate Government (State/Central) where inspection certification prior to commissioning is mandatory, shall be complied with. (*see* Reg. No. 32 from CEA measures related to safety and electric supply Regulations).

Compliance to environmental related norms set up by CPCB and SPCB shall be verified.

Applicable Petroleum Rules in respect of storage of fuel are followed.

7.2 Site Requirements

Site shall be checked for compliance of related requirements mentioned under **6**. Applicable fire protection norms shall be complied with.

7.3 Testing Operation

Emergency power supply shall be checked at distribution point of installation by interrupting primary electrical supply. Start-up, run-up behaviour, operation of auxiliary equipment, switchgear and control gear operation and dynamic deviations shall be checked in respect of voltage and speed.

8 HANDING OVER

8.1 Documentation

It is recommended that a set of, drawings, design sheets, testing certificates manufacturer’s catalogue, instructions for operation and maintenance schedules, trouble-shooting charts, warranties/guarantees, applicable permissions, NOCs from Electrical Inspector, Pollution Control Boards, Structural Stability certificate from structural engineer in respect of roof top installation, test report of electrical contractor shall be handed to owner and owner shall take note and preserve such documents as record.

8.2 Post Commissioning Care and Maintenance

Considering aspect of important aid in Life Safety, critical services, it is very important to follow the schedule of post commissioning checks depending on run time hours or period in months. Entering data in log sheets showing hours of use, cooling water temperature, lub-oil pressure and temperature level, alternator load parameters, carrying out scheduled maintenance, attending corrective measures will provide improved reliability, high uptime and service life longevity of DG set.

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SECTION 2 ELECTRICAL INSTALLATIONS IN CAPTIVE SUB-STATIONS

FOREWORD

This section of National Electrical Code of India (Part 2/Sec 2) is primarily intended to cover the requirements relating to captive distribution substations. Captive sub-station belongs to an individual consumer as a part of electrical installation and does not form a part of public electricity distribution system. The individual consumer who is owner of such installation is responsible for safety related aspects of complete installation, use, operation, maintenance, etc.

1 SCOPE

1.1 Scope of this section of the code (Part 2/Sec 2) includes design, installation, operation, maintenance and safety; related to the portion of installation from the point of supply at 33/22/11 kV to main controlling device after secondary side of transformer and includes apparatus, equipment, devices installed/provided with interconnecting cables, within the premises of substation.

1.2 The guidelines given under this section are applicable to distribution transformer(s) with individual capacity not exceeding 2.5 MVA and sub-station capacity up to 10 MVA and voltage level up to 33 kV.

1.3 Scope does not include the switching-stations and sub-stations in generating plants, electrical distribution system for public, owned by electric supply distribution company/licensee/authority.

2 REFERENCES

2.1 Statutory Provisions

a) Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2010 (as amended to date);

b) Central Electricity Authority (Technical Standards for construction of Electric Plants and Electric Lines) Regulations, 2010 (as amended to date); and

c) Central Electricity Authority (Safety Requirements for Construction Operation and Maintenance of Electric Plants and Lines) Regulations, 2011 (as amended to date)

2.2 Standards

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO No.	*Title*
1180 (Part 1) : 2014	Outdoor type oil immersed distribution transformers up to and including 2 500 kVA, 33 kV — Specification: Part 1 Mineral oil immersed
1180 (Part 3) : 2021	Outdoor/indoor type liquid immersed distribution transformers up to and including 2 500 kVA, 33 kV — Specification: Part 3 Natural/synthetic ester liquid immersed
1641 : 2013	Fire safety of buildings (general): General principles of fire grading and classification — Code of practice (*second revision*)
1642 : 2013	Fire safety of buildings (general): Details of construction — Code of practice (*second revision*)
1646 : 2015	Fire safety of buildings (general): Electrical installations — Code of practice (*third revision*)
1946 : 1961	Code of practice for use of fixing devices in walls, ceilings and floors of solid construction

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IS/IEC/ISO No.	*Title*
3034 : 1993	Fire safety of industrial buildings: Electrical generating and distributing stations — Code of practice
3043 : 2018	Code of practice for earthing (*second revision*)
10028 (Part 2) : 1981	Code of practice for selection, installation and maintenance of transformers: Part 2 Installation
10028 (Part 3) : 1981	Code of practice for selection, installation and maintenance of transformers: Part 3 Maintenance
IS/IEC 62305 series	Protection against lightning
IS/IEC 61936-1 : 2021	Power Installations exceeding 1 kV AC and 1.5 kV DC — Part 1 AC Installations

3 TERMINOLOGY

For the purpose of this Part, the definitions given in (Part 1/Sec 2) of this Code shall apply.

4 GENERAL AND COMMON ASPECTS

4.1 Stakeholders

For an electrical sub-station, there could be involvement of different stakeholders as given below. There is particular role of every stakeholder on whom the responsibility of compliance of various standards, codes and guidelines mentioned hereunder rests with. Any shortfall and lapse in timely action, may lead to serious consequences which at later stage, are difficult to repair/may not be reversible. The following points describe roles and responsibilities of various stakeholders involved in an installation of electric sub-station. Streamlining of roles and responsibilities will help the to get completed in time and comply all standards, codes and mandated norms, without any defect.

4.1.1 *Roles and Responsibilities*

a) *Owner* — Make appointments of concerned stakeholders with appropriate experience and knowledge. Provide them all information necessary for the work. Clearly state their responsibilities. Execute an agreement in accordance.

b) *Architect* — Coordinate different stakeholders, assess requirement of land/spaces/civil Construction for sub-station and allied work at suitable locations, complying mandated clearances and norms in consultation and mutual agreement with the electrical consultant/contractor. Prepare plans and specifications in accordance with mutual consent of all stakeholders. For details *see* **4.4** below.

c) *Civil Contractor* — Construct the structure, building as per the drawing and specifications. Coordinate and schedule activities with electrical work in consultation with the Electrical Consultant/Contractor. *See* **4.5** below.

d) *Electrical Consultant/Contractor* — Discuss the requirements with the architect and provide details related to land, space, room, construction, required clearances within and around the sub-station and cable routes, equipment movement facility, ventilation, etc. Check availability and requirements related to incoming supply (*see* **4.4** below). Confirm provisions in the plans and related documents. Prepare design and drawings of electrical work as mentioned under **5.3** below. Strictly follow statutory provisions. Check compliances with regulations, standards, codes, approved methods of construction in respect of design and installation of work. Maintain record. Get the work inspected/verified from the authorized person. Certify the work and handover with proper documentation to the owner.

4.2 Statutory Requirements

It is obligatory to observe *Central Electricity Authority Regulations* in respect of safety, construction, etc. The important points are given below.

4.2.1 *Drawing Approval*

Depending on procedures/requirements of the inspectorate wing, drawing approval prior to commencement of work, if necessary, shall be taken.

NOTE — Even though if drawing approval prior to commencement the work is not mandatory, getting the approval will avoid possible changes/alterations, ordered by the authority during inspection, at the stage when the work is completed and ready to commission.

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4.2.2 *Compliance with Regulations*

Installation shall comply provisions of *Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations,* 2010. *Central Electricity Authority (Technical Standards for construction of Electric Plant and Lines) Regulations*, 2010; as amended to date.

4.2.3 *Permission prior to Commissioning*

After completion of installation, before energizing, conditions as envisaged under Regulation 43 of *CEA (Measures relating to Safety and Electric Supply) Regulations,* shall be observed.

4.2.4 *Periodical Inspection/Verification*

In respect of completed and already commissioned installations, mandated periodical inspection as envisaged under *Regulation 30 of CEA (Measures relating to Safety and Electric Supply) Regulations*, shall be carried out.

NOTE — Also refer Part 1 Section 17 of this code.

4.2.5 *Documentation*

Documentation related to statutory requirements shall be properly maintained as record and shall be produced as and when required by the authorities.

4.3 Planning

4.3.1 *Exchange of Information*

It is most important that there should be an exchange of information between the stakeholders as mentioned under **4.1** above. The requirements of various working agencies must be called at planning stage for compilation and to schedule the activities.

4.3.2 *Preliminary Assessment of Electrical Power Requirement*

At preliminary planning stage, it is necessary to assess approximate load requirement to decide capacity of the transformer sub-station. This is necessary for the architect to make provision of required land/area of substation. It is also necessary to check suitable supply source in vicinity, form where electric supply line will enter the premises and how it can be routed.

4.3.3 *Coordination Between Different Utility Service Providers*

Especially in project works, many agencies work together to provide different utility services. During installation, to avoid conflicts in space to be utilized and also possible damages to the work executed, planning is necessary. For this, various activities of different agencies should be listed and compiled. These activities shall be properly put together in an orderly manner. A bar-chart of coordinated activities shall be prepared and monitored.

4.4 Architectural Requirements

In line with **4.1.1**(b) drawings shall show location, layout, constructional details related to ventilation, fire prevention, routes of cables, clearances between other services, for example, clearance between underground electric cable and gas pipe line; provisions for movement of heavy apparatus like transformer, as elaborated under following points. These provisions shall be in confirmation with electrical consultant/contractor.

4.4.1 *Location*

Sub-station shall comprise consumer's transformer(s) along with allied apparatus, cabling and also supplier's apparatus like supply controlling device, metering equipment as well. Following points shall be considered for deciding the location:

a) *Deciding Location for Supplier's Apparatus* — It shall be checked if supplier's consent is necessary to decide the location to install his apparatus, which will facilitate 24/7 access to the concerned personnel, without any hindrance. Depending on site conditions, location may be adjacent to or away from owner's sub-station.

b) *Deciding Location of Consumer's Transformer Sub-station* — Capacity of sub-station, type of transformer – dry/oil filled, surface of building/structure in the vicinity, transportability, are some of the factors from which suitable location can be decided. Apart from this, load barycenter, distribution and its layout deciding and length, size of LV distribution cables also influence location of the sub-station.

NOTE — While deciding location, data of mean sea level, maximum flood level shall be taken from the local authority. To survive under possible disaster, transformer sub-station shall be at safe location considering possibility of threats of submergence under natural

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calamity. In respect of transformer location within residential and commercial buildings directives as given under Regulation 44 of CEA (measures relating to Safety and Electric Supply) Regulations shall be taken into consideration.

4.4.2 *Layout/Construction Plan/Cable Routing*

a) As per the regulations segregated provision to install supplier's control gear/RMU, metering unit from the consumer's sub-station is necessary. So, adequate provision of shed/room shall be done as per the Supply Code approved by Regulatory commission.

b) Depending on indoor or outdoor sub-station; electrical consultant/contractor shall provide constructional, structural load related requirements, to the architect. In respect of external layout; details about yard boundaries, earth stations, adequate passage for movement of equipment, and clearances from other structures, shall be given. For indoor installation, constructional details shall include door openings, ventilation*, cable duct, oil drain arrangement, and oil soak pit, within/located away from the transformer, depending on oil content [*see* CEA Reg. 44, IS 10028 (Part 2) and IS/IEC 61936-1].

Within the premises, routes of cables, depth below ground and required/clearances from other services shall also be informed. Related documents with mutual consent between the architect and the electrical consultant/ contractor shall be maintained as record.

4.4.3 *Fire Prevention, Life Safety Provisions*

Considering fire hazards likely to be initiated from the electrical apparatus/installation work; certain requirements have been specified in CEA Regulations, National Building Code, National Electrical Code of India and IS/IEC 61936-1. Out of these requirements, some relate to architectural plans, specifications and civil construction work. Architectural plans and specification shall include all related requirements in consultation with the electrical consultant/contractor.

4.5 Civil Work

Construction of sub-station, door opening, windows, cable duct/trench, oil drain arrangement, ramps, lifting facility, building material with fire rating as per F0/F1 class, structural stability, where required, shall be as per the drawings and specifications finalized by the architect and the electrical consultant/contractor.

5 ELECTRICAL DESIGN

5.1 Load Assessment

To decide capacity of transformer(s), necessary inputs shall be taken from the user. Further precise assessment of load shall be done. It shall include:

a) Aggregate load with bifurcation of resistive, inductive, non-linear load;

b) Additional load in near future; and

c) Type, behavior/pattern of load, anticipated daily and annual load cycle.

5.2 Selection and Installation of Equipment

5.2.1 Electrical power installations and equipment shall be capable of withstanding electrical, mechanical, climatic and environmental influences anticipated on site.

Site selection should take into account matters including, but not limited to:

a) Access to allow for construction, maintenance and operations activities;

b) Community impact including proximity to sensitive sites, visual, noise, amenity and traffic;

c) Environmental impact including consideration of pollution, ventilation, fauna and flora;

d) Impact of topography, earthquake zones, fault lines, flood paths, swamps, avalanches or landslides;

e) Soil conditions, including thermal and electrical resistivity and soil contamination; site dimensions;

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* Proper ventilation is very important point from point of view of trouble-free service during the service life. IS 10028 (Part 2) (*see* 7.3.1.6) specifies heat output for different capacities of transformer. Considering this and the maximum temperature limit as mentioned in IS 2026 (Part 2), or manufacturer's recommendations, considering air changes ventilation shall be considered.

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f) Line corridors; and
g) Site security.

5.2.2 The design shall take into account:

a) The purpose of the installation;
b) The user requirements such as power quality, reliability, availability, and ability of the Electrical network to withstand the effects of transient conditions such as starting of large Motors, short power outages and re-energization of the electrical power installation;
c) Load conditions, design short circuit currents, etc.;
d) The safety of the operators and the public;
e) The environmental influence; and
f) The possibility for extension (if required) and maintenance.

The user shall define preferences for specific maintenance features and identify the safety requirements to be met for levels of segregation of the switchgear and control gear to ensure minimal plant shutdown. Where necessary, the levels of segregation of switchgear shall be such as to minimize the spread of a fault, including a fire, occurring in any defined module into adjacent modules. There are operating conditions of low occurrence or low cumulative duration which can occur and for which specific design criteria and measures required to maintain safety conditions and to avoid damage to electrical or plant equipment are subject to agreement between the supplier and user. The generators shall be capable of meeting the requirements for connection to the power system grid or local grid, for example, voltage regulation, frequency response, etc.

For the fundamental requirements of selection and erection refer 4 of IS/IEC 61936-1.

6 INSTALLATION

6.1 Transformer

Requirements for indoor and outdoor transformers including clearances shall be in accordance with 8.7.2 of IS/IEC 61936-1.

6.2 Earthing System

Requirements for earthing system shall be in accordance with 10 of IS/IEC 61936-1.

7 FIRE PREVENTION

Requirements for provisions on Protection against fire shall be in accordance with 8.7 of IS/IEC 61936-1.

8 VERIFICATION AND TESTING

Requirements for verification shall be in accordance with 11 of IS/IEC 61936-1.

9 OPERATION AND MAINTENANCE MANUAL

Requirements for operation and maintenance manual requirements shall be in accordance with 12 of IS/IEC 61936-1.

10 DOCUMENTATION

Requirements for documentation shall be in accordance with 7.1.3 of IS/IEC 61936-1.

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NATIONAL ELECTRICAL CODE OF INDIA

PART 3 LOW-VOLTAGE ELECTRICAL INSTALLATIONS — REQUIREMENTS FOR SPECIAL INSTALLATIONS OR LOCATIONS

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PART 3 LOW-VOLTAGE ELECTRICAL INSTALLATIONS — REQUIREMENTS FOR SPECIAL INSTALLATIONS OR LOCATIONS

FOREWORD

This Part 3 of the code covers the requirements for electrical installations for special purposes and at special locations. It can also be classified as electrical installations in non-industrial buildings. The requirements for electrical installations in industrial buildings has been detailed in Part 4 of the code. While a majority of installations could be categorically classified as non- industrial, an industrial complex would necessarily incorporate sub-units such as offices, residential quarters and support services which are either housed or fall in the category of non-industrial buildings. The requirement stipulated in Part 3 and Part 4 of this Code would therefore require judicious application.

With the current trend in power utilization, it would also be extremely difficult to classify electrical installations based on power requirement or the voltage of supply, as large buildings for non-industrial purposes consume sufficient power to consider them at par with the consumption of light industrial establishments. It is therefore necessary to consider for initial assessment of the installation the guidelines given in Part 1/Sec 8 this Code, which are better defined than the earlier terminology used for classifying installations. Also, this part specifies the requirements for installations in certain special purposes like supplies for electrical vehicles and furniture that require special attention for safety and ease of usability.

Part 3 of this Code, therefore covers requirements for several types of special applications and non-industrial occupations. In case of typical occupancies that strictly fall into any of these, recourse shall be made to the general guidelines stipulated in Part 1.

This Part consists of the following Sections:

Section 1 Domestic dwellings

Section 2 Locations containing a bath or shower

Section 3 Swimming pools and fountains

Section 4 Rooms and cabins containing sauna heaters

Section 5 Construction and demolition site installations

Section 6 Conducting locations with restricted movement

Section 7 Caravan parks, camping parks and similar locations

Section 8 Marinas and similar locations

Section 9 Medical locations

Section 10 Exhibitions, shows and stands

Section 11 Furniture

Section 12 Extra-low-voltage lighting installations

Section 13 Community facilities and workplaces

Section 14 Electrical installations in caravans and motor caravans

Section 15 Supplies for electric vehicles

Section 16 Operating or maintenance gangways

Section 17 Temporary electrical installations for structures, amusement devices and booths at fairgrounds, amusement parks and circuses

Section 18 Heating cables and embedded heating systems

Section 19 Office building, shopping and commercial centres and institutions

Section 20 Hotels

Section 21 Sports buildings

Section 22 Specific requirements for electrical installations in multistoried buildings

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SECTION 1 DOMESTIC DWELLINGS

FOREWORD

This section will give guidelines particularly in respect of Electrical Installations in Domestic Dwellings. The portion in this section shall be read with Part 1 Section 9 Wiring Installations. The recommendations given here under are to call for specific attention primarily to provide safe electrical environment from the point of view of users having no age band, who are uninstructed, with whom one cannot expect to have any technical knowledge and capability to identify possible electrical threats/hazards. Another point to consider is designing layouts, selecting fittings in respect of lighting, ventilation, power outlets to suite needs of such users at home; not for any particular period of day like office hours but for round the clock, which will provide comfort, ease of operation and convenience.

1 SCOPE

This standard (Part 3/Sec 1) covers issues related to Electrical Installation from design to testing, commissioning, handing over and further maintenance in respect of domestic dwellings.

NOTE — Domestic Dwellings cover bungalows, row-houses, apartments/flats, *chawls*, hutments used for residential purpose, but do not include lodges, hotels, hostels, dormitories; for which Part 3/Sec 20 shall apply. Also, it does not include special provisions in respect of multi-storeied buildings, for which Part 3/Sec 22 shall be referred.

2 REFERENCES

2.1 Statutory Provisions

Section 53 of *Electricity Act,* 2003 dealing with 'Protecting Public from Dangers of Electricity'.

Central Electricity Authority (Measures related to Safety and Electric Supply) Regulations, 2010, with further amendments.

2.2 Standards

IS No.	*Title*
4648 : 1968	Electrical layouts in residential buildings
3646 (Part 2) : 1966	Code of practice for interior illumination
15707 : 2006	Testing evaluation installation and maintenance of a.c. electricity meters
8061 : 1976	Code of practice for design, installation and maintenance of service lines up to and including 650 V
SP 7 : 2016	National Building Code
SP 72 : 2010	National Lighting Code

3 TERMINOLOGY

For the purpose of this section, the definitions given in Part 1/Sec 2 and Part1/Sec 9 of this Code shall apply.

4 GENERAL AND COMMON ASPECTS OF ARCHITECTURAL DESIGN, PLANNING AND CIVIL CONSTRUCTION WORK FROM THE PERSPECTIVE OF ELECTRICAL INSTALLATIONS AND CHARACTERISTICS

4.1 Civil and Architectural Aspects

The objective of this section is to highlight needs of required base of infrastructure, related to architectural and civil planning and coordination. To consider electrical needs, appointment of electrical consultant/contractor is necessary from planning stage, so that question of incorrigible mistakes will not arise. The important points to be considered are given below;

a) Routes and service entry points;
b) Electrical meter rooms;

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c) Shafts/ducts;
d) Interior design;
e) Aesthetics and electrical safety;
f) Ceiling fans
g) Exhaust fans;
h) Fire rating;
j) Wall thickness;
k) Water leakages/seepages;
m) Bathrooms/washrooms; and
n) Earthing.

For details 4 of Part 1/Sec 9, shall be referred.

4.2 Environment

The following environmental factors shall apply to electrical installations in domestic dwellings:

Environment	*Characteristics*	*Remarks*
(1)	(2)	(3)
Presence of water	Probability of presence of water is negligible	—
Presence of foreign solid bodies	The quantity or nature of dust or foreign solid bodies is not significant	—
Presence of corrosive or polluting substances	The quantity and nature of corrosive or polluting substances is not significant	Applicable for most of the locations except for dwellings situated by sea or in industrial zone in which case categorization AF2 applies (*see* Part 1/Sec 8)
Mechanical stresses	Impact and vibration of low severity	Household and similar conditions
Seismic effect and lighting		Depends on the location of the building

4.3 Utilization

The following aspects utilization shall apply:

Utilization	*Characteristics*	*Remarks*
(1)	(2)	(3)
Capability of persons	Uninstructed persons	Applies to all domestic installations
Contact of persons	Persons in normally situations	
Conditions of evacuation during emergency	Low density occupation, easy conditions of evacuation	Buildings of normal or low height used for one or two family dwellings
	Low density occupation, difficult conditions of evacuation	Apartment houses including high-rise flats
Nature of processed of stored material	No significant risks	

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5 ELECTRICAL DESIGN, INSTALLATION

5.1 *General*

Electrical design, layouts and installation shall be done keeping following points in mind on the basis of priority.

a) Safety;
b) Functionality;
c) Ease of operation; and
d) Aesthetics.

While designing layouts sustainability under respective environment, situation from the point of view of domestic installations is important, e.g. distance/clearing to be maintained between heat generating appliances in kitchen. Another point is requirements of user and perspective of architect in respect of electrical fixtures and appliances. Electrical consultant or contractor has to provide wiring installation to suit these requirements within the framework of codes and safety norms, hence role of electrical contractor/consultant begins from initial planning stage.

5.2 Electrical Contractor, Consultant

5.2.1 *Appointment*

To avoid conflicts between electrical and civil work, aesthetics and electrical safety norms, ascertain related provisions of spaces, constructional requirements, avoid last time corrective measures/adjustments (which sometimes may turn out to be impossible to correct), appointment of chartered electrical safety engineer/licensed electrical contractor is necessary from initial stage. Under the circumstances of any conflict between civil and electrical work, it shall be seen that the problem gets resolved under mutual agreement without compromising safety.

5.2.2 *Flawless Design*

User/occupant being uninstructed person and not expected to have technical knowledge, is not allowed by law to interfere with electrical installation. Under urgency and in absence/unavailability of electrician user shall not attempt to resolve problem. This situation may arise due to frequent trouble arising out of defective installation. Therefore, it is important point to have sufficient experience specific to such type of installations to the electrical designer/consultant, so that the electrical installation will be safe and trouble free.

5.3 Wiring Systems

Wiring systems have been given under **5.3** of Part 1/Sec 9. Broadly wiring may either be surface type or concealed. Point to note here is in surface wiring it is easy to make and accommodate after thought changes. In case of concealed type wiring since the subsequent changes are difficult, involve breakages, likely to contradict predetermined values of load on circuits; prior decision or anticipations in respect of interior layout is very important.

5.4 Material and Selection

Material shall conform IS specifications and certified accordingly. Selected material shall be sustainable under the situation and possible external influences as mentioned under **5.4** of Part 1/Sec 9.

5.4.1 *Cables*

It is recommended to use FRLSH/HFFR grade copper cables for internal wiring installation. Size of wires shall be selected correlating to current carrying capacity as per situation (*see* **5.5** of Part 1/Sec 9) and shall not be less than that recommended under Table 1. The current carrying capacity shall be net after considering all de-rating factors, for example, maximum allowable voltage drop (*see* **5.7** of Part 1/Sec 9).

NOTES

1 It shall be noted that there is vast difference in current carrying capacity of conductor of same size, depending situation, reference method of installation (*see* **5.5.2** of Part 1/Sec 9); which may reduce the capacity to 50 percent. So size shall be carefully selected.

2 Class 1/2 conductor shall preferably be used for fixed wirings.

5.4.2 *Wire Enclosures - conduits/Trunking*

For surface type wiring, conduits or trunking (also known as casing and capping) may be used. However, trunking shall not be used where it is likely to be get concealed including areas above false ceiling. For concealed wiring selection of metal/non-metal PVC conduits shall be made depending on situation. PVC trunking or conduits shall be FR grade and conduits shall have High Mechanical Strength (HMS) or at least Medium Mechanical Strength

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(MMS). Metal conduits shall be selected where mechanical damages are likely to occur, for example, places may to get infected with rodents like voids/areas above false ceiling. Size shall be so selected that after drawing of wires 50 percent area will remain free. (for details *see* clause **5.9** from Part 1/Sec 9).

5.4.3 *Accessories and Boxes*

There is wide scope to select accessories to suite aesthetic needs. But selection shall be done considering sustainability under respective environment and class of user. Delicate, press-fit type accessories may not survive under rough use. Boxes may be metallic or non-metallic for metal conduits preference shall be given to metal boxes. Non-metal boxes shall be FR grade. Plug sockets if positioned below 1.2 m from floor level, shall be shuttered type only.

5.4.4 *Fittings/Fixtures/Appliances*

Lighting fixtures shall be capable to give desired lumen output, suite functional requirements and human comfort in respect of CCT, CRI and glair index. Preference shall be given to BEE star rated fittings. Heat dissipation factor shall also be considered with respect to location/base on which fitting is to be installed.

5.5 Installation

5.5.1 *Wire Enclosures and Routing*

Routing of conduits/trunking shall be near and parallel to the edges of wall. Considering single phase distribution, separate enclosure shall be used for each phase (in case of three phase supply). Also, other wire enclosures of extra low voltage systems, for example, telephone, data, sound system, CCTV, control cables of automation, shall be separate with adequate spacing in between. In kitchens, from the point of view of safety, routes shall not conflict with gas pipelines/heat generating devices.

NOTE — For concealed type wiring work must be planned and coordinated with the activities of civil work.

5.5.2 *Switch-boards*

Followings points shall be noted in respect of switch-boards for general lighting, switch-boards for power outlets, and special purpose switch-boards.

NOTE — Locations of switch-boards have been recommended in general, however additional safety and accessibility must be considered from the point of view of children and disabled persons.

5.5.2.1 *Switch boards-lighting*

Location of general light and fan switch boards shall be positioned close to door frame and on opposite side of hinged edge of door, so that a person while entering can have immediate access to switch board. If a room has two doors; lighting control shall be provided on switch boards located near both doors. For the purpose use of two way switches may be made. General height shall be reachable and 1.2 m above ground level.

NOTE — It is recommended to provide a onboard 6A plug socket outlet on every lighting switchboard which insures availability of neutral and earth, which is required when additional board/extension is needed in future, which is possible if within limit of allowable loadcpoints on that circuit.

5.5.2.2 *Switch boards – power outlets*

Plug outlet boards for shall be located as near as possible from the position/proposed/anticipated location of appliance to avoid mess of loose hanging/suspended cords. If position of switch-board is above top of table/platform; it shall be 150 mm above the surface of table/platform top. Plug outlets if required at lower level shall be 200 mm above finished floor level and such plug sockets must be shuttered type. For wall mounted a.c. units suitable height may be above lintel level.

5.5.2.3 *Switch boards – specific to utility area*

Following additional points may be considered in respect of switchboard installation depending use of room/area.

a) *Hall/living room* — Additional switchboard may be provided adjacent to and accessible from sitting location for particular light/fan/plug outlet/charging point.

b) *Kitchen* — Location of power outlets shall be above working platform adjacent to the actual/anticipated position of appliance and shall not be behind the appliance. Special care shall be taken in respect of heat generating devices to maintain safe distance.

c) *Bedrooms* — Switchboards with two way controls for light fan shall be provided adjacent to bed location but not behind head position and shall be accessible from both ends of double bed. There shall be points for night

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lamp/path light, reading lights and plug outlet for mobile phone/laptop charging. A switchboard shall also be provided near dressing mirror for light and plug outlets portable appliances like hair dryer.

d) *Passages/staircase* — Location shall be at entry/start point. Switchboards with two way control may be provided at both ends depending on distance/convenience.

e) *Terrace/balcony* — If sitting arrangement is considered plug outlets shall be provided adjacent to sitting area. Considering location of festive lamps/decoration, provisions of plug outlets at suitable location but safe from weather effects shall be made.

f) *Wet areas - bathrooms/toilets* — Boards shall be located away from area where there are chances of splashing of water. Preference shall be given to provide a switchboard immediate outside the door so that switch can be operated before entering and at the time of leaving, considering difficultly in locating switchboard in dark. Switchboard for mirror light above washbasin and plug outlet for appliance like electric razor shall be adjacent to mirror.

5.5.3 *Distribution*

Proper distribution is the basis of safe and trouble free electrical installation. Following guidelines will help to design the distribution.

5.5.3.1 *Circuits for lighting load*

Lighting load comprising lights, fans, 6A plug on boards shall be separated from power load. There shall be an independent lighting circuit for:

a) Each room, access of which is controlled by door (attached balcony/terrace may be included within the circuit of room);

b) Common areas, for example, passages, verandah;

c) Toilets; and

d) External lighting.

NOTE — Maximum points on any lighting circuit shall not exceed 24 or load shall not exceed 1 000 W. Provision of separate circuit shall be done if the load exceeds. Refer 5.6 for consideration of load.

5.5.3.2 *Circuits for power load*

There shall be independent circuit for:

a) Air-conditioner;

b) Water heater;

c) Oven/cooking range having load 2k W or above;

d) Washing machine/dishwasher having load 2k W or above; and

e) EV charging.

Maximum points of 16A shall not exceed 2 or load shall not exceed 3000 W on each circuit. Provision of separate circuit shall be done if the load exceeds.

5.5.3.3 *Circuits for Inverter/UPS used as standby electrical supply*

There shall be a separate circuit(s) comprising phase and neutral for the points to be provided on the supply from Inverter/UPS. Depending on load provision of separate DB may be necessary. Colour coding of such wires shall be brown/grey to identify the circuits easily. Neutral of such circuits shall not be looped anywhere with the points/circuits having no backup of inverter/UPS supply.

5.5.3.4 *Cables-size*

In domestic dwellings there are more occasions requiring additions and alterations in existing wiring installation due to purchases of new gadgets, changes in interior layouts. This may involve extra loading on the cables. Anticipating this aspect, it is desirable to consider one size higher for cables. For guidance, following table may be referred for considering minimum cross section of conductor.

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Table 1 Recommended Minimum Nominal Cross-sectional Areas of Conductor

(*Clause* 5.4.1)

Use	Size (2 + E) copper
Point wiring for light/fan/bell/independent plug 6A	1.5 mm^2
Branch circuit (DB to switch board) limited to total 10 points/800W	1.5 mm^2
Branch circuit (DB to 6/16A power outlets 2 Nos.) for general use or 1 No. independent point for Water heater/Microwave/OTG/Induction, total max. load 3 kW/circuit	2.5 mm^2
Branch circuit (DB to 16/25A power point 1 No.) e.g. A.C. 2TR/3TR total max. load 5kW/circuit.	4.0 mm^2
Mains/sub-mains for total connected load up to 5 kW	4 mm^2
Mains/sub-mains for total connected load > 5 kW and < 7 kW	6 mm^2
Mains/sub-mains for total connected load > 7 kW and < 10 kW	10 mm^2/4 mm^2 or 6 mm^2 (4 + E)*

* For 3-ph supply and load un-balance within 10 percent use 4 mm^2, if load un-balance likely to exceed, use 6 mm^2 (4+E)

NOTE — Mains for connected load equal to or above 10 kW; apply diversity factor, work out required current carrying capacity, find out suitable size from Annex C of Part 1 Section 9 and choose one size higher cable in anticipation of future additions.

5.5.3.5 *Neutral*

Neutral may be looped within respective circuit only. Size of neutral shall not be less than the phase conductor. Neutral shall not get individually isolated. For the purpose in single phase, SPN or DP and in three phase TPN or FP switches/MCBs shall be used.

5.5.3.5 *Cables – colour code*

Colour code shall generally follow norms specified in Part 1/Sec 9 for wiring installations. Circuit wires used for supply from inverter/standby supply arrangement shall be distinct.

5.5.3.6 *Marking/identification*

Ferruling shall be done with a mark of identification of circuit at every termination which shall also correspond to marking on DB.

5.5.3.7 *Provision of DB(s)*

Distribution board shall be of suitable type and size having required ways to accommodate number of circuits. Depending on expanse, provision of sub-distribution board/separate distribution board for lighting circuits and power circuits may be made. In case of three phase supply and single phase distribution DB with per phase isolation facility shall be preferred.

5.5.3.8 *Location of DB*

Location of distribution boards shall be in common areas like passages/lobby where entry is not restricted by lockable door. It shall be observed that, for easy operation and control during urgency/emergency, its position shall be within reach to an adult person without the aid of any tackle. Easy accessibility is also a mandatory requirement as per CEA safety regulations.

5.5.3.9 *MCBs*

Circuits having light, fan, on board plug socket shall be protected with 6A MCB. Circuits providing supply to more than two power outlets of 6A shall be protected with 6/10A MCB. Circuits providing supply to power outlets 16A up to two numbers, shall be protected with 16A MCB. Circuits providing supply to 25A power outlet shall be protected with 20/25A MCB. MCBs for lighting load may be of B series. MCBs for circuits of power outlets shall be B or C series depending on anticipated appliance going to be connected on that point, for example, motors, Air-Conditioners C series MCBs shall be provided.

NOTE — Use of old conventional Fuse/Kit-kat based DBs are not recommended for Domestic Dwellings from the point of view of safety, (*see* Note below **6.6.2** of Part 1/Sec 9).

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5.5.3.10 *Residual current devices (RCDs)*

As per CEA (Measures Relating to Safety and Electric Supply) Regulations, 2010 (as amended), it is mandatory to provide RCD of 30 mA sensitivity to every electrical installation of capacity 1 kW and above to protect person from electrical shock. However, considering aspect of life safety, it is recommended to provide RCD to all installations without considering band of minimum load of 1 kW. To maintain supply redundancy, avoid blackouts provision of number of RCDs may be made suitably on each phase/each DB or particular appliance. RCD having 300 mA sensitivity shall also be installed at point of supply to prevent possibility of fire arising out of leakages.

NOTE — RCDs are also known as RCCBs or ELCBs.

5.5.4 *Point Wiring-lighting*

5.5.4.1 *Recommended values of illumination*

Table 2 gives recommended values of illumination level. For further details refer SP 72 National Lighting Code.

5.5.4.2 *Recommended points*

Table 3 below shows recommended points on the basis of minimum functional requirement related to use and utility of the area. Actual requirement may vary to higher side.

Table 2 Recommended Levels of Illumination for Different Parts of Domestic Dwellings

(*Clause* 5.5.4.1)

Sl No.	Location	Illumination Level lux
(1)	(2)	(3)
i)	Entrances, hallways	100
ii)	Living room	300
iii)	Dining room	150
iv)	Bedroom:	
	a) General	300
	b) Dressing tables, bed heads	200
v)	Games or recreation room	100
vi)	Table games	300
vii)	Kitchen	200
viii)	Kitchen sink	300
ix)	Laundry	200
x)	Bathroom	100
xi)	Bathroom mirror	300
xii)	Sewing	700
xiii)	Workshop	200
xiv)	Stairs	100
xv)	Garage	70
xvi)	Study	300

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Table 3 Minimum Recommended Points as per Functional Requirement

(*Clause* 5.5.4.2)

Portion of Dwelling Unit	Light Point Per 10-12 m^2 or Part	Fan/ex Fan Point Per 10-12 m^2 or Part	Bell Point	Cable TV	Telephone
Hall/Living room	2	1		1	1*
kitchen/dining	2	1 + 1			
Bed room	4	1		1*	
bath/toilet	2	1			
passage/verandah	1				
balcony/terrace	1				
Entrance	1		1		
servant room/garage	2	1	1		
Dry balcony	1				

* Optional provision

NOTES

1 Depending on number of rooms and area of room points shall be worked out.

2 Depending on extent of area of dwelling unit, internal communication facility may be a necessity. Intercom with additional telephone points may be considered at other locations including bathrooms.

5.5.5 *Points – power Outlets 6A/16A/25A*

With the increasing use of domestic gadgets sufficient number of power points shall be provided considering future requirement. This provision at initial stage helps proper sizing of cables and protections, which at later stage often raise problems of undesirable overloading to which existing wiring installation is not designed.

Table 4 Recommended Power Outlets Depending on Anticipated Use of Appliance

(*Clause* 5.5.5)

Portion of Dwelling Unit	6A Power Outlet Per 10-12 m^2 Or Part	6/16A Power Outlet Per 10-12 m^2 or Part	20/25 A Power Outlet
Hall/Living room	6[a]	1[b]	
kitchen/dining	2[c]	4[d]	
Bed room	6[e]	1[f]	1[g]
bath/toilet	1[h]	1[i]	
passage/verandah	1[j]		
balcony/terrace	1[j]		
Entrance	1[j]		
servant room/garage	2[j]	1[j]	
Dry balcony or available space		1[k]	

[a] TV, set top box, music system/DVD, mobile charging, movable/portable gadgets
[b] General purpose, vacuum cleaner, room heater
[c] Water purifier, general purpose- small mixer
[d] Fridge, microwave/OTG, induction, mixer/grinder
[e] Two bedside tables, TV, Set top box, computer, printer
[f] General purpose- room heater
[g] A.C.
[h] General purpose-shaver/drier
[i] Water heater
[j] Festive lighting/general purpose
[k] Washing machine/dishwasher

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5.6 Load Consideration

For electrical design consideration of total connected load and diversity is important. Load can either be decided as custom requirement or anticipated/assessed general requirement.

5.6.1 For custom requirements tables 5 and 6 may be used to consider load depending on point of utility.

Table 5 Determination of Load of Lighting Points

(*Clause* 5.6.1)

Connected Device on the Outlet of Point Wiring	Load Consideration
Light point*	50 W
Fan point	75 W
Power outlet 6A	100 W
NOTES	
1* Light point may be utilized for a conventional incandescent lamp/tube light with ballast or single/group of LED lighting fixtures.	
2 Fan shall include all types/sweeps/exhaust.	
3 If actual rating of appliance is known, it may be taken into consideration subject to envisaged changes.	

Table 6 Determination of Load on Power Points

(*Clause* 5.6.1)

Commonly Connected Devices on the Outlet of Power Point	Load Consideration in W
Bathroom	
Storage type water heater	2000
Instant hot water geyser	3000
Dry balcony	
Washing Machine	2000
Dish washer	1500
Kitchen	
Electric Hot Plate	2000
Induction hot plate	2000
Electric oven	2000
Microwave	2000
Mixer/grinder	500
Fridge	500
Toaster/kettle	800
Air fryer	1500
Kitchen exhaust hood	350
Other	
A.C 1TR/1.5 TR/2 TR	1250/1500/2000
Room heater	1000
Computer	150
TV	100
Iron	800

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5.6.2 When there is no custom requirement, load may be considered on the basis of watts per m^2 of carpet area. For design purpose load for domestic dwellings may be considered as $75W/m^{2.}$

NOTE — Sometimes Supply Company may set parameters to consider load per unit area, while sanctioning. Under the circumstances higher value shall be considered.

5.7 Earthing

5.7.1 Important extracts of Mandatory Provisions under CEA Regulations :

Regulation 16

'the supplier shall be provide and maintain on the consumer's premises for the consumer's use, a suitable earthed terminal in accessible position at or near the point of commencement of supply'.

Further proviso states:

'*provided that in case of installation of voltages exceeding 250 V the consumer shall, in addition to the afore mentioned earthing arrangement, provide his own earthing system with an independent electrode.'*

Regulation 41

(x) no person shall make connection with earth by the aid of, nor shall he keep it.in contact with, any watermains not belonging to him except with the consent of the owner thereof and of the Electrical Inspector.

(xiv) all metal casing or metallic coverings containing or protecting any electric supply line or apparatus shall be connected with earth and shall be so joined and connected across all junction and other openings as to make good mechanical and electrical connection throughout their whole length:

Provided that conditions mentioned in this regulation shall not apply, where the supply voltage does not exceed 250 V and the apparatus consists of wall tubes or brackets, electroliers, switches, ceiling fans or other fittings, other than ,portable hand lamps and portable and transportable apparatus, unless provided with earth terminal and to class-II apparatus and appliances.

Provided further that where the supply voltage is not exceeding 250 V and, where the installations are either new or renovated, all plug sockets shall be of the three pin type, and the third pin shall be permanently and efficiently earthed.

Without prejudice to the above mandatory provision Owner shall get it verified periodically from the electrical agency that:

a) Connections with water or any other metallic line shall not be opted as earth connection.
b) All electrical appliances, fittings provided with earth terminal/3 pin plug are properly connected with earth.
c) Earthing is in good condition. And, wherever consumer has his/her own earth electrode it shall properly maintained and tested at least once in a year during summer value of which shall not exceed 2 ohms.
d) Under the multiple neutral earthing system, if suppliers neutral is earthed in consumer's premises, consumer's earth electrode shall maintain distance of at least 3 m. In case of multiple consumers, Earth Bus shall be of adequate capacity to which individual consumer's earth conductor is connected. Such connections must be done with properly crimped lug duly tightened with nut bolt. Since copper conductor is recommended for wiring installations in domestic dwellings, preference may be given to copper earth electrode and bus to avoid contact related issues between different metals. Under unavoidable conditions bimetallic lug shall be used.

5.8 Fans, Light fittings, Appliances

5.8.1 *Fans*

Provision of ceiling, exhaust and other fans shall be done in accordance with **9.2** of Part 1/Sec 9 of this code.

5.8.2 *Lighting Fixtures*

Provision of lighting fixtures shall be done in accordance with **9.1** of Part 1/Sec 9 of this code. Recommended illumination level may also be referred from IS 4648.

5.8.3 *Fixed and Portable Appliances*

For appliances other than class II, proper connectivity to earth shall be checked. Connections shall be through shielded cord only. Heat generating appliances/parts shall be safely located and shall be provided with suitable thermostat.

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5.9 Service Connections, Meters

Safety issues and maintenance of electrical service line, meter, switchgears, etc; at the point of supply/in meter room are the matters of individual as well as joint concerns of owner of dwelling and supplier of electricity. Following points shall be noted in this regard.

5.9.1 *Electrical Meter Rooms*

Meter rooms shall be separate. It shall be planned to have sufficient head room and clear space in front of meters, control switches (at least 1m). Space on wall shall be sufficient to accommodate required number of meters at such height that readings can be taken without aid of any tackle. Also the switchgears shall be at least 0.5 m above floor level and within such height to have an easy access for operation. The meter room shall be well ventilated, protected from external influences like sun, rain, water seepages, entry of rodents. Location of meter room shall be suitably adjacent or nearest to cable duct/shaft/vertical route of mains.

5.9.2 *Supplier's Obligations*

Regulation 13 and 14 of CEA Regulations gives mandate in respect of responsibilities of supplier and consumer as below:

'13(1) The supplier shall ensure that all electric supply lines, wires, fittings and apparatus belonging to him or under his control, which are on a consumer's premises, are in a safe-condition and in all respects fit for supplying electricity and the supplier shall take precautions to avoid danger arising on such premises from such supply' lines, wires, fittings and apparatus'.

'13(2) Service lines placed by the supplier on the premises of a consumer which are underground or which are accessible shall be so insulated and protected by the supplier as to be secured under all ordinary conditions against electrical, mechanical, chemical or other injury to the insulation,

14, Switchgear on consumer's premises.- (1) The supplier shall provide a suitable switchgear in each conductor of every service line other than an earthed or earthed\ neutral conductor or the earthed external conductor of a concentric cable within a\ consumer's premises, in an accessible position and such switchgear shall be contained within an adequately enclosed fire-proof receptacle:

Provided that where more than one consumer is supplied through a common service line, each such consumer shall be provided with an independent· switchgear at the point of rigid junction to the common service,

5.9.3 *Owner's Obligations*

'13(3) The consumer shall, as far as circumstances permit, take precautions for the safe custody of the equipment on his premises belonging to the supplier'. 'The consumer shall also ensure that the installation under his control is maintained in a safe condition'.

6 TESTING AND HANDING OVER

Before handing over installation to the owner for use, Electrical Contractor shall carryout tests and perform visual checks as per the guidelines given under **10** of Part 1/Sec 9. Handing over to the owner shall be done with proper documentation as given below.

6.1 Documents shall be Handed Over to Owner

Owner shall be provided with documents as listed below. These documents shall be kept for record and will be of importance when work of additions/alteration/modifications involves in future.

6.1.1 Electrical service connection details relating to sanctioned/connected load.

6.1.2 Copy of test report of the electrical installation given by electrical contractor.

6.1.3 Single line diagram of electrical installation.

6.1.4 Instructions/trouble shooting chart in respect with the use, limit of maximum load, operation, safety of Electrical Installation and precautions to be taken while making changes in existing installation.

6.1.5 Emergency contacts in respect with any possible problem with Electrical Installation.

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6.1.6 Wiring details of the house showing the conduits, wires in each conduit with circuit identification, pull boxes, junction boxes, switchboxes, fittings, earthing wire routing, etc at their proper locations should also be handed over to facilitate easy tracing of wires in case required.

6.2 Documents to be Handed over to Society/Association/Building Committee of Owners

Following documents related with common electrical installation(s) shall be handed over.

6.2.1 Load sanctioned letter of electric supply company.

6.2.2 Electrical service connection details in respect of common energy meters sanctioned/connected load, security deposit paid.

6.2.3 Single line diagram from the tapping point of service cable to the point of supply (incoming terminal of consumers switch/MCB installed near energy meter.

6.2.4 Copy of test report of the electrical installation given by electrical contractor in respect of electrical installation connected on common meters.

6.2.5 Copies of the approvals/permissions/licenses received from the respective authority; instructions, liabilities and responsibilities;

INFORMATIVE NOTE — Under the set of documents, owner/stakeholders of domestic dwelling(s) are also required to possess following NOCs, permissions, licenses, instructions, liabilities, etc; which respective agency shall handover; some of which do not come under the scope of this section.

a) Generating set/s (CEA Reg. 32);
b) High-rise building (CEA Reg. 36);
c) HT installation (CEA Reg. 43); if installation is owned by consumer/s;
d) Lift/s (Rule 5, Mah. Lift Rules);
e) Warranties/Guarantees and initial AMCs of Lift/s, Generating set, UPS and batteries and also in respect of installation handed over to Supply Company etc. as per applicable;
f) Instructions in respect of maintenance and operation of water pump, Lift and handling emergency. Telephone numbers of emergency services;
g) List of liabilities, responsibilities to be undertaken:
    1) Maintaining electrical installation (related to common facilities like lights, water pump, fire-fighting equipment), in good condition so as to cause no danger.
    2) Renewing AMCs in respect of generating set, lifts after defect liability period. Due dates shall be given.
    3) Safeguarding electrical installation belonging to supply company in the premises, for example, equipment in meter room.
    4) Communicating electrical inspector within 24 h in respect of any electrical accident.
    5) Any electrical related work to be got done only through license/permit holder person.

7 MAINTENANCE

Proper maintenance is a key to safety, trouble free use, operation and longevity. Even though installation is working smoothly, periodical testing/inspection from the authorized person/Chartered Electrical Safety Engineer is recommended. Periodicity of which shall preferably shall not be more than three years. In respect of portable appliances PAT (Portable Appliance Test) shall be performed (*see* **10.2.2** under Part 1 Section 9). RCD shall be tested every month with the push button provided on it, for confirmation of proper functioning.

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SECTION 2 LOCATIONS CONTAINING A BATH OR SHOWER

FOREWORD

The combination of water and electricity can create dangerous and unintended paths of electrical current. Depending on the amount of current, the duration of exposure, and the current path through the body, electrical exposures can result in a broad range of injuries, from minor tingling to severe burns or death.

This section shall cover the requirements for construction and installation of electrical wiring, and other equipment that could be used in locations containing a bath or shower.

For the purpose of this part of NEC Part 3/Sec 2, the requirements of IS 732 : 2019 and shall apply. This Part 3/Sec 2 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3/Sec 2 parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of the general parts of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

The particular requirements of this section (Part 3/Sec 2) of NEC apply to electrical installations in indoor or outdoor locations where a bath tub and/or a shower is intended to be permanently placed in a specific location.

The extent of the location containing a bath tub and/or a shower is limited by:

a) the lowest finished floor level;

b) a horizontal plane 3 m above the lowest finished floor level;

c) a vertical circumscribing virtual surface at a distance of 4 m from the fixed water outlet for the bath tub or shower; and

d) the volume within the walls, floor and ceiling that border the location containing a bath or shower, measured to a depth of 6 cm.

NOTES

1 Where the shower head and flexible hose are detachable, the fixed water outlet is taken to be at the supply end of the flexible hose.

The requirements of this document also apply to fixed electrical installations in mobile applications, for example caravans, mobile homes, shower containers. This document does not apply to emergency facilities, for example emergency showers used in industrial areas or laboratories.

2 For locations containing a bath or shower for medical treatment, special requirements can be necessary.

3 For prefabricated bath and/or shower units, *see* also IEC 60335-2-105.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC Standard	*Title*
732 : 2019	Code of practice for electrical wiring installations
IEC 60335-2-105	Household and similar electrical appliances — Safety — Part 2-105: Particular requirements for multifunctional shower cabinets
IEC 61558-2-5	Safety of transformers, reactors, power supply units and combinations thereof — Part 2-5: Particular requirements and test for transformer for shavers, power supply units for shavers and shaver supply units
302 (all parts)	Safety of household and similar electrical appliances

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3 TERMINOLOGY

For the purposes of this document, the following terms and definitions apply.—

3.1 Location — Particular place or position

EXAMPLE — A dedicated room, an area of a room (for example, area in a loft), an outdoor area.

3.2 Bath Tub — Basin for the total or substantial immersion of the human body in water, which is intended to be drained after every use.

3.3 Shower — Defined place intended for personal cleaning activity under a spray of water without intentional retention of the water.

3.4 Fixed Partition — Solid barrier or enclosure, including any integrated doors, with some portion attached to the building structure that will deflect water directed against its surface.

NOTES

1 Integrated doors are considered to be closed.

2 A curtain is not a fixed partition.

4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1.5.5 *Assessment of general characteristics*

4.1.5.5.101 *General*

When applying this document, the zones specified in **4.1.5.5.102**, **4.1.5.5.103**, and **4.1.5.5.104** shall be taken into account. For fixed prefabricated bath or shower units, the zones are applied to the situation when the bath or shower basin is in its intended configuration.

Fixed partitions including horizontal or inclined ceilings, walls with or without windows, doors, floors, may limit the extent of locations containing a bath or shower as well as their zones. Where the dimensions of fixed partitions are smaller than the dimensions of the relevant zones, for example partitions having a height lower than 225 cm, the minimum distance in horizontal and vertical direction shall be taken into account (*see* Fig. 2 to Fig. 9).

Shower curtains or equivalent flexible material shall not be used for limiting the zones.

Where a shower is located in zone 1 of a bath tub, the zones for a bath tub apply.

Where for showers there is more than one fixed water outlet, the limit of the zones to be considered are those given by the combination of the zones.

4.1.5.5.102 *Description of zone 0*

Zone 0 is limited:

a) by the interior of a bath tub, *see* Fig. 2 to Fig. 4;
b) for showers:
   1) from the lowest finished floor level up to a horizontal plane at the height of 10 cm above; and
   2) by a vertical circumscribing virtual surface at a distance of 120 cm from the centre of the fixed shower head(s) and/or water outlet(s) limited by fixed partitions restricting the water to enter into the area on the other side of the partition (*see* Fig. 5, Fig. 6, Fig. **7**, Fig. 8 and Fig. 9).
   3) Shower doors intended to be closed when taking a shower are delimiting the zone 0, (*see* Fig. 10).

4.1.5.5.103 *Description of zone 1*

Zone 1 is limited:

a) for a bath tub by:
   1) the floor level below the bath tub;
   2) a horizontal plane lying 225 cm above the floor level below the bath tub or a horizontal plane corresponding to the highest fixed shower head, if any, or fixed water outlet, whichever is higher;
   3) the vertical virtual surface circumscribing the bath tub (*see* Fig. 2 to Fig. 4); and
   4) excluding zone 0.

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b) for showers by:
   1) the lowest finished floor level;
   2) a horizontal plane corresponding to the highest fixed shower head or fixed water outlet or the horizontal plane lying 225 cm above the lowest finished floor level, whichever is higher;
   3) the vertical circumscribing virtual surface at a distance of 120 cm from the centre of the fixed shower head(s) and/or fixed water outlet(s) limited by fixed partitions restricting the water to enter into the area on the other side of the partition;
   4) shower doors intended to be closed when taking a shower, if any, *see* Fig. 10; and
   5) excluding zone 0.

4.1.5.5.104 *Description of zone 2*

Zone 2 is limited:

a) for a bath tub by the:
   1) finished floor level;
   2) horizontal plane corresponding to the highest fixed shower head or fixed water outlet or the horizontal plane lying 225 cm above the finished floor level, whichever is higher; and
   3) vertical virtual surface at the boundary of zone 1 and the parallel vertical virtual surface at a distance of 60 cm from the zone 1 border (*see* Fig 2 to Fig. 4);
b) for showers, there is no zone 2. (*see* Fig. 5 to Fig. 10).

4.2 Protection Against Electric Shock

4.2.1 *General Requirements*

4.2.2 *Replace the Existing Text by the Following:*

The protective measure electrical separation shall only be used for:

a) circuits supplying one item of current-using equipment; or
b) one single socket-outlet.

The protective measure electrical separation for the supply shall not be applied for heating cables and embedded heating systems.

4.2.6 *Replace the existing text by the following:*

The protective measures of obstacles and placing out of reach, as specified in IS 732 : 2019, Annex B shall not be applied.

4.2.7 *Replace the existing text by the following:*

The protective measures of non-conducting location, earth-free local equipotential bonding and electrical separation for the supply of more than one item of current-using equipment, as specified in IS 732 : 2019, Annex C shall not be applied.

4.2.11 *Protective Measure: Automatic Disconnection of Supply*

4.2.11.3 *Requirements for fault protection*

4.2.11.3.1.2 *Protective earthing and protective equipotential bonding*

4.2.11.3.1.2.101 If no protective equipotential bonding in accordance with IS 732 : 2019, **4.2.11.3.1.2** exists, supplementary protective equipotential bonding in accordance with IEC 60364-4-41 : 2005 and IS 732 : 2019, **4.2.15.2** shall be installed within the location.

4.2.14 *Protective Measure: Extra-Low-Voltage Provided by SELV and PELV*

4.2.14.1 *General*

4.2.14.1.101 All electrical equipment installed in zones 0 and 1 shall have basic insulation capable of with standing a test voltage of 500 V a.c. RMS for 1 min.

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All electrical equipment installed in a zone 2 shall have:

basic insulation capable of withstanding a test voltage of 500 V a.c. RMS for 1 min; or

enclosures affording a degree of protection of at least IPXXB or IP2X.

4.2.15 *Additional Protection*

4.2.15.1 *Additional protection: residual current protective devices (RCDs)*

4.2.15.1.101 Except for circuits with protective measures "SELV or PELV" or "protection by electrical separation", additional protection by the use of one or more RCDs having a rated residual operating current not exceeding 30 mA shall be provided for:

circuits serving the location containing a bath tub and/or a shower;

circuits passing through zone 1 and/or zone 2 not serving this location.

5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.1 Common Rules

5.1.2 *Operational Conditions and External Influences*

5.1.2.2 *External influences*

5.1.2.12.101 *Erection of equipment according to external influences*

5.1.2.2.101.1 *General*

Electrical equipment that is likely to be exposed to water jets (e.g. for cleaning purposes) shall have a degree of protection at least IPX5. A higher degree of protection shall be considered if more severe conditions are expected.

Where electrical equipment extends in more than one zone, the requirements of the zone with the most onerous requirements apply.

EXAMPLE — For a luminaire extending from zone 1 to zone 2, the requirements of zone 1 apply.

For flush mounted electrical equipment in parts of walls, floor or ceilings limiting a zone, the requirements of that zone apply.

5.1.2.2.101.2 *Zone 0*

Only fixed current using equipment may be erected provided that the equipment:

complies with the relevant standard and is suitable for use in that zone according to the manufacturer's instructions for use and mounting;

is permanently connected;

is protected by SELV with a rated voltage not exceeding 12 V a.c. or 30 V d.c., with the source of supply installed outside of zones 0 and 1; and

has a degree of protection at least IPX7.

5.1.2.2.101.3 *Zone 1*

Only the following equipment may be erected:

a) current-using equipment protected by SELV or PELV with a rated voltage not exceeding 25 V a.c. or 60 V d.c., with the source of supply installed outside zones 0 and 1; or
b) socket-outlets of circuits protected by SELV or PELV with a rated voltage not exceeding 25 V a.c. or 60 V d.c., with the source of supply installed outside zones 0 and 1; or
c) fixed or stationary current-using equipment permanently connected and suitable for installation in zone 1 according to the manufacturer's instruction for use and mounting; or
d) junction boxes and fittings necessary for the supply of equipment installed according to a), b) and c).

Equipment shall have a degree of protection at least IPX4.

EXAMPLE — Equipment likely to be installed in zone 1 includes hot tubs, shower pumps, ventilation equipment, towel rails, water heating appliances, luminaires, washing machines, active glazing, infrared and ultraviolet emitters.

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5.1.2.2.101.4 *Zone 2*

Only the following equipment may be erected:

fixed current-using equipment, having a degree of protection of at least IPX4, that is permanently connected;

socket-outlets, having a degree of protection of at least IPX4, of circuits protected by SELV or PELV with the source of supply installed outside zones 0 and 1;

electrical accessories, other than socket-outlets, having a degree of protection at least IPX4, that are permanently connected;

shaver supply units according to IEC 61558-2-5. If the shaver supply unit is located such that direct spray from the shower is likely, it shall have a degree of protection of at least IPX4.

5.2 Wiring Systems

5.2.5 *Selection and Erection of Wiring Systems in Relation to External Influences*

5.2.5.3 *Presence of water (AD) or high humidity (AB)*

5.2.5.3.101 Wiring systems that do not supply equipment in zone 0 shall not be routed through zone 0.

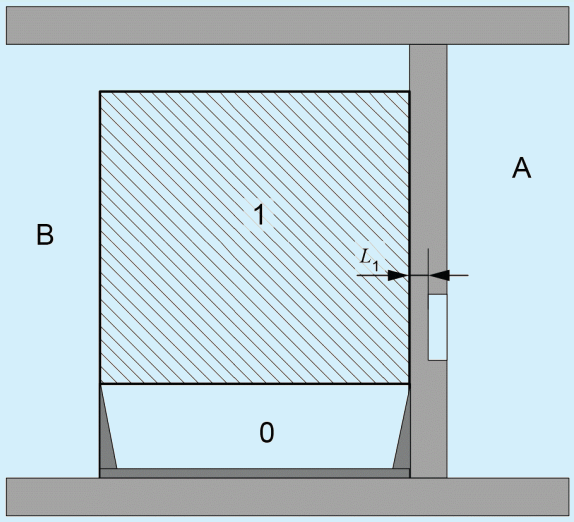
5.2.5.8 *Other mechanical stresses (AJ)*

5.2.5.8.101

NOTE — The following requirements are given to reduce the risk of damaging the wiring caused by drilling holes in the wall, for e.g., mounting handles.

The following requirements apply:

a) Wiring systems supplying current using equipment in zones 0, 1 or 2 and erected in parts of walls which are limiting these zones shall be mounted:



Key

0 Zone 0
1 Zone 1
A Other room
B Bathroom
L_1 Remaining wall thickness, minimum 6 cm

FIG. 1 REMAINING WALL THICKNESS BEHIND ZONES

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either vertically from above or horizontally through the adjacent wall on the rear of the appliance when the fixed equipment is mounted above the bath tub or shower basin, for showers without a basin above the surface of the finished floor level (e.g. water heating appliances);

either vertically rising from below or horizontally through the adjacent wall on the rear of the appliance when the equipment is placed in the space below the bath tub or shower basin.

b) All other embedded wiring systems including their accessories in parts of walls or partitions which limit a zone 0, 1 or 2 shall not be mounted at a depth less than 6 cm from the wall surface limiting the zone, *see* L_1 in Fig. 1.

c) Where a) or b) are not fulfilled, wiring systems may be erected either if:

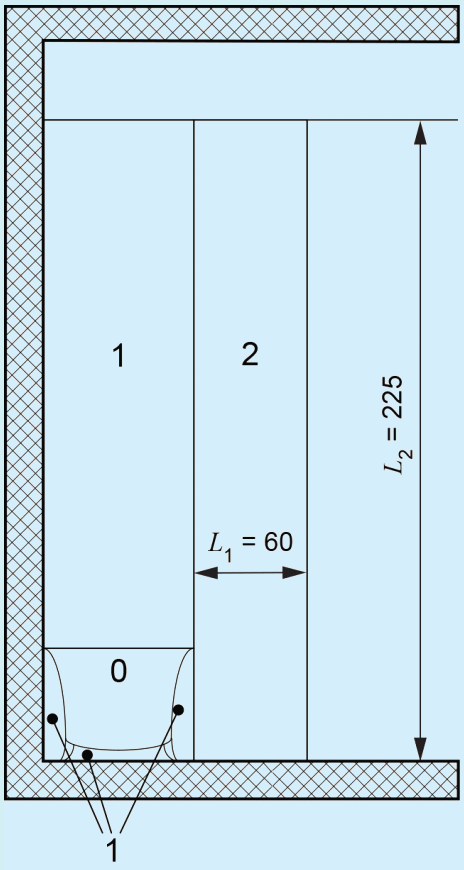
the circuits are protected either by one of the protective measures SELV or PELV or electrical separation; or

the circuits are protected by additional protection according to IS 732 : 2019, **4.2.15.1** provided by RCDs with a rated residual operating current not exceeding 30 mA; such circuits shall contain a protective conductor; or embedded cables incorporating an earthed screen or a metallic covering which complies with the requirements for a protective conductor of the circuit concerned are used; or the cables are enclosed in an earthed conduit, satisfying the requirements for a protective conductor.

5.3 Devices for Protection for Safety, Isolation, Switching, Control and Monitoring

5.3.2 *Devices for Protection Against Indirect Contact by Automatic Disconnection of Supply*

Dimensions in centimetres



Key

0 Zone 0
1 Zone 1
2 Zone 2

FIG. 2 DIMENSIONS OF ZONES: SIDE VIEW OF A BATH TUB

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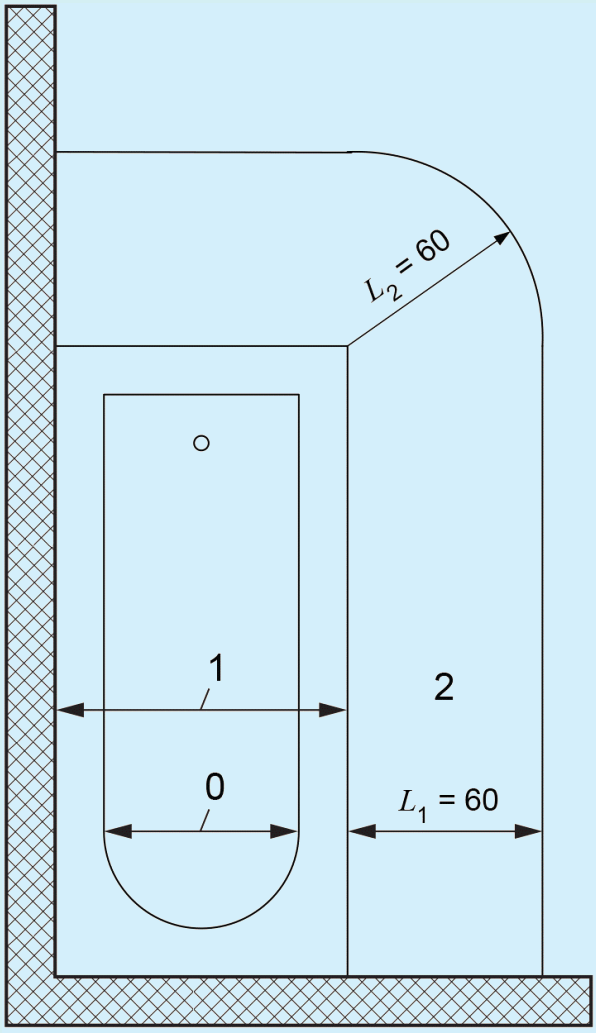
5.3.2.2 *Residual current protective devices*

The type of RCD selected for a circuit shall be compatible with the expected loads to be supplied (i.e. RCD of type a.c., type A, type F or type B).

5.3.2.2.101

101 EXAMPLES OF ZONE DIMENSIONS

Dimensions in centimetres



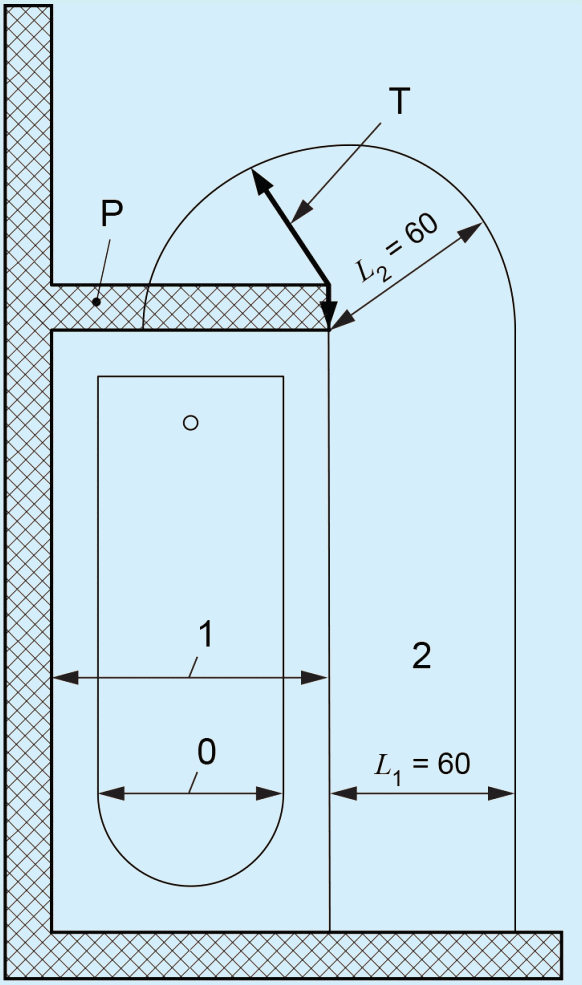
Key

0 Zone 0
1 Zone 1
2 Zone 2

FIG. 3 DIMENSIONS OF ZONES: TOP VIEW OF A BATH TUB WITHOUT PARTITION

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Dimensions in centimetres



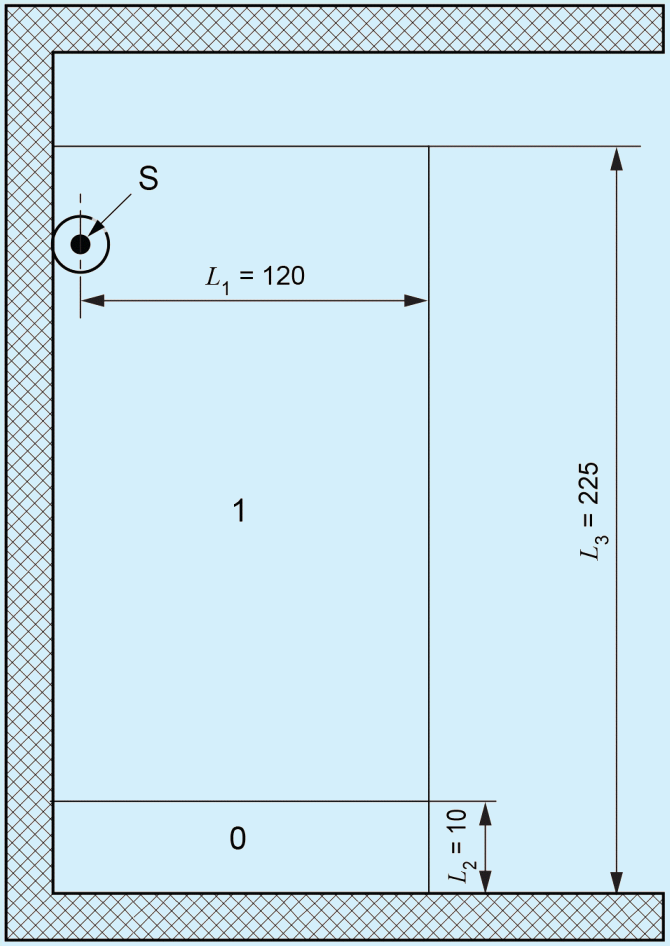
Key

0 Zone 0
1 Zone 1
2 Zone 2
P Fixed partition
T Thread gauge for minimum distance

FIG. 4 DIMENSIONS OF ZONES: TOP VIEW OF A BATH TUB WITH FIXED PARTITION

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Dimensions in centimetres



Key

0 Zone 0

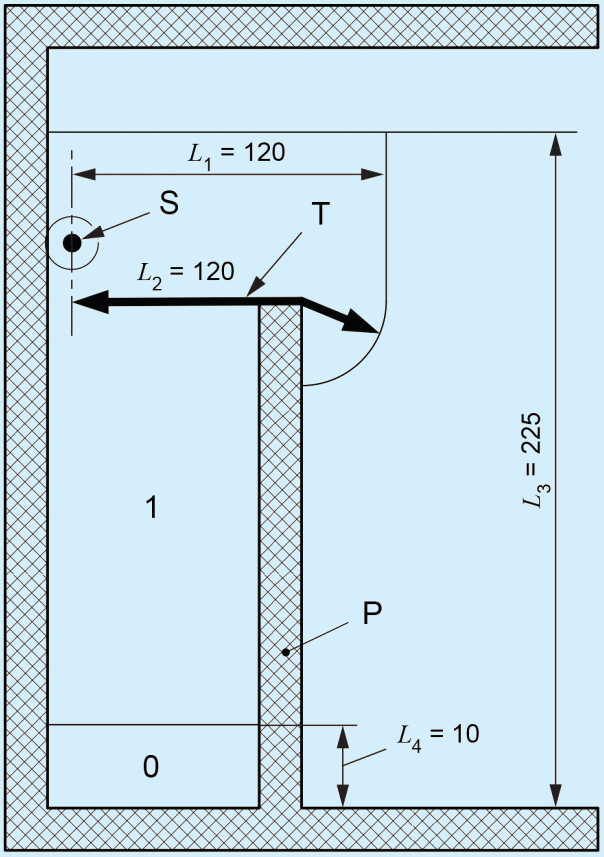
1 Zone 1

S Fixed water outlet

FIG. 5 DIMENSIONS OF ZONES 0 AND 1: SIDE VIEW OF A SHOWER

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Dimensions in centimetres



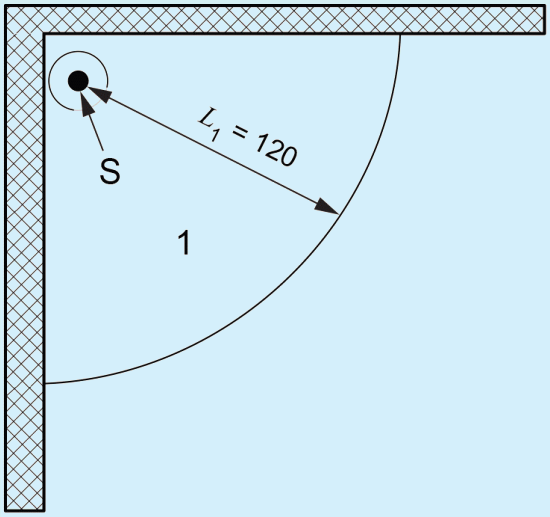
Key

0 Zone 0
1 Zone 1
P Fixed partition
T Thread gauge for minimum distance
S Fixed water outlet

FIG. 6 DIMENSIONS OF ZONES 0 AND 1: SIDE VIEW OF A SHOWER WITH FIXED PARTITION

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Dimensions in centimetres



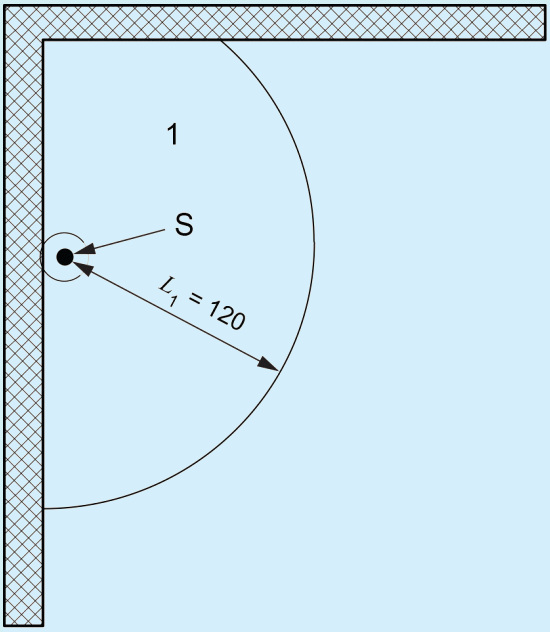
Key

1 Zone 1

S Fixed water outlet

FIG. 7 DIMENSIONS OF ZONES 0 AND 1: TOP VIEW OF A SHOWER WITH FIXED WATER OUTLET CLOSE TO A CORNER

Dimensions in centimetres



Key

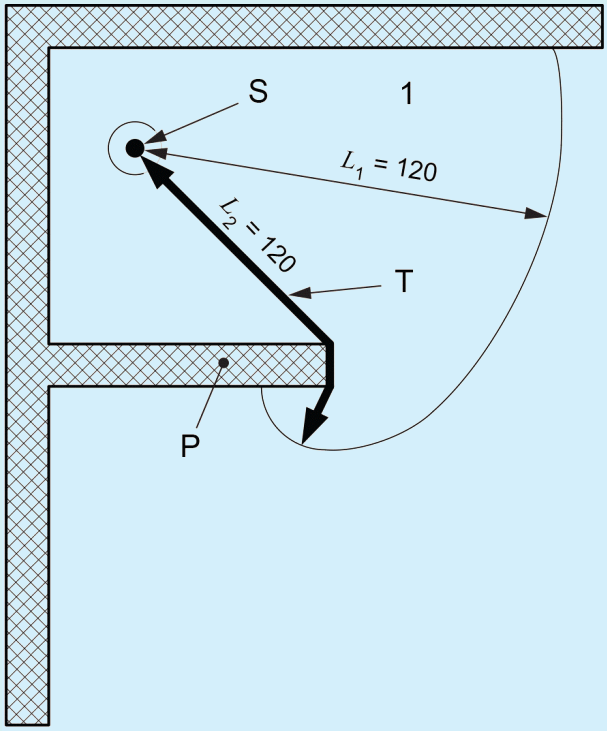
1 Zone 1

S Fixed water outlet

FIG. 8 DIMENSIONS OF ZONES 0 AND 1: TOP VIEW OF A SHOWER WITH FIXED WATER OUTLET AT A DISTANCE FROM A CORNER

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Dimensions in centimetres

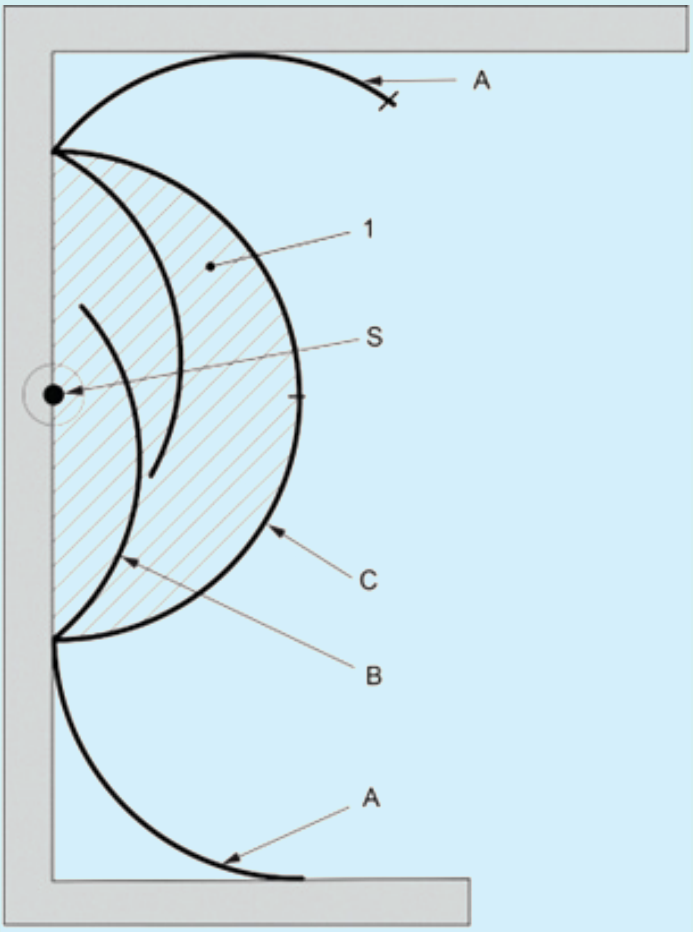


Key

1 Zone 0 and zone 1
P Fixed partition
T Thread gauge for minimum distance
S Fixed water outlet

FIG. 9 DIMENSIONS OF ZONES 0 AND 1: TOP VIEW OF A SHOWER WITH A FIXED PARTITION

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Key

1 Zone 0 and zone 1
A Opened shower door
C Shower doors when shower is in use
B Shower doors when shower is not in use
S Fixed water outlet

FIG. 10 EXAMPLE OF ZONE FOR SHOWER WITH DOORS

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SECTION 3 REQUIREMENTS FOR SWIMMING POOLS AND FOUNTAINS

FOREWORD

Swimming pools and fountains can be classified based on the extent of activity involved and the locations they are situated in. They generally utilise electricity for their functioning. The combination of water and electricity can create dangerous and unintended paths of electrical current. Depending on the amount of current, the duration of exposure, and the current path through the body, electrical exposures can result in a broad range of injuries, from minor tingling to severe burns or death.

This section shall cover the requirements for construction and installation of electrical wiring, and other equipment that could be used in swimming pools and fountains.

For the purpose of this part of NEC Part 3 Section 3, the requirements of IS 732 : 2019 and shall apply. This Part 3/Sec 3 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3/Sec 3 parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of the general parts of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

The particular requirements of this section of NEC apply to electrical installations of:

a) basins of swimming pools and paddling pools and their surrounding zones;

b) areas in natural waters, lakes in gravel pits and coastal and similar areas, specially intended to be occupied by persons for swimming, paddling and similar purposes, and their surrounding zones. Such areas in natural waters, lakes in gravel pits and coastal and similar areas, are considered as swimming pools;

c) basins of fountains and their surrounding zones.

NOTE — In these areas, in normal use, the effect of an electric shock is increased by a reduction in body resistance and contact of the body with earth potential.

For swimming pools for medical use, special requirements may apply.

This standard does not cover the use of mobile equipment, e.g. pool cleaning equipment.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC No.	*Title*
IEC 60364-7-702 : 2010	Low-voltage electrical installations — Requirements for special installations or locations — Swimming pools and fountains
IEC 60335-2-41	Household and similar electrical appliances — Safety — Part 2-41: Particular requirements for pumps
732 : 2019	Code of practice for electrical wiring installations
IS/IEC 60529 : 1989	Degrees of protection provided by enclosures (IP Code)
16205 (Part 1) : 2017	Conduit systems for cable management: Part 1 General requirements

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IS/IEC No.	*Title*
IEC 60245 (all parts)	Rubber insulated cables — Rated voltages up to and including 450/750 V
IEC 60598-2-18	Luminaires — Part 2: Particular requirements — Section 18: Luminaires for swimming pools and similar applications

3 TERMINOLOGY

For the purposes of this document, the following terms and definitions apply.

3.1 Fountain — Arrangement, typically for decorative purposes, where water issues from a source and fills a basin of some kind.

3.2 Basin of Fountain — Part of the fountain which collects discharged water.

3.3 Swimming Pool — Water basin designed for purposes such as swimming, diving, etc and not for personal cleaning activity.

3.4 Paddling Pool — Water basin with low water level, e.g. for playing or wading.

4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1.5.5 *Assessment of general characteristics*

4.1.5.5.101 *General*

Add the following:

The requirements of this part are based on the dimensions of three zones, zone 0, zone 1 and zone 2 as described in **4.1.5.5.102** to **4.1.5.5.104** (*see* Fig. A-1 to A-4).

For electrical equipment in parts of walls, floors or ceilings limiting the zones specified in **4.1.5.5.102** to **4.1.5.5.104** but being part of the surface of that wall, floor or ceiling, the same requirements that apply for the zone limited by the surface shall be fulfilled unless specific requirements exist (*see* **5.5**).

The width of zone 1 or zone 2 may be reduced by fixed partitions having a minimum height of 2.5 m.

The requirements for swimming pools also apply to paddling pools.

For basins of fountains which are intended to be occupied by persons, the specifications, and requirements for zone 0 and zone 1 for swimming pools apply.

NOTES

1 Fixed partitions are fixed separating walls, walls including windows and doors. The zones are also limited by ceilings, slopes of roofs and floors. Fixed partitions that are lower than 2.5 m are only limiting if they end at a ceiling or slope of a roof.

2 When a fixed partition is erected inside a zone, its effects on the zone are illustrated in Fig. A-3.

3 For the installation of a prefabricated swimming pool, the requirements of this standard are applicable.

4 Annex A provides some examples of the zones.

4.1.5.5.102 *Description of zone 0*

This zone comprises

a) the interior of basins, including any recesses in their walls or floors,
b) the interior of basins for foot cleaning, and
c) the interior of waterjets or waterfalls, and the space below them (*see* Fig. A-4).

NOTE — If the zone cannot be precisely determined under waterjets or waterfalls, it is recommended to take the vertical plane from the rim of the basin as the horizontal limitation of the zone and the maximum height of the water jet or waterfall as the limitation of height.

4.1.5.5.103 *Description of zone 1*

This zone is limited by

a) the zone 0 boundaries,
b) a vertical plane 2 m from the rim of the basin,
c) the floor or surface expected to be occupied by persons, and

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d) the horizontal plane 2.5 m above the floor or the surface expected to be occupied by persons.

NOTE — Inaccessible equipment installed in an enclosure below the surface of a floor or wall or above a ceiling is not considered to be within zone 1 (*see* **5.5.5.101.3)**.

Where the swimming pool contains diving structures, starting blocks, chutes or other components expected to be occupied or accessible by persons, zone 1 also comprises the zone limited by

a) a vertical plane situated 1.5 m around the diving boards, springboards, starting blocks, chutes and other components such as accessible sculptures and decorative basins,
b) the horizontal plane 2.5 m above the highest surface expected to be occupied by persons.

4.1.5.5.104 *Description of zone 2*

This zone is limited by:

a) the vertical plane external to zone 1 and a parallel plane 1.5 m from the former,
b) the floor or surface expected to be occupied by persons, and
c) the horizontal plane 2.5 m above the floor or surface expected to be occupied by persons.

There is no zone 2 for fountains.

NOTE — Inaccessible equipment installed in an enclosure below the surface of a floor or wall or above a ceiling is not considered to be within zone 2 (*see* **5.5.5.101.3**).

4.2 Protection Against Electric Shock

Add the following:

NOTES

1 For selection and erection of socket-outlets, *see* **5.3**.

2 For selection and erection of other equipment, *see* **5.5**.

4.2.1 *General Requirements*

4.2.6 Replace the existing by the following

The protective measures of obstacles and placing out of reach, as specified in Annex B of IS 732, shall not be applied.

4.2.7 Replace the existing by the following

The protective measures of non-conducting location, earth-free local equipotential bonding and electrical separation for the supply of more than one item of current-using equipment, as specified in Annex C of IS 732 shall not be applied.

4.1.101 *Particular Requirements For Each Zone*

Add the following:

4.1.101.1 *Zones 0 and 1 of swimming pools and in areas of natural waters, lakes in gravel pits and coastal and similar areas*

In zones 0 and 1 only protection by SELV at a nominal voltage not exceeding 12 V a.c. or 30 V d.c. is permitted, except where **5.5.104** applies. The source of supply shall be installed external to zones 0 and 1. Where the source of supply is installed in zone 2, **5.3** applies.

4.1.101.2 *Zones 0 and 1 of fountains*

In zones 0 and 1, only the following protective measures shall be employed:

a) SELV (*see* 4.2.14 of IS 732 : 2019), the source of supply being installed external to zones 0 and 1; or
b) automatic disconnection of supply (*see* 4.2.11 of IS 732 : 2019) using a residual current protective device with a rated residual operating current not exceeding 30 mA; or
c) electrical separation (*see* 4.2.13 of IS 732 : 2019), the separation source supplying a single item of equipment and being installed external to zones 0 and 1.

4.1.101.3 *Zone 2 of swimming pools and in areas of natural waters, lakes in gravel pits and coastal and similar areas*

NOTE — There is no zone 2 for fountains.

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One or more of the following protective measures shall be employed:

a) SELV (*see* 4.2.14 of IS 732 : 2019). The source of supply shall be installed external to zone 0 and 1. Where the source of supply is installed in zone 2, **5.3** applies; or

b) automatic disconnection of supply (*see* 4.2.11 of IS 732 : 2019) using a residual current protective device with a rated residual operating current not exceeding 30 mA; or

c) electrical separation (*see* 4.2.13 of IS 732 : 2019). The separation source shall supply a single item of equipment and be installed external to zones 0 and 1. Where the separation source is installed in zone 2, **5.3** applies.

4.2.14 *Protective Measure: Extra-Low-Voltage (SELV and PELV)*

4.2.14.4 *Requirements for SELV and PELV circuits*

Add the following in 4.2.14 of IS 732 : 2019

PELV is not permitted.

4.2.14.4.5 Add the following

Where SELV is used, whatever the nominal voltage, basic protection (protection against direct contact) shall be provided by:

a) barriers or enclosures affording at least the degree of protection according to IEC 60529 IP2X or IPXXB, or

b) insulation capable of withstanding a test voltage of 500 V a.c. for 1 min.

4.2.15 *Additional Protection*

4.2.15.2 *Additional protection: supplementary protective equipotential bonding*

Add the following:

All extraneous-conductive-parts in zones 0, 1 and 2 shall be connected by protective equipotential bonding conductors to the protective conductors of the exposed-conductive-parts of equipment situated in these zones.

NOTES

1 This connection with the protective conductor may be provided in close proximity to the location, for example at an accessory or a distribution board or other equipment.

2 *See* also **5.2.5.8** and **5.5.101**

Extraneous-conductive-parts are conductive parts not forming part of the electrical installation and liable to introduce an electric potential, including the electric potential of a local earth – for the scope of this standard, from outside zones 0, 1 and 2 into these zones.

3 Such parts may, for example, be

a) metallic pipelines for freshwater, waste water, gas, heating, climate control,

b) metallic parts of building construction,

c) metallic parts of the basin construction,

d) metal reinforcement of non-insulating floors,

e) metal reinforcement of concrete basins.

Floors made of individual concrete tiles, the reinforcement of which is fully encapsulated within the tile and not accessible without damaging the tile, are not considered as extraneous-conductive-parts and therefore need not be included in additional protective equipotential bonding.

Concrete tiles without metallic reinforcement, tile coverings and topsoil (e.g. lawn) are not considered as extraneous-conductive-parts and therefore need not be included in additional protective equipotential bonding.

4 The following conductive parts generally need not be included in additional protective equipotential bonding:

a) basin ladders and barriers;

b) diving structure ladders;

c) handrails and handholds on the rim of the basin;

d) grid covers including the mounting frames of overflow pipes;

e) window frames;

f) door frames;

g) starting blocks.

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5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.1 Common Rules

5.1.2.1 *Operational conditions*

5.1.2.2 *External influences*

Add the following:

Electrical equipment shall have at least the IP code (*see* IS/IEC 60529) according to Table 1.

Table 1 Minimum IP Number Per Zone

(*Clause* 5.1.2.2)

Zone	Outdoor, with Waterjets During Cleaning Operation	Outdoor, without Waterjets	Indoor, with Waterjets During Cleaning Operation	Indoor, Without Waterjets
0	IPX5/IPX8	IPX8	IPX5/IPX8	IPX8
1	IPX5	IPX4	IPX5	IPX4
2	IPX5	IPX4	IPX5	IPX2

NOTES

1 IS/IEC 60529 states that, unless there is a relevant product standard, the test conditions for IPX8 are subject to agreement between manufacturer and user.

2 For zone 0, where waterjets during cleaning operations are expected, both IPX5 (to ensure resistance to the operations during the cleaning process) and IPX8 (to ensure resistance to the immersion in the water) are necessary (*see* 4.3 of IS/IEC 60529). Both IPX5 and IPX8 are necessary because IPX8 does not include protection against water jets.

5.2 Wiring Systems

5.2.5 *Selection and Erection in Relation to External Influences*

5.2.5.8 *Other mechanical stresses*

Add the following:

5.2.5.8.101 *Erection according to the zones*

In zones 0, 1 and 2, wiring systems shall not have accessible metallic covering. Metallic coverings which are inaccessible shall be connected to the supplementary equipotential bonding.

NOTE — Cables should be installed in conduits to facilitate rewiring.

5.2.5.8.102 *Limitation of wiring systems according to the zones*

In zones 0 and 1, wiring systems shall be limited to those necessary to supply equipment situated in these zones.

Circuits erected in zone 2 or in walls, ceilings or floors delimiting zones 0, 1 or 2 and supplying equipment outside the zones shall be:

a) embedded at a minimum depth of 5 cm; or
b) protected by a residual current protective device with a rated residual operating current not exceeding 30 mA; or
c) supplied by SELV; or
d) protected by electrical separation.

5.2.5.8.103 *Additional requirements for the wiring of fountains*

Only cables of type 66 according to IEC 60245 series or a type with at least equivalent properties shall be used.

NOTE — Their suitability for permanent contact with water should be declared by the cable manufacturer in addition to compliance with IEC 60245-1 and IEC 60245-4.

Only conduit with classification code X5XX according to the resistance to impact in IS 16205-1/IEC 61386-1 shall be used.

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For fountains not intended to be occupied by persons the following additional requirements shall be met:

a) cables or insulated conductors in non-metallic conduit for electrical equipment in zone 0 shall be installed as far outside the basin rim as possible and run to the electrical equipment inside the basin by the shortest practicable route. The cables shall be installed in conduits to facilitate rewiring;
b) in zones 0 and 1, cables or insulated conductors in non-metallic conduit shall be installed with suitable mechanical protection.

5.2.5.8.104 *Junction boxes*

Junction boxes shall not be installed in zone 0.

In zone 1, only junction boxes for SELV circuits are permitted (*see* **4.1.101**).

5.3 Switchgear and Control Gear

Add the following:

In zone 0, no switchgear or control gear, including socket-outlets, shall be installed.

In zone 1, switchgear, control gear and socket-outlets may be installed only if supplied by SELV, the source of supply of which being installed outside zones 0 and 1. Where the source for SELV is installed in zone 2 its supply circuit shall be protected by a residual current protective device with a rated residual operating current not exceeding 30 mA.

In zone 2, switchgear, control gear and socket-outlets are not allowed unless protected by one of the following protective measures:

a) SELV (*see* 4.2.14.3 of IS 732 : 2019), the source of supply being installed outside zones 0 et 1. Where the source for SELV is installed in zone 2, its supply circuit shall be protected by a residual current protective device with a rated residual operating current not exceeding 30 mA; or
b) automatic disconnection of the supply with additional protection (*see* 4.2.15.1 of IS 732 : 2019), using a residual current protective device with a rated residual operating current not exceeding 30 mA; or
c) electrical separation (*see* 4.2.13 of IS 732 : 2019), supplied individually by the separation source which is installed outside zones 0 and 1. Where the source for electrical separation is installed in zone 2 its supply circuit shall be protected by a residual current protective device with a rated residual operating current not exceeding 30 mA.

5.5 Other Equipment

Add the following:

5.5.101 *Current-Using Equipment Of Swimming Pools*

5.5.101.1 In zones 0 and 1, only fixed current-using equipment especially designed for use in swimming pools may be installed, taking into account the requirements of **5.4.1.2** and **5.4.1.4**.**2**.

5.5.101.2 Fixed connected swimming pool cleaning equipment intended to be used in zones 0 and 1 shall be supplied by SELV not exceeding 12 V a.c. or 30 V d.c. with the source being installed outside zones 0 and 1. Where the source of supply is installed in zone 2, 5.3 applies (*see* **3.3.4.1.101.1**).

5.5.101.3 Feed pumps, or other special electrical equipment especially intended for use in swimming pools located in a room or location adjacent to the swimming pool and accessible via a hatch (or door) located on the deck surrounding the swimming pool, shall be protected by one of the following protective measures:

a) SELV not exceeding 12 V a.c. or 30 V d.c. with the source being installed outside zones 0 and 1. Where the source of supply is installed in zone 2, **5.3** applies (*see* **4.1.101.1**);
b) electrical separation according to 4.2.13 of IS 732 with simultaneous fulfilment of the following conditions:
    1) where the pump or other equipment is connected to the swimming pool basin, the connection shall only be made by non-conductive water piping;
    2) it shall only be possible to open the hatch or the door by means of a key or tool;
    3) all equipment installed in the room or location shall have a degree of protection of at least IPX5 or such protection shall be provided by an enclosure.

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c) automatic disconnection of the power supply with simultaneous fulfilment of the following conditions:
   1) where the pump or other equipment is connected to the swimming pool basin, the connection shall be made by either electrically insulated water piping, or metal water piping connected to the pool basin's equipotential bonding:
   2) it shall only be possible to open the hatch or the door by means of a key or tool;
   3) all equipment installed in the room or location shall have a degree of protection of at least IPX5 or such protection shall be provided by an enclosure;
   4) additional equipotential bonding shall be installed in accordance with **4.2.15.2**;
   5) the equipment shall be protected by a residual current protective device with a rated residual operating current not exceeding 30 mA.

NOTE — The room where the equipment is located is considered to be outside zones 1 and 2.

5.5.102 *Underwater Lighting of Swimming Pools*

Luminaires for use in the water or in contact with the water shall comply with IEC 60598-2-18.

Underwater lighting located behind watertight portholes and serviced from behind shall be installed in such a way that no intentional or unintentional conductive connection between any exposed-conductive-part of the underwater luminaires and any conductive parts of the portholes can occur.

5.5.103 *Electrical Equipment of Fountains*

Electrical equipment in zones 0 and 1 shall be inaccessible, e.g. by use of mesh glass or by grids which can be removed only by tools.

Electric pumps shall comply with the requirements of IEC 60335-2-41.

5.5.104 *Special Requirements for The Installation of Low Voltage Electrical Equipment in Zone 1 of Swimming Pools*

5.5.104.1 Fixed equipment (e.g. filtration systems, jet stream pumps), especially intended for use in swimming pools and supplied at low voltage, is allowed in zone 1 provided all the following requirements are met:

a) the equipment shall be located inside an enclosure equivalent to supplementary insulation and providing protection against mechanical impact AG2;
b) the requirements of **5.5.101.3** apply;
c) the opening of the hatch specified in **5.5.101.3** shall result in the disconnection of all live conductors of the equipment located in the enclosure. The supply cable and the main disconnecting means shall be installed in a way which provides protection of class II or equivalent insulation.

5.5.104.2 For swimming pools where there is no zone 2, lighting equipment supplied by circuits other than SELV not exceeding 12 V a.c. or 30 V d.c. (*see* **4.1.101.1**) may be installed in zone 1 on a wall or on the ceiling provided that both the following requirements are fulfilled:

a) the circuit is protected by automatic disconnection of supply and additional protection by using a residual current protective device with a rated operating current not exceeding 30 mA, and
b) the height of the lower part of the lighting equipment is at least 2 m from the lower limit of zone 1.

5.5.105 *Floor And Ceiling Heating Systems*

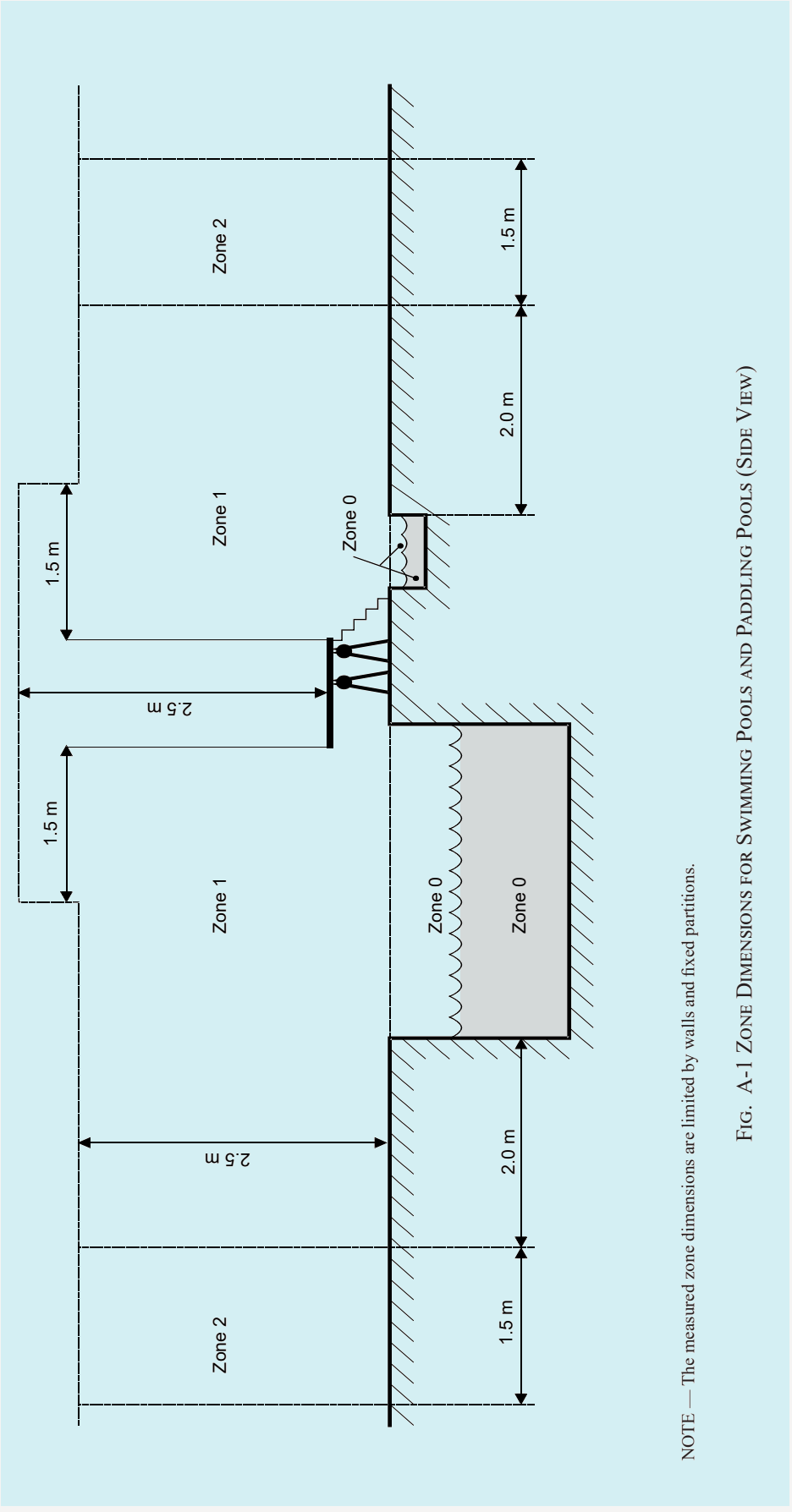
NOTE — *See* also IEC 60364-7-753.

Electric heating units embedded in the floor may be installed, provided that they are protected by either:

a) SELV (*see* 4.2.14 of IS 732 : 2019), the source of supply being installed outside zones 0 and 1. Where the source of supply is installed in zone 2, **5.6.5.5** applies; or
b) automatic disconnection of supply, the heating unit being covered by an embedded earthed metallic grid or by an embedded earthed metallic sheath connected to the supplementary equipotential bonding specified in **4.2.15.2** and the supply circuit being additionally protected by a residual current device with a rated residual operating current not exceeding 30 mA.

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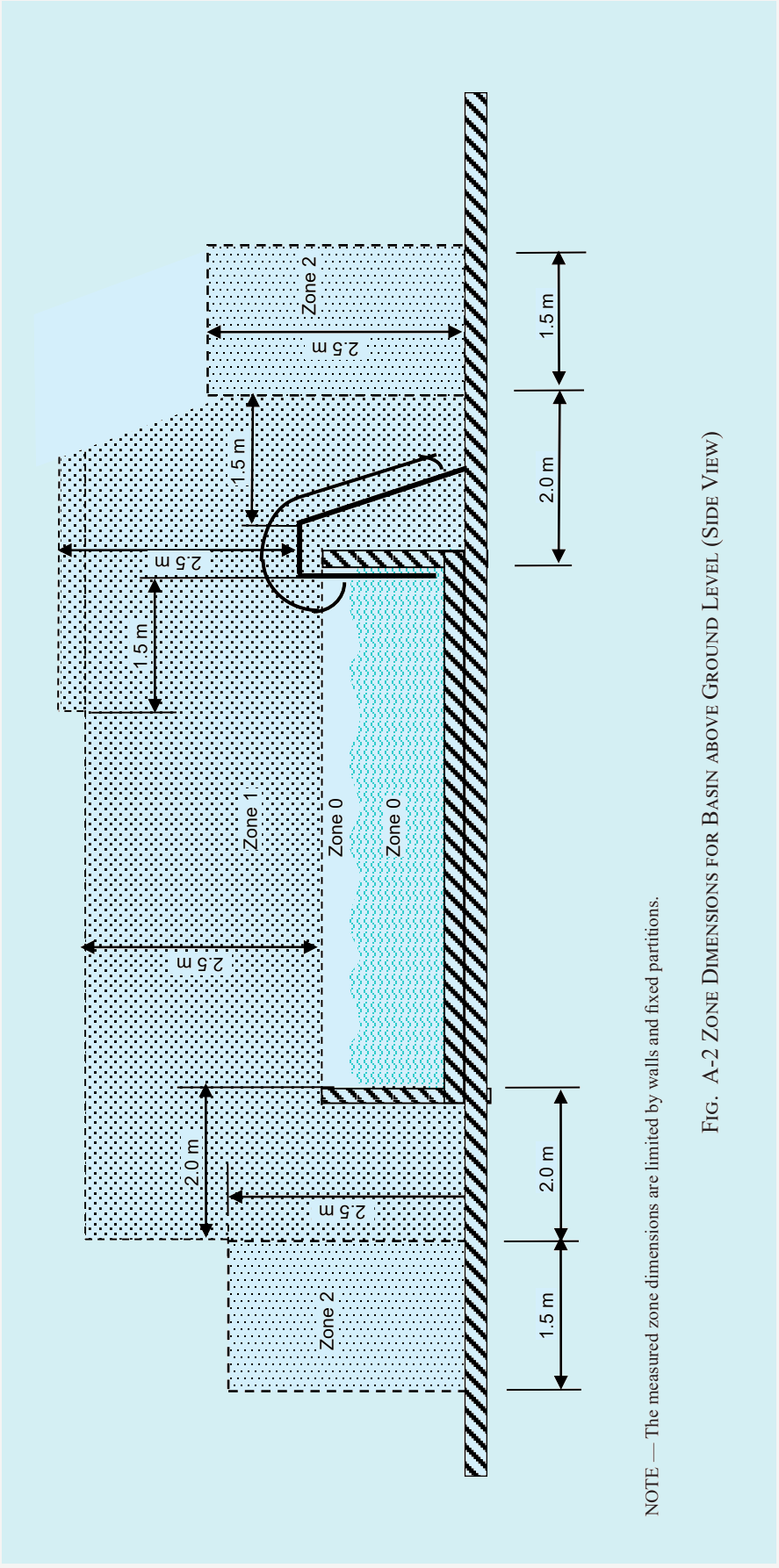
ANNEX A
(informative)
EXAMPLES OF ZONES



NOTE — The measured zone dimensions are limited by walls and fixed partitions.

FIG. A-1 ZONE DIMENSIONS FOR SWIMMING POOLS AND PADDLING POOLS (SIDE VIEW)

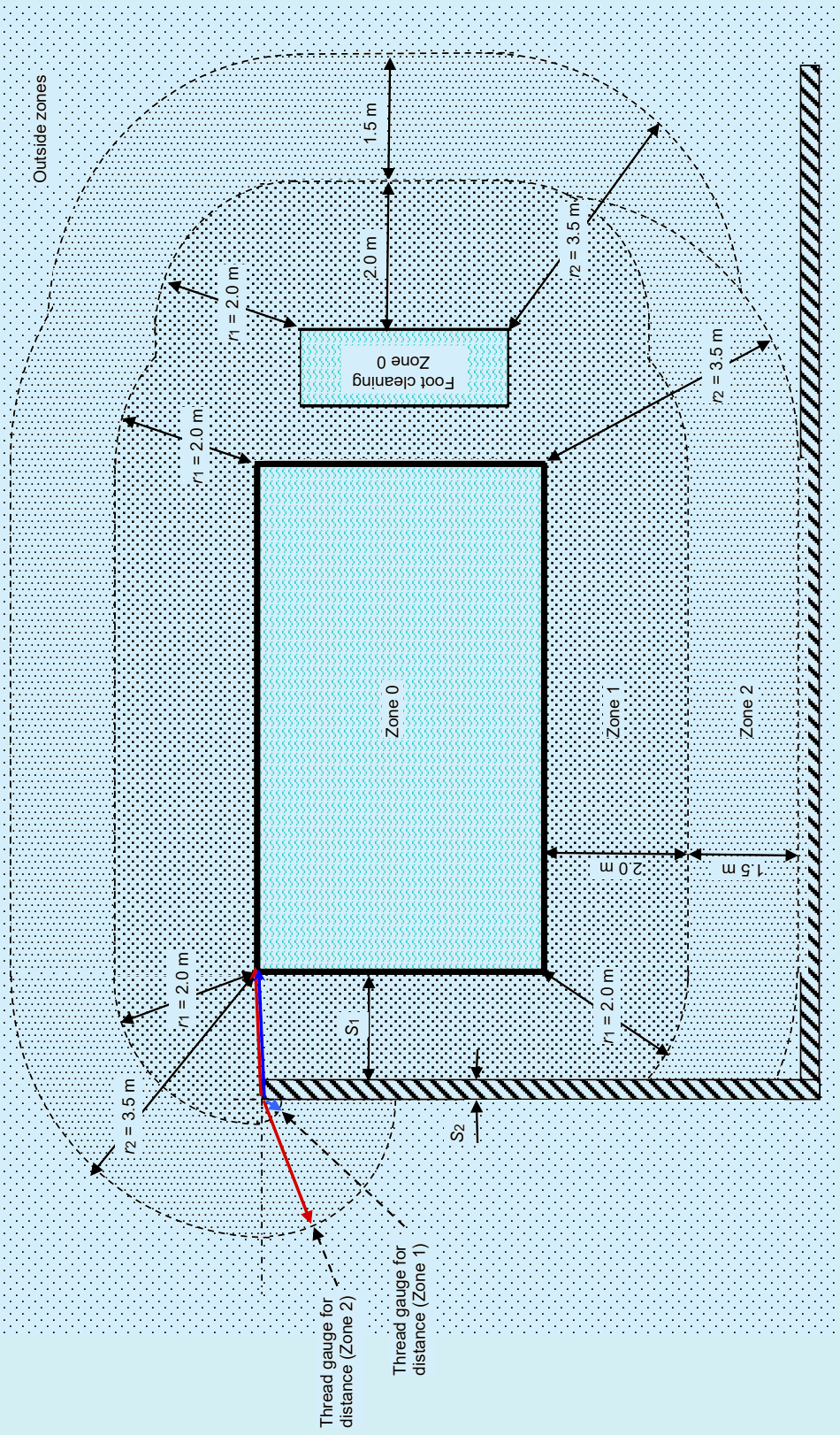
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NOTE — The measured zone dimensions are limited by walls and fixed partitions.

FIG. A-2 ZONE DIMENSIONS FOR BASIN ABOVE GROUND LEVEL (SIDE VIEW)

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NOTE — The thread gauge for distance could be, in this case, a string of specified length.

FIG. 3 EXAMPLES OF ZONE DIMENSIONS (TOP VIEW) WITH FIXED PARTITIONS OF HEIGHT AT LEAST 2.5 M

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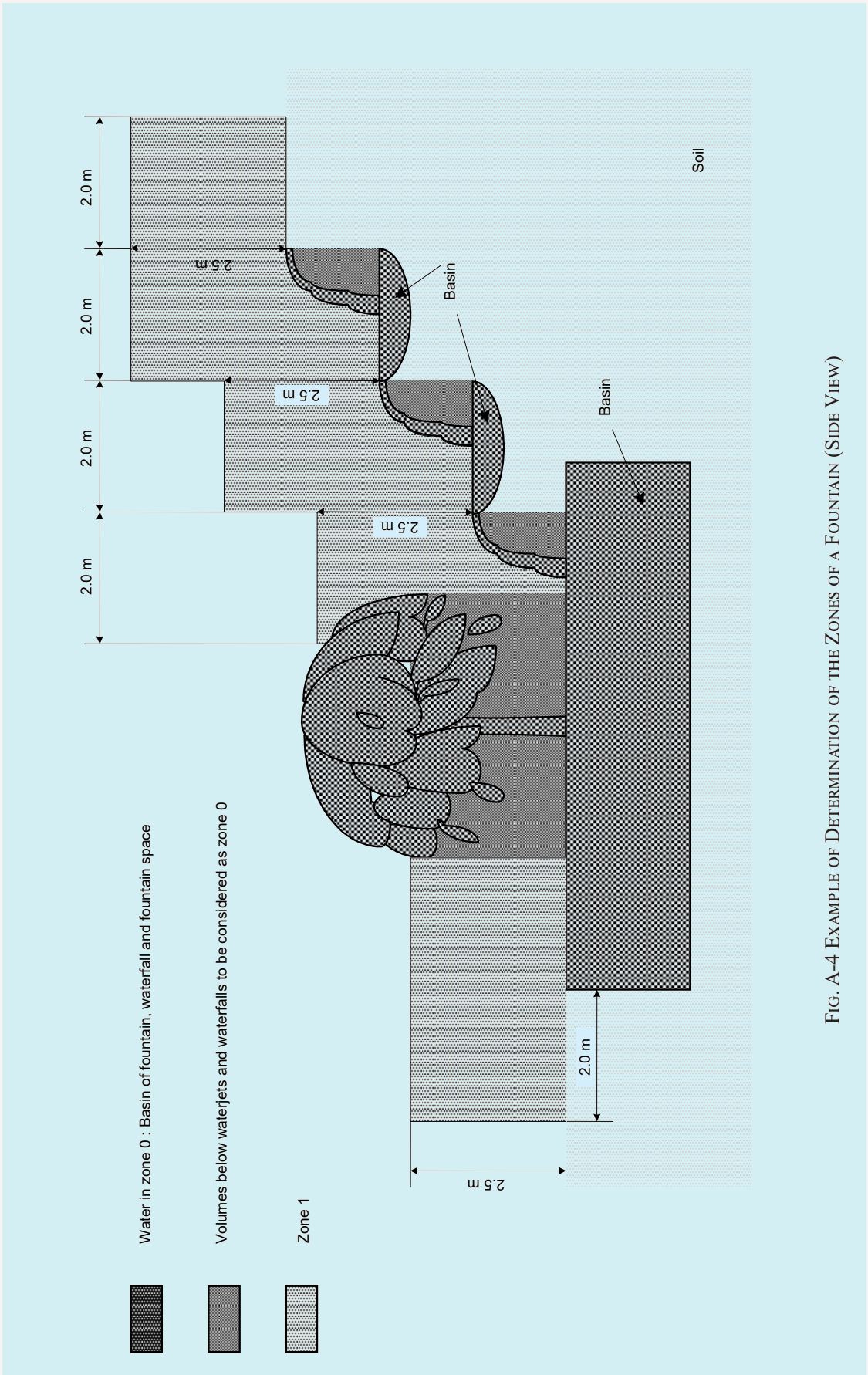


FIG. A-4 EXAMPLE OF DETERMINATION OF THE ZONES OF A FOUNTAIN (SIDE VIEW)

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SECTION 4 REQUIREMENTS FOR SPECIAL INSTALLATIONS OR LOCATIONS — ROOMS AND CABINS CONTAINING SAUNA HEATERS

FOREWORD

Rooms and cabins containing sauna heaters are considered as special locations necessitating distinct electrical requirements because of the increased electric shock risk associated with, extreme high temperatures with high humidity, lack of clothing and reduced skin resistance. This section shall cover the requirements for construction and installation of electrical wiring, and other equipment that could be used in locations containing sauna heaters.

For the purpose of this part of NEC Part 3/Sec 4, the requirements of IS 732 : 2019 shall apply. This Part 3/Sec 4 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3/Sec 4 parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of the general parts of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

The particular requirements of this section (Part 3/Sec 4) of NEC apply to:

a) sauna cabins erected on site, for example, in a location or in a room.

b) the room where the sauna heater is, or the sauna heating appliances are installed. In this case the whole room is considered as the sauna.

They do not apply to prefabricated sauna cabins complying with a relevant equipment standard.

Where facilities like cold water basins or showers, etc. are installed, the requirements of Part 3/Sec 2 also apply.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC Number	*Title*
732 : 2019	Code of practice for electrical wiring installations
NEC Part 3/Sec 2	National Electric Code: Part 3 Requirements for special installations or locations. Section 2 Locations containing a bath or shower
IEC 60335-2-53	Household and similar electrical appliances — Safety — Part 2-53: Particular requirements for sauna heating appliances

4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1.5.5 *Assessment of general characteristics*

4.1.5.1.1 *General*

When applying this standard, the zones specified in **4.1.5.11.1** to **4.1.5.11.3** shall be taken into account.

4.1.5.11.1 *Description of Zone 1*

Zone 1 is the volume containing the sauna heater limited by the floor, the cold side of the thermal insulation of the ceiling and a vertical surface circumscribing the sauna heater at a distance 0.5 m from the surface of the sauna heater. If the sauna heater is located closer than 0.5 m to a wall, then zone 1 is limited by the cold side of the thermal insulation of that wall.

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4.1.5.11.2 *Description of zone 2*

Zone 2 is the volume outside zone 1, limited by the floor, the cold side of the thermal insulation of the walls and a horizontal surface located 1.0 m above the floor.

4.1.5.11.3 *Description of zone 3*

Zone 3 is the volume outside zone 1, limited by the cold side of the thermal insulation of the ceiling and walls and a horizontal surface located 1.0 m above the floor.

4.2 Protection for Safety – Protection Against Electric Shock

4.3.2.3.11 Protection against direct contact shall be provided for all electrical equipment by:

a) barriers or enclosures affording a degree of protection of at least IPXXB or IP2X, or
b) insulation capable of withstanding a test voltage of 500 V a.c. r.m.s for 1 min.

4.1.2.1 *Protection against direct contact*

4.1.2.1.101 *Obstacles*

Protection against direct contact by means of obstacles is not permitted.

4.1.2.1.102 *Placing out of reach*

Protection against direct contact by placing out of reach is not permitted.

4.2.11.3.3 *Additional protection by residual current protective devices (RCDs)*

Additional protection shall be provided for all circuits of the sauna, except for the sauna heater, by the use of one or more residual current protective devices with a rated residual operating current not exceeding 30 mA.

4.1.2.2 *Protection against indirect contact*

4.1.2.2.101 *Non-conducting location*

Protection against indirect contact by using the protective measure: non-conducting location is not permitted.

4.1.2.2.102 *Protection by earth-free local equipotential bonding*

Protection against indirect contact by using the measure: earth-free local equipotential bonding is not permitted.

5 SELECTION AND ERECTION OF EQUIPMENT – COMMON RULES

5.1.2.2 *External influences*

The equipment shall have at least the degree of protection IP24.

If cleaning by use of water jets may be reasonably expected, electrical equipment shall be at least IPX5.

Three zones are defined as shown in Fig. 1:

a) in zone 1: only equipment belonging to the sauna heater shall be installed;
b) in zone 2: there is no special requirement concerning heat resistance of equipment;
c) in zone 3: the equipment shall withstand a minimum temperature of 125 °C and the insulation of wires shall withstand a minimum temperature of 170 °C (*see* also **5.2** below for wiring).

5.2 Selection and Erection of Electrical Equipment – Wiring Systems

The wiring systems should be preferably installed outside the zones, that is, on the cold side of the thermal insulation. If the wiring system is installed in zone 1 or 3, that is, on the warm side of the thermal insulation, it shall be heat-resistant according to **5.1.2.2** of this section. Metallic sheaths and metallic conduits shall not be accessible in normal use.

5.3 Selection and Erection of Electrical Equipment – Isolation, Switching and Control

5.3.7.6 *Functional switching (control)*

Switchgear and controlgear which forms part of the sauna heater equipment or of other fixed equipment installed in zone 2, may be installed within the sauna room or cabin according to the manufacturer's instructions. Other switchgear and controlgear, for example, lighting, shall be placed outside the sauna room or cabin. Socket-outlets shall not be erected within the location containing the sauna heater.

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5.5 Other Equipment

Sauna heating appliances shall be installed according to manufacturer's instructions, *see* 7.12.1 of IEC 60335-2-53.

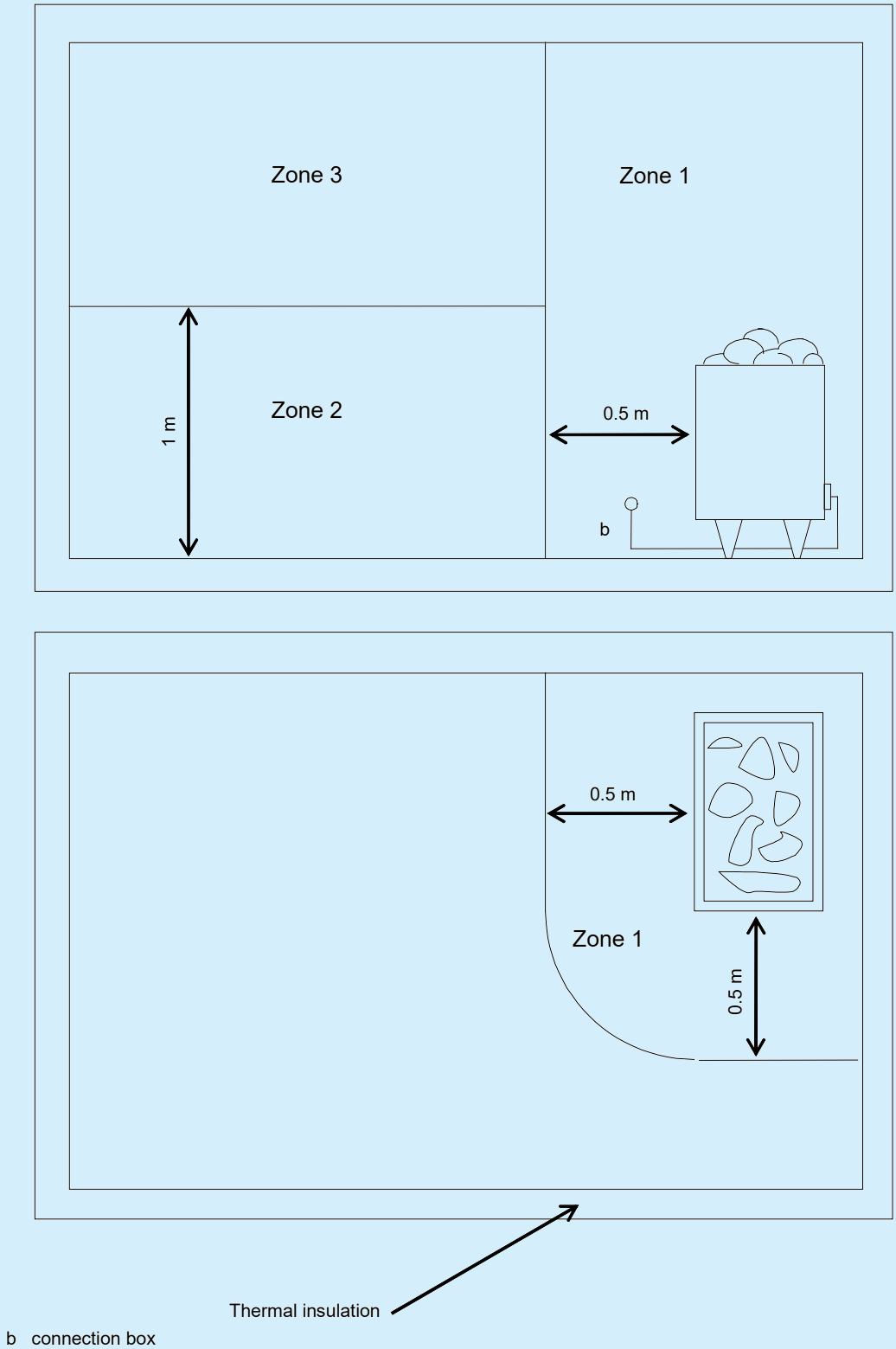


FIG. 1 ZONES OF AMBIENT TEMPERATURE

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SECTION 5 REQUIREMENTS FOR SPECIAL INSTALLATIONS OR LOCATIONS — CONSTRUCTION AND DEMOLITION SITE INSTALLATIONS

FOREWORD

There is some confusion about the standard, maintenance, and testing of appliances and equipment on construction and demolition sites. Because of the short-term nature of these sites, the electrical equipment used is often sourced from multiple locations, or multiple contractors. It can be difficult to ensure that they have been appropriately maintained and tested prior to their use on the site. This section provides requirements electrical installations for the purpose of the 'construction and demolition work'.

For the purpose of this part of NEC Part 3 Section 5, the requirements of IS 732 : 2019 shall apply. This Part 3 Section 5 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 5 parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of the general parts of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

The requirements of this section (Part 3/Sec 5) of NEC apply to installations for construction and demolition sites for use during the period of the construction or demolition work which are intended to be taken out of service upon completion of the works. Examples include the following:

a) construction work of new buildings;
b) repair, alteration, extension or demolition of existing buildings or parts of existing buildings;
c) engineering works;
d) earthworks;
e) work of similar nature.

The requirements apply to fixed or moveable installations.

The requirements do not apply to installations in administrative locations of construction sites (for example, offices, cloakrooms, meeting rooms, canteens, restaurants, dormitories, toilets).

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
IS/IEC 61439-4 : 2012	Low-voltage switchgear and controlgear assemblies: Part 4 Particular requirements for assemblies for construction sites (ACS)
IS/IEC 60309-2 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 2 Dimensional interchangeability requirements for pin and contact-tube accessories (*first revision*)
IS/IEC 60309-1 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 1 General requirements (*first revision*)
IEC 60245-4 : 2011	Rubber insulated cables — Rated voltages upto and including 450/750 V — Part 4: Cords and flexible cables

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4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1.5.5 *Assessment of general characteristics*

4.1.5.5.101 The clearances for overhead lines above construction sites shall be agreed with the owner of the overhead power line, on the basis of the dimensions of the construction site machines, such as cranes, and equipment, such as ladders and scaffolding, to be used.

4.1.5.6 *Purposes, supplies and structure*

4.1.5.9 *Supplies*

The following note is added:

NOTE — A single construction site can be served by several sources of supply, including generating sets; *see* 5.5.2 of IS 732.

4.1 Protection for Safety

4.1.2 *Protection against Electric Shock*

4.2.6 *Replace with the following:*

The protective measures:

a) obstacles, and

b) placing out of reach

as specified in IS 732 : 2019, Annex B shall not be used.

4.2.7 *Replace with the following:*

The protective measures:

a) non-conducting location,

b) earth-free equipotential bonding, and

c) electrical separation for the supply of more than one current-using equipment as specified in IS 732 : 2019, Annex C shall not be used.

4.2.101 Circuits supplying socket-outlets with rated current up to and including 32 A and other circuits supplying hand-held electrical equipment with rated current up to and including 32 A shall:

a) be protected by automatic disconnection of supply together with additional protection by the use of residual current devices having a rated residual operating current not exceeding 30 mA (*see* IS 732 : 2019, 4.2.15.1), or

b) be supplied by SELV or PELV (*see* IS 732 : 2019, 4.2.14), or

c) have electrical separation of circuits (*see* IS 732 : 2019, 4.2.13), each socket-outlet and hand-held electrical equipment being supplied by an individual isolating transformer or by separate windings of an isolating transformer.

4.2.11 *Protective Measure: Automatic Disconnection of Supply*

4.2.11.3 *Requirements for fault protection*

4.2.11.3.2 *Automatic disconnection in case of a fault*

4.2.11.3.2.101 For circuits supplying socket-outlets with a rated current exceeding 32 A, residual current devices shall be used as disconnection devices.

4.2.14 *Protective Measure: Extra-Low Voltage Provided By SELV and PELV*

4.2.14.4 *Requirements for SELV and PELV circuits*

4.2.14.4.5 *Replace the subclause with the following:*

Irrespective of the nominal voltage, in a.c. and d.c. circuits, the requirement for basic protection shall be provided by the following:

a) insulation in accordance with IS 732 : 2019, A.1, or

b) barriers or enclosures in accordance with IS 732 : 2019, A.2.

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4.5 Protection Against Voltage Disturbances And Electromagnetic Disturbances

4.5.3.3.2 *Protection against transient overvoltage of atmospheric origin or due to switching*

4.5.3.3.2.101 Cranes, lifts, cement mixers and similar items of equipment are liable to produce switching overvoltages. Where such equipment is present, consideration should be given to the need for protection against switching overvoltages.

5 SELECTION AND ERECTION OF EQUIPMENT

5.1 Common Rules

5.1.1 *Compliance with Standards*

5.1.1.1 *Add the following:*

All assemblies on construction and demolition sites (ACS) for the distribution of electricity shall be in compliance with the requirements of IS/IEC 61439-4.

Where interchangeability is required:

a) socket-outlets with a rated current not exceeding 16 A shall comply with IS/IEC 60309-2 or relevant national standards, and

b) socket-outlets with a rated current exceeding 16 A but not exceeding 125 A shall comply with IS/IEC 60309-2.

Socket-outlets shall comply with IS/IEC 60309-1 where:

a) the rated current exceeds 125 A, or

b) interchangeability is not required.

5.1.2 *Operational Conditions and External Influences*

5.1.2.2 *External influences*

Add the following:

Consideration shall be given to the risk of damage to electrical equipment by corrosive substances, movement of structures and vehicles, wear and tear, tension, flexing, impact, abrasion, severing and ingress of liquids or solids.

5.2 Wiring Systems

5.2.5.8 *Other mechanical stresses (AJ)*

5.2.5.8.101 To avoid damage, cables should not be run across site roads or walkways. Where this is necessary, special protection against mechanical damage and contact with construction plant machinery shall be provided.

Particular attention shall be given to the protection of surface run and overhead cables against mechanical damage, given the environment and activities at the construction site.

Flexible cables that are subject to movement shall be IEC 60245-4 type 66 or equivalent, resistant to abrasion and to water.

5.3 Isolation, Switching and Control

5.3.7 *Isolation and Switching*

5.3.7.3 *Isolation*

5.3.7.3.2 *Devices for isolation*

The following requirements are added:

Each assembly for construction sites (ACS) shall incorporate devices for isolating the incoming supply.

Devices for isolating the incoming supply shall be suitable for securing in the off position (*see* 5.3.7.3.1.2 of IS 732 : 2019) (for example, by providing a padlocking facility on the device or by locating the device inside a lockable enclosure). Safety and standby supplies shall be connected by means of devices arranged to prevent interconnection of the different supplies.

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5.6 Safety Services

Add the following:

Site conditions may require the provision of safety services, for example escape lighting.

6 VERIFICATION

6.101 Site work is in a constant state of change and, therefore, the associated electrical installation is subject to risk of damage or misuse. Therefore, in addition to initial and periodic verification, the installation shall be inspected frequently, for example daily, weekly, or monthly, as appropriate. Examples of some items to be inspected include:

a) the adequacy of connections and the condition of the protective conductors;

b) the condition of flexible conductors and their connections to portable equipment and hand-held equipment;

c) the rating and condition of fuses and the setting of the circuit-breakers to ensure that they are not unduly altered; and

d) the functioning of residual current devices.

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SECTION 6 CONDUCTING LOCATIONS WITH RESTRICTED MOVEMENT

FOREWORD

In most installations, access to earthed metal and conducting surfaces is fairly limited and the contact area of the body is generally comparatively low. As a result the likelihood of receiving a fatal electric shock is relatively small. In a conducting location where movement is restricted the situation is quite different.

Conducting locations with restricted movement are classed as special locations as the risk of electric shock is greatly increased. Work in these locations is often done by persons who are not electrically skilled. Conducting locations with restricted movement. Location is comprised mainly of metallic or other conductive parts. A person within the location will come into contact with a substantial portion of the conducting surface. The possibility of breaking the contact between the body and the conducting surface is limited.

For the purpose of this part of NEC Part 3 Section 6, the requirements of IS 732 : 2019 shall apply. This Part 3 Section 6 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 6 clauses are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of the general parts of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

The particular requirements of this section (Part 3/Sec 6) apply to:

a) fixed equipment within conducting locations with restricted movement; and

b) supplies to equipment used within conducting locations with restricted movement.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)

3 TERMINOLOGY

For the purposes of this document, the following terms and definitions apply.

3.1 Conducting Location With Restricted Movement —Location surrounded by mainly extraneous-conductive-parts and where contact through one or more points on a person's body with the extraneous-conductive-parts is likely and where there is limited possibility of interrupting this contact.

4 PROTECTION FOR SAFETY

4.2 Protection against Electric Shock

General Requirements:

The following requirement is added:

4.1.1 In conducting locations with restricted movement the following protective measures apply to circuits supplying the following current-using equipment:

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a) For the supply to hand-held tools and portable equipment:
   1) SELV (4.2.14 of IS 732), or
   2) electrical separation (4.2.13 of IS 732) subject to only one item of equipment being connected to a secondary winding of the isolating transformer.

      NOTE — An isolating transformer may have several secondary windings.

b) For the supply to handlamps:
   1) SELV (4.2.11 of IS 732).

      NOTE — A fluorescent luminaire with built-in step-up transformer with electrically separated windings transformer supplied at SELV is equally permitted.

c) For the supply to fixed equipment:
   1) automatic disconnection of the supply (*see* 4.2.11 of IS 732) with supplementary equipotential bonding (*see* 4.2.15.2 of IS 732) that shall connect exposed-conductive-parts of fixed equipment and the conductive parts of the location, or
   2) SELV (*see* 4.2.14 of IS 732), or
   3) PELV (*see* 4.2.14 of IS 732) where equipotential bonding shall be provided between all exposed-conductive-parts, all extraneous-conductive-parts inside the conducting location with restrictive movement, and the connection of the PELV system to earth, or
   4) electrical separation (*see* 4.2.13 of IS 732) subject to one item of equipment being connected to a secondary winding of the isolating transformer, or
   5) by use of Class II equipment or equipment having equivalent insulation (*see* 4.2.12 of IS 732) provided the supplying circuits are protected by additional protection by the use of residual current devices (*see* 4.2.15.1 of IS 732) with a rated residual operating current not exceeding 30 mA.

      NOTE — A fluorescent luminaire with built-in step-up transformer with electrically separated windings and supplied at SELV is equally permitted.

4.2.3 *Replace the existing text with the following*

For the supply to mobile equipment, one of the following protective measures shall be applied:

a) SELV in accordance with IS 732 : 2019, 4.2.14, or
b) electrical separation for the supply of one item of current using equipment in accordance with IS 732 : 2019, 4.2.13.3.

   NOTE — An isolating transformer can have several secondary windings.

For the supply to fixed equipment, one of the following protective measures shall be applied:

a) automatic disconnection of the supply in accordance with IS 732 : 2019, 4.2.11 together with additional protection by supplementary equipotential bonding in accordance with IS 732 : 2019, 4.2.15.2, or
b) SELV in accordance with 4.2.14 of IS 732 : 2019.
c) PELV in accordance with 4.2.14 of IS 732 : 2019 together with equipotential bonding between all exposed-conductive-parts and extraneous-conductive-parts and the connection of the PELV system to earth, or
d) electrical separation for the supply of one item of current using equipment in accordance with IS 732 : 2019, 4.2.13, or
e) double or reinforced insulation in accordance with 4.2.12 of IS 732 : 2019 together with additional protection by the use of a residual current device (RCD) with a rated residual operating current not exceeding 30 mA.

4.2.6 *Replace the requirement with the following:*

The protective measures of obstacles and placing out of reach in accordance with IS 732 : 2019, Annex B shall not be used.

4.2.13 *Protection against both direct and indirect contact*

The following requirements are added:

4.2.13.101 *Sources for SELV and PELV*

4.2.13.101.1 with restrictive movement, unless they are part of the fixed installation within the conducting location with restricted movement as provided by item c) of **4.2.1** of this section.

4.2.13.102 *Requirements for unearthed circuits (SELV)*

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4.2.13.102.1 Basic protection (protection against direct contact) in accordance with **4.2.14.4** shall be provided, irrespective of the nominal voltage of the SELV circuits.

4.2.13.103 *Requirements for earthed circuits (PELV)*

4.2.13.103.1 Basic protection (protection against direct contact) in accordance with **4.2.14.4** shall be provided, irrespective of the nominal voltage of the PELV circuits.

4.2.12 *Protection against Direct Contact*

The following requirements are added:

4.2.12.101 *Obstacles*

Protection by means of obstacles (Annex B, **B.2**) is not permitted.

4.2.12.102 *Placing out of reach*

Protection by placing out of reach (Annex B, **B.3**) is not permitted.

4.2.13 *Protective measure: electrical separation*

The following requirements are added:

Only circuits and the protective measures for supplying equipment indicated in **4.2.1** of this section are permitted.

4.2.13.101 *Equipotential bonding and functional earth*

If a functional earth is required for certain equipment, for example measuring and control apparatus, equipotential bonding shall be provided between all exposed-conductive-parts, extraneous-conductive-parts inside the conducting location with restrictive movement and the functional earth.

4.2.13.3 *Requirements for fault protection*

4.2.13.3.2 *Add the following requirement:*

The source shall be situated outside the conducting location with restricted movement, unless the source is part of the fixed installation within the location.

4.2.13.3.7 *Electrical separation*

4.2.13.3.7.1 The source with protective separation in accordance with **4.2.13** of shall be situated outside the conducting location with restrictive movement, unless the source is part of the fixed installation within the conducting location with restrictive movement.

4.2.14 *Protective measure: extra-low-voltage provided by SELV and PELV*

4.2.14.3 *Sources for SELV and PELV*

The following requirements are added:

4.2.14.3.101 Sources for SELV and PELV shall be situated outside the conducting location with restricted movement, unless they are part of the fixed installation within the conducting location with restricted movement.

4.2.14.4 *Requirements for SELV and PELV Circuits*

4.2.14.4.5 *Replace the first paragraph and first two dashed items with the following:*

If the nominal voltage exceeds 25 V a.c. or 60 V d.c., or if the equipment is immersed, basic protection shall be provided for SELV and PELV circuits by:

a) insulation in accordance with A.1 of IS 732 : 2019, or
b) barriers or enclosures in accordance with A.2 of IS 732 : 2019.

4.2.15 *Additional Protection*

4.2.15.1 *Additional protection: supplementary protective equipotential bonding*

4.2.15.2.1 *The following requirement is added:*

Where functional earthing is required, supplementary equipotential bonding shall be provided between all exposed-conductive-parts, extraneous-conductive-parts and the terminals for functional earthing.

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SECTION 7 REQUIREMENTS FOR SPECIAL INSTALLATIONS OR LOCATIONS — CARAVAN PARKS, CAMPING PARKS AND SIMILAR LOCATIONS

FOREWORD

This section applies to the electrical installations in caravan/camping parks and similar locations providing connection points for supplying leisure accommodation vehicles (including caravans) and tents. It covers circuits intended to supply residential park homes in caravan parks, camping parks and similar locations. In addition it also specifies requirements to socket outlet requirements, RCD protection, and external influences.

For the purpose of this part of NEC Part 3/Sec 7, the requirements of IS 732 : 2019 shall apply. This Part 3/Sec 7 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3/Sec 7 clauses are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of the general parts of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

The particular requirements contained in this section (Part 3/Sec 7) apply only to circuits intended to supply leisure accommodation vehicles, tents or residential park homes in caravan parks, camping parks and similar locations.

NOTE — For the purposes of this document caravan park includes camping parks and similar locations.

The particular requirements do not apply to the internal electrical installations of leisure accommodation vehicles, mobile or transportable units or residential park homes.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No./Other Publications	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
12360 : 1988	Voltage bands for electrical installations including preferred voltages and frequency
16205 (Part 24) : 2017	Conduit systems for cable management: Part 24 Particular requirements conduit systems buried under ground
17050 : 2018/ IEC 62262 : 2002	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
IS/IEC 60309-2 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 2 Dimensional interchangeability requirements for pin and contact-tubes accessories (*first revision*)
IS/IEC 60309-1 : 2002	Plugs, socket-outlets and couplers for industrial purposes — Part 1: General requirements
IEC 60309-4 : 2006	Plugs, socket-outlets and couplers for industrial purposes — Part 4: Switched socket-outlets and connectors with or without interlock

3 TERMINOLOGY

For the purposes of this document, the following terms and definitions apply.

3.1 Leisure Accommodation Vehicle — Unit of living accommodation for temporary or seasonal occupation that may meet the requirements for the construction and use of road vehicles.

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3.1.1 *Caravan* — Trailer leisure accommodation vehicle, used for touring, that meets the requirements for the construction and use of road vehicles.

3.1.2 *Motor Caravan* — Self-propelled leisure accommodation vehicle, used for touring, that meets the requirements for the construction and use of road vehicles.

NOTE — The motor caravan is either adapted from a series production vehicle, or designed and built on an existing chassis, with or without the driving cab, the accommodation being either fixed or demountable.

3.1.3 *Mobile Home* — Transportable leisure accommodation vehicle that includes means for mobility but does not meet the requirements for the construction and use of road vehicles.

3.2 Caravan/Tent Pitch — Plot of ground intended to be occupied by a leisure accommodation vehicle or tent

3.3 Caravan Park — Camping Park Area of land that contains two or more caravan or tent pitches.

3.4 Residential Park Home — Factory-produced relocatable dwelling

4 ASSESSMENT OF GENERAL CHARACTERISTICS

4.1.5.6 *Purposes, supplies and structure*

4.1.5.8 *Conductor arrangement and system earthing*

4.1 5.8.2 *Types of system earthing*

4.1.5.8.2.1 *TN-systems*

Add the following:

For a TN-system, the final circuit for the supply to a leisure accommodation vehicle, tent or residential park home shall not include a PEN conductor.

4.1.5.9 *Supplies*

4.1.5.9.1 *General*

4.1.5.9.1.101 The nominal supply system voltage shall be selected from IS 12360/IEC 60038.

The nominal supply voltage of the installation for the supply of leisure accommodation vehicles shall not exceed 230 V a.c. single-phase and/or 400 V a.c. three-phase and 48 V d.c.

4.1 Protection for Safety

4.1.2 *Protection against Electric Shock*

General requirements

4.2.6 *Add the following:*

The protective measures of obstacles and placing out of reach as specified in Annex B of IS 732 shall not be used.

4.2.7 *Add the following:*

The protective measures of non-conducting location and earth-free local equipotential bonding as specified in Annex C of IS 732 : 2019 shall not be used.

4.2.11.3.3 *Additional Protection*

4.2.15.1 *Residual current protective devices (RCDs)*

Add the following:

Every socket-outlet shall be individually protected by an RCD having a rated residual operating current not exceeding 30 mA. Devices selected shall disconnect all live conductors.

A final circuit intended for the fixed connection for a supply to a mobile home or a residential park home shall be individually protected by an RCD having a rated residual operating current not exceeding 30 mA. Devices selected shall disconnect all live conductors.

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5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

See IS/IEC TS 61439-7.

5.1 Selection and Erection of Electrical Equipment – Common Rules

5.1.2 *Operational Conditions and External Influences*

5.1.2.2 *External influences*

Add the following:

NOTE — In a caravan park or camping park, special consideration is given to the protection of people, due to the fact that the human body can be in contact with earth potential, to the protection of wiring due to tent pegs or ground anchors and to the movement of heavy or high vehicles.

5.2.5.3.101 *Presence of water (AD)*

Equipment shall be selected with a degree of protection of at least IPX4 in order to protect against water splashes (AD4).

5.2.5.4.101 *Presence of solid foreign bodies (AE)*

Equipment shall be selected or provided with a degree of protection of at least IP4X in order to protect against the ingress of very small objects (AE3).

5.2.5.6.101 *Impact (AG)*

Equipment installed in a campsite shall be protected against mechanical damage (impact of high severity AG3). Protection of the equipment shall be afforded by one or more of the following:

a) the position or location shall be selected to avoid damage by any reasonably foreseeable impact;
b) local or general mechanical protection shall be provided; and
c) equipment that complies with a minimum degree of protection against external mechanical impact of IK08 (*see* IS 17050 : 2018/IEC 62262 : 2002) shall be installed.

5.2 Wiring Systems

5.2.4 *Types of Wiring Systems*

5.2.4.7 *Several circuits in one cable*

5.2.4.7.101 *Supply for the caravan or tent pitch*

The preferred method of supply for feeding the caravan pitch or tent pitch electrical supply equipment is by means of underground distribution circuits.

5.2.4.7.101.1 *Underground cables*

An underground distribution circuit shall, unless provided with additional mechanical protection, be buried at a sufficient depth to avoid being damaged, for example by tent pegs or ground anchors or by the movement of vehicles.

A depth of 0.6 m is generally considered as a minimum depth to fulfill this requirement. Alternatively the cable may be installed outside the pitch or other area where tent pegs or ground anchors may be driven.

NOTE — For conduit systems buried underground, *see* IS 16205-24.

5.2.4.7.101.2 *Overhead cables or overhead insulated conductors*

Every overhead conductor shall be insulated.

Poles and other supports for overhead wiring shall be located or protected so that they are unlikely to be damaged by any foreseeable movement of vehicles.

Every overhead conductor shall be at a height above ground of not less than 6 m in all areas subject to the movement of vehicles and 3.5 m in all other areas.

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5.3 Isolation, Switching and Control

5.3.4 *Devices for Protection Against Overcurrent*

In addition the following applies:

Every socket-outlet shall be individually protected by an overcurrent protective device, in accordance with the requirements of 4.4 of IS 732.

A fixed connection for a supply to a mobile home or residential park home shall be individually protected by an overcurrent protective device, in accordance with the requirements of 4.4 of IS 732.

5.3.7 *Isolation and Switching*

5.3.7.3 *Isolation*

5.3.7.3.1 *General*

5.3.7.3.1.1 *Add the following:*

At least one means of isolation shall be installed in each distribution cabinet. This device shall disconnect all live conductors.

5.5 Other Equipment

5.5.101 *Socket-Outlets*

5.5.101.1 Every socket-outlet shall comply with IS/IEC 60309-2.

Every socket-outlet shall meet the degree of protection of at least IP44 or such protection shall be provided by an enclosure.

To prevent the socket contacts being live when accessible, every socket-outlet or connector shall either comply with IS/IEC 60309-2 and shall be interlocked and classified according to IS/IEC 60309-1 : 1999, or shall be part of an interlocked self-contained product complying with IEC 60309-4 and classified according to IEC 60309-4 : 2006.

5.5.101.2 Every socket-outlet shall be located as close as practicable to the caravan pitch or tent pitch to be supplied.

Socket-outlets shall be installed in the distribution board or in separate enclosures.

5.5.101.3 In order to avoid any hazard due to long connection cables no more than four socketoutlets shall be grouped together in any one enclosure. To ensure that the degree of protection is maintained when the socket-outlets are in use, no more than four socket-outlets shall be mounted within the same enclosure.

Columns (pillars) should be located so as to minimize the need for extension cables to cross gangways, etc.

5.5.101.4 Every caravan pitch or tent pitch shall be supplied with at least one socket-outlet.

5.5.101.5 The current rating of socket-outlets shall be not less than 16 A.

5.5.101.6 The lowest part of any socket-outlet shall be placed at a height between 0.5 m and 1.5 m from the ground. In special cases of extreme environmental conditions, it is permitted to exceed the stated maximum height of 1.5 m. In such cases, special measures shall be taken to ensure the safe insertion and removal of plugs.

NOTE — This can be necessary if the caravan park or camping park risks being flooded. This can also be necessary if the caravan park is used during winter after heavy snow falls.

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SECTION 8 REQUIREMENTS FOR SPECIAL INSTALLATIONS OR LOCATIONS — MARINAS AND SIMILAR LOCATIONS

FOREWORD

Marinas and similar locations are considered to be locations with an increased risk of electric shock. This is because of the presence of water, a reduction in body resistance, and contact of the body with Earth potential. In this Section we give an overview of the requirements of electrical circuits intended to supply houseboats and pleasure craft in marinas and similar locations

For the purpose of this part of NEC Part 3/Sec 8, the requirements of IS 732 : 2019 shall apply. This Part 3 Section 8 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 8 parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

The particular requirements specified in this section (Part 3/Sec 8) of NEC apply only to circuits intended to supply pleasure craft or houseboats in marinas and similar locations.

NOTE — In this part "marina" means "marina and similar locations".

The particular requirements do not apply to the supply of house boats if they are directly supplied from the public network.

The particular requirements do not apply to the internal electrical installations of pleasure craft or house boats.

NOTES

1 For electrical installations of pleasure craft, *see* IEC 60092-507.

2 The electrical installations of house boats should comply with the general requirements of IEC 60364, together with the relevant particular requirements of IEC 603647.

For the remainder of the electrical installation of marinas and similar locations the general requirements of IEC 60364 together with the relevant particular requirements of IEC 603647 apply.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
IS/IEC 60309-2 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 2 Dimensional interchangeability requirements for pin and contact-tubes accessories (*first revision*)
IS/IEC 60309-1 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 1 General requirements (*first revision*)
IS 12360 : 1988	Voltage bands for electrical installations including preferred voltages and frequency
IS 17050 : 2018/ IEC 62262 : 2002	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
IS/IEC 61558 (Part 2/Sec 4) : 2009	Safety of transformers, reactors, power supply units and similar product for supply voltages up to 1100 V: Part 2-4 Particular requirements and tests for isolating transformers and power supply units incorporating isolating transformers

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3 TERMINOLOGY

For the purposes of this document, the following terms and definitions apply.

3.1 Pleasure Craft — Any boat, vessel, yacht, motor launch, houseboat or other floating craft used exclusively for sport or leisure.

3.2 Marina — Facility for the mooring of pleasure craft with fixed wharves, jetties, piers or a pontoon arrangement capable of berthing one or more pleasure craft.

3.3 Houseboat — Floating decked structure which is designed or adapted for use as a place of permanent residence often kept in one place on inland water.

4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1.5.6 *Purposes, supplies and structure*

4.15.8 *Conductor arrangement and system earthing*

4.1.5.8.2 *Types of system earthing*

4.1.5.8.2.1 *TN-systems*

Add the following:

For a TN-system, the final circuits for the supply of pleasure craft or houseboats shall not include a PEN conductor.

4.1.5.9 *Supplies*

4.1.5.9.1.101 *Add the following:*

The nominal supply system voltage shall be selected from IS 12360.

The nominal supply voltage shall not exceed 230 V single-phase, or 400 V three-phase.

4.1 Protection for Safety

4.2 Protection against Electric Shock

4.2.11.2 *Requirements for basic protection*

ANNEX B

B-2 OBSTACLES

Protection by obstacles shall not be used.

B-3 PLACING OUT OF REACH

Protection by placing out of reach shall not be used.

ANNEX C

C-1 NON-CONDUCTING LOCATION

Protection by non-conducting location shall not be used.

NOTE — This precludes the use of class 0 equipment.

C-2 PROTECTION BY EARTH-FREE LOCAL EQUIPOTENTIAL BONDING

Protection by earth free local equipotential bonding shall not be used.

4.2.13 *Protective Measure: Electrical Separation*

Where the protective measure of electrical separation is used for supplying pleasure craft compliance with all the requirements of **4.2.13** and with **4.2.13.3.2** and **4.2.13.3.6** shall be ensured.

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4.2.13.3.2 The circuit shall be supplied through a fixed isolating transformer complying with IS/IEC 61558-2-4.

The protective conductor of the supply to the isolating transformer shall not be connected to the earth terminal in the socket-outlet supplying the pleasure craft.

NOTE — *See* Annex A.

4.2.13.3.6 Add the following:

The equipotential bonding of the pleasure craft shall not be connected to the protective conductor of the shore supply.

5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.1.2 *Operational Conditions and External Influences*

5.1.2.2 *External influences*

Add the following:

NOTE — For marinas particular attention is given in this part to the likelihood of corrosive elements, movement of structures, mechanical damage, presence of flammable fuel and the increased risk of electric shock due to:

a) presence of water;
b) reduction in body resistance;
c) contact of the body with earth potential.

5.2.5.4 *Presence of water (AD)*

In marinas, equipment installed on or above a jetty, wharf, pier or pontoon shall be selected as follows, according to the external influences which may be present:

a) water splashes (AD4): IPX4;
b) water jets (AD5): IPX5;
c) water waves (AD6): IPX6.

5.2.5.4 *Presence of solid foreign bodies (AE)*

Equipment installed on or above a jetty, wharf, pier or pontoon shall be selected with a degree of protection of at least IP4X in order to protect against the ingress of very small objects (AE3).

5.2.5.5 *Presence of corrosive or polluting substances (AF)*

Equipment installed on or above a jetty, wharf, pier or pontoon shall be suitable for use in the presence of atmospheric corrosive or polluting substances (AF2). If hydrocarbons are present AF3 is applicable.

5.2.5.6 *Impact (AG)*

Equipment installed on or above a jetty, wharf, pier or pontoon shall be protected against mechanical damage (impact of medium severity AG2). Protection shall be afforded by one or more of the following:

a) the position or location of the equipment shall be selected to avoid being damaged by any reasonably foreseeable impact;
b) local or general mechanical protection shall be provided;
c) equipment shall be installed which complies with a minimum degree of protection for external mechanical impact of IK07 (*see* IS 17050 : 2018/IEC 62262 : 2002).

5.2.4 *Types of Wiring Systems*

709.521.7 *Wiring systems of marinas*

709.521.7.1 The following wiring systems are suitable for distribution circuits in marinas:

a) underground cables;
b) overhead cables or overhead insulated conductors;
c) cables with copper conductors and thermoplastic or elastomeric insulation and installed within an appropriate cable management system taking into account external influences such as movement, impact, corrosion and ambient temperature;

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d) mineral-insulated cables with PVC protective covering;

e) armoured cables with a thermoplastic or elastomeric covering;

f) other cables and materials that are no less suitable than those listed under a), b), c), d) or e) above.

709.521.7.2 The following wiring systems shall not be used on or above a jetty, wharf, pier or pontoon:

a) overhead cables and overhead conductors in free air suspended from or incorporating a support wire, e.g. as installation method N^{os}. 35 and 36 in Table 19, Annex R of IS 732;

b) insulated conductors in conduits, trunking etc., e.g. as installation methods N^{os}. 4 and 6 in Table 19, Annex R of IS 732;

c) cables with aluminium conductors; and

d) mineral-insulated cables.

709.521.7.3 Cables and cable management systems shall be selected and installed so that mechanical damage due to tidal and other movement of floating structures is prevented.

Cable management systems shall be installed to allow the drainage of water/condensate e.g. by sloping way and/or drainage holes.

709.521.7.4 *Underground cables*

Underground distribution circuits shall, unless provided with additional mechanical protection be buried at a sufficient depth to avoid being damaged, e.g. by movement of vehicles.

NOTES

1 A depth of 0.5 m is generally considered as a minimum depth to fulfil this requirement.

2 For conduit systems buried underground, *see* IS 16205-24/IEC 61386-24.

709.521.7.5 *Overhead cables or overhead insulated conductors*

All overhead conductors shall be insulated.

Poles and other supports for overhead wiring shall be located or protected so that they are unlikely to be damaged by any foreseeable movement of vehicles.

Overhead conductors shall be at a height above ground of not less than 6 m in all areas subjected to movement of vehicles movement and 3.5 m in all other areas.

5.3.2 *Devices for Protection against Indirect Contact by Automatic Disconnection of supply*

5.3.2.2 *Residual current protective devices (RCD's)*

Add the following:

Every socket-outlet with a rated current up to 63 A shall be individually protected by an RCD having a rated residual operating current not exceeding 30 mA. The RCD selected shall disconnect all poles, including the neutral.

Every socket-outlet with a rated current above 63 A shall be individually protected by an RCD having a rated residual operating current not exceeding 300 mA. The RCD selected shall disconnect all poles, including the neutral.

Account should be taken of the need for selectivity, e.g. by the use of Type S.

Every final circuit intended for the fixed connection of a supply to a house boat shall be protected individually by an RCD having a rated residual operating current not exceeding 30 mA. The RCD selected shall disconnect all poles, including the neutral.

5.3.4 *Devices for Protection against Overcurrent*

In addition the following applies:

Each socket – outlet shall be individually protected by an overcurrent protective device, in accordance with the requirements of 4.4 of IS 732.

Every final circuit intended for the fixed connection of a supply to a house boat shall be individually protected by an overcurrent protective device, in accordance with the requirements of 4.4 of IS 732.

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5.3.7 *Isolation and Switching*

5.3.7.3 *Isolation*

5.3.7.3.1 *General*

5.3.7.3.1.1 At least one means of isolation shall be installed in each distribution board. This device shall disconnect all live conductors including the neutral conductor.

5.5 *Other Equipment*

5.5.101 *Socket-Outlets General*

5.5.101.1 Every socket-outlet with a current rating up to 63 A shall comply with IEC 60309-2. Every socket-outlet with a current rating over 63 A shall comply with IEC 60309-1.

Every socket-outlet shall meet the degree of protection of at least IP44 or such protection shall be provided by an enclosure.

Where the codes AD 5 or AD 6 are applicable the degree of protection shall be at least IPX5 or IPX6 respectively.

5.5.101.2 Every socket-outlet shall be located as close as practicable to the berth to be supplied.

Socket-outlets shall be installed in the distribution board or in separate enclosures.

5.5.101.3 In order to avoid any hazard due to long connection cords no more than four socket-outlets shall be grouped together in any one enclosure.

NOTE — *See* Annex B regarding recommended notices to be placed in marinas adjacent to each group of socket-outlets.

5.5.101.4 One socket-outlet shall supply only one pleasure craft or house boat.

5.5.101.5 In general single phase socket-outlets with rated voltage 200 V – 250 V and rated current 16 A shall be provided.

Where greater demands are envisaged socket-outlets with higher ratings may be provided.

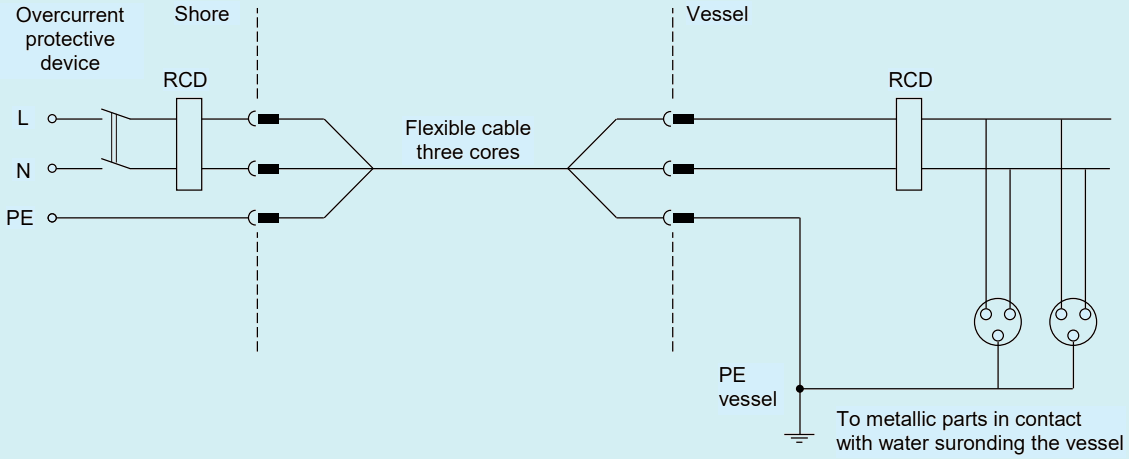
5.5.101.6 Every socket-outlet, both on fixed jetties or piers and on floating pontoons, shall be placed in such a position as to avoid the effect of splashing and/or submersion unless appropriate measures are taken.

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ANNEX A

(*Informative*)

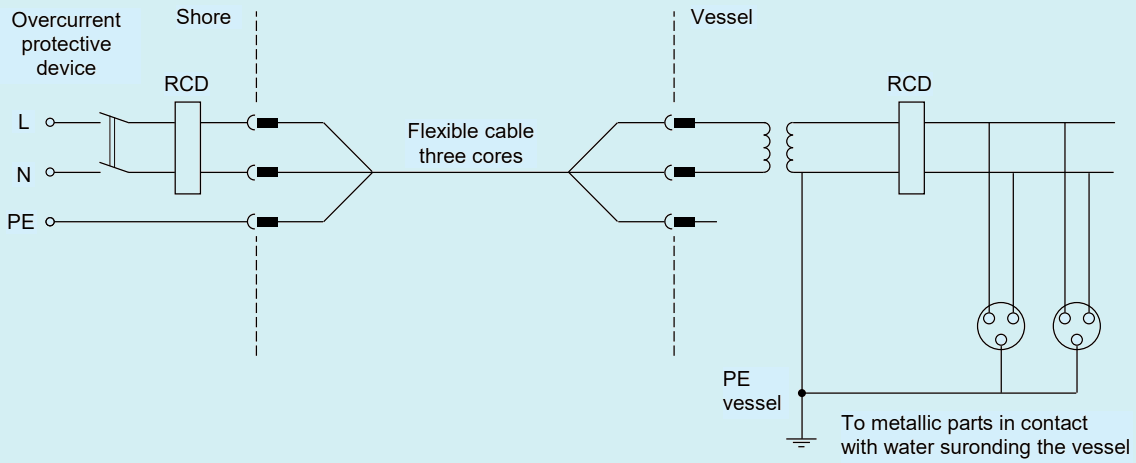
EXAMPLES OF METHODS OF OBTAINING SUPPLY IN MARINAS



NOTE — In the Fig. A.1 through A.5 functional switches are not shown.

There is a risk of electrolytic corrosion resulting from circulating galvanic currents in the protective conductor to shore.

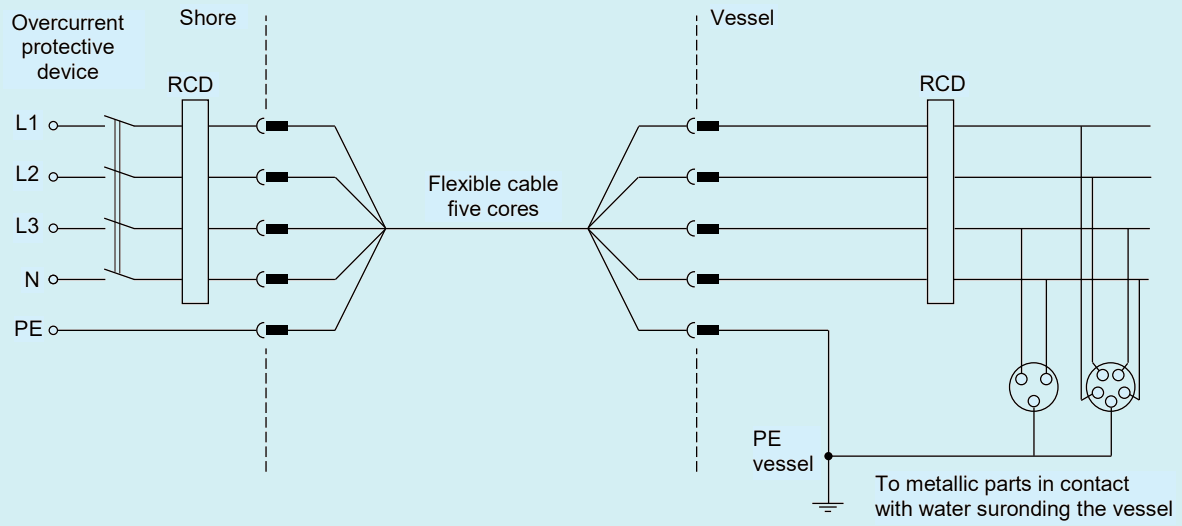
FIG. A-1 DIRECT CONNECTION TO A SINGLE PHASE MAINS SUPPLY



No connection shall be made between the PE conductor of the vessel and the PE conductor of the shore supply. This is to prevent galvanic currents circulating between the hull of the vessel and metallic parts on the shore side.

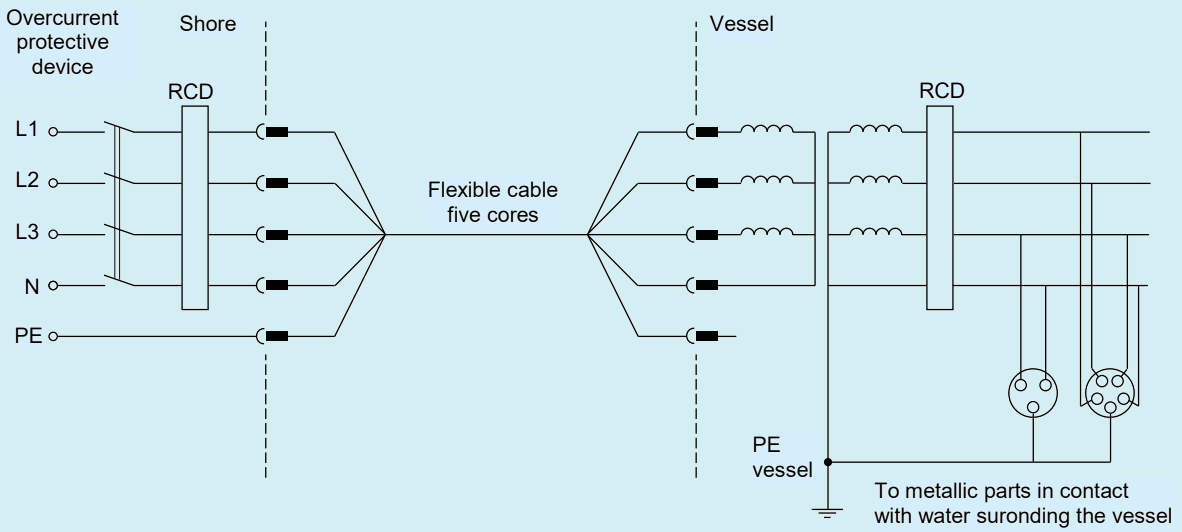
FIG. A-2 DIRECT CONNECTION TO A SINGLE PHASE MAINS SUPPLY WITH AN ISOLATING TRANSFORMER ON THE VESSEL

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There is a risk of electrolytic corrosion resulting from circulating galvanic currents in the protective conductor to shore.

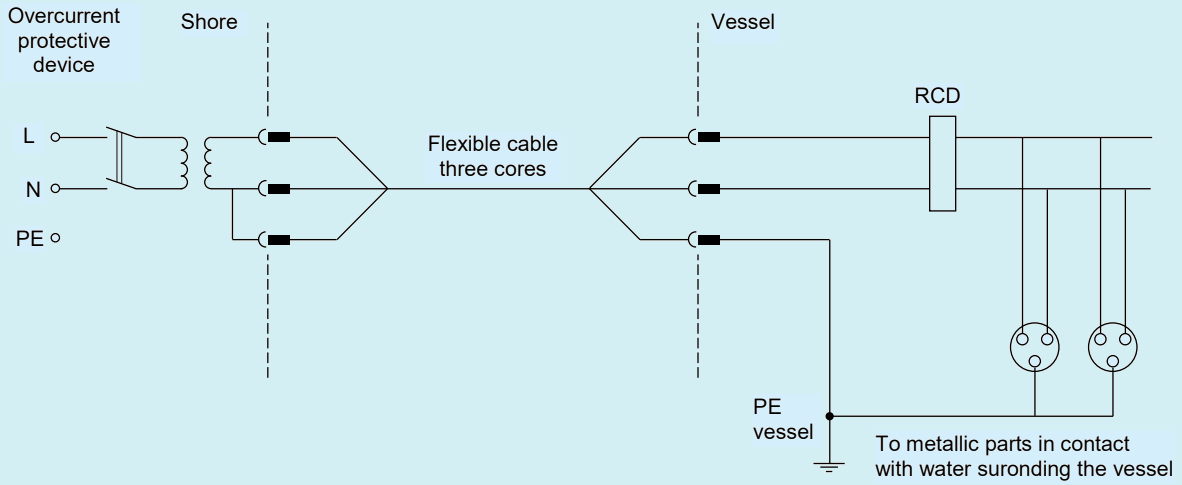
FIG. A-3 DIRECT CONNECTION TO A THREE PHASE MAINS SUPPLY



No connection shall be made between the PE conductor of the vessel and the PE conductor of the shore supply. This is to prevent galvanic currents circulating between the hull of the vessel and metallic parts on the shore side.

FIG. A-4 DIRECT CONNECTION TO A THREE PHASE MAINS SUPPLY WITH AN ISOLATING TRANSFORMER ON THE VESSEL

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No connection shall be made between the PE conductor of the supply on the vessel and the PE conductor of the shore supply. This is to prevent galvanic currents circulating between the hull of the vessel and metallic parts on the shore side.

Only one socket-outlet shall be connected to each secondary winding of the isolating transformer.

The metallic parts of the vessel in contact with the water are bonded to the PE of the vessel.

FIG. A-5 CONNECTION TO A SINGLE-PHASE SUPPLY THROUGH A SHORE-MOUNTED ISOLATING TRANSFORMER

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ANNEX B

(*Informative*)

EXAMPLE OF AN INSTRUCTION NOTICE TO BE PLACED IN MARINAS

B-1 It is recommended that the marina operator provides every pleasure craft operator who wishes to connect a pleasure craft to an electrical supply with an up-to-date copy of this instruction notice and also installs an up-to-date, clearly legible and weather protected copy of this instruction notice at every supply point.

B-2 The instruction notice should be in the national language(s) of the country and in English.

B-3 The instruction notice should contain, at least, the following:

INSTRUCTIONS FOR CONNECTION TO THE SHORE SUPPLY

This marina provides a direct, earthed, connection to the shore supply.

General

a) Unless you have an isolating transformer fitted on board to isolate the electrical system on your craft from the shore supply, there is an increased risk of galvanic corrosion (electrolysis) damaging your craft.

b) The supply voltage at this marina is ……[1)] V, ……[1)] Hz (normally 230 V 50 Hz single-phase and 400 V 50 Hz three-phase), supplied by socket-outlets complying with IEC 60309-2.

c) Measures should be taken to prevent the connecting flexible cable or the connectors from falling into the water during connection and disconnection.

d) Only the connecting flexible cable from the craft should be connected to any socket–outlet.

e) Only one craft should be connected to one socket-outlet.

f) The connecting flexible cable should be undamaged and in one length, without joints and the connectors should be in good condition.

g) Moisture, dust and salt in the craft appliance inlet can constitute a serious hazard. Examine the appliance inlet: clean and dry it, if necessary, before plugging in the connecting flexible cable from the marina shore supply.

h) It is dangerous for unskilled persons to attempt repairs or alterations. If any difficulty arises, consult the marina operator.

On arrival

a) After mooring, switch off all current-using equipment on the craft.

b) Examine the flexible cable and its connectors to ensure it is undamaged and in good condition.

c) Connect the flexible cable first at the appliance inlet of the craft and then at the shore supply.

d) Ensure the cable is placed where it will no be damaged and ensure that it will not a trip hazard to other persons.

Before leaving

a) Switch off all current-using equipment on the craft.

b) Disconnect the flexible cable from the socket–outlet on the shore and then from the appliance inlet on the craft.

c) Replace the cover on the appliance inlet on the craft to prevent the ingress of water.

d) Coil up the connecting flexible cable, ensure that the connectors are clean and dry, and store the cable in a dry location where it will not be damaged.

[1)] To be completed by the marina operator.

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BIBLIOGRAPHY

IEC 60092-507, Electrical installations in ships – Part 507: Pleasure craft

IEC 60364-5-52, Electrical installations of buildings – Part 5-52: Selection and erection of electrical equipment – Wiring systems

IEC 61386-24, Conduit systems for cable management – Part 24: Particular requirements – Conduit systems buried underground

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SECTION 9 REQUIREMENTS FOR MEDICAL LOCATIONS

FOREWORD

In medical locations it is necessary to ensure the safety of patients likely to be subjected to the application of medical electrical equipment. For every activity and function in a medical location, the particular requirements for safety have to be considered. Safety can be achieved by ensuring the safety of the installation and the safe operation and maintenance of medical electrical equipment connected to it. The use of medical electrical equipment on patients undergoing intensive care (of critical importance) has called for enhanced reliability and safety of electrical installations in hospitals so as to improve the safety and continuity of supplies which is met by application of this standard. Variations of the standard to further enhance safety and reliability are acceptable.

1 SCOPE

The particular requirements of this section (Part 3/Sec 9) of NEC apply to electrical installations in medical locations so as to ensure safety of patients and medical staff. These requirements, mainly, refer to hospitals, private clinics, medical and dental practices, health care centers and dedicated medical rooms in the work place. The requirements in this section shall be considered in addition to the requirements in other parts of NEC for medical locations.

NOTES

1 It may be necessary to modify the existing electrical installation, in accordance with this standard, when a change of utilization of the location occurs. Special care should be taken where intracardiac procedures are performed in existing installations.

2 Where applicable this standard can also be used in veterinary clinics. The requirements of this part do not apply to medical electrical equipment.

3 For medical electrical equipment; refer to the IS 13450 series.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
12032 (Part 1) : 1987	Graphical symbols for diagrams in the field of electrotechnology: Part 1 General information
12032 (Part 11) : 1987	Graphical symbols for diagrams in the field of electrotechnology: Part 11 Architectural and topographical installation plans and diagrams
13450 (Part 1) : 2018	Medical electrical equipment: Part 1 General requirements for basic safety and essential performance (*second revision*)
14700 (Part 3/Sec 2 and 3) : 2018	Electromagneticcompatibility (EMC): Part 3 Limits
IEC 61000-2 series	Electromagnetic compatibility (EMC) — Part 2: Environment
IEC 61082-1 : 2014	Preparation of documents used in electrotechnology — Part 1: Rules
IEC 61557-8 : 2014	Electrical safety in low voltage distribution systems up to 1000 Vac. and 1500 Vd.c. — Equipment for testing, measuring or monitoring of protective measures — Part 8: Insulation monitoring devices for IT systems
IEC 61558-2-15 : 2011	Safety of transformers + reactors + power supply units and combinations thereof — Part 2-15: Particular requirements and tests for isolating transformers for the supply of medical locations
13450 (Part 1) : 2018	Medical Electrical Equipment Part 1 General Requirements for Basic Safety and Essential Performance

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3 DEFINITIONS

For the purposes of this part of NEC, the following definitions apply.

3.1 Medical Location — Location intended for purposes of diagnosis, treatment (including cosmetic treatment), monitoring and care of patients.

NOTE — To ensure protection of patients from possible electrical hazards, additional protective measures need to be applied in medical locations. The type and description of these hazards can vary according to the treatment being administered. The manner in which a room is to be used necessitates some division into different areas for differing medical procedures.

3.2 Patient — Living being (person or animal) undergoing medical or dental investigation or treatment.

NOTE — The person under treatment for cosmetic purposes may be considered, as far as this standard is concerned, as a patient.

3.3 Medical Electrical Equipment — Electrical equipment provided with not more than one connection to particular supply mains and intended to diagnose, treat or monitor the patient under medical supervision and which:

a) makes physical or electrical contact with the patient,
b) transfers energy to or from the patient, and
c) detects such energy transfer to or from the patient.

NOTE— The equipment includes those accessories defined by the manufacturer as being necessary to enable normal use of the equipment.

3.4 Applied Part — Part of the medical electrical equipment which in normal use:

a) Necessarily comes into physical contact with the patient for the equipment to perform its function,
b) can be brought into contact with the patient, or
c) needs to be touched by the patient.

3.5 Group 0 — Medical location where no applied parts are intended to be used.

3.6 Group 1 — Medical location where applied parts are intended to be used as follows:

a) Externally; and
b) Invasively to any part of the body, except where Group 2 applies.

3.7 Group 2 — Medical location where applied parts are intended to be used in applications such as intracardiac procedures, operating theatres and vital treatment where discontinuity (failure) of the supply can cause danger to life.

NOTE — An intracardiac procedure is a procedure whereby an electrical conductor is placed within the heart of a patient or is likely to come into contact with the heart, such conductor being accessible outside the patient's body.In this context, an electrical conductor includes insulated wires such as cardiac pacing electrodes or intracardiac ECG electrodes, or insulated tubes filled with conducting fluids.

3.8 Medical Electrical System — Combination of items of equipment, at least one of which is an item of medical electrical equipment and inter-connected by functional connection or use of a multiple portable socket-outlet.

NOTE— The system includes those accessories which are needed for operating the system and are specified by the manufacturer.

3.9 Patient Environment — Any volume in which intentional or unintentional contact can occur between patient and parts of the system or between patient and other persons touching parts of the system (for illustration, *see* Fig.1).

NOTE — This applies when the patient's position is pre-determined, if not, all possible patient positions should be considered.

3.10 Main Distribution Board — Board in the building which fulfils all the functions of a main electrical distribution for the supply building area assigned to it and where the voltage drop is measured for operating the safety services.

3.11 Medical IT System — IT electrical system having specific requirements for medical applications.

3.12 electric source for safety services-electric source intended to be used as part of an electric supply system for safety services.

3.13 medical insulation monitoring device (MED-IMD)-specific insulation monitoring device (IMD) dedicated to monitor medical IT systems.

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3.14 insulation fault location system (IFLS) - device or combination of devices used for insulation fault location in IT systems, where the insulation fault location system is used in addition to an insulation monitoring device and is used to locate insulation faults.

4 ASSESSMENT OF GENERAL CHARACTERISTICS

For assessment of general characteristics, please refer **4.1.5.5** of IS 732 for relevant items given under this clause. Additional requirements have been mentioned against each sub-clause below.

4.1 The assessment shall be made in conjunction with medical staff and the person(s) responsible for medical safety, shall consider what effects discontinuity of the electric supply will have on the ME equipment or ME systems including:

1) the duration of the discontinuity (failure) of the electrical supply;
2) the effect of any supply interruption on the treatment, monitoring or examination, including if any procedure repetition is hazardous to the patient or if it is impossible to repeat the examination results.

A comprehensive assessment shall be performed to identify the proper electrical supply requirements for the ME equipment, ME systems and supporting electrical equipment intended to be used.

Having identified these requirements, the appropriate classification for the medical location shall be determined. In order to determine the extent of a medical location, all possible patient positions shall be considered.

Where assessment shows any given location that falls into both group 1 or group 2 categories, the location shall be classified as group 2.

NOTES

1 For the classification of electric supply systems for safety services, *see* 5.6 of IS 732 and **8** of this document.

2 Guidance on the allocation of a group number and classification of electric supply systems for safety services for medical locations is shown in Annex A.

5 PURPOSES, SUPPLIES AND STRUCTURE

5.1 Types of System Earthing

The TN-C system is not allowed in medical locations and medical buildings downstream of the main distribution board.

5.2 Power Supply

5.2.1 *General*

In medical locations the distribution system should be designed and installed to facilitate the automatic change-over from the main distribution network to the electrical safety source feeding essential loads (according to IS 732).

5.2.2 Supplies for electric supply systems for safety services and standby systems in medical locations of group 1 and group 2

In medical locations of group 1 and group 2, the distribution system shall be designed and installed to facilitate the automatic transfer switching or automatic change-over equipment from the main distribution network to the electric source for safety services feeding essential loads (*see* 5.6 of IS 732). Consideration shall be given to all other essential medical and non-medical loads.

Consideration should also be given to the inrush current of any connected equipment.

NOTE — This could also apply to group 0 medical locations.

5.2.3 Power supply for medical locations of group 2

In case of a single fault in the power supply, a total loss of power shall be prevented. This may be achieved by:

– provision of two independent supply lines, and/or

- a UPS within the same fire section for supplying the medical IT system, or
- a UPS that supplies a number of group 2 locations.

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6 PROTECTION FOR SAFETY

For Protection for Safety, please refer to relevant items under 4 of IS 732. Additional requirements have been mentioned against each sub-clause below.

6.1 Protection Against Electric Shock

6.1.1 *Protection against Both Direct and Indirect Contact*

6.1.1.1 *SELV and PELV*

When using SELV and/or PELV circuits in medical locations of group 1 and group 2, the nominal voltage applied to current-using equipment shall not exceed 25 V r.m.s. a.c. or 60 V ripple free d.c.. Protection by insulation of live parts according to 4.2.12.1 of IS 732 and by barriers or enclosures according to 4.2.12.2 of IS 732 is essential.

In medical locations of group 2, exposed-conductive-parts of equipment (for example, operating theatre luminaries), shall be connected to the equipotential bonding conductor.

6.1.2 *Protection Against Direct Contact*

6.1.2.1 *Obstacles*

Protection by obstacles is not permitted.

6.1.2.2 *Placing out of reach*

Protection by placing out of reach is not permitted.

Only protection by insulation of live parts or protection by barriers or enclosures is permitted.

6.1.3 *Protection Against Indirect Contact*

6.1.3.1 *Automatic disconnection of supply*

6.1.3.1.1 *Disconnection of supply*

In medical locations of group 1 and group 2, the following shall apply:

a) For IT, TN and TT systems, the conventional touch voltage U_L shall not exceed 25 V ($U_L \leq 25$ V); and

b) For TN and IT systems, Table 1 shall apply.

Table 1 Maximum Disconnecting Times

(*Clause* 6.1.3.1.1)

TN system		IT system		
Installation Nominal Voltage	Disconnecting Time s	Installation Nominal Voltage	Disconnecting Times s	
*U*o a V		*U*o/*U* V	Neutralnot distributed	Neutral distributed
120	0.35	120-240	0.4	1
230	0.2	230/400	0.2	0.5
277	0.2	277/480	0.2	0.5
400, 480	0.05	400/690	0.06	0.2
580	0.02[b]	580/1 000	0.02[b]	0.08

[a] *U*o is the voltage between phase and neutral.

[b] If such disconnecting time cannot be guaranteed, it is necessary to take other protective measures, such as supplementary equipotential bonding.

NOTE— Disconnection of supply when overload or short-circuit conditions occur, can be achieved by different design methods within the procedures of the general rules in order to satisfy the required safety level.

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6.1.3.1.1.1 *TN systems*

In medical locations of group 1, in final circuits with overcurrent protective devices rated up to 32 A, residual current protective devices with a rated residual operating current not exceeding 30 mA shall be used.

In medical locations of group 2 protection by automatic disconnection of supply by means of residual current protective devices with a rated residual-operating current not exceeding 30 mA shall only be used on the following circuits that are supplying only one single equipment:

Final circuits of ME equipment and ME systems shall be for the exclusive use of such equipment.

Except those of the medical IT system, additional protection by residual current protective devices with a rated residual operating current not exceeding 30 mA shall be used in all final circuits as follows:

a) medical locations of group 1 with overcurrent protective devices rated 32A and below; and
b) medical locations of group 2.

6.1.3.1.1.2 *TT systems*

In medical locations of group 1 and group 2, the requirements of TN systems apply and, in all cases, residual current protective devices shall be used.

6.1.3.1.1.3 *Medical IT system*

In Group 2 medical locations, an IT system shall be used for final circuits and where the same final circuit is connected to more than one ME equipment or ME system, located within the patient environment, excluding:

a) equipment with a rated power greater than 5kVA;
b) X-ray equipment; and
c) the supply of movements of fixed operating tables.

In medical locations of group 2, the supply to final circuits for socket-outlets for ME equipment and ME systems used for life-support of the patient, shall not be automatically disconnected in the event of a first fault.

For each group of rooms serving the same function, at least one separate medical IT system is necessary. The medical IT system shall be equipped with an insulation monitoring device in accordance with IEC 61557-8 with the following specific requirements:

a) The a.c. internal impedance shall be at least 100 kΩ;
b) The test voltage shall not be greater than 25 V d.c.;
c) The injected current, even under fault conditions, shall not be greater than 1mA peak; and
d) Indication shall take place at the latest when the insulation resistance has decreased to 50 kΩ. A test device shall be provided;

NOTE — The necessary additional requirements on IMDs given above are at this time not covered in the equipment standard IEC 61557-8. They will be removed from this publication as soon as they have been treated in the relevant equipment standard.

For each medical IT system, an acoustic and visual alarm system incorporating the following components shall be arranged at a suitable place so that it can be permanently monitored (audible and visual signals) by the medical staff:

a) A green signal lamp to indicate normal operation;
b) A yellow signal lamp which lights when the minimum value set for the insulation resistance is reached. It shall not be possible for this light to be cancelled or disconnected;
c) An audible alarm which sounds when the minimum value set for the insulation resistance is reached. This audible alarm may be silenced; and
d) The yellow signal shall go out on removal of the fault and when the normal condition is restored.

Monitoring of overload and high temperature for the medical IT transformer is required.

6.1.3.1.2 *Supplementary equipotential bonding*

In each medical location of group 1 and group 2, supplementary equipotential bonding conductors shall be installed and connected to the equipotential bonding bus bar for the purpose of equalizing potential differences between the following parts, located in the “patient environment”:

a) Protective conductors;
b) Extraneous-conductive-parts;

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c) Screening against electrical interference fields, if installed;

d) Connection to conductive floor grids, if installed; and

e) Metal screen of the isolating transformer, if any.

NOTE — Fixed conductive non-electrical patient supports such as operating theatre tables, physiotherapy couches and dental chairs should be connected to the equipotential bonding conductor unless they are intended to be isolated from earth.

6.1.3.1.3 In medical locations of group 2, the resistance of the conductors, including the resistance of the connections, between the terminals for the protective conductor of socket-outlets and of fixed equipment or any extraneous-conductive-parts and the equipotential bonding bus bar shall not exceed 0.2 Ω.

NOTE— This resistive value can also be determined by the use of a suitable cross-sectional area of the conductor.

6.1.3.1.4 The equipotential bonding bus bar shall be located in or near the medical location. In each distribution board or in its proximity, an additional equipotential bonding bar shall be provided to which the supplementary equipotential bonding conductor and protective earth conductor shall be connected. Connections shall be so arranged that they are clearly visible and easily disconnected individually.

6.1.4 *Fire Protection*

In medical locations of Group 1 and 2 Arc Fault Detection Devices (AFDDs) are not required to be installed.

In medical locations of Group 0 any Arc Fault Detection Device (AFDD) used shall be subject to a risk assessment.

6.1.5 Protection for safety – Protection against voltage disturbances and electromagnetic disturbances

6.1.5.1 Measures against electromagnetic influences

Special consideration shall be given to electromagnetic interference and electromagnetic compatibility. Further information is provided in Annex C.

7 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

For Selection and erection of electrical equipment, please refer relevant items under **5** of IS 732. Additional requirements have been mentioned against each item below.

7.1 Common Rules

7.1.1 *Operational Conditions and External Influences*

7.1.1.1 *Operating conditions*

7.1.1.1.1 *Transformers for medical IT systems*

It is recommended that the medical IT distribution board is located within 25 m of the point of use. The distribution board should be easily accessible for maintenance which will require it to be located on the same level and the same fire section as the load it serves.

Distribution boards shall be installed outside the group 2 medical locations and should be safely guarded against unauthorized persons.

The rated voltage U_n on the secondary side of transformers shall not exceed 250 V a.c.

7.1.1.1.2 *Medical IT systems for group 2 medical locations*

Transformers shall be in accordance with IEC 61558-2-15, with the following additional requirements:

The leakage current of the output winding to earth and the leakage current of the enclosure, when measured in no-load condition and the transformer supplied at rated voltage and rated frequency shall not exceed 0.5 mA.

Single-phase transformers shall be used to form the medical IT systems for portable and fixed equipment and the rated output shall not be less than 0.5 kVA and shall not exceed 10 kVA.

If the supply of three-phase loads via an IT system is also required, a separate three-phase transformer shall be provided for this purpose with output line-to-line voltage not exceeding 250 V.

7.1.1.2 *External influences*

NOTE — Where appropriate, attention should be given to prevention of electromagnetic interference.

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7.1.1.2.1 *Explosion risk*

NOTES

1 Requirements for medical electrical equipment for use in conjunction with flammable gases and vapors are contained of IS 13450 (Part 1).

2 Where hazardous conditions are likely to occur (for example, in the presence of flammable gases and vapors),special precautions may be required.

3 Prevention of build-up of static electricity is recommended.

Electrical devices (for example, socket-outlets and switches) shall be installed at a distance of at least 0.2 m horizontally (center to center) from any medical gas-outlets, so as to minimize the risk of ignition of flammable gases.

7.1.1.3 *Diagrams, documentation and operating instructions*

Plans of the electrical installation together with records, drawings, wiring diagrams and modifications thereto, as well as instructions for operation and maintenance, shall be provided for the user.

NOTE — Drawings and wiring diagrams should be in accordance with IS 12032 and IEC 61082-1.

The relevant documents are in particular:

a) Block diagrams showing the distribution system of the normal power supply and power supply for safety services in a single-line representation. These diagrams shall contain information on the location of the sub-distribution boards within the building;

b) Main and sub-distribution board block diagrams showing switchgear and control-gear and distribution boards in a single-line representation;

c) Architectural diagrams according to IS 12032 (Part 11);

d) Schematic diagrams of controls;

e) Instructions for operation, inspection, testing and maintenance of storage batteries and power sources for safety services;

f) Computational verification of compliance with the requirements of standards (e.g. with Automatic disconnection of supply);

g) List of loads permanently connected to the power supply for safety services indicating the normal currents and, in the case of motor-operated loads, the starting currents; and

h) A logbook containing a record of all tests and inspections which require to be completed prior to commissioning.

7.2 Wiring Systems

Any wiring system within group 2 medical locations shall be exclusive to the use of equipment and fittings in that location.

7.3 Switchgear and Control-gear

7.3.1 *Protection of Wiring Systems in Medical Locations of Group 2*

Total selectivity shall be ensured for any prospective overcurrent: In case of a short-circuit in a final circuit the incoming circuits of the upstream distribution board shall not be interrupted.

Overcurrent protection against short-circuit and overload current is necessary for each final circuit. Overload current protection is not allowed in the feeder circuits upstream and downstream of the transformer of medical IT-system.

7.4 Other Equipment

7.4.1 *Lighting Circuits*

In medical locations of group 1 and group 2, at least two different sources of supply shall be provided for some of the luminaries by two circuits. One of the two circuits shall be connected to the safety service.

In escape routes, alternate luminaries shall be connected to the safety service (*see* Safety services).

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7.4.2 *Socket-outlet Circuits in the Medical IT System for Medical Locations of Group 2*

At each patient's place of treatment, for example, bedheads, the configuration of socket-outlets shall be as follows:

a) Either a minimum of two separate circuits feeding socket-outlets shall be installed; or

b) Each socket-outlet shall be individually protected against overcurrent.

Where circuits are supplied from other systems (TN-S or TT systems) in the same medical location, socket-outlets connected to the medical IT system shall either:

a) be of such construction that prevents their use in other systems, or

b) be clearly and permanently marked.

7.4.3 *Architecture of Special Safety Supply System in Operation Theatre*

Operating Rooms require impeccable availability and quality of Electric power to ensure maximum patient safety. There shall be dedicated UPS system to ensure the back-up power for at least 3 h. Refer **6.1.3.1.1** Table 1 for safety provisions.

In Group 2 rooms that is operating rooms, an isolated power system panel shall be used for circuits powering medical electrical equipment and systems for survival and surgical applications.The above system architecture shall be supplied as integrated solution comprising of electrical switchgear, insulation monitoring device, medical rated transformer(as per NABH and this section's guidelines) connected to building management system on non proprietory or open protocol communication system.Medical Rated Transformer shall conform to IEC 61558-2-15 and need to be protected against overload and short circuit and temperature monitoring of transfomrer is needed. Insulation monitoring device shall conform to IEC 61557-8. An audible and visual alarm shall be provided to alert medical and facility personnel. For optimum operation of medical equipments,prevention of electromagnetic disturbance is necessary. The above system shall be tested to attenuate electromagnetic disturbances according to **4.5** of IS 732, IEC 61000-2 and IS 14700 (Part 3) (*see* Fig. 2).

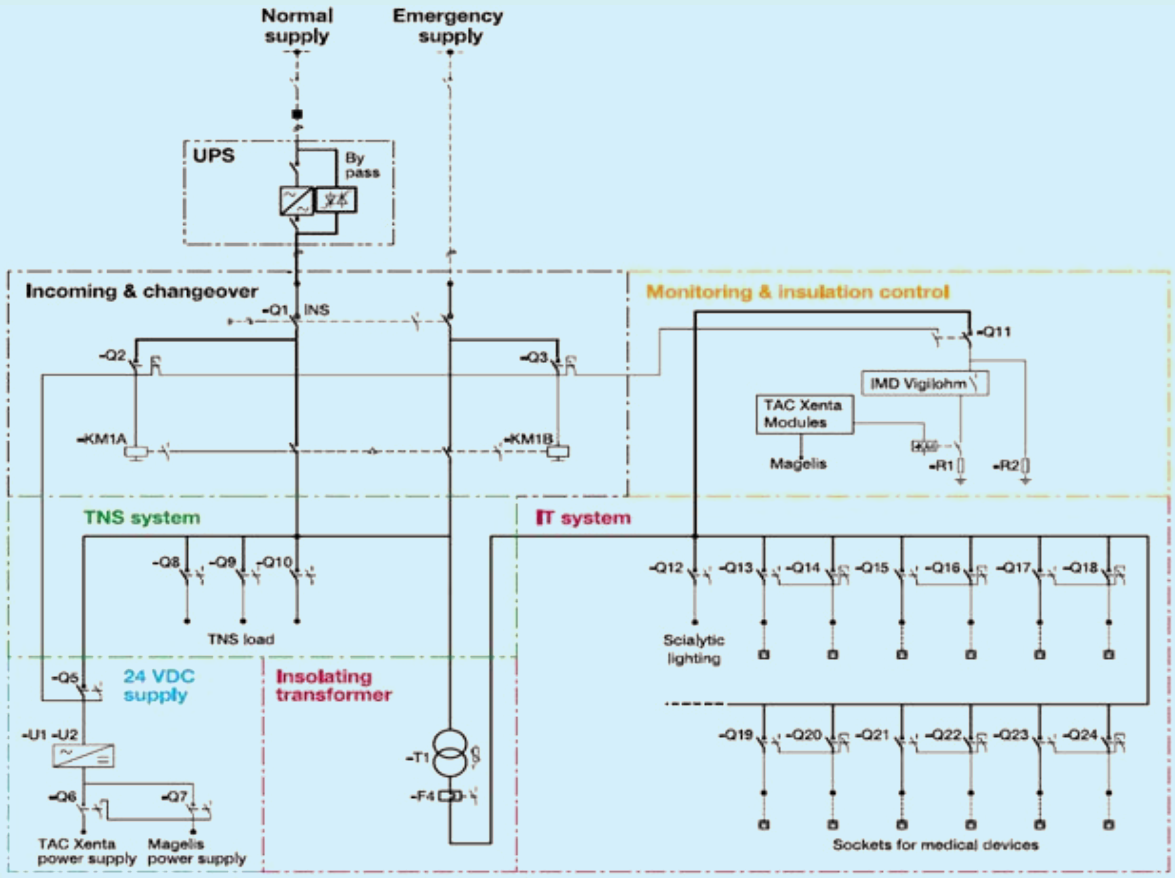


FIG.1 ARCHITECTURE OF SPECIAL SAFETY SUPPLY SYSTEM IN OPERATION THEATRE 8 SAFETY SERVICES

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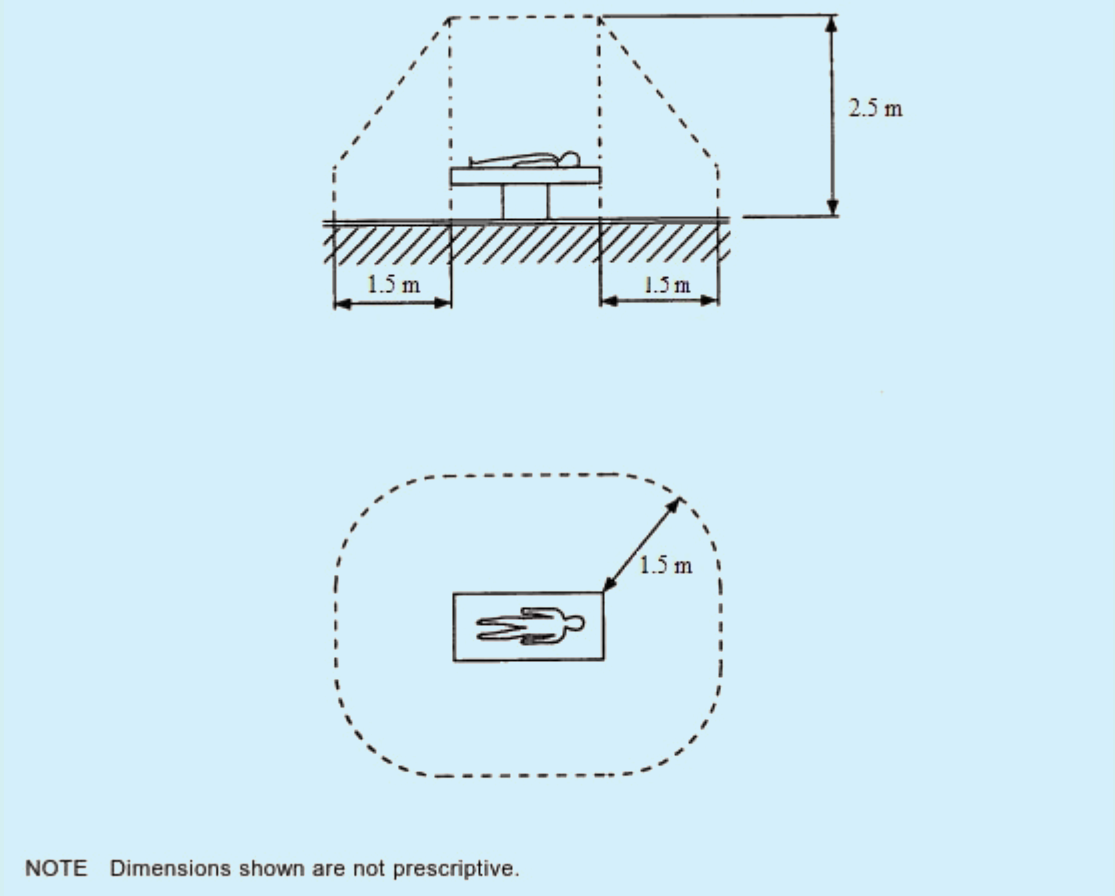


FIG. 2 EXAMPLE OF PATIENT ENVIRONMENT

8.1 Sources

Classification of safety services are given in Annex A.

8.2 General Requirements for Safety Power Supply Sources of Group 1 and Group 2

8.2.1 In medical locations, a power supply for safety services is required which, incase of a failure of the normal power supply source, shall be energized to feed the equipment stated in detailed requirements for safety power supply services with electrical energy for a defined period of time and within a pre-determined changeover period.

8.2.2 If the voltage at the main distribution board drops in one or several line conductors by more than 10 percent of the nominal voltage, a safety power supply source shall assume the supply automatically.

The supply transfer should be achieved with a delay in order to cater for auto re-closure of circuit-breakers of incoming supplies (short-time interruptions).

8.2.3 For interconnecting cables between the individual components and sub-assemblies of safety power supply sources, see wiring systems.

NOTE — The circuit which connects the power supply source for safety services to the main distribution board should be considered a safety circuit.

8.2.4 Where socket-outlets are supplied from the safety power supply source they shall be readily identifiable.

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8.3 Detailed Requirements for Safety Power Supply Services

8.3.1 *Power Supply Sources with A Change-Over Period Less Than or Equal to 0.5 s*

In the event of a voltage failure on one or more-line conductors at the distribution board, an electrical source for safety services shall be used which is capable of providing power supply for a period of at least 3 h for:

a) luminaries of operating theatre tables;

b) ME equipment containing light sources or equipment essential to the application.

As an example, this equipment may include endoscopes and essential equipment, such as monitors; and

c) critical life-supporting ME equipment.

The power supply shall be restored within a change-over period not exceeding 0.5 s.

The duration of 3 h battery may be reduced to 1 h, if a power source as diesel Generator is installed.

8.3.2 *Power Supply Sources with A Change-Over Period Less Than or Equal to 15 s*

Equipment according to Safety lighting and Other services shall be connected within 15 s to a safety power supply source capable of maintaining it for a minimum period of 24 h, when the voltage of one or more line conductors at the main distribution board for the safety services has decreased by more than 10 percent of the nominal value of supply voltage and of a duration greater than 3 s.

NOTE — The duration of 24 h can be reduced to a minimum of 3 h if the medical requirements and the use of the location, including any treatment, can be concluded and if the building can be evacuated in a time which is well within 24 h.

8.3.3 *Power Supply Sources with a Changeover Period Greater than 15 s*

Equipment other than those covered by ‘less than or equal to 0.5 s’ and ‘less than or equal to 15 s’, which is required for the maintenance of hospital services, may be connected either automatically or manually to a safety power supply source capable of maintaining it for a minimum period of 24 h. This equipment may include, for example:

a) Sterilization equipment;

b) Technical building installations, in particular air conditioning, heating and ventilation systems, building services and waste disposal systems;

c) cooling equipment; and

d) cooking equipment.

8.4 Safety Lighting Circuits

8.4.1 *Safety Lighting*

In the event of mains power failure, the necessary minimum illuminance shall be provided from the safety services source for the following locations. The changeover period to the safety source shall not exceed 15 s:

a) escape routes, stores, staircases ;

b) Lighting of exit signs/points;

c) Locations for switchgear and control-gear for emergency generation sets and for main distribution boards of the normal power supply and for power supply for safety services;

d) Rooms in which essential services are intended. In each room at least one luminaryshall be supplied from the power source for safety services;

e) Rooms of group 1 medical locations. In each room at least one luminary shall be supplied from the power supply source for safety services; and

f) Rooms of group 2 medical locations. A minimum of 50 percent of the lighting shall be supplied from the power source for safety services.

NOTE — The values for minimum illuminance can be given by national and/or local regulations.

8.5 Other Services

Services other than lighting which require a safety service supply with a changeover period not exceeding 15 s may include, for example, the following:

a) selected lifts for firemen;

b) ventilating systems for smoke extraction;

c) paging systems;

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d) Medical electrical equipment used in group 2 medical locations which serves for surgical or other measures of vital importance. Such equipment will be defined by responsible staff;

e) Electrical equipment of medical gas supply including compressed air, vacuum supply and narcosis (anesthetics) exhaustion as well as their monitoring devices; and

f) Fire detection, fire alarms and fire extinguishing systems.

9 VERIFICATION

The dates and results of each verification shall be recorded.

9.1 Initial Verification

The tests specified below under items a) to e) in addition to the requirements of IS 732, shall be carried out, both prior to commissioning and after alterations or repairs and before-commissioning.

a) Functional test of insulation monitoring devices and the over load monitoring of medical IT systems and acoustical/visual alarm systems.

b) Measurements to verify that the supplementary equipotential bonding is in accordance with Supplementary equipotential bonding.

c) Verification of the integrity of the facilities required with Supplementary equipotential bonding for equipotential bonding.

d) Verification of the integrity of the requirements of Safety services for safety services.

e) Measurements of leakage current of the output circuit and of the enclosure of medical IT transformers in no-load condition.

9.2 Periodic Verification

Periodic verification of items a) to e) of Initial verification shall be carried out in accordance with local/national regulations. If no local/national regulations exist, the following intervals are recommended:

a) Functional testing of changeover devices: 12 months;

b) Functional testing of insulation monitoring devices: 12 months;

c) Checking, by visual inspection, settings of protective devices: 12 months;

d) Measurement verifying the supplementary equipotential bonding: 36 months ;

e) Verifying integrity of facilities required for equipotential bonding: 36 months;

f) Monthly functional testing of:

   1) Safety services with batteries: 15 min;

   2) Safety services with combustion engines: until rated running temperature is achieved; 12 months for “endurance run”;

   3) Safety services with batteries: capacity test;

   4) Safety services with combustion engines: 60 min;

   In all cases at least 50 percent to 100 percent of the rated power shall be taken over.

g) Measurement of leakage currents of IT transformers: 36 months; and

h) Checking of the tripping of RCDs at IΔN: not less than 12 months.

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ANNEX A

(*Normative*)

CLASSIFICATION OF SAFETY SERVICES FOR MEDICAL LOCATIONS

Table A-1 Classification of Safety Services Necessary for Medical Locations

(*see also* IS 732)

Class 0 (no-break)	Automatic supply available at no-break
Class 0.15 (very short break)	Automatic supply available within 0.15s
Class 0.5 (short break)	Automatic supply available within 0.5s
Class 15 (medium break)	Automatic supply available within 15s
Class > 15 (long break)	Automatic supply available in more than 15s

NOTES

1 Generally, it is unnecessary to provide a no-break power supply for medical electrical equipment. However, certain microprocessor-controlled equipment may require such a supply.

2 Safety services provided for locations having differing classifications should meet that classification which gives the highest security of supply. Refer to Annex B for guidance on the association of classification of safety services with medical locations.

3 The notation “within” implies “≤ ”.

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ANNEX B

(*Informative*)

EXAMPLES FOR ALLOCATION OF GROUP NUMBERS AND CLASSIFICATION FOR SAFETY SERVICES OF MEDICAL LOCATIONS

B-1 A definitive list of medical locations showing their assigned groups is impracticable, as the use to which locations (rooms) might be put will differ within a country.

The accompanying list of examples is provided in Table B-1 as a guide only.

Table B-1 List of Examples

(*Clause* B-1)

Medical location	Group			Class	
	0	1	2	≤ 0.5 s	> 0.5s ≤ 15 s
1. Massage room	x	X			X
2. Bedrooms		X			
3. Delivery room		x		X[a]	X
4. ECG, EEG, EHG room		x			X
5. Endoscopic room		X[b]			X[b]
6. Examination or treatment room		X			X
7. Urology room		X[b]			X[b]
8. Radiological diagnostic and therapy room, other than mentioned under 21		X			X
9. Hydrotherapy room		X			X
10. Physiotherapy room		X			X
11. Anesthetic room			X	X[a]	X
12. Operating theatre			X	X[a]	X
13. Operating preparation room		X	X	X[a]	X
14. Operating plaster room		X	X	X[a]	X
15. Operating recovery room		X	X	X[a]	X
16. Heart catheterization room			X	X[a]	X
17. Intensive care room			X	X[a]	X
18. Angiographic examination room			X	X[a]	X
19. Haemodialysis room		X			X
20. Magnetic resonance imaging (MRI) room		X			X
21. Nuclear medicine		X			X
22. Premature baby room			X	X[a]	X

[a] Luminaries and life-support medical electrical equipment which needs power supply within 0.5s or less.

[b] Not being an operating theatre.

B-2 TERMINOLOGY

Terms listed in Table B-1.

B-2.1 Massage Room

B-2.2 General Ward (Bedrooms)

Medically used room or group of rooms in which patients are accommodated for the duration of their stay in a hospital, or in any other medical establishment.

B-2.3 Delivery Room

Room in which the birth takes place.

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B-2.4 Electrocardiography Room (ECG), Electroencephalography Room (EEG), Electrohystero-Graphy Room (EHG)

B-2.5 Endoscopic Room

Room intended for application of endoscopic methods for the examination of organs through natural or artificial orifices.

Examples of endoscopic methods are bronchoscopic, laryngoscopic, cystoscopic, gastroscopic and similar methods, if necessary, performed under anesthesia.

B-2.6 Examination or Treatment Room

B-2.7 Urology Room (Not Being an Operating Theatre)

Room in which diagnostic or therapeutic procedures are performed on the urogenital tract using medical electrical equipment, such as X-ray equipment, endoscopic equipment and high-frequency surgery equipment.

B-2.8 Radiological Diagnostic Room (Radiological Diagnostic and Therapy Room)

B-2.8.1 *Radiological Diagnostic Room*

Room intended for the use of ionizing radiation for display of internal structures of the body by means of radiography or fluoroscopy or by the use of radio-active isotopes or for other diagnostic purposes.

B-2.8.2 *Therapy Room*

Room intended for the use of ionizing radiation to obtain therapeutic effects.

B-2.9 Hydrotherapy Room

Room in which patients are treated by hydrotherapeutic methods Examples of such methods are therapeutic treatments with water, brine, mud, slime, clay, steam, sand, water with gases, brine with gases, inhalation therapy, electrotherapy in water (with or without additions), massage thermotherapy and thermotherapy in water (with or without additions).

Swimming pools for general use and normal bathrooms are not considered as hydrotherapy rooms.

B-2.10 Physiotherapy Room

Room in which patients are treated by physiotherapeutic methods.

B-2.11 Anesthetic Room

Medically used room in which general inhalation anesthetics are administered.

NOTE — The anesthetic room comprises for instance the actual operating theatre, the operating preparation room, the operating plaster room and treatment room.

B-2.12 Operating Theatre

Room in which surgical operations are performed.

B-2.13 Operating Preparation Room

Room in which patients are prepared for an operation, for example, by administering anesthetics.

B-2.14 Operating Plaster Room

Room in which plaster of paris or similar dressings are applied while anesthesia is maintained.

NOTE — Such a room belongs to the operating room group and is usually spatially connected to it.

B-2.15 Operating Recovery Room

Room in which the patient under observation recovers from the influence of anesthesia.

NOTE—Such a room is usually very close to the operating room group but not necessarily part of it.

B-2.16 Heart Catheterization Room

Room intended for the examination or treatment of the heart using catheters. Examples of applied procedures are measurement of action potentials of the hemodynamic of the heart, drawing of blood samples, injection of contrast agents or application of stimulants.

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B-2.17 Intensive Care Room

Room in which bed patients are monitored independently of an operation by means ofmedical electrical equipment Body actions may be stimulated if required.

B-2.18 Angiographic Examination Room

Room intended for displaying arteries or veins, etc. with contrast media.

B-2.19 Haemodialysis Room

Room in a medical establishment intended to connect patients to medical electrical equipment in order to detoxicate their blood.

B-2.20 Magnetic Resonance Imaging (MRI)

B-2.21 Nuclear Medicine

B-2.22 Premature Baby Room

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ANNEX C

(*Informative*)

C-1 GUIDANCE CONCERNING ELECTROMAGNETIC INTERFERENCES (EMI)

The following values may be outdated and should be updated with the appropriate parts of the

IEC 61000 series. Some equipment will be more sensitive to electromagnetic interference (EMI). Therefore, the EMI limits of the medical equipment should be those recommended by the manufacturer.

Disturbances are not expected, if the magnetic induction B at 50 Hz does not exceed the following values at the patient position:

a) Btt = 0,1 μT for electromyogram (EMG);
b) Btt = 0,2 μT for electroencephalogram (EEG); and
c) Btt = 0,4 μT for electrocardiogram (ECG).

In general, these limit values are not exceeded, if the following minimum distances in all directions are observed between electrical equipment, which can cause magnetic disturbances, and the places of patient examination:

a) where inductive equipment with large output is used, a distance of 6 m in general is sufficient;

   Examples of such equipment:

   – transformer of the electrical power installation, for example of the IT system;
   – permanently installed motors, especially motors with nominal output exceeding 3 kW.

b) between multi-strand cables and lines of the electrical power installation and patient positions to be protected, in accordance with Table C-1.

Table C-1 Minimum Distances

Conductor Cross-section	Minimum Distance
10 mm^2 to 70 mm^2	3 m
95 mm^2 to 185 mm^2	6 m
> 185 mm^2	9 m

Larger distances may be required with single conductors. If there is a requirement to check the adherence of limit values, it is recommended to have an experts opinion.

Further mitigation measures may be:

a) passive (electrically) protective screening of the sources of electromagnetic fields;
b) passive (electrically) protective screening of the medical locations with special electromagnetic compatibility (EMC) needs;
c) use of active compensation systems;
d) use of equipment with lower sensitivity against external electromagnetic fields.

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SECTION 10 REQUIREMENTS FOR SPECIAL INSTALLATIONS OR LOCATIONS — EXHIBITIONS, SHOWS AND STANDS

FOREWORD

This section provides requirements for temporary electrical installations associated with exhibitions, shows and stands. Such installations may be installed indoors or outdoors within permanent or temporary structures. The electrical installation of the building, if any, in which the exhibition, show or stand will take place, will not be considered.

For the purpose of this part of NEC Part 3 Section 10, the requirements of IS 732 : 2019 shall apply. This Part 3 Section 10 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 10 clauses are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

The particular requirements of this section (Part 3/Sec 10) of NEC apply to the temporary electrical installations of exhibitions, shows and stands (including mobile and portable displays and equipment).

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
IEC 60332-1-1 : 2015	Tests on electric and optical fibre cables under fire conditions — Part 1-1: Test for vertical flame propagation for a single insulated wire or cable — Apparatus
IEC 60332-3 : 2018	Tests on electric and optical fibre cables under fire conditions : Test 3 Test for vertical flame spread of vertically-mounted bunched wires or cables — Apparatus
IS/IEC 60309-1 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 1 General requirements
IS/IEC 60309-2 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 2 Dimensional interchangeability requirements for pin and contact-tube accessories
IEC 60364-7-705 : 2006	Low-voltage electrical installations — Part 7-705: Requirements for special installations or locations — Agricultural and horticultural premises
15885 (all Parts) : 2011	Safety of lamp controlgear
IS/IEC 61558 (all parts)	Safety of power transformers, powerSupply units and similar
16205 (all Parts) : 2017	Conduit systems for cable management
14927 (all parts) : 2001	Cable trunking and ducting systems for electrical installations
IEC 61034 (all parts)	Measurement of smoke density of cables burning under defined conditions
IEC 60227 (all parts)	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V
IEC 60245 (all parts)	Rubber insulated cables — Rated voltages up to and including 450/750 V

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3 TERMINOLOGY

For the purposes of this document, the following terms and definitions apply.

3.1 Exhibition — Event intended for the purpose of displaying and/or selling products etc., which can take place at any suitable location, for example a room, building or temporary structure or outdoors.

3.2 Show — Display, presentation or performance which can take place in any suitable location, for example a room, building or temporary structure or outdoors.

3.3 Stand — Area or temporary structure used for display, marketing, sales, entertainment, etc.

3.4 Temporary Structure — Unit or a part of a unit including mobile portable units, situated indoors or outdoors, designed and intended to be assembled and dismantled.

3.5 Temporary Electrical Installation — Electrical installation erected and dismantled in conjunction with, for example the stand or display with which it is associated.

3.6 Origin of the Temporary Electrical Installation — Point on the permanent installation or other source of supply from which electrical energy is delivered to the temporary electrical installation.

4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1.5.6 *Purposes, supplies and structure*

4.1.5.9 *Supplies*

Add the following:

The nominal supply voltage to earth of electrical installations in exhibitions, shows and stands shall not exceed 230 V RMS a.c. or 350 V ripple free d.c..

4.2 Protection for Safety-Protection against Electric Shock

General requirement

4.2.6 *Replace the requirement with the following:*

The protective measures:

a) obstacles, and

b) placing out of reach.

as specified in IS 732, Annex B shall not be used.

4.2.7 *Replace the requirement with the following:*

The protective measures:

a) non-conducting location,

b) earth-free equipotential bonding, and

c) electrical separation for the supply of more than one current-using equipment as specified in IS 732, Annex C shall not be used.

4.2.101 All final circuits not exceeding 32 A supplying socket-outlets, all final circuits for lighting, except emergency lighting and all final circuits supplying hand-held electrical equipment that has a rated current not exceeding 32 A shall:

a) be protected by automatic disconnection of supply together with additional protection by the use of residual current devices (RCD) having a rated residual operating current not exceeding 30 mA (IS 732, 4.2.15.1.1), or

b) be supplied by SELV or PELV (IS 732, 4.2.14), or

c) have electrical separation of circuits (IS 732, 4.2.13), each socket-outlet and hand-held electrical equipment being supplied by an individual isolating transformer or by separate windings of an isolating transformer.

4.2.11 *Protective Measure: Automatic Disconnection of Supply*

4.2.11.3 *Requirements for fault protection*

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4.2.11.3.2 *Automatic disconnection in case of a fault*

4.2.11.3.2.101 For circuits supplying temporary structures, RCDs shall be used as automatic disconnection devices.

4.2.11.4 *TN system*

4.2.11.4.101 A PEN conductor shall not be used in the installation.

4.2.14 *Protective Measure: Extra-Low Voltage provided by SELV and PELV*

4.2.14.4 *Requirements for SELV and PELV circuits*

4.2.14.4.5 *Replace the subclause with the following:*

Irrespective of the nominal voltage, in a.c. and d.c. circuits, the requirement for basic protection shall be provided by the following:

a) basic insulation in accordance with A-1 of IS 732, or
b) barriers or enclosures in accordance with A-2 of IS 732.

4.2.15 *Additional Protection*

4.2.15.2 *Additional protection: supplementary protective equipotential bonding*

Add the following:

In locations intended for livestock, consideration shall be given to applying the relevant supplementary protective equipotential bonding requirements of IEC 60364-7-705.

4.3.1 *Protection against Thermal Effects*

4.3.2 *Precautions where Particular Risks of Fire Exist*

4.3.2.4 *Locations with combustible constructional materials*

4.3.2.4.101 *Heat generation*

Lighting equipment such as incandescent lamps, spotlights and small projectors, and other equipment or appliances with high temperature surfaces shall be suitably guarded, and installed and located in accordance with the relevant standard. All such equipment shall be arranged well away from combustible material to prevent contact.

Showcases and signs shall be constructed of materials having an adequate heat resistance, mechanical strength, electrical insulation and ventilation, taking into account the combustibility of exhibits in relation to the heat generation.

Stand installations containing a concentration of electrical apparatus, lighting fittings or lamps liable to generate excessive heat shall not be installed unless adequate ventilation provisions are made, for example well-ventilated ceilings constructed of incombustible material.

5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.1 Common Rules

5.1.101 Control and protective switchgear shall be placed in closed cabinets which can only be opened by the use of a key or a tool, except for those parts designed and intended to be operated by ordinary persons (BA1 in IS 732, Table 7).

5.1.1 *Compliance with Standards*

5.1.1.1 *Add the following:*

Where interchangeability is required:

a) socket-outlets with a rated current not exceeding 16 A shall comply with IS/IEC 60309 or relevant national standards, and
b) socket-outlets with a rated current exceeding 16 A but not exceeding 125 A shall comply with IS/IEC 60309-2.

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Sockets-outlets shall comply with IS/IEC 60309-1 where:

a) the rated current exceeds 125 A, or

b) interchangeability is not required.

5.2 Wiring Systems

5.2.101 Conductors shall have a cross-sectional area of not less than 1.5 mm^2 copper.

Cables shall be in accordance with IEC 60227 (all parts) or IEC 60245 (all parts), as appropriate.

Flexible cables shall not be laid in areas accessible to the public unless they are protected against mechanical damage.

5.2.4 *Types of Wiring Systems*

5.2.4.101 Where no fire alarm system is installed in a building used for exhibitions, etc. cable systems shall be either:

a) non-flame propagating according to IEC 60332-1-1 or IEC 60332-3 (all parts), and low smoke according to IEC 61034 (all parts), or

b) single or multicore unarmoured cables enclosed in metallic or non-metallic conduit or trunking, providing resistance to flame propagation in accordance with IS 16205 (all parts) or IS 14927 (all parts), providing a degree of protection of at least IP4X or IPXXD.

5.2.9 *Electrical Connections*

Joints shall not be made in cables except where necessary as a connection into a circuit. Where joints are made, these shall be either using connectors in accordance with the relevant IEC standards or the connection shall be made in an enclosure with a degree of protection of at least IP4X or IPXXD.

5.3 Isolation, Switching and Control

5.3.6 *Co-ordination of various Protective Devices*

5.3.6.3 *Discrimination between residual current protective devices*

Replace the first paragraph with:

Discrimination between residual current protective devices installed in series shall be provided.

5.3.7 *Isolation and Switching*

5.3.7.3 *Isolation*

5.3.7.3.1.1 *Add the following:*

Every separate temporary structure, such as a vehicle, a stand or a unit, intended to be occupied by one specific user and each distribution circuit supplying outdoor installations shall be provided with their own readily accessible and properly identifiable means of isolation.

5.5 Other Equipment

5.5.101 *ELV Transformers and Electronic Converters*

Multiple connection extra low voltage (ELV) transformers shall conform with IEC 61558 (all parts) or provide an equivalent degree of safety.

Particular care shall be taken when installing ELV transformers, which shall be mounted out of arm's reach of the public and shall have adequate ventilation. Access by skilled (BA5 in in IS 732, Table 7) or instructed (BA4 in IS 732, Table 7) persons for testing and maintenance shall be provided.

Electronic converters shall conform with IS 15885 (all parts).

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5.5.3 *Luminaires and Lighting Installations*

5.5.3.3 *General requirements for installations*

5.5.3.3.101 *Luminaires*

Luminaires mounted below 2.5 m (arm's reach) from floor level or otherwise accessible to accidental contact shall be firmly and adequately fixed, and so sited or guarded as to prevent risk of injury to persons or ignition of materials.

5.5.3.3.102 *Lampholders*

Insulation piercing lampholders shall not be used unless the cables and lampholders are compatible, and providing the lampholders are non-removable once fitted to the cable.

5.5.3.3.103 *Electrical discharge lamp installations*

5.5.3.3.103.1 *General*

Circuits, other than the internal wiring of an exhibit not covered by a relevant product standard, operating at voltages exceeding 230/400 V a.c. derived from an installation of a lower nominal voltage, shall meet the requirements of **5.5.3.3.103.2** to **5.5.3.3.103.4**.

5.5.3.3.103.2 *Location*

The sign or lamp shall be installed out of arm's reach or shall be adequately protected to reduce the risk of injury to persons.

5.5.3.3.103.3 *Installation*

The facia or stand fitting material behind luminous tube signs or lamps shall be non-ignitable and protected as required by national standards.

Controlgear with output voltages higher than 230/400 V a.c. shall be mounted on non-ignitable material.

5.4.5.5 *Emergency switching devices*

A separate circuit shall be used to supply such signs, lamps or exhibits, which shall be controlled by an emergency switch.

The switch shall be easily visible, accessible and marked in accordance with the requirements of the local authority.

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SECTION 11 REQUIREMENTS FOR SPECIAL INSTALLATIONS OR LOCATIONS — FURNITURE

FOREWORD

In recent times, there are an increasing number of furniture products sold in the market that are designed using electrical components to enhance the features beyond those normally considered important for furniture (strength, durability and comfort). Therefore it imperative that the furniture industry has reliable access to information to ensure compliance, and of course safety for the end-users.

These enhancements may include power outlets, USB outlets, wi-fi induction chargers, short range wireless communication controllers and Bluetooth connected speakers/devices. This section provides the requirements for electrical installations included in furniture.

For the purpose of this part of NEC Part 3 Section 2, the requirements of IS 732 : 2019 shall apply. This Part 3 Section 2 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 2 clauses are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

The particular requirements of this (Part 3/Sec 11) of NEC apply to the wiring system of furniture (and similar fitments) which is connected to the electrical installation.

Examples are beds, cupboards, desks and shop display cases, in which electrical equipment such as luminaires, installation couplers according to IEC 61535, socket-outlets, switching devices and wiring systems are installed.

The requirements of this part apply to all kinds of furniture, regardless of the connection to the electrical installation of the building, as long as the furniture together with its electrical installation is not the subject of another IEC publication.

The requirements of this part apply to electrical equipment of furniture connected to a supply with a nominal voltage U_O not exceeding 230 V and a total load current not exceeding 32 A.

These requirements do not apply to electrical appliances and equipment specifically designed for installation in furniture and which are the subject of other IEC standards, for example radios, TV receivers, refrigerators and laboratory tables, installed in the furniture and ready for connection to the electrical installations of buildings via plugs and socket-outlets. For special locations, other specific requirements may apply, for example *see* Part 3/Section 2 of NEC.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
14772 : 2020	General requirements for enclosures for accessories for household and similar fixed electrical installations — Specification
IEC 60227-3 : 1997	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V — Part 3: Non-sheathed cables for fixed wiring

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IS/IEC/ISO Number	*Title*
IEC 60227-5 : 2011	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V — Part 5: Flexible cables (cords)
IEC 60245-1 : 2007	Rubber insulated cables — Rated voltages up to and including 450/750 V: Part 1 General requirements
IEC 60245-4 : 2011	Rubber insulated cables — Rated voltages up to and including 450/750 V-Part 4 Cords and flexible cables
IEC 61535 : 2019	Installation couplers intended for permanent connection in fixed installations
IEC 62440 : 2008	Electric cables with a rated voltage not exceeding 450/750 V — Guide to use

3 TERMINOLOGY

For the purposes of this document, the following terms and definitions apply.

3.1 Furniture — Movable or immovable articles such as desks, chairs, tables and work benches, cupboards, shelves and beds which are used for activities associated with work or leisure.

4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.2 Protection for Safety – Protection against Electric Shock

4.2.15 *Additional Protection*

4.2.15.1 *Additional protection: residual current protective devices (RCDs)*

4.2.15.1.1

Add the following:

The electrical installation of the furniture shall be protected by an RCD with a rated residual operating current not exceeding 30 mA.

5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.2 Wiring Systems

Add the following:

5.2.5.116 *Selection of wiring system*

The wiring system for connecting furniture to the electrical installation shall be:

a) rigid cable according to IEC 60227-3 or IEC 60245-1, if connected by permanent connection or installation coupler, as applicable; or of ordinary or heavy class of duty according to IEC 62440; and

b) rubber-insulated flexible cables and cords according to IEC 60245-4 or PVC-insulated flexible cables to IEC 60227-5 of ordinary or heavy class of duty according to IEC 62440, if connected by means of a plug and socket-outlet or by an installation coupler according to IEC 61535, as applicable.

Furniture intended to be moved shall be wired using flexible cables or cords according to IEC 60245-4 or IEC 60227-5.

Cables and cords shall be suitably protected against damage. They shall be securely fixed to the furniture or located in cable ducting, cable trunking, conduit, articulated systems for cable guiding, or a channel specially formed during the construction of the furniture.

5.5 Other Equipment

Add the following:

5.5.101 *Selection of Accessories*

Flush mounted boxes shall fulfil the requirements for hollow wall boxes according to IS 14772.

Surface mounted boxes shall comply with IS 14772.

Installed accessories shall be oriented or provided with a means to prevent the risk of electrical hazards from liquid spillage that can be reasonably expected.

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SECTION 12 EXTRA-LOW-VOLTAGE LIGHTING INSTALLATIONS

FOREWORD

Extra-low voltage (ELV) lighting is commonly used in domestic and commercial installations, particularly in the form of recessed downlighter luminaires. Specific requirements relating to ELV lighting installations are introduced in this section of NEC. The chapter also includes information on the requirements for the enclosure of terminations and joints in ELV lighting installations and on methods to be employed for minimising the spread of fire when installing downlighters.

For the purpose of this part of NEC Part 3 Section 12, the requirements of IS 732 : 2019 shall apply.

This Part 3 Section 12 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 12 clauses are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

The particular requirements of this section (Part 3/Sec 12) of NEC apply to the selection and erection of extralow voltage lighting installations supplied from sources with a maximum rated voltage of 50 V a.c. or 120 V d.c.

NOTES

1 For the definition of an extralowvoltage lighting system *see* IEC 60598-2-23.

2 a.c. voltages are given as r.m.s. values.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
IEC 60570 : 2019	Electrical supply track systems for luminaires
IEC 60598-2-23 : 2020	Luminaires — Part 2-23: Particular requirements — Extra-low-voltage lighting systems for filament lamps
IEC 60998-2-1 : 2002	Connecting devices for low-voltage circuits for household and similar purposes — Part 2-1: Particular requirements for connecting devices as separate entities with screw-type clamping units
IEC 60998-2-2 : 2002	Connecting devices for low-voltage circuits for household and similar purposes — Part 2-2: Particular requirements for connecting devices as separate entities with screwless-type clamping units
IEC 61347-2-2 : 2011	Lamp controlgear— Part 2-2: Particular requirements for d.c. or a.c. supplied electronic step-down convertors for filament lamps
IEC 61347-2-13 : 2016	Lamp controlgear — Part 2-13: Particular requirements for d.c. or a.c. supplied electronic controlgear for LED modules
IS/IEC 61558-2-6 : 1997	Safety of power transformers, powersupply units and similar: Part 2 Particular requirements, Section 6 Safety isolating transformers for general use

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4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1 Protection for Safety

4.2 Protection against Electric Shock

4.2.14 *Protective Measure: Extra-Low-Voltage provided by SELV and PELV*

Add the following:

For extralowvoltage lighting installations only SELV shall be applied. Where bare conductors are used, the maximum voltage shall be 25 V a.c. or 60 V d.c. according to **4.2.14.4.5**.

The source of the ELV lighting installation can be one of the following:

A safety isolating transformer complying with IS/IEC 61558-2-6 : 2009.

Parallel operation of transformers in the secondary circuit is allowed only if they are also paralleled in the primary circuit and the transformers have identical electrical characteristics.

A safety isolating convertor complying with Annex I of IEC 61347-2-2 : 2000, for incandescent lamps, or IEC 61347-2-13 : 2006, Annex I for LED.

Parallel operation of convertors is not permitted.

4.3 Protection against Thermal Effects

4.3.2.3 *Locations with risks of fire due to the nature of processed or stored materials*

Add the following:

The manufacturer's installation instructions shall be followed, including those relating to mounting on flammable or non-flammable surfaces.

Luminaires and their accessories shall be designed and placed to avoid harmful heating of materials or surroundings.

NOTE — *See* also IS 732 : 2019, 5.5.3.

Add the following:

4.3.2.106 *Fire risk of transformers/convertors*

Transformers shall be either:

protected on the primary side by the protective device required in **4.3.2.107.2**; or

shortcircuit proof (both inherently and noninherently), *see* IS 732, (Annex EE, Annex A) for the symbol.

Electronic convertors shall comply with IEC 61347-2-2 : 2000 and, for LED-modules with IEC 61347-2-13 : 2006, Annex I.

NOTE — It is recommended that converters marked with the symbol 

are used. The temperature value limitation (of the convertor) within the triangle is given only as an example.

4.3.2.107 *Fire risk due to short-circuit*

4.3.2.107.1 If both circuit conductors are uninsulated, they shall be either:

a) provided with a special protective device complying with the requirements of **4.3.2.107.2**;
b) supplied from a transformer or a convertor, the power of which does not exceed 200 VA; or
c) conductors of a system complying with IEC 60598223 : 1996.

4.3.2.107.2 *The special protective device against the risk of fire shall comply with the following requirements:*

a) continuous monitoring of the power demand of the luminaires;
b) automatic disconnection of the supply circuit within 0.3 s in case of a short-circuit or failure which causes a power increase of more than 60 W;
c) automatic disconnection while the supply circuit is operating with reduced power (for example by gating control or a regulating process or a lamp failure) if there is a failure which causes a power increase of more than 60 W;
d) automatic disconnection in the case of switching on the supply circuit if there is a failure which causes a power increase of more than 60 W; and

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e) the special protective device shall be fail-safe.

NOTE — Account needs to be taken of starting currents.

4.4 Protection against Overcurrent

4.4.1.104 *Protection against overcurrent in ELV lighting installations*

The use of selfresetting overcurrent protective devices is permitted only for transformers up to 50 VA.

5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.2 Wiring Systems

5.2.4 *Types of Wiring System*

5.2.4.1

Replace the text by the following:

The following wiring systems shall be used:

a) insulated conductors in conduit or cable trunking/ducting systems;
b) rigid cables;
c) flexible cables or cords;
d) systems for ELV lighting according to IEC 60598-2-23 : 1996;
e) track systems according to IEC 60570 : 2003; and
f) bare conductors (*see* **5.2.4.106**).

Where parts of the ELV lighting installation are accessible, the requirements of 4.3.3 of IS 732 also apply.

Metallic structural parts of buildings, for example, pipe systems or parts of furniture, shall not be used as live conductors.

Add the following:

5.2.4.106 *Bare conductors*

If the nominal voltage does not exceed 25 V a.c. or 60 V d.c., bare conductors may be used provided that the extralowvoltage lighting installation complies with the following requirements:

a) the lighting installation is designed, installed or enclosed in such a way that the risk of a shortcircuit is reduced to a minimum;
b) the conductors used have a minimum cross sectional area according to **5.2.7** of this section ; and
c) the conductors or wires are not placed directly on combustible material.

For suspended bare conductors, at least one conductor and its terminals shall be insulated, for that part of the circuit between the transformer and the protective device, to prevent a short-circuit.

NOTE — Where bare conductors are used, consideration should be given to the possible presence of combustible material.

Add the following:

5.2.4.107 *Suspended systems*

Suspension devices for luminaires, including supporting conductors, shall be capable of carrying five times the mass of the luminaires (including their lamps) intended to be supported, but not less than 5 kg.

Terminations and connections of conductors shall be made by screw terminals or screwless clamping devices complying with IEC 60998-21 : 2002 or IEC 60998-22 : 2002.

Safety of the installation due to expected stresses in the conductors shall be in accordance with 5.5.3.5.2 of IS 732.

Insulation piercing connectors and termination wires, with counterweights, hung over suspended conductors shall not be used.

In the case of a suspended system with bare conductors it shall be fixed to walls or ceilings by insulated fixing means and shall be continuously accessible throughout the route.

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5.2.6 *Current-Carrying Capacities*

Add the following:

NOTE — Values of current-carrying capacity for uninsulated conductors are under consideration.

5.2.7 *Cross-Sectional Areas of Conductors*

Replace the text by the following:

The minimum cross-sectional area of the ELV conductors which are connected to the output terminals or terminations of transformers/convertors shall be chosen according to the load current.

In the case of systems with luminaires suspended from the conductors, the minimum cross-sectional area of the ELV conductors which are connected to the output terminals or terminations of transformers/convertors shall be 4 mm^2, for mechanical reasons.

5.2.8 *Voltage Drop in Consumers' Installations*

Replace the text by the following:

In ELV lighting installations, the voltage drop between the transformer and the furthest luminaire shall not exceed 5 percent of the nominal voltage of the ELV installation.

5.3 Isolation, Switching and Control

5.3.1 *General and Common Requirements*

Add the following:

5.3.1.104

Protective devices shall be easily accessible.

Protective devices may be located above false ceilings, which are movable or easily accessible, provided that information is given about the presence and location of the device.

If the identification of a protective device for a circuit is not immediately evident, a sign or diagram (label) close to the protective device shall identify the circuit and its purpose.

SELV sources, protective devices or similar equipment mounted above false ceilings or in a similar place shall be permanently connected.

SELV sources and their protective devices shall be installed so as to:

a) avoid mechanical stress on their electrical connections; and
b) be adequately supported; and
c) avoid overheating of the equipment due to thermal insulation.

5.3.7 *Isolation and Switching*

Where transformers are operated in parallel, the primary circuits shall be permanently connected to a common isolating device.

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SECTION 13 REQUIREMENTS FOR SPECIAL INSTALLATIONS OR LOCATIONS — COMMUNITY FACILITIES AND WORKPLACES

FOREWORD

Community facilities and work places can be of various types depending on the size of the civil structure or the extent of activity involved in the building. High-rise buildings housing office complexes are common, calling for a coordinated planning while designing the electrical services therein. In small buildings with comparatively moderate loads, supply is normally at medium voltage and the distribution of power is less complex. However, in the case of multi-storied office-cum-commercial complex, where the large number of amenities is to be provided calls for a more complex distribution system. Some of such buildings has to incorporate a standby/emergency power plant for essential service needs.

For the purpose of this part of NEC Part 3/Sec 13, the requirements of IS 732 : 2019 shall apply. This Part 3/Sec 13 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 13 parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

This section (Part 3/Sec 13) of NEC provides additional requirements for electrical installations applicable to community facilities and workplaces.

Typical examples of community facilities and workplaces are listed below:

a) assembly halls, assembly rooms;
b) exhibition halls;
c) theatres, cinemas;
d) sports arenas;
e) sales areas;
f) restaurants;
g) hotels, guest houses, residential care homes;
h) schools;
j) enclosed car parks;
k) meeting places, swimming halls, airports, railway stations, high-rise buildings; and
m) workshops, factories and industrial plants.

Access routes and escape routes are part of the above-mentioned examples.

The necessity of providing safety services in special buildings and areas may be governed by national regulations which may contain more stringent requirements.

NOTE — For safety services *see* 5.6 of IS 732.

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2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS Number	*Title*
732 : 2019	Code of practice for electrical wiring installations

3 TERMINOLOGY

For the purposes of this document, the following terms and definitions apply.

3.1 Community Facility

Location, building or part of a building open to the public.

3.2 Workplace

Location, building or part of a building in which employees conduct activities relating to their employment.

4 PROTECTION FOR SAFETY

4.1.2.3 *Protection Against Thermal Effects*

4.3.2 *Precautions where Particular Risks of Fire Exist*

4.3.2.2 *Conditions of evacuation in an emergency*

Add the following:

4.3.2.2.101 For communal facilities and workplaces the appropriate condition (BD2, BD3 of BD4) shall be established and the appropriate sub clauses of 4.3 of IS 732 have to be taken into account.

4.3.2.3.7

Add the following:

4.3.2.3.7.101 Motors which are not supervised continuously shall be protected by a thermal protective device or shall be impedance protected motors.

This requirement does not apply to:

a) motors in workplaces with a nominal power less than 500 W; and
b) motors which will not be overheated in the event of stalling.

5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.3 Isolation, Switching and Control

5.3.7 *Isolation and Switching*

Add the following:

5.3.7.101 The distance between the means of switching off for the electrical installation and the place where the corresponding supply cables enter the building shall be as short as practicable.

NOTE — National regulations may require that a means of switching off the electrical installation be provided. Such regulations may also prescribe its location and that it be either installed at an effectively locked location near the entrance to the building or directly accessible by authorized persons only from the outside.

5.3.7.102 If there is equipment in the premises that must remain energized when the building is unoccupied, the electrical installation shall be designed accordingly.

NOTE — Consideration should be given to the provision of separate circuits for such equipment.

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5.5 Other Equipment

5.5.3 *Luminaires and Lighting Installations*

Add the following:

5.5.3.101 *Maintenance of lighting circuits*

5.5.3.101.1 Maintenance of adequate levels of illumination shall be determined by a risk assessment of the premises taking account of the classification of Table 7 of IS 732.

NOTE — In some countries legislation may impose additional requirements.

The different options are as follows:

a) Locations with low risk: single normal lighting final circuit.

NOTE — This is valid for code BD1 in Table 7 of IS 732.

b) Other locations: two or more normal lighting final circuits with luminaires supplied in such a way that failure of any one circuit will not leave any part of the location with an insufficient level of illumination.

If RCDs are used no RCD shall protect more than one final circuit..

NOTE — This is valid for codes BD2 to BD4 in Table 7 of IS 732.

NOTE — Emergency lighting circuits as required can be added to either option.

5.5.3.101.2 If the normal lighting of a location accessible to the public can be dimmed, means shall be provided to reinstate the full level of illumination by an appropriately located switch.

NOTE — In areas such as some places of entertainment it may be necessary to ensure lighting cannot be operated by unauthorized persons.

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SECTION 14 REQUIREMENTS ELECTRICAL INSTALLATIONS IN CARAVANS AND MOTOR CARAVANS

FOREWORD

The particular requirements of this section apply to the electrical installations in caravan/camping parks and similar locations that provide connection points for supplying leisure accommodation vehicles (including caravans) and tents. This section contains specific requirements for the electrical installations in caravans and motor caravans.

For the purpose of this part of NEC Part 3 Section 14, the requirements of IS 732 : 2019 and shall apply. This Part 3 Section 14 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 14 parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of the general parts of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

1.1 The particular requirements of this section of the code (Part 3/Section 14) apply to electrical installations in caravans and motor caravans.

They apply to those electrical circuits and equipment intended for the use of the caravan for habitation purposes.

1.2 They do not apply to those electrical circuits and equipment for automotive purposes.

They do not apply to the electrical installations of mobile homes, residential park homes and transportable units.

NOTES

1 For mobile homes and residential park homes the general requirements apply.

2 For transportable units, *see* 3 of IEC 60364-7-717. For the purposes of this document, caravans and motor caravans are referred to as "caravans".

The particular requirements of some parts from the NEC Part 3 can also apply to such installations in caravans, for example, NEC Part 3 Section 2.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
732 : 2019	Code of practice for electrical wiring installations
IEC 60038 : 2009	IEC standard voltages
IEC 60332-1-2 : 2015	Tests on electric and optical fibre cables under fire conditions — Part 1-2: Test for vertical flame propagation for a single insulated wire or cable — Procedure for 1 kW pre-mixed flame
IS/IEC 60947-2 : 2016	Low-voltage switchgear and controlgear — Part 2: Circuit-breakers (*first revision*)
12640 (Part 1) : 2016	Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs): Part 1 General rules
12640 (Part 2) : 2016	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs): Part 1 General rules

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IS/IEC/ISO Number	*Title*
14927 (Part 1 and Part 2) : 2001	Cables trunking and ducting systems for electrical installations
IEC 61084 (all parts)	Cables trunking and ducting systems for electrical installations
IEC 61386-25 : 2011	Conduit systems for cable management — Part 25: Particular requirements — Conduit fixing devices
16205 : 2017	Conduit systems for cable management
IS/IEC 60309-2 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 2 Dimensional interchangeability requirements for pin and contact-tube accessories
IEC 62423 : 2009	Type F and Type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses

3 TERMINOLOGY

For the purposes of this standard, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

a) IEC Electropedia: available at http://www.electropedia.org/.

b) ISO Online browsing platform: available at http://www.iso.org/obp.

3.1 Leisure Accommodation Vehicle — Unit of living accommodation for temporary or seasonal occupation that may meet the requirements for the construction and use of road vehicles.

3.2 Caravan—Trailer leisure accommodation vehicle, used for touring, that meets the requirements for the construction and use of road vehicles.

3.3 Motor Caravan—Self-propelled leisure accommodation vehicle, used for touring, that meets the requirements for the construction and use of road vehicles.

NOTE — A motor caravan is either adapted from a series production vehicle, or designed and built on an existing chassis, with or without the driving cab, the accommodation being either fixed or dismountable.

3.4 Mobile Home— Transportable leisure accommodation vehicle that includes means for mobility but does not meet the requirements for the construction and use of road vehicles.

3.5 Residential Park Home—Factory produced relocatable dwelling.

4 PURPOSES, SUPPLIES AND STRUCTURE

For requirements of purposes supplies and structure, relevant items under 4.1 of IS 732 may be referred. Additional requirements have been mentioned against each item below.

4.1 Supplies

4.1.1 *General*

The nominal supply system voltage shall be selected from IEC 60038.

The nominal a.c. supply voltage of the installation of the caravan shall not exceed 230 V single-phase, or 400 V three-phase.

The nominal d.c. supply voltage of the installation of the caravan shall not exceed 48 V.

5 PROTECTION FOR SAFETY

For requirements of protection for Safety, relevant items under **4** of IS 732 may be referred. Additional requirements have been mentioned against each item below.

5.1 Protection against Electric Shock

5.1.1 The protective measures of obstacles and placing out of reach as specified in Annex B of IS 732 shall not be used.

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5.1.2 The protective measures of non-conducting locations and earth-free local equipotential bonding as specified in Annex C of IS 732 shall not be used.

NOTE— This precludes the use of class 0 equipment.

5.1.3 *Protective Measure: Automatic Disconnection of Supply*

5.1.3.1 *Protective equipotential bonding*

Metal frame parts or thereto connected construction parts shall be connected through main protective bonding conductors to the main earthing terminal within the caravan.

5.1.4 *Protective Measure: Electrical Separation*

The protective measure: electrical separation shall not be used, except for a shaver socket-outlet.

5.1.5 *Protective Measure: Extra-Low Voltage Provided by SELV and PELV*

Any part of a caravan installation operating at extra-low voltage shall comply with the requirements of 4.2.14 of IS 732.

For extra-low voltage d.c. power sources, a maximum of 48 V are allowed. In exceptional cases, when a.c. extra-low voltage is required, the voltage (rms) is not allowed to exceed 48 V.

The requirements of this Part are also applicable to extra low-voltage d.c. installation. *See* Annex B for recommendations that can be applied in addition.

5.1.6 *Additional Protection*

5.1.6.1 *Additional protection: residual current protective devices (RCDs)*

Addition:

Where protection by automatic disconnection of supply is used, a residual current device with a rated residual operating current not exceeding 30 mA, complying with IS/IEC 60947-2, IS 12640 (Part 1), IS 12640 (Part 2) or IEC 62423 breaking all live conductors, shall be provided. Each supply inlet shall be directly connected to its associated RCD.

NOTE — This implies that there cannot be any taps or junctions in this connection.

Consideration should be given to the characteristics of the load in selection of the type of RCD.

5.2 Protection Against Overcurrent

5.2.1 *Final Circuits*

Each final circuit shall be protected by an overcurrent protective device which disconnects all live conductors of that circuit.

6 SELECTION AND ERECTION OF EQUIPMENT

For selection and erection of electrical equipment, relevant items under 5 of IS 732 shall be referred. Additional requirements have been mentioned against each item below.

6.1 Common Rules

6.1.1 *Introduction*

6.1.1.1 *General*

Where there is more than one electrically independent installation, each independent installation shall be supplied by a separate connecting device and shall be segregated (in accordance with general rules) such that supplies at different voltages cannot be interconnected.

NOTE — Independent installations. An installation is an assembly of associated electrical equipment having co-ordinated characteristics to fulfil specific purposes.

6.1.2 *Operational Conditions and External Influences*

6.1.2.1 *External influences*

Consideration shall be given to the foreseeable external influences to which the caravan will be subjected.

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6.1.3 *Identification*

6.1.3.1 *General*

Instructions for use shall be provided with the caravan so that the caravan can be used safely.

The instructions shall comprise:

a) a description of the installation;
b) a description of the function of the RCD(s) and the use of the test button;
c) a description of the function of the main isolating switch (es);
d) the text of the instructions of Annex A.
e) additional instructions necessary for user maintenance.

6.2 Wiring Systems

6.2.1 *Types of Wiring Systems*

6.2.1.1 The wiring system shall use one or more of the following:

a) insulated single-core cables, with flexible class 5 conductors, in non-metallic conduit or non-metallic trunking system;
b) insulated single-core cables, with stranded class 2 conductors (minimum of seven strands), in non-metallic conduit or non-metallic trunking system; and
c) sheathed flexible cables.

All cables shall as a minimum meet the requirements of IEC 60332-1-2.

Non-metallic conduit systems shall comply with the relevant part of IS 16205 (all parts) or IEC 61386 (relevant parts).

Cable trunking systems and cable ducting systems shall comply with the relevant part of IEC 61084 (all parts).

6.2.2 *Selection and Erection of Wiring Systems in Relation to External Influences*

6.2.2.1 *Vibration (AH)*

6.2.2.1.1 As the wiring will be subjected to vibration, all wiring shall be protected against mechanical damage either by location or by enhanced mechanical protection. Wiring passing through metalwork shall be protected by means of suitable bushes or grommets, securely fixed in position. Precautions shall be taken to avoid mechanical damage due to sharp edges or abrasive parts.

6.2.2.2 *Other mechanical stresses (AJ)*

6.2.2.2.1 All cables, unless enclosed in rigid conduit, trunking, or flexible conduit shall be supported at intervals not exceeding 0.4 m for vertical runs and 0.25 m for horizontal runs.

6.2.3 *Cross-Sectional Areas of Conductors*

6.2.3.1 The cross-sectional area of every conductor shall be not less than 1.5 mm^2 copper or copper equivalent.

6.2.4 *Electrical Connections*

Connections between cables or conductors shall only be made in connecting boxes or by electrical equipment.

NOTE — Connections also include junctions and taps.

6.2.5 *Proximity of Wiring Systems to Other Services*

6.2.5.1 *Proximity to non-electrical services*

6.2.5.1.1 *Add the following at the end of 5.2.11.3.1 of IS 732:*

No electrical equipment including wiring systems, except:

a) ELV (extra low voltage) equipment for gas supply control; and
b) cables running through a gas compartment without connection shall be installed in any gas cylinder compartment.

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Such electrical installations and components shall be constructed and installed so that they are not a potential source of ignition.

Where cables have to run through such a compartment such cables shall be protected against mechanical damage by installation within a continuous conduit or duct passing through the compartment at a height of not less than 500 mm above the base of the cylinders.

Where installed in a position where it is likely to be subject to mechanical damage this conduit or duct shall be able to with stand an impact equivalent to AG3 without visible physical damage.

6.3 Isolation, Switching and Control

6.3.1 *Isolation and Switching*

6.3.1.1 *Isolation*

6.3.1.1.1 Each independent installation shall be provided with its own main isolating switch which shall disconnect all live conductors and which shall be suitably placed in a readily accessible location in the caravan. In an installation consisting of only one final circuit, the isolating switch may be the overcurrent protection device providing such a device meets the requirements for isolation.

6.3.1.1.1.1 A notice in durable material shall be permanently fixed in the vicinity of the main isolating switch inside the caravan, bearing the text shown in Annex A in the official language(s) of the country in which the caravan is to be sold for the first time, in indelible and easily legible characters.

6.4 Earthing Arrangements and Protective Conductors

6.4.1 *Protective Conductors*

6.4.1.1 *Types of protective conductors*

Circuit protective conductors shall be incorporated in a multicore cable or in a conduit or trunking together with the live conductors.

6.4.2 *Protective Bonding Conductors for Connection to the Main Earthing Terminal*

The terminations of protective bonding conductors connecting the conductive structure of the unit shall be accessible and protected against corrosion.

6.5 Other Equipment

6.5.1 *General Requirements*

6.5.1.1 *Inlets*

6.5.1.1.1 Any a.c. electrical inlet on the caravan shall be an appliance inlet complying with IS/IEC 60309-2.

6.5.1.1.2 The inlet, if any, shall be installed

a) not more than 1.8 m above ground level,
b) in a readily accessible position,
c) have a minimum protection of IP44 with or without a connector engaged, and
d) the inlet shall not protrude significantly beyond the body of the caravan.

6.5.1.2 *Accessories*

6.5.1.2.1 Every low-voltage socket-outlet, other than a shaver socket-outlet, shall incorporate an earth contact.

6.5.1.2.2 Every socket-outlet supplied at extra-low voltage shall have its voltage visibly marked.

6.5.1.2.3 Where an accessory is located in a position in which it is exposed to the effects of moisture it shall be constructed or enclosed so as to provide a degree of protection not less than IPX4.

6.5.1.2.4 Each luminaire in a caravan shall preferably be fixed directly to the structure or lining of the caravan. Where a pendant luminaire is installed in a caravan, provision shall be made for securing the luminaire to prevent damage when the caravan is moved.

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Accessories for the suspension of pendant luminaires shall be suitable for the mass suspended and the forces associated with vehicle movement.

6.1.5.2.5 A luminaire intended for dual voltage operation shall comply with the appropriate standard.

6.1.5.2.6

Table 1 Cross-sectional Areas of Flexible Cords and Cables for Caravan Connection

(*Clause* 6.1.5.2.6)

Rated Current A	Minimum Cross-Sectional Area mm^2
16	2.5
25	4
32	6
63	16
100	35

The appliance inlet installed under **6.5.1.1** shall comply with IS/IEC 60309-2, and the means of connection to the caravan pitch socket-outlet shall comprise the following:

a) a plug complying with IS/IEC 60309-2.

b) a flexible cord or cable.

   1) of 25 m (± 2 m) continuous length,

   2) of harmonized code designation IEC 60245 (code 57) or equivalent,

   3) incorporating a protective conductor, with a colour identification according to the appropriate IEC standard, and

   4) with a cross-sectional area in accordance with Table 1, and

c) a connector complying with IS/IEC 60309-2.

The means of connection to the caravan pitch socket-outlet need not be supplied with the caravan.

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ANNEX A

(*Normative*)

(*Clause* 6.1.3.1)

INSTRUCTIONS FOR ELECTRICITY SUPPLY

A-1 CONNECTION

a) Before connecting the caravan installation to the electricity supply, check that:
   1) the supply available at the caravan pitch supply point is suitable for the caravan electrical installation and appliances, the voltage, frequency and current rating are suitable,
   2) the cable and means of connection are suitable, and
   3) the main isolating switch in the caravan is in the OFF position.

   WARNING — The caravan supply flexible cable should be fully uncoiled to avoid damage by overheating.

b) Check the cable, the plug and the connector for damage.

c) Open the cover of the appliance inlet provided at the caravan, if any, and insert the connector of the flexible cable.

d) Insert the plug of the flexible cable into the electricity outlet provided on the pitch supply point.

e) Switch on the caravan main isolating switch.

f) Check the operation of residual current devices fitted in the caravan by depressing the test buttons and reset.

In case of doubt or, if after carrying out the above procedure the supply does not become available, or if the supply fails, consult the caravan park operator.

A-2 DISCONNECTION

Switch off at the caravan main isolating switch, unplug the cable, first on the caravan pitch supply point side and then at the caravan appliance inlet, if any.

A-3 PERIODIC INSPECTION

Preferably not less than once every three years and annually if the caravan is used frequently, the caravan electrical installation and supply cable should be inspected and tested by a competent electrician and a report on their condition obtained.

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ANNEX B

(*Informative*)

(*Clause* 5.1.5)

EXTRA LOW-VOLTAGE DC INSTALLATIONS

B-1 PURPOSES, SUPPLIES AND STRUCTURE

B-1.1 Supplies

B-1.1.1 *Sources of Supply*

The supply should be obtained from one or more of the following sources:

a) the electrical installation of the towing vehicle;
b) an auxiliary battery mounted in the caravan;
c) a low-voltage d.c. supply via a transformer/rectifier unit complying with IS 302-1 and IS/IEC 61558-2-6;
d) a d.c. generator that is driven by any form of energy; and
e) solar photovoltaic (PV) power supply systems or similar.

B-2 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

B-2.1 Common Rules

B-2.1.1 *Identification*

B-2.1.1.1 *General*

The following information should be provided in the instructions for use and should be in the official language(s) of the country in which the caravan is to be sold:

a) A warning worded as follows: “Any replacement of an auxiliary battery should be of the same type and specification as that originally specified by the caravan manufacturer”.
b) Instructions on the maintenance and recharging of an auxiliary battery where it is fitted. Where a battery charger is provided, instructions on its safe use should be included.
c) Instructions on selecting and installing an auxiliary battery in a compartment, if the caravan is intended for the installation of an auxiliary battery.
d) Details of the warning notice specified in **B-2.4.1.3.7** and its importance for safety.
e) In order to ensure safe operation of the electrical installation, a simplified diagram of the wiring of the ELV and LV installation, with details of the cable colours and/or marking and the nominal values of the overcurrent protective devices should be provided.
f) Type of appliances that can be used and from what source of supply.
g) Instructions for the correct operation and maintenance of fitted appliances, as supplied by the appliance manufacturer.
h) A warning worded as follows: “Always disconnect the electrical connector between the towing vehicle and the caravan before connecting an LV supply to the caravan and before charging the caravan battery by any other means”.

B-2.1.2 *Prevention of Mutual Detrimental Influence*

B-2.1.2.1 The ELV installation should be so installed that the protective measures of the LV installation against direct contact, or in case of indirect contact are not impaired.

It should be ensured that operating currents of the ELV installation do not flow in the protective conductors of the LV installation.

B-2.2 Wiring Systems

B-2.2.1 *Types of Wiring Systems*

Cables should be of stranded construction and should comply with IEC 60227 (all parts), IEC 60245 (all parts) or IS/ISO 6722 (all parts).

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B-2.2.2 *Current-Carrying Capacities*

The cross-sectional areas of the conductors selected for the fixed wiring should be in accordance with Annex C. Annex C does not apply to sensor and data lines.

B-2.2.3 *Voltage Drop in Consumers' Installations*

Under normal service conditions, the voltage at the terminals of any fixed current-using equipment should be greater than the lower limit corresponding to the IEC standard relevant to the equipment. Where the equipment is not the subject of an IEC standard, the voltage at the terminals should be such as not to impair the safe functioning of that equipment. In the absence of precise data, a voltage drop of 0.8 V from the power supply to the equipment may be allowed.

The charging current I_c [A] to determine the voltage drop is established by Formula (B.1).

$$I_c = \frac{c \cdot 0.1}{t} \quad \text{(B.1)}$$

where,

I_c = the charging current, in A;

c = the battery capacity, in Ah; and

t = the period, in h.

B-2.2.4 *Proximity of Wiring Systems to Other Services*

B-2.2.4.1 *Proximity to non-electrical services*

B-2.2.4.1.1 *Cable runs and LPG installations*

Cables including those used for automotive purposes should not be run through a compartment or housing intended for liquefied petroleum gas storage cylinders. Where cables have to run through such a compartment or housing, they should be run at a height of not less than 500 mm above the base of the cylinders, and such cables should be protected against mechanical damage by installation within a continuous gas tight conduit or duct passing through the compartment.

Where installed, this conduit or duct should be able to withstand an impact equivalent to AG3 without visible physical damage.

ELV cables and electrical equipment are only to be installed within the LPG cylinder compartment or housing if the installation serves the operation of the gas cylinders (for example, indication of empty gas cylinders) or is for use within the compartment or housing. Such electrical installations and components should be constructed and installed so that they are not a source of ignition and are in accordance with the relevant standards for any hazardous area classification of the compartment or housing.

B-2.3 Isolation, Switching and Control

B-2.3.1 *Devices for Protection against Overcurrent*

B-2.3.1.1 *General requirements*

B-2.3.1.1.1 The overcurrent protective device for the power supply from the towing vehicle should be installed as near as possible to the auxiliary battery, but in no case more than 1 000 mm away. The overcurrent protective device for the auxiliary battery should be fitted at the end of the battery cable and before the fixed installation. The ELV output of the transformer/rectifier unit and of the d.c. generator should be provided with an overcurrent protective device unless this is already incorporated within the unit or generator. The protective device should be installed as near as possible to the unit or generator and, in all cases, upstream of the distribution circuits.

B-2.3.1.1.2 Overcurrent protective devices should be either fuse links according to ISO 8820 (all parts) or suitable miniature circuit-breakers.

B-2.3.1.1.3 Fuses should be physically protected against accidental mechanical damage.

B-2.3.1.1.4 Overcurrent protective devices should not be fitted in a fuel storage compartment or fuel storage housing intended for the storage of liquefied petroleum gas cylinders or in the compartment for housing an auxiliary battery.

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B-2.4 Other Equipment

B-2.4.1 *General Requirements*

B-2.4.1.1 *Inlets*

The inlet, when the plug is disconnected, should be protected against the ingress of water, foreign bodies and accidental damage.

B-2.4.1.2 *Accessories*

The means of connection to the towing vehicle should be supplied with the caravan and comprise the following:

e) a plug complying with IS 13461 and IS 13460 or ISO 11446 (all parts), and

f) a flexible cord or cable with the number of cores with the minimum cross-sectional area and the allocation according to Table B-1 and a length not exceeding 5 m, and

g) a connectorcomplying with IS 13461 and IS 13460 or ISO 11446 (all parts).

Table B-1 Functional Allocation and Cross-sectional Areas of Cores for Caravan Connectors

(*Clause* B-2.4.1.2)

Core No.	Function	Contact Numbers		Minimum Cross-sectional Area mm²
		ISO 11446	IS 13461	
1	Left-hand direction – indicator light	1	1	1.5
2	Rear fog light	2	2	1.5
3	Common return for core nos. 1,2, 4, 5, 6, 7 and 8	3[a]	3[a]	2.5
4	Right-hand direction – indicator light	4	4	1.5
5	Right hand-rear position and marker lights, and rear-registration-plate illumination device	5	5	1.5
6	Stop lights	6	6	1.5
7	Left-hand rear position and marker lights, and rear-registration-plate illumination device	7	7	1.5
			IS 13460	
8	Reversing light	8	1	1.5
9	Continuous power supply	9	4	2.5
10	Power supply controlled by ignition switch	10	6	2.5
11	Return for core No. 10	11[a]	7[a]	2.5
12	Coding for coupled trailer	12	2	–
13	Return for core No. 9	13[a]	3[a]	2.5
14	No allocation	–	5	1.5

[a] These return circuits should not be electrically connected in the trailer.

B-2.4.1.3 *Auxiliary batteries*

B-2.4.1.3.1 *Type of battery*

An auxiliary battery should be of the rechargeable type.

NOTE — Non-rechargeable batteries are not auxiliary batteries. They can be used in caravans, provided that they are used in circuits separated from other sources of electrical supply.

B-2.4.1.3.2 *Capacity*

An auxiliary battery should have a minimum capacity of 60 Ah at a 20 h discharge period.

It is recommended to use a battery designed to be discharged over long periods at a relatively low current.

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B-2.4.1.3.3 *Terminals*

Auxiliary battery terminals should be clearly and durably marked "+" and "–". Connections to auxiliary battery terminals should be securely clamped or bolted to ensure continuous contact and should be insulated unless the auxiliary battery is provided with an insulating device.

B-2.4.1.3.4 *Location*

An auxiliary battery should be placed in a separate compartment with easy access for maintenance or removal. The battery should be secured to prevent movement, for example when the caravan is in motion.

B-2.4.1.3.5 *Auxiliary battery compartment*

A tray should be installed under an auxiliary battery if the electrolyte of this battery is liquid. The tray should be sufficient to hold 20 percent of the volume of the electrolyte.

The interior of an auxiliary battery compartment should be ventilated and protected against the corrosive effects of acid-laden gases, by one of the following methods:

h) installing a sealed auxiliary battery that incorporates an external ventilating kit that is taken to the exterior of the caravan;

j) installing an auxiliary battery in an enclosed battery compartment that is protected internally against corrosion and is ventilated to the exterior of the caravan by means of a suitable tube with a minimum inside diameter of 10 mm at the top of the auxiliary battery compartment in accordance with the battery manufacturer's instructions or as supplied by the manufacturer of the auxiliary battery; or

k) ventilating the compartment at low-level and high-level to the exterior of the caravan and constructing the interior of the compartment, including the sides of the ventilator openings, of acid-resistant material or providing it with an anti-corrosive finish. If the compartment opens into the interior of the caravan, the lid should provide an air seal. The minimum size of ventilation should be not less than 80 mm^2 at low level and not less than 80 mm^2 at high level.

If an auxiliary battery is not provided, then the position and instructions for the installation of the battery and compartment, in accordance with a), b) or c) of this sub-clause, should be included in the instructions for use and a notice should be fixed in or near the proposed location stating: "For instructions on auxiliary battery installation, see the instructions for use".

When the manufacturer makes no provision for the installation of an auxiliary battery, the following statement should be made in the instructions for use: "This caravan has not been designed to accommodate an auxiliary battery. Do not fit one".

B-2.4.1.3.6 *Auxiliary battery cables*

Cables from an auxiliary battery should be protected by additional sheathing or taping up to the overcurrent protective device.

B-2.4.1.3.7 *Warning notice*

A warning notice should be fixed in a prominent position near the auxiliary battery or displayed on the lid of the auxiliary battery compartment. This warning should be in the official language(s) of the country in which the caravan is to be sold and should state: "Switch off all appliances and lamps before disconnecting the auxiliary battery."

The auxiliary battery compartment should be additionally marked "Smoking prohibited" in accordance with IS 12349 and in the language(s) of the country in which the caravan is to be sold.

B-2.4.1.4 *Other sources of supply*

B-2.4.1.4.1 *Generators and transformer/rectifier units*

If a supply is obtained from a generator or from a low-voltage supply via a transformer/rectifier unit, the extra-low voltage at the output terminals of the supply unit should be maintained between 11 V minimum and 15 V maximum with applied loads varying from 0.5 A minimum up to the maximum rated load of the supply unit. Over the same load range, alternating voltage ripple should not exceed 1.2 V_{pp}.

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B-2.4.1.4.2 *Regenerative sources*

Regenerative energy sources, such as wind energy, solar energy, should be installed only for charging batteries and such sources should only generate extra-low voltage.

Regenerative energy sources should only be operated with a device which prevents overcharging of the battery (ies).

B-2.4.1.5 *Charging of auxiliary battery and operation of refrigerator*

B-2.4.1.5.1 The circuit to charge an auxiliary battery should be separate from a circuit to operate a refrigerator.

B-2.4.1.5.2 The charging circuit for an auxiliary battery should be energized only when the engine of the towing vehicle is running.

B-2.4.1.6 *Terminal block*

If the connection between the connecting cable(s) and the caravan's fixed wiring is by means of a terminal block, it should have a protective cover. If the terminal block is positioned externally it should have a cover providing a degree of protection of not less than IP34 as given in IS/IEC 60529.

B-2.4.1.7 *Appliances*

B-2.4.1.7.1 *General*

The caravan manufacturer's technical specification should state whether an ELV appliance is suitable for use with a supply obtained from a d.c. generator or a transformer/rectifier unit.

Appliances suitable for operation on both 12 V a.c. and 12 V d.c. are permitted provided that the a.c. and the d.c. systems are segregated and interconnection is prevented.

B-2.4.1.7.2 *Selection and connection of appliances*

All appliances should be fitted and connected in accordance with the appliance manufacturer's instructions. Where polarity-sensitive appliances are fitted and connected, only those that have terminals clearly marked "–" and "+", or that have two conductors, indicating polarity by colour or by identification tags or sleeves marked "–" and "+"should be used.

B-2.4.1.8 *Socket-outlets*

ELV socket-outlets should be two pole non-reversible and should be of a different type from those provided for any low-voltage installation. The voltage and maximum power rating of the circuit should be stated on or adjacent to the socket-outlets.

B-2.4.1.9 *Battery charger*

If a battery charger is connected to a low-voltage a.c. supply, it should comply with the relevant clauses of IEC 60335-2-29. The d.c. output should either be electronically regulated or the maximum d.c. output of the charger in A should be limited to 10 percent of the capacity of the auxiliary battery in Ah at 20 h discharge rate.

B-2.4.1.10 *External lights*

Lights, such as door lamps, fixed outside on a caravan should be constructed or enclosed to provide protection against the ingress of water with a degree of protection of not less than IP34 according to IS/IEC 60529.

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ANNEX C

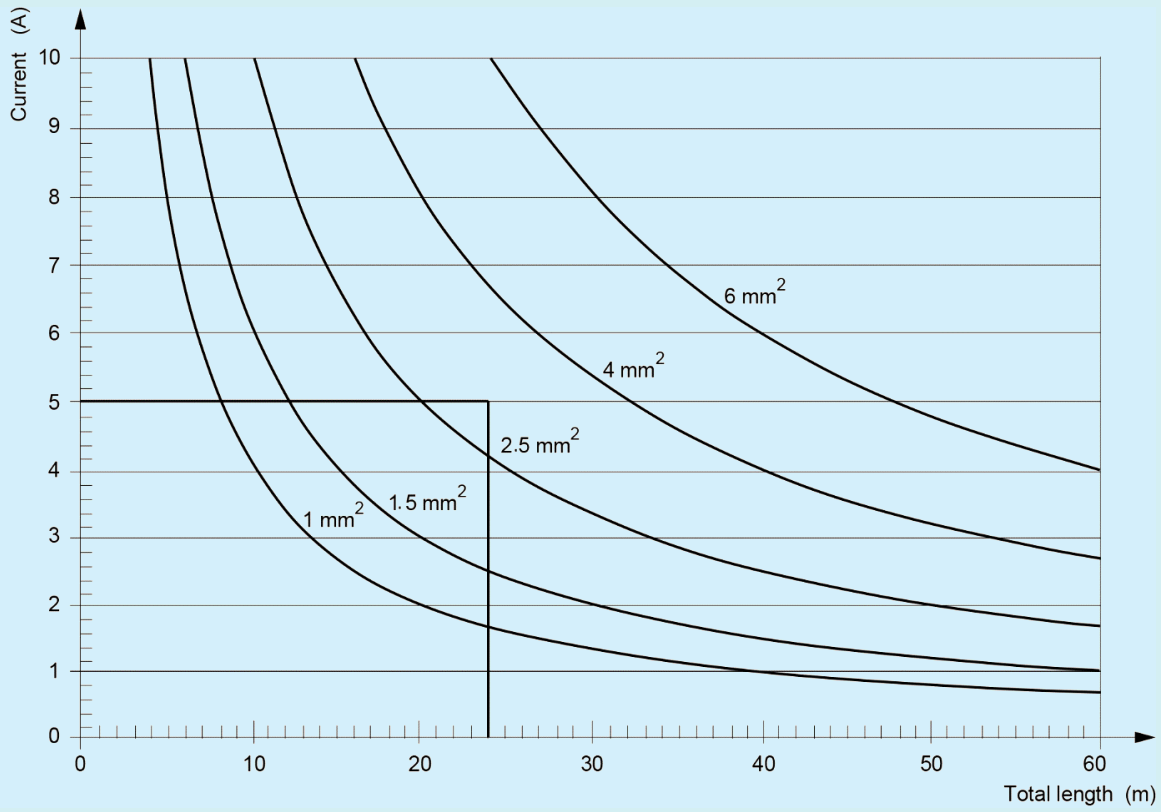
(*Informative*)

(*Clause* B-2.2.2)

CURRENT-CARRYING CAPACITIES

C-1 The minimum conductor cross-sectional areas are to be selected from graphs (*see* Fig. C-1 and Fig. C-2) or calculated according to Formula (C-1).

C-1.1 Graphs for Obtaining Minimum Cross-Sectional Areas

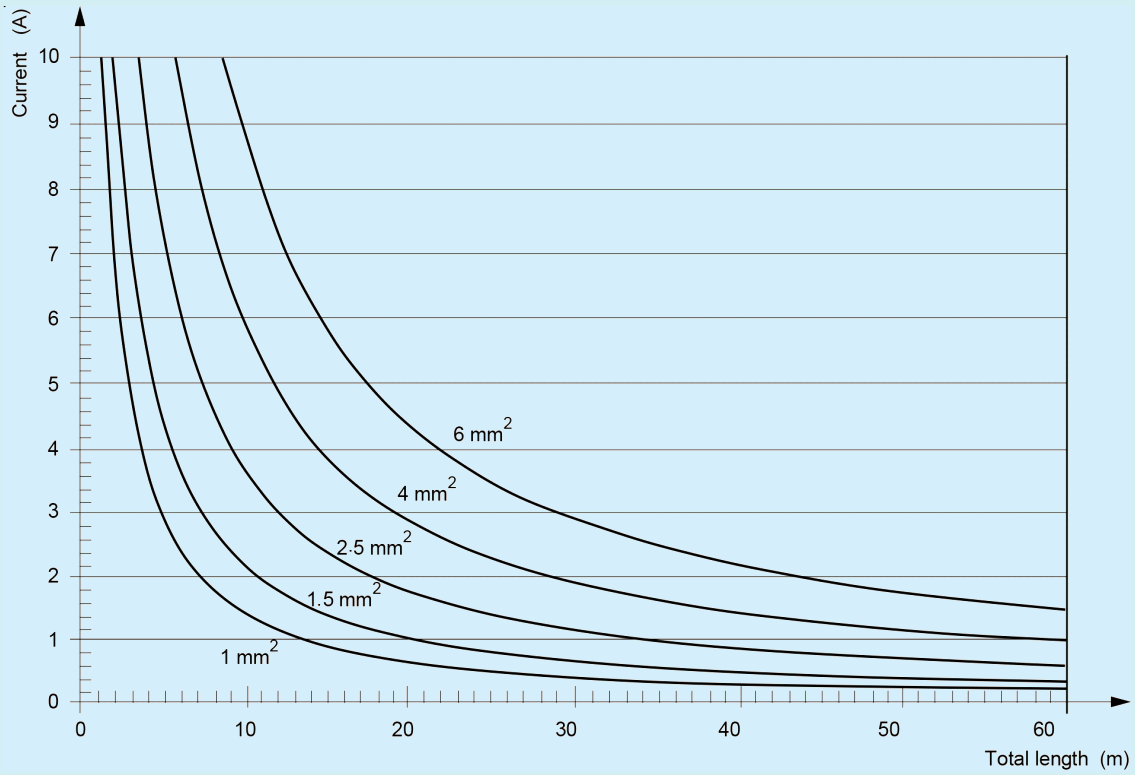


Total length of both cables (positive and negative), in m (route length is half above length)

To obtain the minimum cross-sectional area for a circuit with a design current of 5 A and a total cable length of 24 m (12 m route length), the cross-sectional area of the conductors of that circuit should not be less than 4 mm^2.

FIG. C-1 GRAPH FOR OBTAINING MINIMUM CROSS-SECTIONAL AREA FOR CONDUCTORS FOR FIXED WIRING INSTALLATIONS WITH A VOLTAGE DROP OF 0.8 V

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Total length of both cables (positive and negative), in m (route length is half above length)

FIG. C-2 GRAPH FOR OBTAINING MINIMUM CROSS-SECTIONAL AREA FOR CONDUCTORS FOR BATTERY CABLE INSTALLATIONS WITH A VOLTAGE DROP OF 0.3 V

C-1.2 Calculation of the Minimum Cross-sectional Areas

The cross-sectional areas may be calculated from the following formula:

$$A = \frac{\rho \cdot L \cdot I}{U_v} \qquad \text{(C.1)}$$

where

A = the cross-sectional area of conductor, in mm^2;

ρ = the resistivity of copper (0.019 89 Ω mm^2/m at 50 °C);

L = the total length (feed and return cable) of the conductors, in m;

I = the total current, in A; and

U_V = the permissible voltage drop.

(0.3 V for auxiliary battery charging cables, 0.8 V for fixed wiring cables).

With intermediate values, the result of the calculation should be rounded to the next higher cross-sectional area.

C-2 The graphs in Fig. C-1 and Fig. C-2 and Formula (C-1) are based on a conductor operating temperature of 50 °C.

If cables are installed for use under conditions of temperatures higher than 50 °C the minimum cross-sectional area of the conductors should be increased.

C-3 If the appliance manufacturer requires a voltage drop which is different from 0.3 V or 0.8 V, this value should be inserted for U_V in Formula (C-1).

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SECTION 15 SUPPLIES FOR ELECTRIC VEHICLES

FOREWORD

Electric vehicle supply equipment (EVSE) supplies electricity to an electric vehicle (EV). Commonly called charging stations or charging docks, they provide electric power to the vehicle and use that to recharge the vehicle's batteries. EVSE systems include the electrical conductors, related equipment, software, and communications protocols that deliver energy efficiently and safely to the vehicle. Electric vehicle charging is a new load for low voltage electrical installations that can present some challenges.

This section shall cover the requirements for supplies of electrical vehicles.

For the purpose of this part of NEC Part 3 Section 15, the requirements of IS 732 : 2019 shall apply.

This Part 3 Section 15 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 15 parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable.

The section of Part 3 supplement, modify or replace certain of the general requirements contained in IS 732.

The clause numbering appearing after 3.3 refers to the corresponding parts or clauses of IS 732. Numbering of clauses does not, therefore, necessarily follow sequentially. Numbering of additional text is shown by the addition of ".101 (Eg 3.3.4.4.5.5.101) & 201 (Eg. 3.3.3.201), etc". Numbering of figures and tables takes the number of this part followed by a sequential number. For annexes, the numbering of figures and tables takes the letter of the annex, the number of the part and a sequential number.

1 SCOPE

The particular requirements of this section (Part 3/Sec 15) apply to:

a) circuits intended to supply energy to electric vehicles, and

b) circuits intended for feeding back electricity from electric vehicles.

Circuits covered by this standard are terminated at the connecting point.

NOTES

1 The requirements for EV supply equipment for conductive charging and the relevant charging modes are described in IS 17017 (all parts). The requirements for EV supply equipment for wireless power transfer are described in IEC 61980 (all parts).

2 This standard does not cover the assessment of the risk of explosion due to the possible production of hydrogen/other flammable gases during the battery recharging phase.

3 Requirements specified in electricity regulation (with amendments) shall be complied.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
732 : 2019	Code of practice for electrical wiring installations
IS/IEC 60309-1 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 1 General requirements
IS/IEC 60309-2 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 2 Dimensional interchangeability requirements for pin and contact-tube accessories
IS/IEC 60947-2 : 2016	Low-voltage switchgear and controlgear: Part 2 Circuit-breakers
IS/IEC 60269 (all parts)	Low voltage fuses
IS/IEC 60898 (all parts)	Electrical accessories — Circuit-breakers for overcurrent protection for household and similar installations

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IS/IEC/ISO Number	*Title*
IEC 60898-3 : 2019	Electrical accessories — Circuit-breakers for overcurrent protection for household and similar installations — Part 3: Circuit-breakers for d.c. operation
12640 (Part 1) : 2016	Residual current circuit-breakers without integral overvoltage protection for household and similar uses (RCCBs): Part 1 General rules
12640 (Part 2) : 2016	Residual current operated circuit-breakers with integral overvoltage protection for household and similar uses (RCBOs): Part 1 General rules
IS/IEC 61558-2-4 : 2009	Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V: Part 2-4 Particular requirements and tests for isolating transformers and power supply units incorporating isolating transformers
17017 (all parts)	Electric vehicle conductive charging system
IEC 61851 (all parts)	Electric vehicle conductive charging system
IS 17050 : 2018/ IEC 62262 : 2002	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
IEC 62423 : 2009	Type F and type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses
IEC 62196 (all parts)	Plugs, socket-outlets, vehicle connectors and vehicle inlets — Conductive charging of electric vehicles
IEC 62196- 1 : 2014	Plugs, socket-outlets, vehicle connectors and vehicle inlets — Conductive charging of electric vehicles — Part 1: General requirements
IEC 62196-2 : 2016	Plugs, socket-outlets, vehicle connectors and vehicle inlets — Conductive charging of electric vehicles — Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories
IEC 61557-9 : 2014	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. — Equipment for testing, measuring or monitoring of protective measures — Part 9: Equipment insulation fault location in IT systems
IEC 61557-8 : 2014	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. — Equipment for testing, measuring or monitoring of protective measures — Part 8: Insulation monitoring devices for IT systems
IEC 61140 : 2016	Protection against electric shock — Common aspects for installation and equipment
IEC 60947-6-2 : 2007	Low-voltage switchgear and controlgear — Part 6-2: Multiple function equipment — Control and protective switching devices (or equipment) (CPS)
IEC 60364 (all parts)	Low-voltage electrical installations
IEC 60364-8-2 : 2018	Low-voltage electrical installations — Part 8-2: Prosumer's low-voltage electrical installations[1)]
IEC 62955 : 2018	Residual direct current detecting device (RDC-DD) to be used for mode 3 charging of electric vehicle
IEC 61980 (all parts)	Electric vehicle wireless power transfer (WPT) systems
IEC 62196-3 : 2014	Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles— Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers
IEC TS 62196	Plugs, socket-outlets, vehicle connectors and vehicles inlet – Conductive charging of electric vehicles — Part 4: Dimensional compatibility and interchangeability requirements for d.c. pin and contact-tube accessories for class II or class III applications[2)]

[1)] Under preparation. Stage at the time of publication IEC RFDIS 60364-8-2 : 2018.

[2)] Under preparation. Stage at the time of publication IEC TS BPUB 62196-4 : 2018

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3 TERMS AND DEFINITIONS

For the purposes of this standard, in addition to definitions given in IS 732 the following terms and definitions shall apply.

3.1 Electric Vehicle Electric Road Vehicle EV— Any vehicle propelled by an electric motor drawing current from a rechargeable energy storage system (RESS), intended primarily for use on public roads.

3.2 Connecting Point —Terminating point in the fixed installation where energy is transferred to/from one electric vehicle.

EXAMPLE — A socket-outlet, a vehicle connector or a wireless power transfer device.

NOTE — to entry: The connecting point may be part of the fixed installed EV supply equipment.

3.3 Demand Factor — ratio, expressed as a numerical value or as a percentage, of the maximum demand of a circuit or a group of circuits within a specified period, to the corresponding total installed load of the circuit(s).

NOTE — In using this term, it is necessary to specify to which level of the system it relates.

3.4 EV Charging Station — Stationary part of EV supply equipment connected to the supply network.

3.5 EV Supply Equipment— Equipment or a combination of equipment, providing dedicated functions to supply electric energy from a fixed electrical installation or supply network to an EV for the purpose of charging.

3.6 Load Control— Electrical (energy) management system ensuring that the sum of load currents of dedicated circuits does not exceed a predetermined value.

4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1.5.6 *Purposes, supplies and structure*

4.1.5.6.1 *Maximum Demand and Diversity*

Add the following:

It shall be considered that in normal use each single connecting point is used at its rated current or at the configured maximum charging current of the charging station. The means for configuration of the maximum charging current shall only be made by the use of a key or a tool and only be accessible to skilled or instructed persons.

NOTE — For this application the demand factor of the final circuit supplying the connecting point (for example, the socket-outlet) is equal to 1.

Since all the connecting points of the installation can be used simultaneously, the diversity factor of the distribution circuit shall be taken as equal to 1 unless a load control is included in the EV supply equipment or installed upstream or a combination of both.

4.1.5.8 *Conductor Arrangement and System Earthing*

4.1.5.8.2.1 *TN systems*

Add the following:

In a TN system, a circuit supplying a connecting point shall not include a PEN conductor.

4.1.5.10 *Division of Installation*

Add the following:

A dedicated circuit shall be provided for the transfer of energy from/to the electric vehicle.

4.2 Protection For Safety - Protection Against Electric Shock

4.2.6 *General Requirements*

Replace the existing text by the following:

The protective measure obstacles as specified in B-2 of IS 732 shall not be applied.

The protective measure placing out of reach, as specified in B-3 of IS 732 may only be applied where an automatic connection system in accordance with IEC 61851 series used.

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4.2.7 The protective measures as specified in Annex C of IS 732 : 2019 shall not be applied.

4.2.11 *Protective Measure: Automatic Disconnection of Supply*

4.2.11.3 *Requirements for fault protection*

4.2.11.3.3 *Additional protection*

Replace the existing text by the following:

Each a.c. connecting point shall be individually protected by a residual current device (RCD) with a rated residual operating current not exceeding 30 mA.

NOTE — This requirement implies that this RCD is not used for protecting other connecting points or current-using equipment.

4.2.13 *Protective Measure: Electrical Separation*

4.2.13.3 *Requirements for fault protection*

4.2.13.3.2

Replace the requirements as follows:

The separated circuit shall be supplied through an isolating transformer complying with IS/IEC 61558-2-4, and the voltage of the separated circuit shall not exceed 500 V.

4.1.2.6 *Protection against Voltage Disturbances and Electromagnetic Disturbances*

4.1.2.6.2

Add the following after the first paragraph:

A connecting point accessible to the public is considered as part of a public service and therefore shall be protected against transient overvoltages.

4.5.4 *Measures Against Electromagnetic Influences*

4.5.4.1 *General*

Add the following:

4.5.4.1.101 The equipment for wireless power transfer shall not impair the safety and the proper functioning of the electrical installation and shall be installed according to the manufacturer's instructions.

5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.1 Common Rules

5.1.1 *Compliance With Standards*

Add the following:

5.1.1.101 For conductive power transfer, EV charging stations shall comply with the appropriate parts of the IS 17017.

5.1.1.102 Wireless power transfer (WPT) systems for EVs shall comply with the appropriate parts of the IEC 61980 series.

5.1.2 *Operational Conditions and External Influences*

5.1.2.2 *External influences*

Add the following:

5.1.2.2.101 *Presence of water (AD)*

When installed outdoors, the equipment shall be selected with a degree of protection of at least IPX4 in order to protect against water splashes (AD4).

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5.1.2.2.102 *Presence of solid foreign bodies (AE)*

When installed outdoors, the equipment shall be selected or provided with a degree of protection of at least IP4X in order to protect against the ingress of small objects (AE3).

5.1.2.2.103 *Impact (AG)*

Equipment installed in public areas shall be protected against mechanical damage considering an impact of high severity (AG3). This protection shall be provided by one or more of the following:

a) by locating the equipment to avoid damage by any reasonably foreseeable impact;
b) by providing local or general mechanical protection of the equipment; and
c) by selecting and erecting equipment with a minimum degree of protection against external mechanical impact in accordance with the requirements of IS 17050/IEC 62262 of IK08.

5.3 Selection and Erection of Electrical Equipment – Isolation, Switching and Control

5.3.1 *Common Rule*

Add the following:

5.3.1.101 The requirements of **5.3.1.102** and from **5.3.2** to **5.3.6.3** shall be achieved either by the selection and erection of the appropriate equipment in the fixed installation or by the selection of an EV charging station which incorporates the appropriate equipment or a combination of both.

NOTES

1 The requirements for the selection and erection of devices for isolation, switching and control of the wireless power transfer system are covered by 5.3 of IS 732.

2 The in-cable control and protection device (IC-CPD) according to IS 17120/IEC 62752 is not designed for use in fixed installations.

5.3.1.102 For circuits described in 5.3.2.2.101, and if more than one electric vehicle is supplied from the same unearthed supply, it is recommended to use an insulation fault location system (IFLS) according to IEC 61557-9 to detect the faulty circuitry within the shortest possible time.

5.3.2 *Devices for Protection against Indirect Contact by Automatic Disconnection of Supply*

5.3.2.2 *Residual current protective devices*

Add the following:

5.3.2.2.101 RCDs protecting each connecting point in accordance with **4.2.11.3.3** shall comply at least with the requirements of an RCD type A and shall have a rated residual operating current not exceeding 30 mA.

Where the EV charging station is equipped with a socket-outlet or vehicle connector complying with IS 17017/IEC 62196 (all parts), protective measures against d.c. fault current shall be taken, except where provided by the EV charging station. The appropriate measures, for each connection point, shall be as follows:

a) the use of an RCD type B;
b) the use of an RCD type A in conjunction with a residual direct current detecting device (RDC-DD) complying with IEC 62955; or
c) the use of an RCD type F in conjunction with a residual direct current detecting device (RDC-DD) complying with IEC 62955.

RCDs shall comply with one of the following standards: IS 12640 (Part 1), IS 12640 (Part 2), IS/IEC 609472 or IEC 62423.

NOTE — **5.3.2.2.101** is not applicable in case the connecting point is protected by other protective measures against electric shock such as SELV or electric separation.

5.3.2.2.1.1 RCDs shall disconnect all live conductors.

5.3.2.3 *Insulation monitoring devices*

Add the following:

5.3.2.3.101 Except where a protective device is installed to interrupt the circuit in the event of a first earth fault, an insulation monitoring device (IMD) in accordance with IEC 61557-8 shall be provided.

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If the IMD is not part of the EV charging station then it is recommended that the IMD provides the following two response values:

a) *Pre-warning* — If the insulation resistance falls below 300 Ω/V an optical and/or acoustical signal should be issued to the user. An ongoing charging session may continue but a new charging session shall not take place.
b) *Alarm*—If the resistance falls below 100 Ω/V an optical and/or acoustical signal should be issued to the user. The charging circuit should shut down within 10 s.

5.3.4 *Devices for Protection Against Overcurrent*

Add the following:

5.3.4.101 Except where EV supply equipment in accordance with IS 17017-1 having more than one connecting point is installed and incorporates the necessary overcurrent protective device required by IS 17017-1, **13.1**, each connecting point shall be supplied individually by a final circuit protected by an overcurrent protective device complying with IS/IEC 60947-2, IEC 60947-6-2 or IS 12640 (Part 2) or with the relevant parts of the IS/IEC 60898 series or the IS/IEC 60269 series.

NOTE — The EV supply equipment can have multiple connecting points.

5.3.6 *Co-ordination of Various Protective Devices*

5.3.6.3 *Discrimination between residual current protective devices*

Where required for service reasons, selectivity shall be maintained between the RCD protecting a connecting point and an RCD installed upstream.

5.4 Earthing Arrangements and Protective Conductors

5.4.3 *Protective Conductors*

Add the following:

5.4.3.101 Control signals on the protective conductor (PE) shall not flow into the fixed electrical installation upstream of the EV charging station; equipment shall be selected accordingly.

NOTES

1 The requirement is to prevent such signals, and the related devices impairing the correct functioning of the devices installed to provide the protective measure of automatic disconnection of supply (for example, RCD).

2 This requirement can be achieved by using a galvanic separation of the control electronics.

3 Temporary currents used to perform the test of the continuity of protective conductors for safety purposes are not considered as signal currents.

5.5 Other Equipment

Add the following:

5.5.101 *Socket-Outlets and Vehicle Connectors*

5.5.101.1 Where the connecting point is a socket-outlet or a vehicle connector, it shall comply with:

a) IS/IEC 60309-1 or IEC 62196-1, where interchangeability is not required,
b) IS/IEC 60309-2, IS 17017 (Part 2/Sec 2)/IEC 62196-2, IS 17017 (Part 2/Sec 3)/IEC 62196-3 or IEC TS 62196-4 where interchangeability is required, or
c) the national standard for socket-outlets, provided the rated current does not exceed 16 A.

Except where electrical separation is used, each socket-outlet shall have an earthing contact connected to the protective conductor (PE).

5.5.101.2 Every socket-outlet or vehicle connector shall be located as close as practicable to the EV parking place to be supplied.

5.5.101.3 Portable socket-outlets shall not be used.

5.5.101.4 One socket-outlet or vehicle connector shall supply only one electric vehicle at the same time.

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5.5.101 *EV Charging Stations*

EV charging stations for public use shall be so designed as to facilitate easy access to the charging point regardless of where the vehicle inlet is located on the electric vehicle.

5.5.2 *Low Voltage Generating Sets*

5.5.2.1 *General*

Add the following as e)

e) Electric vehicle

5.5.2.2 *General requirements*

Add the following:

5.5.2.2.101 Where electric vehicles are intended to feedback energy to the electric installations, the requirements of IEC 60364-8-2[3)] apply.

NOTE — Additional requirements for circuits intended for feeding back electricity from electric vehicles are under consideration.

5.5.2.7 Additional requirements for installations where the generating set may operate in parallel with other sources including systems for distribution of electricity to the public.

5.5.2.7.2 Item b) shall be replaced by

b) The socket-outlet or vehicle connector shall comply with IS 17017 (all parts).

6 VERIFICATION

Under preparation. Stage at the time of publication IEC RFD IS 60364-8-2 : 2018.

6.2 Initial Verification

6.2.1 *General*

6.2.1.1

Add the following:

The existing installation which is influenced shall also be verified with respect to compliance with the requirements of IS 732 : 2019 (for example, requirements for protection against overcurrent due to the increase of load current).

6.2.1.5

Add the following:

NOTE — For periodic verification, follow CEA safety regulation.

[3)] Under preparation. Stage at the time of publication IEC RFDIS 60364-8-2 : 2018.

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SECTION 16 REQUIREMENTS FOR OPERATING OR MAINTENANCE GANGWAYS

FOREWORD

A gangway is a narrow walkway or platform that provides safe access to a ship, truck, or train. Gangways are typically used for two purposes: to allow passage or people and/or cargo to/from docks, moored marine vessels, or aircraft, or in the maintenance and loading/unloading of land-based trucks and trains. The models used for ships or boats are typically long so that they don't slip off platforms or provide unsafe crossing for personnel walking on them and terms like "tower," "truss," or "telescoping" are added to better describe how and where the marine loading platforms are used.

For the purpose of this part of NEC Part 3 Section 16, the requirements of IS 732 : 2019 shall apply. This Part 3 Section 16 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 16 parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

The requirements of this part of National electric code apply to basic protection and other aspects in restricted access areas with switchgear and controlgear assemblies, including requirements for operating or maintenance gangways.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

International Standard	*Title*
732 : 2019	Code of Practice for Electrical Wiring Installations

4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1.5.5 *Assessment of general characteristics*

Add the following requirements:

For restricted access areas the following apply:

a) restricted access areas shall be clearly and visibly marked by appropriate signs;

b) unauthorized persons shall not have access to restricted access areas; and

c) door(s) provided for closed restricted access areas shall allow easy evacuation to the outside by opening without the use of a key, tool or any other device which is not part of the opening mechanism.

4.2.8 *Replace the paragraph with the following requirements:*

In restricted access areas where it is not reasonably practicable to provide protective measures for basic protection (protection against direct contact) in accordance with IS 732, minimum distances are required.

NOTES

1 *See* 4.1.5.5 of IS 732 for assessment of general characteristics when deciding to use this method of protection.

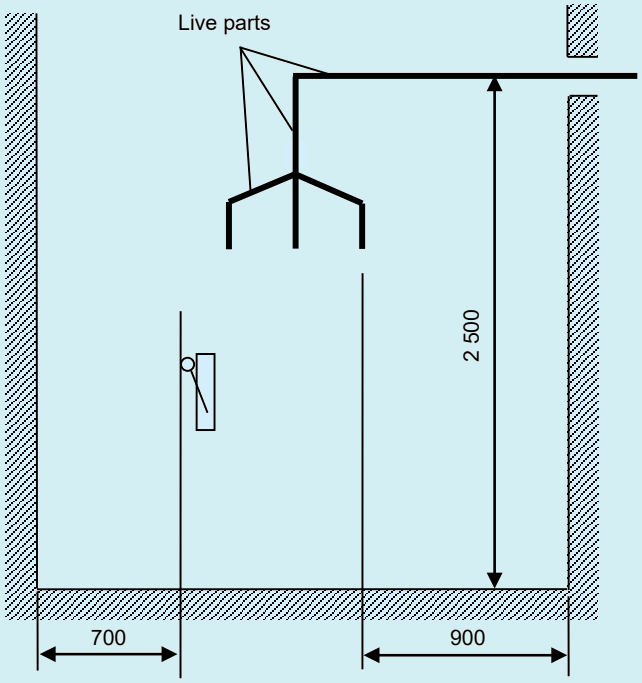
2 In cases of protective devices with high ratings, such as a large circuit-breaker, greater distances may be necessary to permit withdrawal of the device.

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4.2.8.101 Where the gangway has unprotected live parts arranged on one side only (*see* Fig. 1), the minimum distances shall be:

a) width of gangway between the wall and live parts 900 mm;
b) free passage in front of controls (handles, etc.) 700 mm;
c) height of live parts above the floor 2 500 mm.

Dimensions in millimetres



The 2 500 mm height above the floor given as the minimum distance to live parts applies only in the gangway where it is possible for persons to stand or walk.

FIG. 1 GANGWAYS IN INSTALLATIONS WITH LIVE PARTS ON ONE SIDE

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4.2.8.102 Where the gangway has live parts on both sides (*see* Fig. 2), the minimum distances shall be:

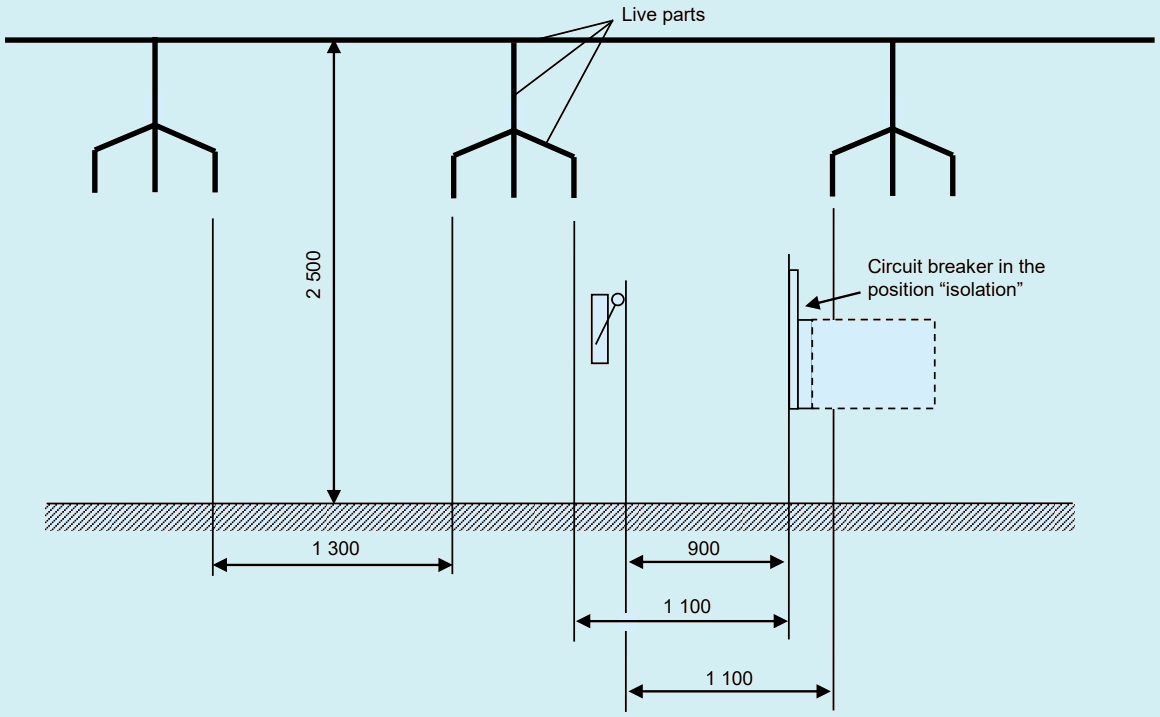
a) width of gangway between live parts 1 300 mm;

b) minimum distance between the front of the handle and the live parts on the opposite side of the gangway 1 100 mm;

c) minimum free passage in front of controls (handles, isolation position of circuit-breakers, etc.) 900 mm;

d) height of live parts above the floor 2 500 mm.

Dimensions in millimetres



The 2 500 mm height above the floor given as the minimum distance to live parts applies only in the gangway where it is possible for persons to stand or walk.

FIG. 2 GANGWAYS IN INSTALLATIONS WITH LIVE PARTS ON BOTH SIDES

5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.1.3 *Accessibility*

Add the following paragraphs:

5.1.3.101 *Requirements for operating and maintenance gangways*

The width of gangways and access areas shall be adequate for work, operational access, emergency access, emergency evacuation and for the movement of equipment.

Gangways shall permit equipment doors or hinged panels to be opened to at least 90° (*see* also Annex A, **A.1**).

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5.1.3.101.1 *Restricted access areas where the protective measure of barriers or enclosures applies*

Where the protective measure is provided by barriers or enclosures in accordance with 4.2 of IS 732, the following minimum distances apply (*see* Fig. 3):

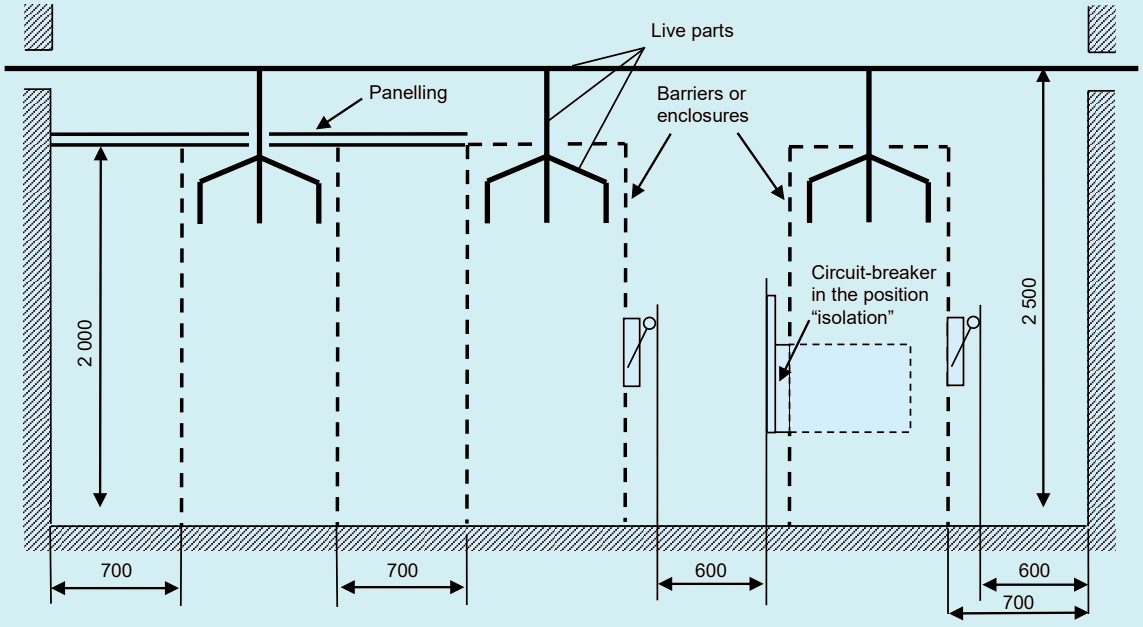
a) width of gangways with barriers or enclosures between switch handles and circuit-breakers in position "isolation" or switch handles and the wall — 600 mm;

b) width of gangway between barriers or enclosures and other barriers or enclosures, or barriers or enclosures and the wall — 700 mm;

c) height of panelling above the floor — 2 000 mm;

d) height of live parts above the floor — 2 500 mm.

Dimensions in millimetres



NOTES

1 Where additional workspace is needed e.g. for special switchgear and controlgear assemblies, larger dimensions may be required.

2 The above dimensions apply after all parts of the panelling have been mounted and closed and to circuit-breakers in the position ''isolation''.

FIG. 3 GANGWAYS IN INSTALLATIONS WHERE THE PROTECTIVE MEASURE OF BARRIERS OR ENCLOSURES APPLIES

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5.1.3.101.2 *Restricted access areas where the protective measure of obstacles applies*

Where the protective measure of obstacles applies in accordance with IS 732, the following minimum distances apply (*see* Fig. 4):

a) width of gangway between obstacles and switch handles, or obstacles and the wall, or switch handles and the wall — 700 mm;

b) height of panelling above the floor — 2 000 mm;

c) height of live parts above the floor — 2 500 mm.

Dimensions in millimetres

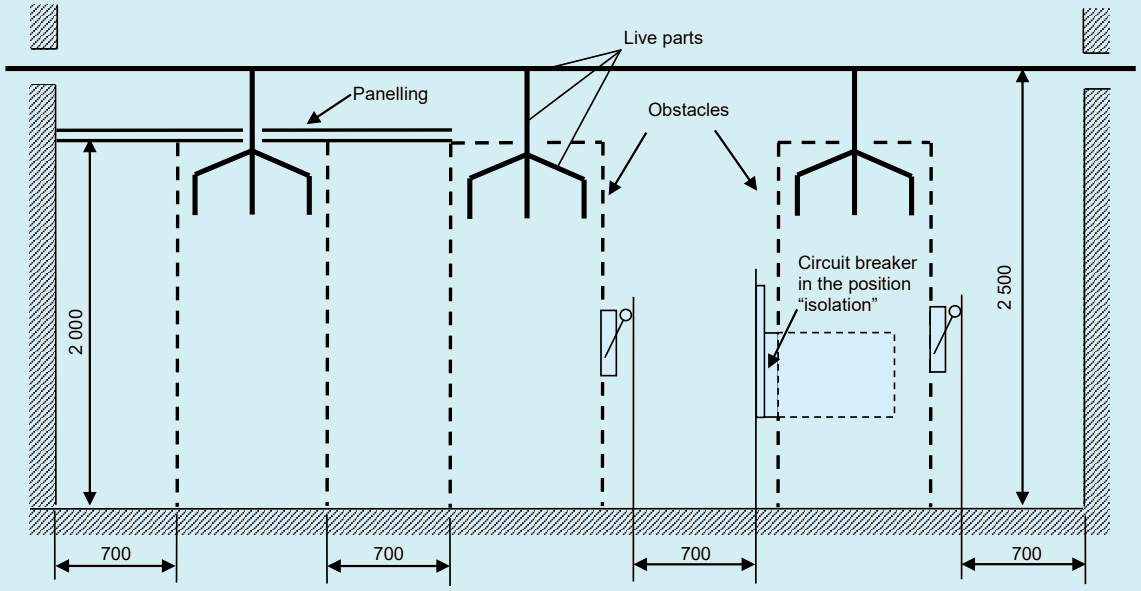


FIG. 4 GANGWAYS IN INSTALLATIONS WHERE THE PROTECTIVE MEASURE OF OBSTACLES APPLIES

NOTE The above dimensions apply after all parts of the panelling have been mounted and closed and to circuit-breakers in the position "isolation".

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5.1.3.101.3 *Access of gangways*

Gangways longer than 10 m shall be accessible from both ends.

NOTES

1 This may be accomplished by placement of the equipment a minimum of 700 mm from the end walls (*see* Fig. 5) or by providing an access door, if needed, on the opposite end wall. Closed restricted access areas with a length exceeding 20 m shall be accessible by doors from both ends.

2 For closed restricted access areas with a length exceeding 6 m, accessibility from both ends is recommended.

Dimensions in millimetres

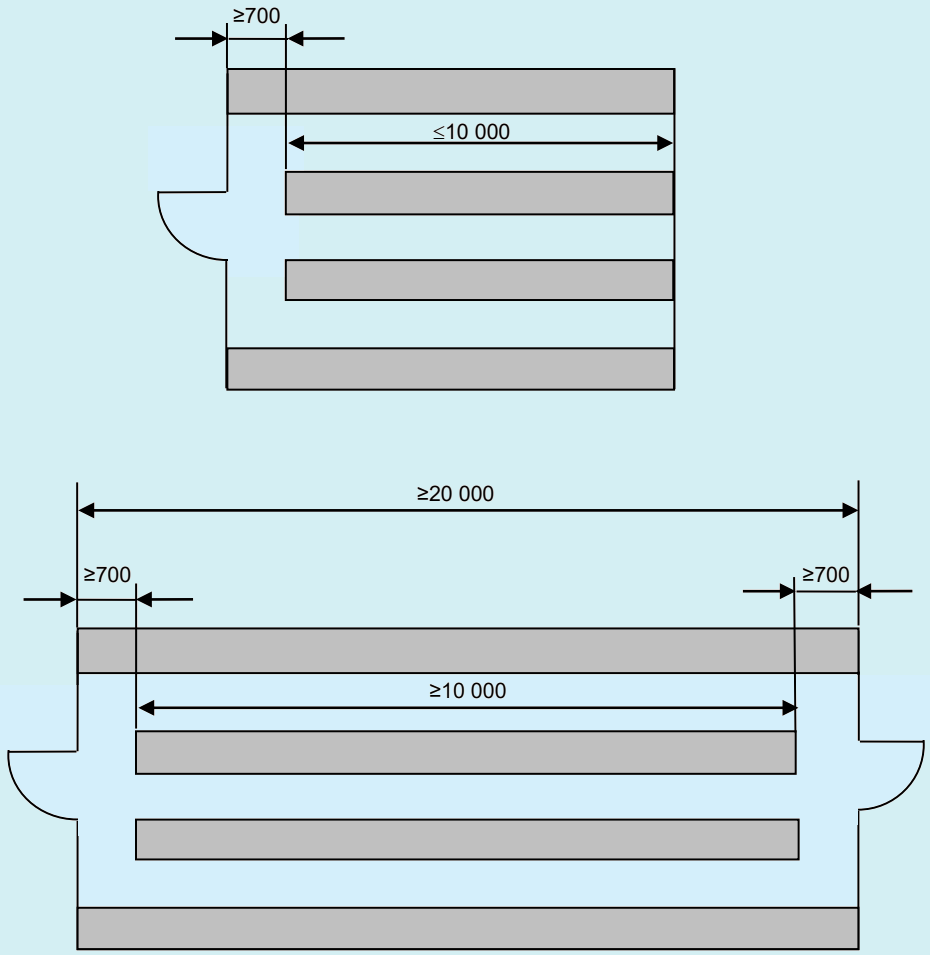


FIG. 5 EXAMPLES OF POSITIONING OF DOORS IN LONG CLOSED RESTRICTED ACCESS AREAS

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ANNEX A

(*Normative*)

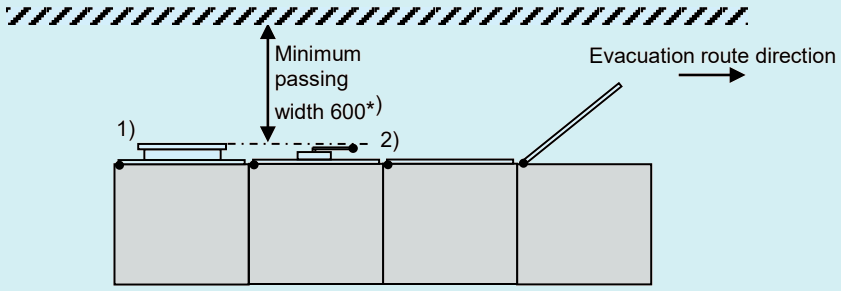
ADDITIONAL REQUIREMENTS FOR CLOSED RESTRICTED ACCESS AREAS

A-1 EVACUATION

To permit easy evacuation, the doors of any equipment inside the location shall close in the direction of the evacuation route. Gangways shall permit equipment doors or hinged panels to be opened to a minimum of 90° (*see* Fig. A-1).

NOTE — Fig. A-1, A-2 and A-3 show the minimum width of gangways and distances for passing in case of evacuation.

Dimensions in millimetres



*) A minimum width of 600 mm lies between the wall and the circuit-breaker in the “fully withdrawn” position.

1) Circuit-breaker in the “completely extracted and isolated” position

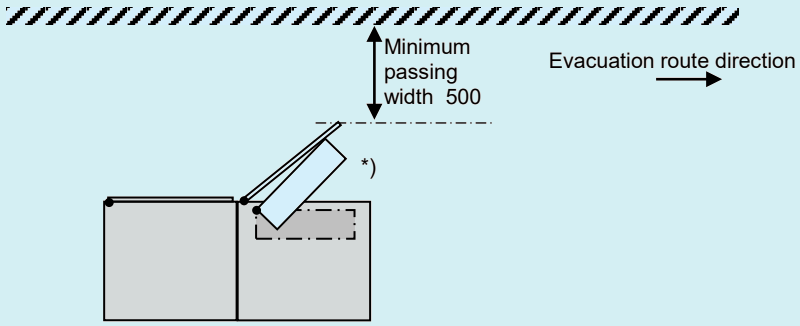
2) Handles (e.g. for controls or equipment)

FIG. A-1 MINIMUM PASSING WIDTH IN CASE OF EVACUATION – CASE 1

For doors which can be fixed in the open position or circuit-breakers or equipment which are withdrawn fully for maintenance (position: completely extracted) a minimum distance of 500 mm shall be provided between the door edge or circuit-breaker/equipment edge and the opposite side of the gangway. (*see* Fig. A-2 and A-3).

NOTE — *See* Fig. A-3 for the minimum passing width in case of circuit-breaker in position: completely extracted.

Dimensions in millimetres

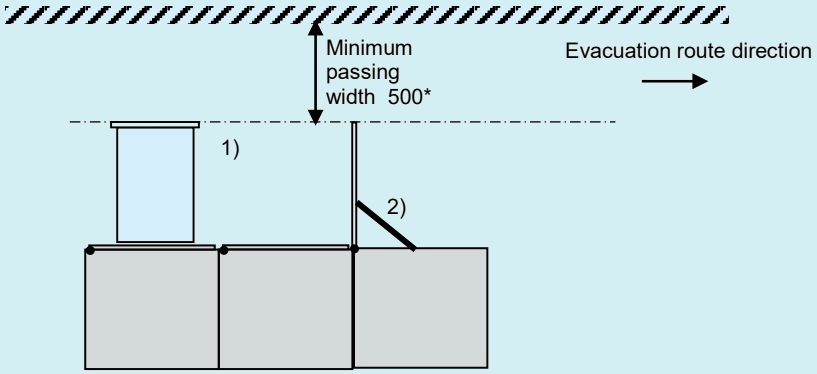


*) Hinged mounting rack

FIG. A-2 MINIMUM PASSING WIDTH IN CASE OF EVACUATION – CASE 2

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Dimensions in millimetres



*) A minimum width gangway of 500 mm shall be provided between the wall and the circuit-breaker in the "fully withdrawn" position or the door which has been fixed in the open position.

1) Completely withdrawn circuit-breaker

2) Door fixed in open position

FIG. A-3 MINIMUM PASSING WIDTH IN CASE OF EVACUATION – CASE 3

Doors giving access to gangways in closed restricted access areas shall open outwards (*see* Fig. 5) and they shall have the following minimum dimensions:

a) width: 700 mm;
b) height: 2 000 mm.

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ANNEX B

(*Informative*)

ADDITIONAL INFORMATION FOR CLOSED RESTRICTED ACCESS AREAS

B-1 VENTILATION AND CONDITIONING

Closed restricted access areas should be either:

a) ventilated with the air being exhausted outdoors (naturally or mechanically), or

b) air-conditioned.

NOTES

1 The ventilation is installed in order to prevent introduction of dust in the equipment.

Air conditioning should be used, where necessary, to ensure a suitable temperature is maintained.

2 Switchgear and controlgear of distribution boards and accumulators are designed for temperature ranges specified by the manufacturer.

B-2 CONSTRUCTION AND LIGHTING

Gangways should have a firm, even floor and should be provided with adequate lighting.

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SECTION 17 TEMPORARY ELECTRICAL INSTALLATIONS FOR STRUCTURES, AMUSEMENT DEVICES AND BOOTHS AT FAIRGROUNDS, AMUSEMENT PARKS AND CIRCUSES

FOREWORD

A temporary electrical installation is generally defined as a temporary electrical installation that is only intended to be in place for a short period of time. This Section specifies the minimum electrical installation requirements to facilitate the safe design, installation and operation of temporary erected mobile or transportable electrical machines and structures that incorporate electrical equipment. The machines and structures are intended to be installed repeatedly and temporarily, without loss of safety, at fairgrounds, amusement parks, circuses or similar places.

For the purpose of this part of NEC Part 3 Section 17, the requirements of IS 732 : 2019 shall apply. This Part 3 Section 17 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 17 parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of the general parts of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

This section of NEC specifies the minimum electrical installation requirements to facilitate the safe design, installation and operation of mobile, temporarily or permanently installed electrical machines and structures which incorporate electrical equipment. The machines and structures are intended to be installed repeatedly, without loss of safety, temporarily or permanently, at fairgrounds, amusement parks, circuses or any other places.

The object of this part of IS 732 is to define the electrical installation requirements for such structures and machines, both being either integral parts or constituting the total amusement device.

This part does not apply to the electrical equipment of machines (*see* IS 16504-1/IEC 60204-1).

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
732 : 2019	Code of practice for electrical wiring installations
12640 (Part 1) : 2016	Residual current circuit -breakers without integral overvoltage protection for household and similar uses (RCCBs): Part 1 General rules
12640 (Part 2) : 2016	Residual current operated circuit-breakers with integral overvoltage protection for household and similar uses (RCBOs) — Part 1 General rules (*first Revision*)
IS/IEC 61558-2-6 : 1997	Safety of power transformers, power supply units and similar: Part 2 Particular requirements for safety isolating transformers for general use
IEC 60364-3 : 1993	Electrical installations of buildings — Part 3: Assessment of general characteristics
IEC 60364-4-481 : 1993	Electrical installations of buildings — Part 4: Protection for safety — Chapter 48: Choice of protective measures as a function of external influences — Section 481: Selection of measures for protection against electric shock in relation to external influences

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IS/IEC/ISO Number	*Title*
IS 16504-1 : 2019/ IEC 60204-1 : 2016	Safety of machinery — Electrical equipment of industrial machines — Part 1: General requirements
IS 12360 : 1988/ IEC 60038 : 2009	Voltage bands for electrical installations including preferred voltages and frequency
IEC 60050 (826) : 2004	International Electrotechnical Vocabulary (IEV) — Chapter 826: Electrical installations of buildings
IEC 60332-1 (all Parts)	Tests on electric cables under fire conditions — Part 1: Tests on a single vertical, insulated wire or cable
IEC 60332-3 : 2018	Tests on electric cables under fire conditions — Part 3: Tests on bunched wires or cable
IS/IEC 60947-2 : 2016	Low-voltage switchgear and controlgear — Part 2: Circuit-breakers
IEC 61034 (all parts)	Measurement of smoke density of cables burning under defined conditions
IEC 61046 : 1993	d.c. or a.c. supplied electronic step-down convertors for filament lamps — General and safety requirements
IEC 62020 : 2020	Electrical accessories — Residual current monitors for household and similar uses (RCMs)
CEN TC 152	Non-permanent structures and equipment for fairgrounds and amusement parks: Safety

3 TERMINOLOGY

For the purpose of this part of IEC 60364, the definitions given in IEC 60050 (826) as well as the following definitions apply.

3.1 Fairground

Area where one or more stands, amusement devices or booths are erected for leisure use.

3.2 Booth

Unit, usually movable, intended to accommodate equipment generally for pleasure or demonstration purposes.

3.3 Stand

Area or temporary structure used for display, marketing, sales, entertainment.

3.4 Amusement Device

Ride, stand, textile or membrane building, side stall, side show, tent, booth, grandstand intended for the entertainment of the public.

4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1 Protection for Safety

4.1.5.5 *Assessment of general characteristics*

4.1.5.6 *Purposes, supplies and structure*

4.1.5.9 *Supplies*

4.1.5.9.101 *Voltage*

The nominal supply voltage of temporary electrical installations in booths, stands and amusement devices shall not exceed 230/400 V a.c. in accordance with IS 12360/IEC 60038.

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4.1.5.9.102 *Supply from the public network*

Irrespective of the number of sources of supply, the phase and neutral conductors from different sources shall not be interconnected. The instructions of the supply network operator shall be followed.

4.2 Protection against Electric Shock-Protection against Electric Shock in Normal Service - (Protection against Direct Contact, or Basic Protection)

4.2.11 *Protection against indirect contact - Protection by automatic disconnection of supply*

NOTE — For supplies to large a.c. motors, the use of RCDs with time delay is recommended.

4.2.11.4 *TN system*

If the supply is a TN system, only the TN-S system shall be used.

4.2.11.6 *IT system*

Where an alternative system is available, an IT system shall not be used. IT systems, however, may be used for d.c. applications in accordance with IEC 62020. Where an IT system is used, permanent earth fault monitoring shall be provided.

4.2.15.1 *Additional protection by residual current devices*

Except for emergency lighting, all final circuits for lighting, socket-outlets rated up to 32 A and portable equipment connected by means of flexible cable or cord with a current-carrying capacity of 32 A or less shall be additionally protected by RCDs with a rated residual operating current not exceeding 30 mA.

This requirement does not apply to socket-outlets supplied by a circuit incorporating one or more of the protective measures specified below:

a) protection by SELV;

b) protection by electrical separation;

c) protection by automatic disconnection of supply and reduced low voltage.

4.2.15.2 *Supplementary equipotential bonding*

4.2.15.2.101 In locations used for animals, supplementary equipotential bonding shall connect all exposed conductive parts and extraneous conductive parts which can be touched simultaneously to the protective conductor of the installation.

4.2.15.2.102 *Isolation*

Every separate temporary electrical installation for amusement devices and each distribution circuit supplying outdoor installations shall be provided with its own readily accessible and properly identified means of isolation.

4.2.101 *Protection against Electric Shock in Normal Service*

Protective measures against direct contact by means of obstacles (*see* Annex B, B-2 of IS 732 : 2019) and by placing out of reach (*see* Annex B, B-3 IS 732 : 2019) shall not be used.

4.2.102 *Protection against Electric Shock in Case of a Fault*

Protective measures against indirect contact by non-conducting location (*see* 4.2.11.3 of IS 732 : 2019) and by earth-free equipotential bonding (*see* Annex C, C-2 of IS 732 : 2019) shall not be used.

4.2.103 *Choice of Protective Measures as a Function of external influences-Selection of Measures for Protection against Electric Shock in Relation to External Influences*

For the application of the protective measure against indirect contact by automatic disconnection of supply, the conventional voltage limit in locations in which animals may be present is UL = 25 V a.c. r.m.s. or 60 V ripple-free d.c., or the maximum disconnecting time is that indicated in Table 48A of IEC 60364-4-481.

These conditions also apply to locations connected by conductive parts to the locations where animals may be present.

4.2.104 *Choice of protective measures against indirect contact*

4.2.104.1 Automatic disconnection of supply to the temporary structures shall be provided at the origin of the installation by RCDs with a rated residual operating current not exceeding 300 mA. These RCDs shall incorporate

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a time delay in accordance with IS/IEC 60947-2 or be of the S-type in accordance with IS 12640-1/IEC 61008-1 or IS 12640-2/IEC 61009-1 for discrimination with RCDs protecting final circuits.

NOTE — The recommendation for additional protection relates to the increased risk of damage to cables in temporary locations.

4.2.104.2 In order to prevent all supplies from being disconnected and causing danger (including non-electrical danger by the loss of motive power or lighting), it may be necessary to utilise more than one circuit.

4.3.2 *Protection against Fire*

4.3.2.101 A motor which is automatically or remotely controlled and which is not continuously supervised shall be fitted with a manually reset protective device against excess temperature.

5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.1 Common Rules

Switchgear and controlgear shall be placed in cabinets which can be opened only by the use of a key or a tool, except for those parts designed and intended to be operated by ordinary persons (Code BA1), as defined in Table 7 of IS 732.

5.1.4.2 *Wiring systems*

5.2.4 *Types of Wiring Systems*

5.2.4.9.101 *Cables*

Where appropriate, cables shall be of flexible construction.

Armoured cables or cables protected against mechanical damage shall be used wherever there is a risk of mechanical damage.

All temporary power distribution cables shall be multicore, except for circuits above 125 A where single-core cables may be used.

All cables shall meet the requirements of IEC 60332-1.

NOTE — Where enhanced performance is required, cables should meet the requirements of IEC 60332-3; where low smoke cables are needed, the minimum recommended performance is given in IEC 61034-2.

Cables shall have a minimum voltage designation of 450/750 V, except that, within amusement devices, cables and cords having a minimum voltage designation of 300/500 V may be used.

The routes of cables buried in the ground shall be marked at suitable intervals. Buried cables shall be protected against mechanical damage.

5.2.9 *Electrical Connections*

Joints shall not be made in cables and cords, except where necessary as a connection to a circuit. Any joint shall be made in an enclosure affording a degree of protection not less than IP4X or IPXXD.

Where strain may be transmitted to terminals, cable anchorage shall be provided.

5.3 Switchgear and Controlgear

5.3.7.3.2 *Devices for isolation*

Devices for isolation shall disconnect all phases, poles and the neutral.

5.3.7.3.2.101 *General*

Every electrical installation of a booth, stand or amusement device shall have its own means of isolation and over-current protection, which shall be readily accessible.

5.3.7.5.4.2 *Emergency switching device*

A separate circuit shall be used to supply such signs or lamps, which shall be controlled by an emergency switch. The switch shall be easily visible, accessible and marked in accordance with the requirements of the local authority.

5.3.7.5.4.2.101 *Safety isolating transformers and electronic converters*

Multiple connection safety isolating transformers shall comply with IS/IEC 61558-2-6 or provide an equivalent degree of safety.

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A manually reset protective device shall protect the secondary circuit of each transformer or electronic converter (*see* IS 16504-1/IEC 60204-1).

Safety isolating transformers shall be mounted out of arm's reach of the public and shall have adequate ventilation. Access by skilled or instructed persons for testing and protective device maintenance shall be provided.

Electronic converters shall conform to IEC 61046.

Enclosures containing rectifiers and transformers shall be adequately ventilated and the vents not obstructed when in use.

5.3.7.6.101 *Socket-outlets and plugs*

An adequate number of socket-outlets shall be installed to allow the user's requirements to be met safely.

Not more than one flexible cable or cord shall be connected to a plug, unless the plug is specifically designed for multiple connection.

Multi-way plug-in type adapters shall not be used.

5.3.101 *Electrical supply*

At each amusement device, there shall be a connection point readily accessible and permanently marked to indicate the following essential characteristics:

a) rated voltage;
b) rated current;
c) rated frequency.

5.5 Other Equipment

5.5.2 *Low-Voltage Generating Sets*

5.5.2.101 *Generators*

All generators shall be so located or protected as to prevent danger and injury to people through inadvertent contact with hot surfaces and dangerous parts. Reference to injury and danger in this subclause also includes non-electrical danger and injury.

Electrical equipment associated with the generator shall be mounted securely and, if necessary, on anti-vibration mountings.

Significant changes in generator frequency and/or voltage shall be prevented.

Where a generator supplies a temporary installation, using a TN, TT or IT system, care shall be taken to ensure that the earthing arrangements are in accordance with 5.4.2.1 of IS 732 and, in cases where earth electrodes are used, with 5.4.2.2 of IS 732.

For TN systems, all exposed conductive parts shall be connected to the generator using a protective conductor with a cross-sectional area in accordance with 5.4.3 of IS 732.

The neutral conductor of the star-point of the generator shall, except for IT-systems, be connected to the exposed conductive parts of the generator.

5.5.3.1 *Lighting installation*

5.5.3.2.1.101 *Luminaires*

All luminaires and decorative chains shall be securely attached to the structure or support intended to carry them. Their weight shall not be carried by the supply cable, unless it has been selected and erected for this purpose.

Luminaires and decorative chains mounted less than 2.5 m (arm's reach) above floor level or otherwise accessible to accidental contact shall be firmly fixed, and so sited or guarded as to prevent risk of injury to persons or ignition of materials. Access to the fixed light source shall only be possible after removing a barrier or an enclosure, which operation shall require the use of a tool.

5.5.3.3.101 *Lampholders*

Insulation-piercing lampholders shall not be used unless the cables and lampholders are compatible and the lampholders are non-removable once fitted to the cable.

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5.5.3.3.102 *Lamps in shooting galleries*

All lamps in shooting galleries and other side-shows where projectiles are used shall be suitably protected against accidental damage.

5.5.3.3.103 *Floodlights*

When transportable floodlights are used, they shall be mounted so that the luminaire is inaccessible. Supply cables shall be flexible and have adequate protection against mechanical damage.

5.5.3.3.104 *Fire risks for luminaires and floodlights*

Luminaires and floodlights shall be so fixed and protected that a focusing or concentration of heat is not likely to cause ignition of any material.

5.5.3.3.105 *Electrical discharge lamp installations*

Installations of any luminous tube, signs or lamps on a booth, stand or amusement device with an operating voltage higher than 230/400 V a.c. shall comply with the following.

5.5.3.3.106 *Location*

The sign or lamp shall be installed out of arm's reach or shall be adequately protected to reduce the risk of injury to persons.

5.5.3.3.107 *Installation*

The fascia or material behind luminous tube, signs or lamps shall be non-ignitable and protected as required by national regulations.

Controlgear with output voltages higher than 230/400 V a.c. shall be mounted on non-ignitable material.

6 VERIFICATION

The whole electrical installation shall be inspected and tested after each assembly on site.

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SECTION 18 REQUIREMENTS FOR REQUIREMENTS FOR HEATING CABLES AND EMBEDDED HEATING SYSTEMS

FOREWORD

An embedded heating system functions by warming the floor or ceiling of a room. These objects then warm the air in the room. Some systems use electric heating panels to generate heat, which is radiated into rooms, other systems are thermal storage systems. The requirements apply to the installation of electric floor and ceiling heating systems which are erected both as direct acting heating or thermal storage systems. This section contains specific requirements for the installation of embedded heating systems which supplement the general requirements of that standard.

For the purpose of this part of NEC Part 3 Section 18, the requirements of IS 732 : 2019 shall apply. This Part 3 Section 18 of NEC contain particular requirements for special installations or locations which are based on the requirements of the general parts of IS 732 : 2019. Part 3 Section 18 parts are considered in conjunction with the requirements of the general parts.

The particular requirements of this part of NEC supplement, modify or replace certain of the requirements of IS 732 : 2019 being valid at the time of publication of this part. The absence of reference to the exclusion of a part or a clause of a general part means that the corresponding clauses of the general part are applicable. Numbering of clauses does not, therefore, necessarily follow sequentially.

Requirements of other NEC parts being relevant for installations covered by this part also apply. This part may therefore also supplement, modify or replace certain of these requirements. The clause numbering of this part follows the pattern and corresponding references of IS 732 : 2019. If requirements or explanations additional to those of the other parts of the IS 732 : 2019 are needed, the numbering of such items appears as 101, 102, 103, etc.

1 SCOPE

This part of NEC applies to embedded electric heating systems for surface heating. It also applies to electric heating systems for de-icing or frost prevention or similar applications. Both indoor and outdoor systems are covered.

Heating systems for industrial and commercial applications complying with relevant parts of IS/IEC 60519, IEC 62395 and IS/IEC 60079 are not covered.

NOTE — Examples of heating systems covered by this standard are heating systems for walls, ceilings, floors, roofs, drainpipes, gutters, pipes, stairs, roadways, non-hardened compacted areas (e.g. football fields, lawns).

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
732 : 2019	Code of practice for electrical wiring installations
IS/IEC 60079-7 : 2015	Explosive atmospheres: Part 7 Equipment protection by increased safety “e”
IEC 60335-2-96 : 2019	Household and similar electrical appliances — Safety — Part 2-96: Particular requirements for flexible sheet heating elements for room heating
IEC 60364	Low-voltage electrical installations (all parts)
IEC 60800 : 2009	Heating cables with a rated voltage of 300/500 V for comfort heating and prevention of ice formation

3 TERMINOLOGY

For the purposes of this document, the following terms and definitions apply.

3.1 Thermal Storage Floor Heating System

Heating system in which, due to a limited charging period, a restricted availability of electrical energy is converted into heat and dissipated mainly through the surface of the floor to the room to be heated with an intended time delay.

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3.2 Direct Heating System

Heating system which generates heat from electrical energy and dissipates it to the room to be heated with a response time being as low as possible.

3.3 Complementary Floor Heating

Direct heating system integrated into the floor construction, for example, in the border zones close to outer walls, which complements the heat dissipation of a thermal storage floor heating system.

3.4 Heating-Free Area

Area of a surface that is deliberately left free of all parts of the heating system.

3.5 Heating Cable

Cable with or without a shield or a metallic sheath, intended to give off heat for heating purposes.

3.6 Flexible Sheet Heating Element

Heating element consisting of sheets of electrical insulation laminated with electrical resistance material, or a base material on which electrically insulated heating wires are fixed.

3.7 Heating Unit

Heating cable or flexible sheet heating element with rigidly fixed cold leads or terminal fittings which are connected to the terminals of the electrical installation.

3.8 Cold Lead

Insulated cable or cord intended to connect the heating unit with the electrical installation.

3.9 Self-Limiting Heating Cable

Cable that cannot exceed 70 °C when tested according to IS/IEC 60079-7 and which does not require cold leads for connection to the electrical installation.

4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1 Protection for Safety

4.2 Protection against Electric Shock

4.2.6 *Protection by Obstacles and Placing out of Reach*

Replace the requirements with the following:

The protective measures “obstacles” and “placing out of reach” as specified in Annex B of IS 732 : 2019, shall not be used.

4.2.7 *Replace the requirements with the following:*

The protective measures “protection by non-conducting location”, “protection by earth-free local equipotential bonding” and “protection by electrical separation for the supply of more than one item of current-using equipment” as specified in Annex C of IS 732, shall not be used.

4.2.11 *Automatic Disconnection of Supply*

4.2.11.1 *General*

Add the following paragraph:

In the case of heating units which are delivered from the manufacturer without an earthed conductive shield a suitable conductive covering, for example, a mesh metallic grid, with a mesh size of not more than 30 mm for ceilings and floor installations and 3 mm for wall installations, shall be provided on site and connected to the protective conductor of the electrical installation.

Residual current protective devices shall be so selected, and the electrical circuits so subdivided, that any earth-leakage current which may be expected to occur during normal operation of the connected load(s) will be unlikely to cause unnecessary tripping of the device.

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4.2.13 *Protective Measure: Electrical Separation*

Add the following:

Electrical separation is not permitted for wall heating systems.

4.2.15.1 *Additional protection: residual current protective devices (RCDs)*

4.2.15.1.1 *Add, at the end of 4.2.15.1.1 of IS 732 : 2019 the following new paragraph:*

Circuits supplying heating units shall have additional protection by the use of RCDs with a rated residual operating current not exceeding 30 mA. Time delayed type RCDs are not permitted.

4.1.2.3 *Protection against thermal effects*

4.3.3 *Protection against Burns*

Add the following:

Where contact with the skin or footwear is possible, the surface temperature shall be limited.

NOTE — Guidance on limitation of temperature is given in IEC Guide 117.

4.3.4 *Protection against Overheating*

Add the following:

4.3.4.101 *Wall heating systems*

For wall heating systems the heating units shall be provided with a metal sheath or metal enclosure or fine mesh metallic grid. The metal sheath or metal enclosure or fine mesh metallic grid shall be connected to the protective conductor of the supply circuit.

NOTE — This requirement is intended to protect against the effects of overheating caused by a short-circuit between live conductors due to penetration of an embedded heating unit.

4.3.4.102 To meet the requirements of 4.3 of IS 732, special care shall be taken to prevent the heating elements creating high temperatures to adjacent material. This may be achieved by using heating units with temperature self-limiting functions or by separation with heat-resistant materials. The latter may be accomplished by placing on a metal sheet, in metal conduit or at a distance of at least 10 mm in air from the ignitable structure.

5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.1 Common Rules

5.1.1 *Compliance with Standards*

Add the following:

Flexible sheet heating elements shall comply with the requirements of IEC 60335-2-96.

Heating cables shall comply with IEC 60800.

5.1.4 *Identification*

5.1.4.1 *General*

Replace the existing text by the following new text:

Documentation for each heating system shall be provided, containing the following information where relevant:

a) manufacturer and type of heating units;
b) number of heating units installed;
c) length/area of heating units;
d) rated power;
e) surface power density;
f) layout of the heating units in the form of a sketch, drawing or picture;
g) position/depth of heating units;
h) position of junction boxes;
j) conductors, shields and the like;

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k) heated area;
m) rated voltage;
n) rated resistance (cold) of heating units;
p) rated current of overcurrent protective device;
q) rated residual operating current of RCD;
r) the insulation resistance of the heating installation and the test voltage used;
s) the leakage capacitance;
t) product information containing provisions about approved substances in the surroundings of the heating units, with necessary instructions for installation. If materials other than those recommended are used, the manufacturer shall be consulted.

This plan shall be fixed to, or adjacent to, the distribution board of the heating system.

Furthermore, the requirements of Annex A apply.

5.1.5 *Prevention of Mutual Detrimental Influences*

5.1.5.1 *Replace the existing text by the following new text:*

Electric heating systems shall be selected and erected so as to avoid any harmful influence between the heating system and any electrical or non-electrical installations envisaged.

NOTE — For example, an electric heating system can affect other parts of the electrical installation such as reducing the current-carrying capacity of cables of other circuits due to high local ambient temperature caused by the heating system.

Add the following new subclause:

5.1.5.1.101 Heating units shall not cross expansion joints of the building or structure.

5.2 Wiring Systems

5.2.1 *Introduction*

5.2.3 *General*

Add the following new subclause:

5.2.3.101 *Heating-free areas*

For the necessary attachment of room fittings, heating-free areas shall be provided in such a way that the heat emission is not prevented by such fittings.

5.2.5 *Selection and Erection of Wiring Systems in Relation to External Influences*

5.2.5.1 *Ambient temperature (AA)*

Add the following:

5.2.5.1.101 For cold leads (circuit wiring) and control leads installed in the zone of heated surfaces, the increase of ambient temperature shall be taken into account.

5.2.5.4 *Presence of solid foreign bodies (AE)*

Add the following:

5.2.5.4.101 Where heating units are installed there shall be heating-free areas where drilling and fixing by screws and the like may be carried out without risk of damage to the unit(s).

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ANNEX A

INFORMATION FOR THE USER OF THE INSTALLATION

A-1 description of the heating system shall be provided to the person ordering the work upon completion of the installation.

The description shall contain at least the following information:

a) description of the construction of the heating system, especially the installation depth of the heating units;

b) location diagram with information concerning:

   1) the distribution of the heating circuits and their rated power,

   2) the position of the heating units in each room,

   3) particularities which have been taken into account when installing the heating units, for example heating-free areas, complementary heating zones, heating-free areas for fixing means penetrating into the covering material;

c) data on the control equipment used, with relevant circuit diagrams and the dimensioned position of floor temperature and weather conditions sensors, if any;

d) data on the type of heating units and their maximum operating temperature.

The installer shall inform the owner that the description of the heating system includes all necessary information, for example for repair work.

An appropriate number of instructions for use shall be provided to the owner or his agent upon completion. One copy of the instructions for use shall be permanently fixed in or near each relevant distribution board.

The instructions for use shall include at least the following data:

a) description of the heating system and its function;

b) operation of the heating installation in the first heating period in the case of a new building, for example, regarding drying out;

c) operation of the control equipment for the heating system in the dwelling area and in the complementary heating zones, if any;

d) information on restrictions on placing of furniture or similar:

   1) additional floor coverings, for example, carpets with a thickness of >10 mm may lead to higher floor temperatures which can adversely affect the performance of the heating system;

   2) pieces of furniture solidly covering the floor and/or built-in cupboards shall only be placed on heating-free areas,

   3) furniture, such as carpets, seating and rest furniture with pelmets, which in part do not solidly cover the floor may not be placed in complementary heating zones, if any;

e) in the case of ceiling heating systems, restrictions regarding the height of furniture. Cupboards of room height may be placed only below the area of ceiling where no heating elements are installed;

f) dimensioned position of complementary heating zones and placing areas;

g) statement that, in the case of thermal floor, wall and ceiling heating systems, no fixing shall be made into the floor, wall or ceiling, respectively. Excluded from this requirement are heating-free areas. Alternatives shall be given, where applicable.

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SECTION 19 REQUIREMENTS FOR OFFICE BUILDINGS, SHOPPING AND COMMERCIAL CENTRES AND INSTITUTIONS

FOREWORD

Office buildings, shopping and commercial centres can be of various types depending on the size of the civil structure or the extent of activity involved in the building. High-rise buildings housing office complexes are common, calling for a coordinated planning while designing the electrical services therein.

In small buildings with comparatively moderate loads, supply is normally at medium voltage and the distribution of power is less complex. However, in the case of multi-storied office-cum-commercial complex, where the large number of amenities is to be provided calls for a more complex distribution system. Some of such buildings has to incorporate a standby/emergency power plant for essential service needs.

For editorial convenience, and keeping in view the similarly with the type of buildings covered in this section, educational and other institutional buildings are also covered here. Should any special provisions apply to them, they are identified at the relevant clauses. It is not possible to define strictly the type of buildings covered in this Section except in broad terms, an attempt has been made to identify the nature of the occupancy.

1 SCOPE

This Indian Standard (Part 3/Sec 19) of this Code covers requirements for electrical installations in office buildings, shopping and commercial centers and educational and similar institutional buildings.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No.	*Title*
3646 (Part 2) : 1966	Code of practice for interior illumination: Part 2 Schedule for values of illumination and glare index
8061 : 1976	Code of practice for design, installation and maintenance of service lines up to and including 650 V
15707 : 2006	Testing, evaluation, installation and maintenance of ac electricity meters — Code of practice

3 TERMINOLOGY

For the purpose of this Section, the definitions given in Part 1/Sec 2 of this Code shall apply.

3.1 Coincidence Factor – It is the ratio, expressed as a numerical value or as a percentage, of the simultaneous maximum demand of a group of electrical appliances or consumers within a specified period, to the sum of their individual maximum demands within the same period.

4 CLASSIFICATION

The electrical installations covered in this Section, are those in buildings intended for the following purposes:

a) *Office Buildings/Business Buildings* — These include buildings for the transaction of business, for the keeping of accounts and records and similar purposes, professional establishments, offices, banks, research establishments, data processing installations, etc.

b) *Shopping/Commercial Centres/Mercantile Buildings* —These include buildings used as shops, stores, market, for display and sale of merchandise, wholesale or retail, departmental stores, etc.

c) *Educational Buildings* — These include buildings used for schools, colleges and daycare purposes for more than 8 hours per week involving assembly of people for instruction and education (including incidental recreation), etc.

NOTE — Larger assembly buildings recreational occupancies are covered in Part 3/Sec 20 of this Code.

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5 GENERAL CHARACTERISTICS OF INSTALLATIONS

General guidelines on the assessment of characteristics of installations in buildings are given in Part 1/Sec 8 of this Code. For the purpose of installations falling under the scope of this Section the characteristics defined below generally apply.

5.1 Environment

The following environmental factors shall apply to office buildings, shopping and commercial centres and educational/institutional buildings.

Environment	*Characteristics*	*Remarks*
(1)	(2)	(3)
Presence of water	Probability of presence of water is negligible	
Presence of foreign solid bodies	The quantity or nature of dust or foreign solid bodies is not significant	
Presence of corrosive or polluting substances	The quantity and nature of corrosive or polluting substances is not significant	Locations where some chemical products are handled in small quantities, (for example, laboratories in schools and colleges) will be categorized as AF3. For office and other buildings covered by this Section situated by the sea or in industrial zones, producing serious pollution, the categorization AF2 applies
Mechanical stresses	Impact and vibration of low severity	
Seismic effect and lighting		Depends on the location of the building

5.2 Utilization

The following aspects of utilization shall apply:

Utilization	*Characteristics*	*Remarks*
(1)	(2)	(3)
Capability of persons	Uninstructed persons Children Persons adequately advised or supervised by skilled persons	A major percentage of occupants Applies to schools Applies to areas such as building, substations and for operating and maintenance staff
Contact of persons	Persons in non-conducting situations	
Conditions of evacuation during emergency	Low density occupation, easy conditions of evacuation.	Small offices and shops Departmental stores
	High density occupation, difficult conditions of evacuation	High rise office occupation, commercial centres, underground shopping arcades etc.
Nature of processed of stored material	No significant risks	Small shops
	Existence of fire risk	In view of large volume of paper and furniture, for example, office buildings, furniture shops, etc.

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6 SUPPLY CHARACTERISTICS AND PARAMETERS

6.1 Exchange of Information

6.1.1 Proper coordination shall be ensured between the architect, building contractor and the electrical engineer on the various aspects of installations design. From the point of view of the design of the various installations, the following shall be considered:

a) Maximum demand and Coincidence Factor;
b) Type of distribution system, mains and sub mains;
c) Nature of supply (current, frequency, nominal voltages);
d) Prospective short-circuit current at the supply intake point;
e) Division of the installation;
f) Nature of the external influences (*see* **5**);
g) Maintainability of the installations;
h) Nature and details of building services;
    1) Lighting,
    2) Air-conditioning, and
    3) Lifts.
j) Other details as relevant such as, pumps for fire-fighting, lighting, fire-alarm systems, telephones, call-bells, clock systems, etc.;
k) Telephone circuits including extensions and intercom facilities;
m) CCTV for information display and security;
n) Computer installation facility where applicable; and
p) Metering system for different loads.

    NOTE — Fire protection system shall include such details such as locations of detectors, zonal indicators, central control console, public address system for fire-fighting, cable runs and their segregation from the other cable system.

q) Parking area

A complete drawing of layout of the electrical installation shall be prepared together with associated floor plans indicating the details mentioned in (a) to (q). This wiring diagram shall include outlets for lights, sockets, bells, ceiling fans, exhaust fans, location of sectionalized control switches, distribution boards, etc. In special occupancies such as school or college laboratories, the d.c. circuits be identifiable in the layout diagram. (Including protective devices like MCBs, or RCD where ever required.)

6.2 Branch Circuits

6.2.1 The general design of wiring of branch circuits shall conform to those laid down in Part 1/Sec 9 of this Code. However, for special cases such as for communication networks, fire-alarm system and wiring for data-processing equipment, the recommendations of the manufacturer shall apply.

6.2.2 The branch circuit calculations shall be done according to the general provisions laid down in Part 3/Section 1 of this Code. However, the specific demands of the lighting, appliance and motor loads as well as special loads encountered in the types of buildings covered in this Section shall be taken into account.

6.2.3 In offices and showrooms, the interior decoration normally include false ceiling, carpets and curtails. Any wiring laid above the false ceiling should be adequately protected such as by drawing the wires in metallic conduits/GI Cable trays and nor run in open. Wires shall not be covered by carpets. They shall be run at skirting level and encased for mechanical protection.

In modern offices cables/wires shall be laid in floor raceways made of GI/PVC with adequate compartments along with junction boxes/floor boxes

6.2.4 Adequate number of socket-outlets shall be provided for electrically operated office machines such as computers, desktop printers, xerox machines and scanners electrical typewriter, etc., to avoid running of wires and use of multiple outlets from one socket.

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Power circuit (that is 16A/20A points/sockets and outlets) should be separate from the lighting circuit and protection provided for the same should be separate (like MCCBs/RCD).

6.2.5 Areas where corrosive or polluting substance are present intermittently or continuously, such as school laboratories and other buildings located in high industrial pollution zones, socket-outlets shall preferably be of metal clad weatherproof type with covers. The cable trays here could be of hot dip galvanized/SS material (suitable IP protection DBs to be used as per application/surrounding condition).

6.2.6 Lighting circuits shall preferably be combined in switched groups so that lighting can be limited to desks which are occupied. Each lighting circuit shall be protected by MCBs of suitable rating.

6.3 Service Lines

The general provisions laid down in IS 8061 shall apply.

6.4 Building Substations

6.4.1 *General*

The designer of power supply for office buildings and commercial centres shall take into account the great concentration of power demand of the electrical loads. Air-conditioning in office buildings absorbs an especially high proportion of the total power used. Consequently, such occupancies have to be provided with their own substation with vertical and horizontal forms of power distribution.

6.4.2 If the load demand is high, requiring supply at high voltage, accommodation for substation equipment will be required. Main switch room will serve feeders to various load centres, such as air-conditioning plant, elevators, water pumps, etc. Other loads are taken to local distribution boards.

6.4.3 The transformer power rating for the supply of the building shall be sufficient to cater to the highest simultaneous power requirements of the building. Typical proportions of power usage are given as follows:

Part of Electrical Installation	*Part of the Total Power Requirement Percent*	*Coincidence Factor*
(1)	(2)	(3)
Ventilation, heating (air-conditioning)	45	1.0
Power plant (drives)	5	0.65
Lighting	30	0.95
Lifts	20	1.0

6.4.4 The location and layout of building substation shall conform to the general rules laid down in Part 2 of this Code. The substation room shall be well ventilated and inaccessible to birds and reasonably reptile, rodent and insect-proof. Only authorized persons be allowed to enter the substation for operations/maintenance of any kind. Cables leading from the substation to the main building shall preferably be carried underground through ducts or pipes of adequate dimensions. Such pipes shall be properly sealed at both ends to reduce the possibility of rain water flowing through the pipes and flooding the trenches.

6.4.4.1 Buildings should be protected by suitable lightning and surge protectors/arresters.

6.4.5 *Emergency Supply*

Wherever emergency supply is considered necessary, it can be in the form of separate and independent feeder from the undertaking terminated in equipment isolated from the regular supply line. In case of standby supply from diesel generator set, it will be installed as per the general rules laid down in Part 2 of this Code. Automatic transfer switch can be used for the changeover.

6.4.5.1 In office buildings, certain safety and essential services shall be supplied even in the case of mains failure. These are governed by the rules and regulations of the respective authorities. Essential services include amongst others, water-pressure pumps, ventilation installations, essential lighting and lifts. also emergency lights on exit door to be installed. The power requirement of these essential loads is generally about 25 percent of the total power requirement of the building.

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6.4.6 *Switchboards and Panel Boards*

All current carrying equipment shall be totally enclosed, dust-and vermin-proof and if mounted outdoor, shall be of weatherproof construction or housed in weatherproof kiosk or cabin. Switchboards shall be of open type or cubicle type. Cubicle type boards shall be with hinged doors interlocked with switch-operating mechanisms. All switches shall bear labels indicating their functions. Switchboards shall be located away from areas likely to be crowded by the public. Suitable IP protected DBs to be use in the installation.

6.4.7 Selection of equipment shall be made according to the guidelines laid down in Part 1/Sec 16 of this Code. For the purposes of office buildings, shopping and commercial centers, miniature circuit-breakers of adequate capacity shall be preferred to switch fuse units. They can also be effectively used in place of fuses in a distribution board.

6.5 Metering

In multi-storied buildings, a number of offices and commercial centers occupy various areas. Electrical load for each of them would have to be metered separately; the meter-room normally is situated in the ground floor (*see* IS 15707 for further guidance).

6.6 System Protection

6.6.1 *General*

The general rules for protection for safety laid down in Part 1/Sec 22 of this Code shall apply. Reference is also drawn to SP 7 on guidelines for fire protection of buildings. The general rules given below shall apply.

6.6.2 The type of buildings covered in this Section fell under Group B (educational buildings). Group E (business buildings) and Group F (mercantile buildings) from the point of view of fire safety classification (*see* SP 7). Typical firefighting installation requirements are also covered therein. The electrical needs for the appropriate type of installation shall, therefore, be decided accordingly.

6.6.2.1 *Educational buildings (Group B)*

Educational buildings above 2-storeys having an area of more than 500 m^2 per floor shall have besides firefighting equipment, manually operated electrical fire alarm and automatic fire alarm systems.

6.6.2.2 *Business buildings (Group E)*

Besides fire-fighting equipment, automatic fire alarm systems are recommended for offices, banks, professional establishments, parking areaetc, where the buildings are more than 2 storey with floor area above 500 m^2 per floor, and for laboratories with delicate instruments as well as computer installations.

6.5.2.3 *Mercantile buildings (Group F)*

Besides fire-fighting equipment, automatic sprinklers and automatic fire alarm systems are recommended for wholesale establishments, warehouses, transport booking agencies, etc, as well as for shopping areas inside buildings with area more than 500 m^2 on each floor. For other premises and shopping lines with central corridors open to sky, automatic fire-alarm systems shall be installed. Underground shopping centers shall be provided with automatic sprinklers.

6.7 Building Services

6.7.1 *Lighting*

6.7.1.1 The general rules laid down in Part 1/Section 15 of this Code shall apply. The choice of lamps, lighting fittings and general lighting design together with power requirement shall be planned based on the recommended values of illumination and limiting values of glare index given in Table 1. Maximum use of LED lighting should be preferred for energy conservation.

6.7.1.2 In commercial premises, a fairly high level of glare free lighting on working planes and subdued lighting in circulation areas are necessary with suitable protection like MCBs and RCDs. Aesthetics and interior decoration also play a part. Lighting design in showrooms includes high level of lighting in the vertical and horizontal planes, depending on the merchandise exhibited and their layout. Colour temperature characteristics of the light source shall also be taken into account in the case of showroom lighting.

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6.7.1.3 External lighting like street lighting and building façade lighting maybe be connected through suitable Timers/Time switches to have auto switching based on time.

6.7.2 *Air-conditioning*

6.7.2.1 The general rules laid down in Part 1/Sec 15 of this Code shall apply. The design of the air conditioning system, shall take into account the requirements stipulated in the following clauses.

6.7.2.2 Each Split Unit a.c. shall be wired separately from the DB with separate MCB for each for short circuit and overload protection.

6.7.2.3 In case of large air-conditioning installations (500 tons and above) it is advisable to have a separate isolated equipment room together with electrical controls. All equipment rooms shall have provision for mechanical ventilation.

6.7.3 *Lifts and Escalators*

6.7.3.1 The general rules laid down in Part 1/Section 15, of this Code shall apply. However, the design of lifts shall take into account the following recommendations:

6.7.3.2 Occupant load

These shall be as follows:

Sl No.	*Occupancy*	*Occupation Load Gross Area in m^2/Person*
(1)	(2)	(3)
i)	Educational	4
ii)	Business	10
iii)	Mercantile:	
	1) Ground floor and sales	3
	2) Upper sale floor	6

6.7.3.3 Passenger handling capacity (H)

These are expressed in terms of percent of the estimated population that has to be handled in the building in the 5 min peak period as follows:

a) Diversified (mixed) office occupancy 10-15
b) Single purpose office occupancy 15-25

6.7.3.4 *Car speed* — These shall be as follows:

Sl No.	*Occupancy*	*No. of Floors Served*	*Car Speed 20 m/s*
(1)	(2)	(3)	(4)
i)	Office building	4-5	0.5-0.75
		6-12	0.75-1.5
		13-20	Above 1.5
ii)	Shops and departmental stores		2-2.5

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Table 1 Recommended Values of Illumination and Glare Index

(*Clause* 6.6.1.1)

Sl No.	Building	Illumination Lux	Limiting Glare Index
(1)	(2)	(3)	(4)
i)	***Banks***:		
	a) Counters, typing accounting book areas	300	19
	b) Public areas	150	19
ii)	***Libraries***:		
	a) Shelves	70-150	–
	b) Reading rooms (newspaper, magazines)	150-300	19
	c) Reading tables	300-700	22
	d) Book repair and binding	300-700	22
	e) Cataloging, sorting, stock rooms	150-300	19
iii)	***Offices***:		
	a) Entrance halls and reception area	150	–
	b) Conference rooms, executive offices	300	19
	c) General offices	300	19
	d) Business machine operation	450	19
	e) Drawing offices	450	16
	f) Corridors and lift cars	70	–
	g) Stairs	100	–
	h) Lift landings	100	–
	j) Telephone exchanges;		
	1) Manual exchange rooms (on desk)	200	16
	2) Main distribution frame room	150	25
iv)	***Schools and colleges:***		
	a) Assembly halls:		
	1) General	150	16
	2) When used for exams	300	16
	3) Platforms	300	16
	b) Class and lecture rooms:		
	1) Desks	300	16
	2) Black board	200-300	–
	c) Embroidery and sewing rooms	700	10
	d) Art rooms	450	16
	e) Libraries	(*see* Sl No. ii above.)	16
	f) Manual training	[*see* appropriate trades in IS 3646 (Part 2)]	–
	g) Offices	300	19
	h) Staff rooms, common rooms	150	19
	j) Corridors	70	–
	k) Stairs	100	–
v)	***Shops and stores***[1)]:		
	a) General areas	150-300	22
	b) Stock rooms 1)	200	25

Does not cover display (showroom lighting).

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6.7.3.5 For office buildings, it is desirable to have at least a battery of 2 lifts at two or more convenient points. If this is not possible, it is advisable to have at least two lifts side by side at the main entrance and one lift each at different sections of the building for inter-communication. When two lifts are installed side by side, the machine room shall be suitably planned. All machines and switchgear may be housed in one machine room.

6.7.3.6 Each lift should be protected by an RCD of 30 mA sensitivity housed in a separate enclosure accessible to Service.

7 TESTING OF INSTALLATION

The various tests on the installation shall be carried out as laid down in Part 1/Section 17 of this code.

8 MISCELLANEOUS PROVISIONS

8.1 Group Control

The lighting circuits shall preferably be combined in switched groups as well as coordinated to functional groups of desks in an open plan office. The switching points may be combined centrally at the entrance passageways. In order to ensure proper co-ordination with design of the building for daylight use of devices such as automatic light sensors shall be encouraged for controlling lighting groups near windows for energy saving.

8.2 Telephones/Intercoms/Internet

Adequate coordination shall be ensured right from the planning stages with the telephone authorities to determine the needs for the telephone system catering to the various units in office buildings. For private intercom systems, entirely under the control of the user, it is necessary to pre-plan the coordination of external and intercom systems. Suitable single band or dual band routers to be installed depending upon number of users, level of security and throughput.

8.3 Electric Call Bell System

8.1.1 The general guidelines laid down in Part 1/Section 15, regarding installation of electric bells and call system shall be referred to. Depending on the final requirements of the type of occupancy, the type of equipment to be used, wiring and other details shall be agreed to.

8.1.2 A simple call bell system is suitable for small offices whereby service staff may be called to a particular position by the caller. A visible-*cum*-audible indicator/bell panel shall be used. When call points are too numerous on a single indicator panel, such as in large offices, multiple call system shall be preferred. The layout in such a case would be determined by the size of building and staff. Time bell systems shall be installed in schools to give Start-work and Stop-work signals (digital programmable time switches can be used where ever required, that is, to start or stop the work).

8.4 Clock Systems

8.4.1 The general guidelines contained in Part 1/Section 15 shall apply regarding installation and maintenance of master and slave clock systems.

8.4.2 In simple installations, impulse clocks designed to operate at the same current may be connected in one series circuit, with a battery having sufficient voltage to ensure satisfactory operation. In a more complex installation like multistoried office buildings with large number of slave clocks, the impulse clocks may be arranged in number of series circuits. Each of which is connected to a pair of contact on a relay which is operated from the contacts of master clock.

8.4.3 Master clock shall be placed in a dust free location, readily accessible for maintenance at all times.

8.5 Closed Circuit TV

Commercial buildings may require the installations of CCTVs for one of more of the following purposes:

a) Security, and safety; or

b) Information display.

Educational/institutional buildings may use CCTV as a teaching aid for pre-recorded educational programs. Reference shall be made to good practice for installations of such facilities.

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8.6 Emergency Lights for Critical Areas

Battery powered (at least 2 h rating) emergency lights should be installed at critical and strategic locations including emergency exit points. These will provide illumination by self-contained battery source even on failure of a.c. mains. On resumption of a.c. power supply, they will switch back to mains automatically and simultaneous recharge the battery to the required level.

8.7 Emergency Exit Lighting/Signage

Emergency lighting units are essential products that must be fully operational in order to ensure the safety of people in the event of emergency evacuation.

These should have LED bulbs and be capable of remaining ON for at least 2 h during an emergency and shall have IP42 class of protection.

Photo luminescent safety signage should be provided at different strategic locations.

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SECTION 20 REQUIREMENTS FOR HOTELS

FOREWORD

Hotels lodging or rooming houses are of a wide variety, ranging from simple dormitory type accommodation for guests, where only a common bath is provided with no facility for dining/kitchen to the sophisticated star hotels. Increasing competition in the hotel industry as such, coupled with the demand by guests for a variety of comforts, calls for an electrical installation in a hotel with increased sophistication.

The electrical needs of a hotel depend on the type and extent of facilities being provided and the rating of the hotel. The system design would in general be identical with that of any other large building, the actual power requirement expressed in terms of per-unit area or per guest room.

1 SCOPE

This section (Part 3/Sec 20) of the Code covers requirements for electrical installations in buildings, such as hotels and lodging houses.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS/IEC/ISO Number	*Title*
3646 (Part 2) : 1966	Code of practice for interior illumination: Part 2 Schedule for values of illumination and glare index
8061 : 1976	Code of practice for design, installation and maintenance of service lines upto and including 650 V
IS/IEC 60309-1 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 1 General requirements (*first revision*)
IS/IEC 60309-2 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 2 Dimensional interchangeability requirements for pin and contact tube accessories (*first revision*)
SP 7 : 2016	National Building Code of India
SP 72 : 2010	National Lighting Code

3 TERMINOLOGY

For the purpose of this Section, the definitions given in Part 1/Sec 2 of the Code shall apply.

4 CLASSIFICATION

4.1 The electrical installations covered in this Section are those in buildings intended for the following purposes:

a) *Lodging or Rooming Houses* — These include any building or group of buildings in which separate sleeping accommodation for a total of not more than 15 persons on either transient or permanent basis with or without dining facilities, but without cooking facilities for individuals, is provided.

NOTE — The above is distinct from single or two family private dwellings which are covered in Part 3/Sec 1 of this Code.

b) *Hotels* — These include any building or group of buildings in which sleeping accommodation is provided with or without dining facilities for hire to more than 15 persons, who are primarily transient such as hotels, inns, clubs and motels.

NOTE — For the purpose of this Code, restaurants other than those forming part of a large hotel are treated as assembly buildings and are covered in Part 3/Sec 13 of this Code.

4.2 The electrical installations in hotels covered in this Section include the following services:

a) Supply intake,
b) Main distribution centre,
c) Ventilation and exhaust systems,

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d) Kitchen,
e) Laundry,
f) Cold storage,
g) Health club,
h) Swimming pool and filtration plants,
j) Restaurants and bars,
k) Interior lighting,
m) Telephones,
n) Channelized music,
p) Service lifts and passenger lifts,
q) Offices,
r) Fire protection and alarm systems,
s) Banquet halls and conference facilities,
t) Gardens and parking lots and illumination systems therein,
u) Illuminated signs, display lights and decorative illuminations, and
v) Emergency system.

5 GENERAL CHARACTERISTICS OF INSTALLATIONS

General guidelines on the assessment of characteristics of installations in buildings are given in Part 1/Sec 8 of this Code. For the purposes of installations falling under the scope of this Section, the characteristics defined below generally apply (*see* also SP 7).

5.1 Environment

5.1.1 The following environmental factors apply to hotels:

Environment (1)	*Characteristics* (2)	*Remarks* (3)
Presence of water	Probability of presence of water is negligible	Majority of locations in hotels. Traces of water appearing for short periods are dried rapidly by good ventilation.
	Possibility of jets of water from any direction	Applies to gardens
	Possibility of permanent and total covering by water	Locations, such as swimming pools
Presence of foreign solid bodies	The quantity or nature of dust or foreign solid bodies is not significant	
Presence of corrosive or polluting substances	The quantity and nature of corrosive or polluting substances is not significant	For hotels situated by the sea or industrial zones, other categorization applies (*see* Part 1/Section 8 of this Code)
Mechanical stresses	Impact and vibration of low severity	—
Seismic effect and lighting		Depends on the location of the building

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5.2 Utilization

5.2.1 The following aspects of utilization shall apply:

Utilization (1)	*Characteristics* (2)	*Remarks* (3)
Capability of persons	Ordinary, uninstructed persons	A major proportion of occupants in Hotels
	Persons adequately advised or supervised by skilled persons	Applies to areas, such as building substation and for operating and maintenance staff
Contact of persons with earth potential	Persons in non-conducting situations	
Condition of evacuation during emergency	Low density occupation, easy conditions of evacuation	Applies to lodging houses
	High density occupation, difficult conditions of evacuation	Large hotels, high-rise buildings.
Nature of processed of stored material	No significant risks	
	Contamination risks due to presence of unprotected food stuffs	Applies to kitchens

6 SUPPLY CHARACTERISTICS AND PARAMETERS

6.1 Exchange of Information

Proper coordination shall be ensured between the architect, building contractor and the electrical engineer on the various aspects of installation design. In addition to the general aspects which require coordination and identified in other sections, information shall be obtained on the following services:

a) Whether central air-conditioning system is intended. If so, layout of air handling units, fan coil units, ducting, false ceiling and chilled water lines should be obtained.

b) Whether centrally controlled fire-fighting is intended. If so, layout of fire-fighting installation should be obtained.

c) Whether telephone and TV facilities are intended in each room. If so, layout of the telephone installation and TV circuits should be obtained.

d) Whether centrally heated out water system is intended. If so, layout of hot water pipe-line be obtained.

6.2 Branch Circuits

6.2.1 The general provisions for the design of wiring of branch circuits shall conform to those laid down in Part 1/Sec 9 of this Code. However, for special cases such as for communication networks, fire-alarm system, etc, as well as in areas, such as kitchen, laundry, etc, the recommendation of the manufacturer shall apply.

6.2.2 The branch circuit calculations shall be done as laid down in Part 1/Sec 9 of this Code. The specific demands of the lighting, appliance and motor loads, as well as special loads encountered in hotel building shall be taken into account.

6.2.3 In hotel buildings, the interior decor normally includes false ceiling, carpets and curtains. Any wiring laid above the false ceiling should be adequately protected, such as by drawing the wires in metallic conduits and not run in open. Wires shall not be laid under carpets. They shall be run at skirting level and encased for mechanical protection.

6.2.4 *Panel Boards and Switch-boards*

The provisions of Part 1/Sec 9 of this Code shall apply.

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6.2.5 *5ocket-outlets and Plugs*

6.2.5.1 These should be provided in all places where plug-in service is likely to be required, to reduce the need for alterations and extensions of wiring after the hotel building is completed. Duplex or other suitable outlets should be provided as required in the offices and work places for fans, lamps and appliances. The socket-outlets shall preferably have covers. Corridors and staircases shall be provided with sufficient socket-outlets for floor cleaning appliances. These shall be connected in a circuit separate from the circuits for the guest rooms.

6.2.5.2 If provided, use of a central radio receiving system wired with multi-channels piped music system to each room is recommended so that the occupant may choose one of the broadcasts. For such reception, special aerials and related wiring are required. Aerial outlets at rooms are required for portable radios in areas and buildings where reception is poor but in general the aerial built in the set may be adequate.

6.2.5.3 Special convenience outlets in corridors at suitable locations are desirable for use of portable equipment, such as floor cleaning appliances. They should be of the 3-pin type, suitably rated with one-pin earthed.

Heavy duty sockets should also be provided in pantries, kitchens, toilets and utility rooms for use of appliances. Adequate plug-in sockets at proper locations should be provided in banquet halls and other meeting places for flood lights and other appliances.

6.3 Feeders

The general provisions laid down in Part 1/Sec 9 of this Code shall apply.

6.4 Service Lines

The general provisions laid down in IS 8061 shall apply.

6.5 Building Substation

6.5.1 If the load demand is high which requires supply at voltage above 650 V a separate indoor accommodation, as near the main load centre of the hotel as possible shall be provided to accommodate switchgear equipment of supply undertaking and indoor/outdoor accommodation for the transformers. The main distribution equipment of the hotel shall preferably be located next to the substation. Separate feeders shall be provided for major loads like central air-conditioning, kitchen, laundry, swimming pool, lighting of main building and other essential loads.

6.5.2 The supply line should preferably be brought into the building underground to reduce the possibility of interruption of power supply. The accommodation for substation equipment as well as for main distribution panel shall be properly enclosed so as to prevent access to any unauthorized person. It shall be provided with proper ventilation and lighting arrangement.

6.5.3 The location and layout of building sub-station and emergency diesel generating set(s) shall be in conformance with Part 2 of this Code.

6.6 System Protection

6.6.1 *General*

The general rules for protection for safety laid down in Part 1/Sec 22 of this Code shall apply. Reference should be made to SP 7 for guidelines for fire protection of buildings.

6.6.2 For lodging and rooming houses of 3 storey and above, with a floor area more than 200 m^2 with central corridor and rooms on either side, besides fire fighting equipment, manually operated electric fire-alarm system shall be provided. Both manually operated and automatic fire-alarm systems shall be provided in large hotels.

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6.7 Building Services

6.7.1 *Lighting*

6.7.1.1 The general rule laid down in Part 1/Sec 14 of this Code shall apply. The choice of lighting fittings and general lighting design together with power requirements shall be planned based on the recommended values of illumination and limiting values of glare index given in Table 1 [*see* also IS 3646 (Part 2) and SP 72].

Table 1 Recommended Values of Illumination and Glare Index for Hotels

(*Clause* 6.7.1.1)

Sl No.	Building	Illumination, lux	Limiting Glare Index
(1)	(2)	(3)	(4)
i)	Entrance halls, lobby	150	–
ii)	Reception and accounts	300	–
iii)	Dining rooms (tables)	100	–
iv)	Lounges	150	–
v)	Bedrooms:		
	a) General	100	
	b) Dressing tables, bed heads, etc.	200	–
vi)	Writing tables	300	
vii)	Corridors	70	–
viii)	Stairs	100	–
ix)	Laundries	200	25
x)	Kitchens	200	25
xi)	Goods/passenger lifts	70	–
xii)	Cloakrooms/toilets	100	–
xiii)	Bathrooms	100	–
xiv)	Shops/stores	150-300	22

NOTE — The lighting of some of these locations is determined primarily by aesthetic considerations and the above values should be taken as a guide only.

6.7.1.2 In guest bedrooms, it shall be possible to switch the general lighting not only from the entrance but also from the bedside (*see* also **8.4.2**).

6.7.1.3 In bathrooms, the lights should be mounted at head level on both sides of the mirror. Care shall be taken to ensure that there is no glare.

6.7.1.4 Lighting in banquet halls shall be given special consideration in view of its multipurpose utility, such as fairs, dances, fashion shows, conferences, exhibition or concerts. Sufficient number of controlled socketoutlet circuits shall be combined in a switching station from which the entire hall shall be visible.

6.7.1.5 In designing outdoor lighting installations, care shall be taken to ensure that disturbing glare does not reach the rooms of the guests.

6.7.2 *Air-conditioning*

The provisions of Part 1/Sec 15 of this Code shall apply.

6.7.3 *Lifts and Escalators*

6.7.3.1 The general rules laid down in Part 1/Sec 15 of this Code shall apply. However, the design of lifts shall take into account the following recommendations.

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6.7.3.2 *Occupant load*

For hotel buildings, an occupant load of 12.5 gross area, in m^2 per person is recommended.

6.7.3.3 *Passenger handling capacity*

The passenger handling capacity expressed in percent of the estimated population that has to be handled in the 5 min peak period shall be 5 percent for hotel buildings.

6.7.3.4 *Car speed — This shall be as follows:*

Occupancy	*Floors Served*	*Car Speed* m/s
Passenger lifts for low and medium class lodging houses	–	0.5
Hotels	4-5	0.5-0.75

6.7.3.5 For hotel buildings, it is desirable to have at least a battery of two lifts at convenient points of a building. If this is not possible, it is advisable to have at least two lifts side by side at the main entrance, and one lift at different sections of the building for intercommunication.

7 TESTING OF INSTALLATION

The various tests on the installation shall be carried out as laid down in 6 of IS 732.

8 MISCELLANEOUS PROVISIONS

8.1 Call System

The general provisions for electrical bells and call system shall conform to those laid down in Part 1/Sec 15 of this Code. The call system should be a wired electrical system whereby customer may signal for attendance from his room. Two types of systems are recommended:

a) A simple one-watt signal system which connects the room side call stations with a signal at the attendant station. It simultaneously lights a dome light over the door of the room from which the call is originated. The signal at the attendant station may be in the form of an annunciator with a buzzer or a light with a buzzer.

b) A central control panel shall, be set up preferably on the ground floor incorporating a set of indicating panels according to the number of wings. Each indicating panel should have a set of small lamps according to the number of rooms. After-attending the customer, the attendant presses the resetting button which puts the whole equipment to the original condition.

8.2 Telephones

A centralized EPABX System with sufficient P&T lines shall be installed for internal and external communications with the help of operator's assistance as well as directly through this system. These may be connected on a dial system which permits internal communication through the hotel switchboard without the assistance of the operator. At all the rooms, telephone jacks shall be installed so that a telephone may be plugged in any time at any convenient location. Parallel telephones may be provided in the bedrooms. Each room shall also be provided with jacks for broad band multi service facility/internet facility.

8.3 Clock Systems

The general provisions for clock systems shall conform to those laid down in Part 1/Sec 15. The following locations may be provided with clocks:

a) Guest rooms,
b) Main lobby,
c) Telephone switchboard,
d) Dining room,
e) Banquet halls,
f) Kitchen, and
g) Restaurant and bar rooms.

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8.4 Emergency Supply

See also Part 2 of this Code.

8.4.1 In the event of a failure of supply, a large standby power supply usually a diesel driven generating set could be used to partly or entirely supply the loads in the hotel. Emergency lighting shall be confined to essential areas, and the standby power supply shall feed essential and safety installations in the hotel.

8.4.2 Part of the kitchen, storage and refrigeration rooms in the hotel shall also be supplied by the emergency supply. A part of the lighting in each room, corridor, staircases and other circulation areas shall be connected to emergency supply.

8.5 Other Special Installations

The list of such installations is given below:

a) TV sets at main assembly areas and in guest rooms,
b) Lighting in banquet halls,
c) Fire-fighting system,
d) Swimming pool (*see* Annex A),
e) Cold storage,
f) Sauna Heaters (*see* Annex B), and
g) Broad Band Multi Service facility/internet facility.

8.6 For particular requirements for locations containing a bathtub or shower basin, *see* Annex A of Part 3/Sec 1 of this Code.

8.7 Luminous Sign

Photo luminescent safety signage should be provided at different strategic locations.

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ANNEX A

(*Clause* 8.5)

PARTICULAR REQUIREMENTS FOR SWIMMING POOL

A-1 SCOPE

This Annex applies to the basins of swimming pools and paddling pools and their surrounding zones where susceptibility to electric shock is likely to be increased by the reduction of body resistance and contact with earth potential.

A-2 CLASSIFICATION OF ZONES

A-2.1 Reference is drawn to Fig. A-1 and Fig. A-2.

Zone 0 — is the interior of the basin.

Zone 1 — is limited by a vertical plane 2 m from the rim of the basin by the floor or the surface expected to be occupied by persons and the horizontal plane 2.50 m above the floor of the surface.

Zone 2 — is limited by the vertical plane external to Zone 1 and a parallel plane 1.50 m from the former, by the floor or surface expected to be occupied by persons and the horizontal plane 2.50 m above the floor or surface.

NOTE — Where the pool contains diving boards, spring boards, starting blocks or a chute, Zone 1 comprises the zone limited by a vertical plane situated 1.50 m around the diving boards, spring boards and starting blocks, and by the horizontal plane 2.50 m above the highest surface expected to be occupied by the persons.

A-3 PROTECTION FOR SAFETY

A-3.1 Where safety extra-low voltage is used, whatever the nominal voltage, protection against direct contact shall be provided by barriers or enclosures affording at least a protection of IP2X, or insulation capable or withstanding a test voltage of 500 V for 1 min.

A-3.2 All extraneous conductive parts in Zones 0, 1 and 2 shall be bonded with protective conductors of all exposed conductive parts situated in these Zones.

A-4 SELECTION OF EQUIPMENT

A-4.1 Electrical equipment shall have at least the following degrees of protection:

a) *Zone*0 : IP X 8
b) *Zone*1 : IP X 4
c) *Zone*2 : IP X 2 for inside swimming pools. IP X 4 for outside swimming pools.

A-4.2 For Zone 1 and Zone 2, water jet is likely to be used for clearing purpose : IP X 5

This requirement does not apply to instantaneous water heaters complying with IS 302 (Part 2/Sec 35).

A-5 WIRING SYSTEMS

A-5.1 In Zone 0 and Zone 1, wiring systems shall be limited to those necessary to the supply of appliances situated in those zones.

A-5.2 Junction boxes are not permitted in Zone 0 and Zone 1. In Zone 2, they are permitted provided they have the necessary degree of protection as given in **A-4.1**.

A-5.3 In Zone 0 and Zone 1 no switchgear and accessory shall be installed. In Zone 2 socket-outlets are permitted only if they are either:

a) supplied individually by an isolating transformer,
b) supplied by safety extra low voltage, or
c) protected by a residual current protective device.

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A-5.4 If it is not possible to locate socket-outlets may be installed only if they are complying:

a) Outside 1.25 m from the Zone 0 border, and

b) protected by residual current protection device.

A-5.5 The socket-outlets shall comply IS/IEC 60309 (Part 1) and IS/IEC 60309 (Part 2).

A-5.6 An electric heating unit embedded in the floor in Zones 1 and 2 shall incorporate a metallic sheath connected to the local supplementary equipotential bonding and shall be covered by the metallic grid required by **A-3.2**.

A-5.7 In Zone 2, only water heaters are permitted excepting that other equipment supplied by SELV (Safety Extra Low Voltage) at a nominal voltage not exceeding 12 V may be installed.

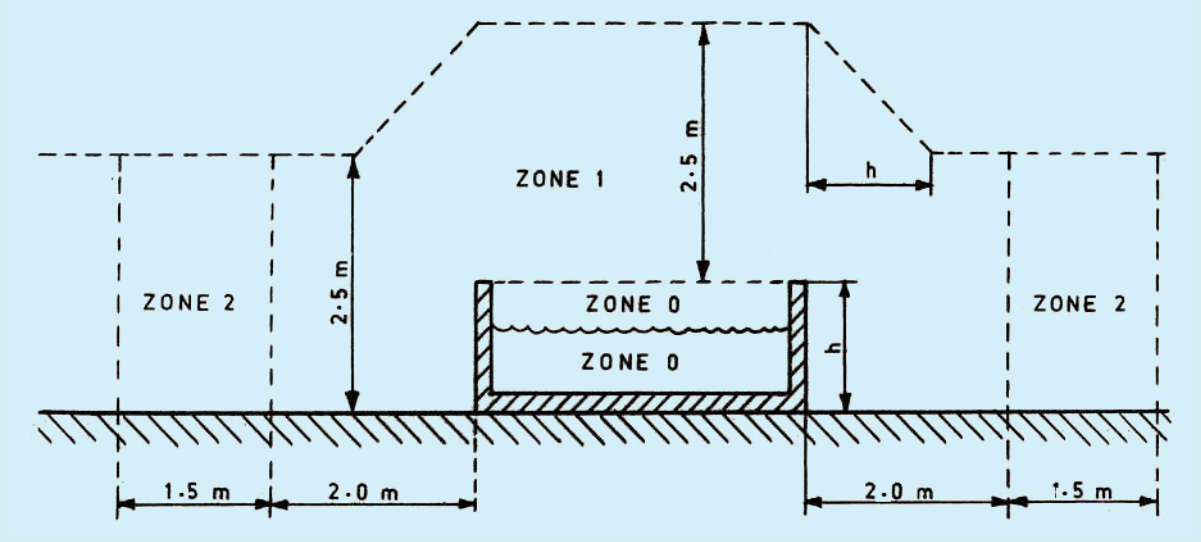


FIG. A-1 ZONE DIMENSIONS FOR BASINS ABOVE GROUND

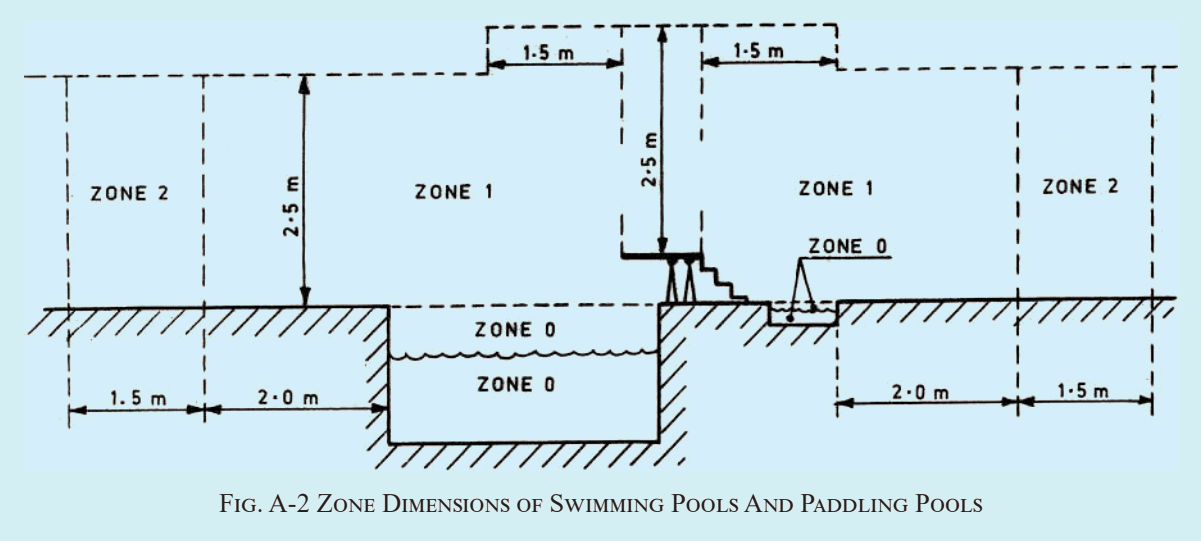


FIG. A-2 ZONE DIMENSIONS OF SWIMMING POOLS AND PADDLING POOLS

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ANNEX B

(*Clause* 8.5)

PARTICULAR REQUIREMENTS FOR LOCATIONS CONTAINING SAUNA HEATERS

B-1 SCOPE

The particular requirements of this Annex apply to locations in which hot air sauna heating equipment is installed.

B-2 CLASSIFICATION OF TEMPERATURE ZONES

The assessment of the general characteristics of the location shall take due consideration of the classification of the four temperature zones which are illustrated in Fig. 3.

B-3 PROTECTION FOR SAFETY

B-3.1 Where Safety Extra Low Voltage (SELV) is used, irrespective of the nominal voltage, protection against direct contact shall be provided by one or more of the following:

a) insulation capable of withstanding a test voltage of 500 V a.c., rms for 1 min.
b) barriers or enclosures, affording at least degree of protection IP 24.

B-3.2 All extraneous conductive parts shall be bonded with protective conductors of all exposed conductive parts situated in these zones and earthed.

B-4 SELECTION OF EQUIPMENT

B-4.1 All equipment shall have at least the degree of protection IP 24.

B-4.2 Equipment should be selected in accordance with the temperature zones as depicted in Fig. B-1 as per the following details:

a) Zone A: only the sauna heater complying with relevant safety standard and equipment directly associated with it shall be installed.
b) Zone B: there is no special requirement concerning heat resistance of equipment.
c) Zone C: equipment shall be suitable for an ambient temperature of 125 °C.
d) Zone D: only luminaries and their associated wiring, and control devices for the sauna heater and their associated wiring shall be installed. The equipment shall be suitable for an ambient temperature of 125 °C.

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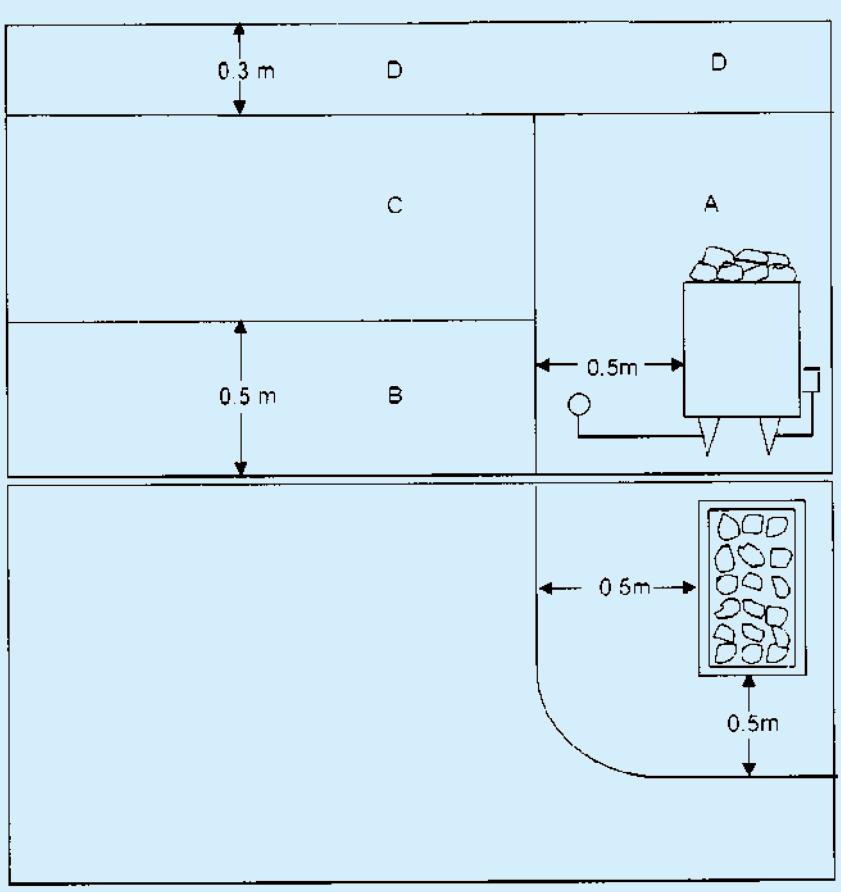


FIG. B-1 CLASSIFICATION OF TEMPERATURE ZONES

B-5 WIRING SYSTEMS

B-5.1 Flexible elastomer insulated and mechanically protected cords complying with appropriate standard, suitable for 150 °C should be used.

B-5.2 Switchgear not built into sauna heater, other than a thermostat and a thermal cut-out shall be installed outside the hot air sauna.

B-5.3 Except as permitted in **B-4.2** and **B-5.2** accessories shall not be installed within the hot air sauna.

B-6 OTHER FIXED EQUIPMENT

Luminaries shall be so mounted as to prevent overheating.

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SECTION 21 REQUIREMENTS FOR SPORTS BUILDINGS

FOREWORD

The design and erection of electrical installation in a sports building have to take into account a multitude of factors that are unique to the type of use to which it is put. In a way the electrical power needs and the external influences in a sports building are quite identical to those for theatres and other multipurpose buildings for cultural events excepting that for international events exacting standards of services and flexibility had to be provided in a multipurpose sports stadia.

Several stadia, especially those of the indoor type are meant for staging a variety of games which between themselves require varying standards of lighting levels. The design of illumination system in a sports building therefore requires consultations with a specialist and the guidelines provided in this Section are purely recommendatory in nature in this respect.

In indoor stadia where, large number of people congregate it is essential to inbuild adequate fire precautions from the point of view of safety. Assessing the need for adequate strength of a standby supply for essential services requires special consideration.

It is to be noted that a sports stadium should preferably be designed for use for other purposes as well, such as the staging of cultural events and this aspect shall be borne in mind while designing the electrical needs of the complex so as to ensure optimum utilization of the facilities.

With the advent of sophisticated stadia in the country as well as keeping in view the accent on sports, this Section of this Code has been set aside to cover such of those specific requirements applicable to sports buildings from the electrical engineering point of view. Taking note of the fact that the type of buildings and their needs for the purposes of sports and games would be quite different between them, only broad guidelines are outlined in this Section. It is recommended that assistance of experts shall be sought in the design of the installation at the early stages itself.

1 SCOPE

This Part 3/Sec 21 of the Code covers requirements for electrical installations in sports buildings and stadia, indoor and outdoor.

2 TERMINOLOGY

For the purpose of this Section, the definitions given in Part 1/Sec 2 of this Code shall apply.

3 CLASSIFICATION OF SPORTS BUILDINGS

3.1 The buildings for the purposes of conducting sports and games are characterized by the criteria that large number of people congregate. Sports complexes not basically meant for exhibition purposes, and not likely to be utilized for other purposes, such as for staging special or cultural events, shall however conform to the special requirements of this Section. The type of building shall therefore be classified as follows:

a) *Based on type of building:*
   1) Indoor stadia.
   2) Outdoor stadia: Stadia meant for use in daylight. Stadia meant for use during night under artificial lighting.

b) *Based on type of game/sport:*
   1) Single game sports hall/stadia.
   2) Multigames hall/stadia.

c) *Based on utility:*
   1) Stadia meant for games only.
   2) Multipurpose stadia for other amusements as well.

d) *Based on audience-factor:*
   1) Stadia/halls meant for exhibition purposes — where groups of people congregate.
   2) Stadia/halls meant for training and pastime — where audience may not normally be present.

   NOTE — Classification d (1) includes stadia meant for staging tournaments and events, and d (2) includes games halls in educational institutions and the like where normally no exhibition is intended.

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3.1.1 *Reference should be made to* **5.5.1.2** *for classification from lighting consideration.*

3.2 The electrical installation needs in sports buildings would therefore be governed by the type of use indicated in **3.1**(a) to (d). A large sports complex may include the following sub-units:

a) Supply intake/voltage of supply;
b) Main substation and satellite substations, if any;
c) Central control room/switch rooms;
d) Electrification of restaurant, health clubs; hospitals, offices and other support structures;
e) Communication facilities (telephone, telex, telegraph, data processing TV, radio and press facilities);
f) Fire protection services;
g) External electrification of gardens and parking lots, service routes, lake fountains (if any);
h) Emergency electric supply system including uninterrupted power requirements;
j) Audio systems, public address/security;
k) De-watering arrangements, sewage disposal, water supply systems;
m) Gas/oil arrangements for sports flame if required; and
n) Miscellaneous requirements for power socket, microphone outlets, score-boards, etc.

4 GENERAL CHARACTERISTICS OF SPORTS BUILDINGS

General guidelines on the assessment of characteristics of installations in buildings are given in Part 1/Section 8 of this Code. For the purposes of installations falling under the scope of this Section, the characteristics given below shall apply.

4.1 Environment

4.1.1 The following environmental factors apply to sports buildings:

Environment (1)	*Characteristics* (2)	*Remarks* (3)
Presence of water	Submersion, possibility of permanent and total covering by water	Locations, such as swimming pools where electrical equipment is permanently and totally covered with water under pressure greater than 0.1 bar.
Presence of foreign solid bodies	The quantity or nature of dust or foreign solid bodies is not significant	Indoor stadia.
	Presence of dust in significant quantify	Outdoor stadia.
Presence of corrosive or polluting substances	Negligible	Covers majority of cases. Stadia and games complexes situated by the sea or industrial zones require special consideration.
Lighting	Negligible	Covers category d(2) (*see* **3.1**) type of installations.
	Indirect exposure to lighting, where hazard from supply arrangements exists	Installations supplied by overhead lines.
	Direct exposure or hazard from exposure of equipment is present	Lighting towers in outdoor stadia.

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4.2 Utilization

The following aspects utilization shall apply:

Utilization (1)	*Characteristics* (2)	*Remarks* (3)
Capability of persons	Uninstructed persons	In sports stadia the sportsmen and spectators fall under this category. However, electrical operating areas are accessible to instructed persons only.
Conditions of evacuation in an emergency	Low density occupation, easy conditions of evacuation	Training halls and the like where people do not congregate.
	High density occupation, difficult conditions of evacuation	Large multipurpose stadia for exhibition purposes.
Nature of processed of stored material	Existence of fire-risks.	Due to furniture and false floor for playing area.

5 SUPPLY CHARACTERISTICS AND PARAMETERS

5.1 Exchange of Information

5.1.1 Proper coordination shall be ensured between the architect building contractor and the electrical engineer on the various aspects of the installation design. In addition to the general aspects which require coordination and identified in other sections, the following data shall specifically be obtained:

a) The total electrical power needs of the stadium including the standby power arrangements, which will decide the voltage of supply, number of substations and their preferred locations, capacity of diesel engine generating sets for standby supply, transformers, switchgear, voltage stabilizers, uninterrupted power supply requirements, etc;

b) In case of indoor stadia, whether air-conditioning is required and if so, the capacity and locations of main plants, air-handling units, pumps, ducting, layout, route of chilled water lines, etc. In case of outdoor stadium, the covered portions like offices, restaurants, are to be air-conditioned or not and their details as above;

c) Details of fire fighting system/fire alarm system envisaged;

d) Details of water supply arrangements, storm water drainage, sewage disposals and pump capacities, locations, etc;

e) Locations of substations, switch rooms, distribution boards, etc;

f) Requirements of audio-communication system for the stadium which includes public address system, car calling system, ambulance call, fire service call, intercom stations, wireless paging system, inter-stadia communication facilities, computer-aided results information, etc;

g) Details of score-boards — that is whether and their power etc, centralized manual or automatic, etc, needs, voltage stability, clock system, etc;

h) Special requirements of press, TV, Radio, telecommunication, games federations, etc;

j) Requirements of lighting, the location of lighting luminaries, type of light source, level of illumination required for various stages like training, TV (black and white or colour) coverage, etc;

k) Requirements for power outlets, speaker outlets, microphone outlets, etc., in playing arena and field; and

m) Other miscellaneous items like electrification of ancillary buildings in the sports complex, restaurants, gas/oil requirements for flame and their controls, fountain lighting system, car park, path way and external electrification.

5.1.2 The following drawings are recommended to be prepared before commencing the installations work:

a) Single line diagram for electrical distribution;

b) Complete layout drawings indicating type and mounting of luminaries and conduit/cable installations for various services. This shall be prepared in coordination with civil and structural engineers;

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c) Wiring diagrams showing switching sequence of luminaries, fire alarm system, public announcement systems, etc;

d) In case of air-conditioning, layout of plants, chilled water piping routes, ducts/grill layout, etc;

e) Layout of public address system envisaged; and

f) Site plan indicating the location of pump houses for storm water drains, water supply, sewage and fire fighting systems, with the proposed source and route of power supply.

5.2 Branch Circuits

5.2.1 The general rules as laid down for other large assembly buildings (*see* Part 3/Sec 19) and as laid down in Part 1 of this Code shall apply.

5.2.2 Wiring installations for general purpose lighting and ventilation needs of the sports buildings shall conform to the requirements laid down in Part 1/Sec 15 of this Code. It is preferable to avoid temporary wiring in electrical central control room.

Whenever floodlight luminaries of more than 1 000 W are installed, it is preferable to have individual branch, circuits to each of the luminaries after considering the economic aspects.

Junction boxes shall be installed near the luminaries from which connection to the light source may be taken by flexible conduits. This will help maintenance work to be carried out without disturbing the positioning of the lighting fittings.

5.2.3 *Panel Boards and Switchboards*

The provision of Part 1/Sec 9 of this Code shall apply. In large stadia, the areas covered by the services shall be segregated into zones and the sub distribution and distribution boards shall be so arranged and marked keeping in view their accessibility in times of need.

5.2.4 *Socket-outlets and Plugs*

For small stadia/halls, the provisions of Part 3/Section 3 of this Code shall apply. The need for special convenience outlets shall be considered for services enumerated in **3.2**(e). Utility socket outlets shall be provided at a height of about 0.3 m from the floor except in field/arena. These shall be of weather-proof type.

5.3 Feeders

5.3.1 The utility shall be consulted as to the type of service available, whether primary or secondary, single-phase or three-phase star or delta.

5.3.2 Outdoor floodlighting installations can be made with either overhead or underground distribution feeders. From the point of view of appearance and minimum interference, the underground system is more desirable where large playing areas are involved.

5.3.3 The underground system shall either be cables directly buried or cables in conduits.

5.4 Building Substation

5.4.1 The electrical needs of sports stadia may vary from 30 kVA to 1 000 kVA, according to the size of the installation. Usually HV supply is used for large multipurpose stadia where power demand is in excess of 500 kVA. The design of location of substation and the diesel generating set, if provided, shall conform to the requirements specified in Part 2 of this Code.

5.4.2 The main substation for a sports building shall preferably be located in such a place that does not interfere with the movement of people congregating. All electrical operating areas, and control rooms shall preferably be segregated from public routes for the sporting events.

5.4.3 Some installations may justify a separate transformer on each pole of the floodlighting tower with primary wiring to each tower. In smaller installations, it may be more economical to reduce the number of transformers by serving several locations from a single transformer through secondary wiring.

5.4.4 For buildings staging national and international sports events, it shall be provided with duplicate power supply so that in the event of failure of one power supply, other one can be able to cater the total load intended to serve. The changeover should be automatic.

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5.4.5 Emergency power supply by DG set/s shall be provided at strategic locations to keep the general lighting and ventilation of the sport buildings in case of normal ac power failure. The changeover should be automatic.

5.5 System Protection

The general rules for the protection of safety laid down in Part 1/Sec 22 of this Code shall apply.

5.5.1 Sports buildings are classified as 'assembly buildings' (Group D) from fire-safety point of view. Besides fire fighting equipment fire-detection and extinguishing system shall be provided as recommended below (*see* also SP 7 : 2016):

Description (1)	*Fire Detection 5ystem* (2)
Big halls for over 5 000 persons Small halls, health clubs, arena, gymnasiums, etc, indoor with or without fixed seats corridors for about 1 000 persons	Automatic sprinkler and alarm system Automatic sprinkler Automatic fire alarm system
Same as above, occupancy for less than 1 000 persons	Same as above
Small indoor games halls for less than 300 persons Grandstands, stadia for outdoor gathering	Automatic fire alarm system Manually operated fire alarm systems, in offices and automatic fire alarm system in stadia, machine room, control room, etc

5.6 Building Services

5.6.1 *Lighting*

The general rules laid down in Part 1/Section 15 of this Code shall apply (*see* also SP 72).

5.6.1.1 *Special design features*

Design of sports lighting, especially in large stadia require considerations of not only the objects to be seen, the background brightness, etc, but the observer's location in the grandstand as well. The following shall be taken into account:

a) Observers have no fixed visual axis or field of view. During the shifting of sight, even the ceiling and luminaries are likely to come into the line of vision.
b) While the game is in play, the objects of regard are not fixed, and mostly moving in a threedimensional space.
c) It is important for observers to be able to estimate accurately the object velocity and trajectory.

5.6.1.2 For the purposes of artificial lighting design, it is recommended to divide the location of sport play into general areas for more than one sport and areas for particular sport.

General areas include field houses, gymnasiums, community centre halls and other multipurpose areas. For the purposes of lighting design, the nature of sports shall be divided as follows:

a) Aerial sports (sports which are aerial in part or whole) — Badminton, basketball, handball, squash, tennis and volleyball.
b) Low level (games which are close to the ground level) — Archery, billiards, bowling, fencing, hockey, swimming and boxing.

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5.6.1.3 *Levels of illumination*

For some representative types of sport, the recommended values of illumination are as given in Table 1.

Table 1 Recommended Values of Illumination

(*Clause* 5.5.1.3)

Sl No.	Sport	Illumination, lux
(1)	(2)	(3)
i)	Archery	
	Target	540
	Shooting line	220
	Badminton	320
	Basketball	540
	Billiards (on table)	540
	Boxing and wrestling	540
ii)	Football (*see* Notes 1 and 2)	
	Class I	1 100
	II	540
	III	320
	IV	220
iii)	Gymnasiums	
	Matches	540
	General exercising	320
	Hockey (field)	220
iv)	Racing	
	Bicycle	320
	Horse	220
v)	Rifle (outdoor)	
	Targets	540 (vertical)
	Firing point	110
	Range	54
vi)	Swimming	
	a) Indoor Exhibition	540
	Underwater[1)]	100 W/m^2 of surface area
	b) Outdoor Exhibition	220
	Underwater	60 percent of indoor
	Tennis (laws) Indoor	540
	Outdoor	320
	Table tennis	540
	Volleyball	220

NOTES

1 It is generally conceded that the distance between the spectators and the play is primary consideration for football, as well as the potential seating capacity of the stand. The following classification is therefore described.

Class I — 30 000 spectators, distance.	over 30 m minimum
Class II — 10 000-30 000 spectators, minimum distance.	over 15-30 m
Class III — 5 000-10 000 spectators,minimum distance.	over 10-15 m
Class IV — 5 000 spectators, minimum distance.	over 10 m

2 For football, uniform illumination shall be provided at ground level as well as vertically for 15 m above ground.

[1)] Levels recommended are for incandescent lamps. For discharge lamps W/m^{2}would be reduced depending upon the efficiency of light source. In order that the installed flux.

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5.6.1.4 *Selection of light sources*

For sports lighting, the following light sources are advantageous together with the considerations indicated against each:

a) *Incandescent lamps (including tungsten halogen)* — Where necessary, over-voltage operation can be used to advantage especially as in sports installations, the lighting systems are used for less than 500 h a year.

b) *Fluorescent lamps* — Advantageous where mounting heights are low and short projection distances are acceptable, for example tennis, bowling, trampoline and a variety of indoor sports.

c) *High intensity discharge lamps* — These are characterized by long life and high human efficiency. However, the inherent time delay for full glow when first energized or when there is power interruption may necessitate use of incandescent lighting system to provide emergency standby illumination in spectator areas.

For sports events, where colour rendition is important, use of fluorescent mercury lamps is recommended.

5.6.1.5 *Miscellaneous considerations for lighting*

a) While selecting and installing high intensity discharge or fluorescent lamps in multipurpose stadia, it is necessary to connect lamps on alternate phases of supply to avoid flicker on rapidly moving objects. Where a quite surrounding is required in order to avoid ballast hum, remote mounting of ballasts shall be considered.

b) Efforts shall be required to coordinate the lighting design for sports events with the illumination requirements for TV or film coverage. A horizontal illumination in excess of 300 lux is considered adequate for operation of black and white TV and film recording. Colour recording calls for more stringent requirements. Colour filming may also need lamps having correlated colour temperature of between 3 000 K to 7 000 K. For film/TV coverage, data on the following shall be necessary:
   1) Camera sensitivity,
   2) Exposure time, and
   3) Effective aperture.

c) *Group switching* — Group switching of luminaries is recommended to have maximum energy saving, after considering the following factors as well:
   1) Separate switching for lighting outside the stadia,
   2) Requirement of lighting for training purpose,
   3) Requirement of lighting for tournaments with film and TV coverage, and
   4) Separate switching for playing arenas.

5.6.2 *Air-conditioning*

5.6.2.1 The requirements for air-conditioning and ventilation as laid down in Part 1/Sec 15 of this Code shall apply.

5.6.3 *Lifts and Escalators*

The general rules laid down in Part 1/Sec 15 of this Code shall apply.

6 TESTING OF INSTALLATIONS

The various tests on the installation shall be carried out as laid down in Part 1/Sec 9 of this Code.

7 MISCELLANEOUS PROVISIONS

7.1 Electrical Audio Systems

The general provisions for the installation of public address systems shall be as laid down in Part 1/Sec 15 of this Code.

In large grandstand stadia, the effect of time delay for the sound from the loudspeakers to reach different sections of the audience would be significant. This shall be avoided in taking proper precautions in the design of electrical audio systems.

7.2 Control Room

The various communication needs of large stadia is normally met with by electronic equipment centrally controlled, requiring specific power supply, and other installation conditions. This would call for special wiring systems with

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synchronizing systems. The technical requirements for these systems concerning voltage and frequency stability are very high. These shall be considered before designing the electrical services of the same.

7.3 Electrical/Electronic Score Board

The power requirements for such equipment would depend on the type of equipment to be installed. Guidelines of the manufacturer shall be adhered to.

7.4 Clock System

Reference shall be made to the provisions in Part 1/Sec 15 of this Code.

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SECTION 22 REQUIREMENTS FOR ELECTRICAL INSTALLATIONS IN MULTI-STOREYED BUILDINGS

FOREWORD

This section gives specific guidelines in respect of Electrical Installation and allied services in multi-storied buildings; for prevention of hazard, emergency likely to be initiated from or due to electrical supply and installation.

One has to understand under hazardous situation risk to human life and also to valuables, property in multi-storeyed buildings is much high compared to buildings with comparatively low height. It may be due to one or more of the following reasons:

a) higher demand of power (kW)/plinth area (m^2) ratio, requiring distribution system with cables, bus ways of heavy current ratings;

b) possible requirement of distribution transformer and equipment at upper levels;

c) limitations in speedy evacuation of persons within building, because of overall higher occupancy and more distance one has to cover to reach ground level or escape level or safe place during emergency,

Hazard, Emergency linked with electrical installation in the building can be:

1) a situation of Fire initiated by undesirable heating/sparking/short circuit/flashover in electrical installation comprising wiring, allied accessories, apparatus, storage devices for electrical power like batteries, and failure in timely operation of protection in case of fault condition;

2) short circuit in electrical installation caused by external fire which happens due to failure of insulation due to heat generated during fire or direct contact with flames, further aggravating the situation;

3) failure* of electrical supply affecting important utility services.

NOTE — This point shall also be taken for consideration where such instance occurs due to the reason other than situation of fire; when there is prolonged or indefinite failure of electrical supply which affects or brings to standstill the functioning of human utility, security services like vertical transportation, water supply, ventilation system, communication system, access control system, etc. leading to emergency.

In situation of fire, generation of smoke aggravates risk to human life. Dense smoke impairing visibility is one of main hindrance in rescue operations and toxicity of smoke leading to suffocation is a great threat to human life.

To summarize, under Risk Assessment, Multi-Storeyed Buildings stand at higher levels. This is basically due to the height which can have serious impact on evacuation under emergency. Therefore, in addition to relevant norms mentioned under different sections of this code, safety parameters for multi-storeyed buildings need to be considered at different level having basic orientation towards prevention of Electrical Fire and sustain electrical supply for emergency services during Fire. The measures recommended may apply depending on the height, 15/24/37.5/70/120/>120 m as categorized under NBC.

NOTE — Provisions of the sections shall also be read with Part 4 Fire and Life safety of NBC.

1 SCOPE

a) This Section of Part 3 is intended to cover specific requirements for electrical installations in multi-storied* buildings targeting: prevention from initiation and aggravation of fire due to electrical installation by identifying and targeting typical areas and points of electrical installations in multistoried buildings and also mitigating risk thereof;

b) maintaining integrity of electrical supply under the situation of fire for the emergency services till the time it may require for evacuation of occupants, move assets of importance like historical archives/valuables etc;

c) provision of standby/alternate electrical supply arrangements, which is also part of point No. (ii) above; and

d) Architectural provisions and civil works necessary for Fire Safe Electrical Installation.

1.2 The requirements specified here are in addition to those specified in respective sections of the Code.

1.3 The scope covers electrical installation related to provision of electrical supply but doesn't cover requirements related to design and installation of:

a) Firefighting equipment,

b) Fire detection system,

c) Public address system,

d) Placement of illuminating sign-boards of escape routes,

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e) Ventilation system,
f) Fire lift(s),
g) Other equipment, systems used in relation with fire prevention and life safety related Act and Rules, Regulations, and
h) Lightning Protection System.

2 REFERENCES

This Part 3/Section 22 of the Code should be read in conjunction with Statutory Provisions and the following Indian Standards:

2.1 Statutory Provisions

2.1.1 Section 53 *Electricity Act,* 2003 — Dealing with 'Protecting Public from Dangers of Electricity'. Central Electricity Authority (Measures related to Safety and Electric Supply) Regulations, 2010, in general and;

2.1.2 Sub-regulations (1) to (5) of Reg. 36 — Provisions for supply and use of electricity in multi-storeyed building more than 15m in height, in particular.

2.2 Standards

IS/IEC/ISO Number.	*Title*
SP 7 : 2016	National Building Code of India
694 : 2010	Polyvinyl chloride insulated unsheathed and sheathed cables/cords with rigid and flexible conductor for rated voltages up to and including 450/750 v (*fourth revision*)
IS 732 : 2019/ IS/IEC 62305 : 2010	Code of practice for electrical wiring installations Code of practice for the protection of buildings and allied structures against lightning
17048 : 2018	Halogen free flame retardant (HFFR) cables for working voltages up to and including 1 100 Volts — Specification
16659 : 2017	Fluids for electrotechnical applications — Unused natural esters for transformers and similar electrical equipment
16081 : 2013	Insulating liquids — Specifications for unused synthetic organic esters for electrical purposes
1646 : 2015	Code of practice for fire safety of buildings (General): Electrical installations
3034 : 1993	Fire safety of industrial buildings — Electrical generating and distributing stations
IEC 61936-1 : 2014	Power installations exceeding 1kV A.C.— Part 1: Common rules
13503 : 2013	Classification of insulating liquids

3 TERMINOLOGY

For the purposes of this Section, the definitions given in Part 1/Sec 2 of the Code shall apply.

4 SPECIAL CONSIDERATIONS

Special considerations shall be given in respect of the following aspects of electrical installations in multi-storied buildings:

a) Architectural and civil work requirements;
b) Material;
c) Wiring installation;
d) Distribution transformer, Sub-stations within buildings;
e) Standby electric supply arrangements; and
(f) Material suitable to maintain supply integrity and survive under fire for specified time.

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5 ARCHITECTURAL AND CIVIL WORK REQUIREMENTS FOR MULTI-STOREYED BUILDING FROM THE PERSPECTIVE OF ELECTRICAL INSTALLATION

See **4** of Part 1/Sec 9 of this code giving guidelines in respect of wiring installations elaborates architectural and civil work requirements. These requirements must be considered from the planning stage and observed during construction.

Following points are important for multi-storeyed buildings.

5.1 Separate Shafts/Ducts

There shall be provision of separate shafts of required fire rating but not less than 2 h for vertical electrical distribution which shall preferably be adjacent to electrical panels. There shall be independent* shaft for:

a) HT power cables;
b) LT power cables/bus-bar trunking; and
c) cable work of extra low voltage systems like telephones, security system, fire alarm, signalling, BMS or data networking etc.

*If independent shaft is not possible, there shall be an arrangement for segregation in between having fire rating same as shaft. No other utility service shall run through these shafts. Shafts shall be accessible at all levels with doors which shall not open in fire escape staircase.

All shafts shall have fire prevention and fire safety provisions as per Part 4 of National Building Code, 2016 and compliance of requirements of local statutory authorities.

5.2 Sub-stations/Generators/Batteries

Location of sub-stations, generator, batteries, and required space/room size shall be precisely planned in consultation with electrical designer and local authorities to comply with the fire norms so that in event of fire equipment related to supply integrity will not get affected.

5.3 Ventilation

Provision of adequate ventilation as per required air-changes recommended in NBC is important for electrical installation especially for transformers, generators, battery rooms, electrical panel rooms or any equipment generating heat while in operation, to keep temperature within permissible range. Excessive temperature is main cause of fast deterioration of insulation, leading to short-circuits, and flashovers.

5.4 Fire Rating

The electrical utility rooms for panels, sub-stations, generators, batteries; doors provided for these rooms and electrical shafts; segregation arrangement within shaft, shall have minimum fire rating of 2 h or as per requirements mentioned under Part 4 of NBC 2016, Central Electricity Authority (measures related to Safety and Electric Supply) Regulations, 2010 with further amendments. In case of any discrepancy higher rating shall be considered

5.5 Spread of Fire

In order to prevent development and spreading of fire and smoke developed anywhere on the routes of electrical distribution system, arrangement shall be done by making compartments to block the routes/entries between rooms, floors, sections with a material capable to withstand fire for minimum 2 h or as required by fire authorities.

5.6 Statutory Approvals

Electrical inspector may require certain conditions to be fulfilled related to architectural/civil works, in respect of locations, placement of certain types of equipment, their clearances, fire rated walls/doors, access routes. Same shall be taken care of at planning stage. In respect of multi-storeyed building approval from electrical inspector shall be taken to check compliance as per CEA Reg. 36.

6 MATERIAL

In multi-storeyed buildings, considering fire as major risk factor concerning electrical installation; selection of material shall be done on the basis of its properties related thermal withstand capacity, flame resistance, smoke characteristics, for example, density and toxicity. Having low density and toxicity are important properties to support evacuation of trapped victims and facilitate rescue operation and prevention of spread of fire.

Selection of material shall also consider aspects of External Influences BD2, BD4, and CB4 in addition/with special attention to those mentioned under Part 1 Section 9 of this code.

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6.1 Cables

Insulation of cables is matter of concern in respect with the issues related with smoke, toxicity, corrosive gasses and sustaining particular temperature. Dense smoke impairs visibility, hampering rescue operations and toxicity causes suffocation leading to serious effects on health which may lead to fatalities. Corrosive gasses may cause damages to the movable property and affect structural strength of building when combines with water under operation of fire fighting system. Its capacity to sustain certain temperature relates to current carrying capacity. Cables used in wiring installations of multi-storeyed buildings shall not become a cause to initiate fire.And if fire occurs in no way cables shall aggravate fire. Cables shall be self-extinguishing. See below recommended types:

a) Minimum flame retardant low smoke and halogen (FRLSH) conforming to IS 694 : 2010;
b) Halogen free flame retardant (HFFR) cables for working voltages up to and including 1100 V, conforming to IS 17048 : 2018;
c) For a wiring installation supplying all critical loads requiring supply integrity for required time period under fire situation; cables shall conform to IS 17505 Specification for Thermosetting Insulated Fire Survival cable for fixed Installation having low emission of smoke and corrosive gases when affected by fire for working voltages up to and including 1100 V A.C. and 1500 v D.C. and shall be suitable to withstand temperature 650°C for 60 min to 950°C 180 min

NOTE — For details of application of FS cables *see* Annex A of IS 17505.

6.2 Cable Enclosures

Conduits/trunking/raceways etc; shall be flame retardant and shall bear properties to maintain circuit intrinsically safe* and provide mechanical protection against external influences which may damage insulation of cables. Selection of metal enclosures and non-metal enclosures shall therefore be made judiciously.

NOTE — ‘intrinsically safe circuit shall denote any circuit operating under its normal operation and anticipated fault conditions, which when exposed to any spark, ignition, or any thermal effect, whilst operating under the above said conditions, is not capable of causing ignition of a given explosive gas atmosphere.

6.3 Bus-bar Trunking (BBT)

Depending on distribution pattern, instead of cables, preference shall be given to bus-bar trunking system in all buildings above 37.5 m height. Sandwich bus trunking shall be preferred to air-insulated type bus trunking. All fittings and fixtures of BBT shall be manufacturer specific and factory made.

NOTE — Bus-bar trunking system is safer than cables as it does not contain any material, which produces corrosive or toxic gases in the event of fire. There is no burning of material in bus-bar trunking system so that the room remains clean and escape routes are not impeded

Apart from life cycle cost, selection between copper and aluminium bus bar may be done considering manufacturer’s specifications related to properties like IACS, tensile strength, thermal conductivity, elastic modulus, weight, size, melting point and specific heat for the required current rating.

6.4 Switchgears, Breakers

Selection of switchgears breakers must correlate assessed current carrying capacity of wire/cable with respect to the situation/method of installation to provide protection against overheating, earth leakage currents and tripping time depending on sustaining capacity under short-circuits leading to flashovers. Switchgears shall have required variable setting facility for overload, short circuit, earth fault, etc. according to load pattern and shall be enclosed in intrinsically safe enclosures.

6.5 Transformers

Potential of threat of fire from transformer is quite high due if it contains of mineral oil which acts as fuel and aggravates and spreads fire due to spilling of oil. Selection of Transformer for multi-storeyed building shall therefore be based on its fire properties.

6.5.1 *Dry Type Transformer*

It is mandatory that the transformers within multi-storeyed building shall be dry type*.

NOTE —* This provision is as per CEA Reg. 44 (2) (vii) (e). However alternatively use of transformers filled with K class insulating liquids maybe made subject to deviations allowed by respective governments – State/Central/UT in the above Regulation.

6.5.2 *Liquid Filled Transformer*

Preference shall be given to transformers filled with K class insulating liquids classified as per IS 13503 having fire point > 300°C and conforming either to IS 16081 : 2013/IEC 61099:2010 for synthetic esters or as per

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IS 16659 : 2017/IEC 62770 : 2013 for natural esters; for distributing power in multi-storeyed building installed within the same premises. (For details *see* **4.25** under Part 1/Sec 22 Electrical Safety);

(a) *Within multi-storeyed building*

Subject to NOTE below **6.5.1**, such transformer may be allowed for installation within building. Following points shall be considered while making use of K class insulating liquids:

1) Manufacturer's specifications;
2) Manufacturer's instructions regarding use, precautions to be taken during of filling, routine maintenance;
3) Properties related with fire point and flash point;
4) Properties related with oxidation; and
5) Properties related to net calorific value/low heat value;

It shall be noted that natural esters have higher fire point than synthetic esters. Synthetic esters have better low heat value than natural esters. Natural esters are susceptible to oxidation hence, IS 16659 : 2017/ IEC 62770 : 2013 does not recommend its use for breathing transformers and hence may be used for sealed transformers. Also proper care in respect of filling and prevention of leakages which comes under maintenance partis necessary so that the liquid doesn't come in contact with air. Synthetic esters can be used both for breathing/non breathing transformers. Designers shall make judicious choice depending on characteristics of Esters.

(b) *Transformer location detached from multi-storeyed building structure*

Subject to availability of required clearance to be maintained from the building and fire rating of adjacent portion of building, transformer may be selected (*see* **8.3.4** under this section). It shall be noted that the required clearance for transformer filled with mineral oil is much higher than the dry or K class insulating liquid filled transformer, as Fire related properties of mineral oil are much poor compared to K class liquids. Therefore, considering limitations and fire risk involved, distribution transformer, even if it is detached from multi-storeyed building, shall be dry type or filled with 'K' class insulating liquid.

7 WIRING INSTALLATION

7.1 General

Design and installation of electrical wiring shall be carried out in conformity with Part 1/Sec 9 of this Code. Special attention shall be given to following points.

7.2 Cables and Enclosures

7.2.1 *Selection of Material*

7.2.1.1 *Cables - FRLSH/HFFR*

For general wiring, selection shall be made as per following recommendations, which shall be treated as minimum baseline: (*see* **6.1** under this section).

a) FRLSH/HFFR – for buildings up to 24 m height.
b) HFFR – for buildings above 24 m height and all public assembly/gathering places, irrespective of height.

7.2.1.2 *FS/Supply integrity cables*

Cables as mentioned under **6.1** c), having capability to survive under fire at required temperature and time shall be used for critical loads (*see* **9.4** under this section) within building depending on survival time and anticipated temperature it has to withstand in consultation with Fire or respective authorities.

7.2.1.3 *Conductor cross-sectional area*

Selection of proper cross-sectional area of conductor of required current carrying capacity, depending on situation (*see* Annex C from Part 1/Section 9 of this code) and factors like harmonics, is very important to prevent heating of conductor beyond permissible limit. It shall be noted that there is a vast variation in current carrying capacity of conductor which may reduce up to 50 percent for the conductor of same cross section but under different situation (*see* **5.8** under Part 1/Section 9 of this code).

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7.2.1.4 *Use of copper*

Owing to the superior properties of copper and maintenance issues during life cycle, it is recommended that use of aluminium shall be minimised, owing to termination problems leading to heating at terminals enhancing the probability of fire. Therefore, it is recommended for secondary distribution of electric power and all cables less than or equal 16 mm^2 copper conductor shall be used.

NOTE — This recommendation is in line with the IS 1646 : 2015 Code of practice for fire safety of buildings (General): Electrical Installations; where in special precautions have been suggested in respect of Aluminium conductors

7.2.2 *Method of Installation*

7.2.2.1 *Enclosures of FR/FRLS grade*

Cables or conductors shall not be installed directly without enclosure like conduits, trunking, raceways. All material of enclosures shall be at least FR grade.

7.2.2.2 *Wiring above false ceiling, in ducts/shafts*

Wiring above false ceiling, in shafts, voids, ducts; which is can be accessed (not concealed in walls); have sufficient availability of oxygen to support fire and which may catch fire due to inbuilt fault or exposure to external fire or likely to be inflicted by external influences like rodents which damage insulation; shall be enclosed in mechanically strong enclosures like metal conduits/trunking.

7.2.2.3 *Segregation*

Separate conduits or multi compartment trunking shall be used for proper segregation between cables of different systems, e.g. power and extra low voltage systems.

7.2.2.4 *Fill factor or space factor*

Fill factor or space factor is one of the important points strictly to be observed for appropriate heat dissipation and maintaining temperature within limit for cables in enclosures. Accordingly, area allowed to be occupied by cables in conduits/trunking shall be strictly governed by **5.9.3.6** of Part 1/Sec 9 of this code.

NOTE — It shall be noted that number of wires drawn through conduits when exceed allowable limit, the excess heat generated starts deteriorating insulation very fast leading to failure and create short circuit. Such work is not easily traceable in external visual inspection and difficult to correct after the work is complete. The person executing the work shall be responsible and certification in this regard from the person supervising and executing the work shall form a procedural requirement.

7.2.3 *Installation within wooden furniture/boxes*

Any installation within furniture shall be done with utmost care. All cable work shall be done with shielded cables in metal conduits or FR/FRLS grade PVC conduits. Any accessory generating spark during operation, e.g. making and breaking of contacts shall not be installed on/within wooden furniture if un avoidable, shall be installed in intrinsically safe enclosure.

7.2.4 *Prevention from Flora/Fauna*

Barricading with grills, pest control and other similar measures are necessary to prevent damages to electrical installation due to rodents, termite, other insects, birds, growth of vegetation which may lead to short-circuit.

7.3 Distribution

7.3.1 *Critical Load*

At the point of main incoming supply circuits for general load and critical loads (*see* the list under **9.4** of this section) shall be segregated. These loads shall have independent control. Suitable arrangement shall be such that during emergency controlling of critical load shall be possible from such location. This arrangement is necessary to have an easy access to fire personnel for any operation as may be necessary at the time of emergency.

7.3.2 *Emergency Power/Alternate Supply Arrangement for Critical Load Comprising of Fire and Life Safety Systems*

To ensure redundancy of supply to critical load, there shall be an arrangement of online UPS system/automatic change over to another source of supply in case of failure of main supply (*see* **9** under this section). Installation shall be tested periodically for hundred percent redundancy and record of such tests shall be maintained.

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7.3.3 *Supply arrangement for Essential Load*

Supply redundancy shall also be considered for other important essential services like water supply/hydro-pneumatic system, lifts; illumination, ventilation or any other such service in common areas, public gathering places failure of which may create panic or health hazard. Distribution layouts shall be so designed that in case of any failure or requirement of outage on a portion/route/electrical shaft of distribution system; such important essential services shall not get hampered. There shall be a provision of supply/ring system* from alternate route/electrical shaft.

NOTE — * Ring system if used shall be with consideration of pros and cons from the point of view of working safety.

7.3.4 *Vertical Distribution*

Vertical distribution shall be through shafts assigned for electrical purpose. It is recommended that instead of cables preference to bus-bar trunking system shall be given.

7.3.5 *Horizontal Distribution*

Also, for horizontal distribution through passages, corridors and similar locations of public movements, gathering places, where number of cables of higher sizes are required, preference to bus-bar trunking shall be given.

7.3.6 *Dampers/Fillers to Restrict Spread of Fire*

Provision of dampers/fillers having capacity to withstand fire shall be done all along vertical routes between floors and horizontal routes between rooms/sections in ducts, shafts, sleeves and similar provisions for distribution of electric cables so that fire/smoke doesn't get spread from one area to other.

NOTE —This is in line with mandatory requirement as per CEA Reg. 36 (5).

7.3.7 *Distribution Boxes/Electrical Control Panels*

Distribution boxes/panels shall be intrinsically safe and installed with all required clearances around. There shall not be any storage around especially within flash boundary. Caution boards shall be displayed with instructions.

7.3.8 *Electrical Panel Room*

Electrical panel room shall not be allowed for installation of any other system/control equipment/storage place. Flash boundaries shall be marked. Door shall be opening outside and shall have minimum fire rating of 2 h or as required by fire authorities. Provision of fire extinguisher shall be made near the door. Adequate ventilation shall be provided so as to maintain temperature within limits.

7.3.9 *Electrical Meter Room/s*

Meter room shall be conspicuously located. Approaches shall be so designed and maintained to cause no hindrance (*see* **4.4.3** from Part 1/Sec 9). There shall be an access to maintenance personnel both from consumers' and supplier's side. Such provision shall also available to fire personnel in case of emergency to isolate complete supply* of the building.

NOTE — * *See* **7.3.12** under this section.

Where the meter rooms are located on upper floors, there shall be provision in vertical shaft with proper segregation for supplier to install his system. Preference shall be given to bus-bar trunking system for distribution. Supplier shall always have an access to such portion for any work related to installation, maintenance. Meter rooms on upper floors shall not open into staircase enclosures and shall be ventilated directly to open air outside.

7.3.10 *Switchgears and Protections*

See **6.6** and **6.7** from Part 1/Sec 9 and related clauses from Section 10 to 14 of this code shall be referred and precise attention shall be given in respect of following points of protective devices, which shall correlate situation, type, and load pattern of installation:

a) Capacity,
b) Settings,
c) Locations, and
d) Accessibility

Considering fire as a major threat in respect of High-rise buildings following points shall be observed.

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7.3.10.1 *RCD 300 mA*

In addition to RCD of 30mA which is for shock protection, a provision of 300mA RCD at the source/point of supply shall be observed, which has been made mandatory from the point of view of fire hazard arising out of leakages.

7.3.10.2 *Arc Fault Detection Device (AFDD)*

In order to mitigate chance of fire due to arc faults which may happen due to worn-out/damaged/stressed/ overheated/loose or oxidised contacts; use of AFDD, is recommended for buildings above 37.5 m height. Depending on risk assessment provision of AFDD shall be made in respective branch circuit of dwelling unit, hotel room, public gathering places, old-age homes, National Archives etc. Combination type AFDD provide protection against parallel arc-faults (between lines, line and neutral/ground), series arc faults (in single conductor due to breakage), O/L, S/C, appropriate selection may be made accordingly. It shall be noted that functioning AFDD shall be checked monthly with test button.

NOTE — Conventional circuit breakers provide protection against overload and short circuits. Under fault condition with higher impedance it may not detect arc fault. For initiation of fire is, it requires ignition and then oxygen keep it burning where surrounding material acts as fuel. Constructional measures have limitations to prevent initial ignition turning into real fire. Fire extinguishing arrangement may prevent consequential extent of damages but cannot prevent fire starting. Under circumstances effective protection is essential, which can be provided by AFDD.

7.3.11 *Reactive and Harmonic Component of Current*

Reactive and harmonic component may cause generation of undesired heat. Provision of suitably designed load centric panel to compensate above factors shall be made.

7.3.12 *Supply Isolation during Emergency*

Sub Regulation (3) of CEA Regulation No. 36 states that:

'The supplier or owner of the installation shall provide at the point of commencement of supply a suitable isolating device with cut-out or breaker to operate on all phases except neutral in the 3-phase, 4-wire circuit and fixed in a conspicuous position at not more than 1.70 meters above the ground so as to completely isolate the supply to the building in case of emergency'.

Interpretation —

a) The provision of a device to isolate complete supply, also called Fireman's Switch, is aimed at restricting further danger of short circuits due to fire and spread of fire and shock hazard, restriction on use of lifts and any other activity running on electrical supply which may aggravate the situation. However, supply to emergency services like rescue operation; fire-fighting shall not get affected with the operation of this control.

b) Suitable arrangement shall be done at the point of supply to separate supply of emergency services make arrangements to identify and mark with instructions conspicuously.

c) Point of commencement of supply is 'incoming terminal of consumer's switch' as per the definition given under regulations. However when there are number of consumers having individual meter&, switch and also if such meters are located at different floors of multi-storeyed building, then providing such switch shall be at termination point of supplier's cable in building from where distribution to individual meter(s) at one or more locations of meter(s) of consumer(s) starts

d) Under the circumstances as mentioned under point c) above it will be supplier's obligation to make provision of such switch and maintain it further as up to point of supply installation is owned by supplier and consumer cannot interfere with supplier's installation.

NOTE — A typical single line diagram given under Annex A may be referred.

7.3.13 *Connections/Terminations*

Special attention shall be given for terminations. Wherever necessary lugs shall be used of appropriate metal and periodic inspection shall be done to rule out occurrence of loose contact, corrosion, hotspotat the points of terminations/joints.

7.3.14 *Testing*

Before use, complete distribution system shall be tested end to end. Certification shall be taken from the electrical contractor for the 'system is safe to use'.

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7.4 Fixtures, Appliances

Faults in electrical appliances of individual owners, lack of precaution in installation, operation/use may become a cause to initiate fire and endanger complete building. Following points shall be noted in this regard.

7.4.1 *Lighting Fixtures*

Many Lighting fixtures generally dissipate heat which is moderate; however, this proportion is high in respect of some of the fixtures/control gears/drivers. Precaution in such cases shall be taken so that situation where it is going to be installed is not fire prone, e.g. adequate ventilation is available, its mounting base is such that it not combustible and will not catch fire easily.

NOTE — Lighting fixtures used as part of emergency services, for example, installation along escape routes and which are connected on the circuit with fire survival cables having supply integrity to withstand certain temperature for particular period of time shall have compatible flameproof properties.

7.4.2 *Appliances Utilised Under Emergency*

The appliances requiring integrity of operation during emergency, for example, fans of ventilation system shall be of so design to withstand fire conditions to such temperature and time, as required under related rules/norms specified under NBC 2016.

7.4.3 *Connections*

Power supply to all appliances shall be given through shielded cords with earth conductor properly connected at both the ends.

7.4.4 *Appliance with Capacitor*

The appliances having capacitor as its integral part shall be taken special care of. There are occurrences of blast due to inferior material quality, lack of maintenance. Considering possible risk, preventive measures shall be taken and maintenance schedule shall be planned accordingly.

All heating appliances shall be checked periodically and maintained for proper working of thermostat and other such devices. Location of such devices shall be away from fire prone material.

7.5 Illumination Design

All escape routes shall be well illuminated with flame proof lighting fixtures. Minimum lux level shall not be less than 10. Circuits shall be so arranged that there shall be 100 percent redundancy to retain required lux level.

Requirements lighting/locations of luminaries as mentioned under Part 4 of NBC, 2016 are given below:

a) As low as possible but at least 2 m above,
b) Near each intersection of corridors,
c) At exits and at each exit door,
d) Near each change of direction in the escape route,
e) Near each staircase so that each flight of stairs receives direct light,
f) Near any other change of floor level,
g) Outside each final exit and close to it,
h) Near each fire alarm call point,
j) Near fire-fighting equipment, and
k) To illuminate exit and safety signs as required by the enforcing authority.

7.6 Exit Signage

Exit signage shall be provided all along escape routes. These signs shall be so located that from the location of any exit sign next sign shall be at such distance and location that it will be clearly visible. Directions shall be clearly marked on it. These signs shall be suitably illuminated.

For details refer Part 4 Life and Safety of NBC,2016.

7.7 Civil Aviation Requirements (CAR)

Provision of obstacle light shall be made on building as per norms set by Director of Civil Aviation, Government of India, under ‘Civil Aviation Requirements’; which follow standards and practice specified by of International Civil Aviation Organisation (ICAO).

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Installation and selection (type/characteristics, like intensity, beam pattern, flash rate, colour and number of lights, locations, etc.) depend on building height (up to 45m/45 to 150m/above 150m) and vicinity from Aerodrome, as specified under CAR (Section 4).

8 ELECTRICAL SUB-STATION

In respect of Electrical Sub-Station providing supply to multi-storeyed building comprising transformer and equipment, mitigating the risk related to Fire is an important aspect. Second aspect is supply redundancy for all essential services. Following points will give guidelines in that respect.

8.1 Location

Location of substation shall be such where a fire fighting service can be reached easily.

8.1.1 Depending on selection of transformer (*see* **6.5** and **8.3.1**), location of distribution transformer and allied equipment may be within multistoreyed building, outside multistoreyed building in open space/room detached from the structure of building (*see* **8.3.4** for clearances).

8.1.2 For indoor type, location shall be preferably on ground floor but not below first basement. It shall be above HFL as declared by local authority.

8.1.3 Location at upper floors may be allowed subject to prior compliance with structural requirements of building. The room shall be adjacent to electrical service shaft. There shall be segregation between transformer and control equipment. All facilities shall be available for mobility of equipment as and when required for the purpose of maintenance, repairs, replacement. The room shall be well ventilated and shall have fire rating of 4 h or as required by fire authorities.

NOTE — Substation comprising power transformers shall not be located within multi-storeyed building. It shall be separate and away from building by such distance conforming to IEC 61936-1 : 2014 and approved by Electrical Inspector, Fire authority.

8.2 Segregation

Within building, there shall be segregation between supplier's installation and consumers' installation. This segregation may be with fire proof walls if so directed by Electrical Inspector.

8.3 Transformer

8.3.1 *Selection*

See **6.5** above to select the type of transformer.

8.3.2 *Risk Assessment*

The fire hazard associated with the transformer outdoor or indoor is dependent on; the capacity of equipment, volume and type of insulating medium, Fire behaviour, the type and proximity and exposure of nearby equipment and structure. Risk shall be evaluated accordingly.

8.3.3 *Clearances*

Recommended clearances as per IEC 61936 : 2014 1 are as under:

a) For K class insulating liquids exceeding 1000 *l* up to 3800 *l*,
   1) clearance from other transformer or non- combustible building surface 1.5 m.
   2) clearance from combustible surface 7.5 m.
b) For K class liquid above 3800 *l*
   1) clearance from other transformer or non-combustible building surface 4.5 m.
   2) clearance from combustible surface 15 m.

   NOTE — For K class liquid filled transformers with enhanced protections, clearances may be reduced (*see* IEC 61936-1 : 2014)
c) For Dry-Type (Fire behaviour F0)
   1) Horizontal 1.5 m.
   2) Vertical 3.0 m.

   NOTE —For dry type transformer sufficient space should be allowed for periodic cleaning of encapsulated transformer windings in order to prevent possible electrical faults and fire hazard caused by deposited atmospheric pollution.

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d) For O class insulating liquids exceeding 1000 *l* up to 2000 *l*,
   1) clearance from other transformer or non-combustible building surface 3.0 m.
   2) clearance from combustible surface 7.5 m.
e) For O class insulating liquids exceeding 2000 *l* up to 20000 *l,*
   1) combustible building surface 5.0 m.
   2) clearance from combustible surface 10 m.

8.3.4 *Precautions in Respect of Liquid Filled Transformer*

If insulating liquid filled transformer is permissible installation shall be such that its burning shall not cause fire hazard to other transformers. For the purpose conditions as mentioned below shall be observed:

a) If oil content exceeds 2000 *l*: it shall not be located in basement where oil drain arrangement cannot be provided;
b) Baffle walls shall be provided of required fire rating between transformers;
c) Provision of soak pit/catchment tank shall be made of capacity of content of largest transformer and if oil content exceeds 9000 *l*: in one tank provision of draining away arrangement shall be made; and
d) A curb (sill) of a suitable height shall be provided at the entrance in order to prevent the flow of oil from a ruptured transformer into other parts of the basement.

If there is an exceptional risk of the transformer being exposed to external fire, special consideration shall be given to:

a) Fire resistant separating walls;
b) Gas tight vessels capable of withstanding internal pressure;
c) Controlled release of hot liquid; and
d) Fire extinguishing systems.

Transformers having capacity 10 MVA or more shall be provided with nitrogen injection system or high velocity water spray/mist deluge system

8.3.6 *Loading – Supply Redundancy*

Loading/distribution of load on transformer/s shall be such that in case of temporary overloads/breakdown/outage/ maintenance work; utility services depending on electric supply from such transformer shall not get affected. Spare capacity/spare transformer facility shall available with change-over/bus coupling facility.

8.4 Cables

8.4.1 The danger of the spread of fire and its consequences shall be reduced, as far as possible, by selecting suitable cables and by method of installation.

8.4.2 Cables having fire resistance characteristics, with low emission of acidic and corrosive smoke/gas shall be used.

8.4.3 Physical separation with provision of different/alternate routing of power circuits from control circuits for high voltage equipment is recommended.

8.4.4 Cables in trenches and buildings shall be laid in such a way that the regulations regarding fire safety of building are not adversely affected. To avoid fire propagation trenches shall be filled with gravel, holes through barriers/compartments shall be sealed with suitable material.

8.5 Protections

All system equipment shall be provided with applicable protections with required settings, coordination and shall be tested periodically and maintained as per norms.

9 ALTERNATE ELECTRICAL SUPPLY

9.1 Standby Arrangement by Consumer/s

Standby arrangement of alternate electrical supply with generating set/UPS or combination of both from consumers' side is one of the main requirements in respect of multistoried building.

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9.2 Standby Arrangement by Supplier

If supplier agrees to provide electrical supply arrangement from a feeder on different circuit/sub-station as an alternate arrangement with RMU of two in one out, same shall be opted.

9.3 Load on Standby Power Supply

The standby arrangement shall be of sufficient capacity to take care of water based fire-fighting equipment, for example, fire-fighting pumps –main, jockey, booster, for sprinkler system and critical load (*see* **9.4**) within building. It shall be designed to have required capacity in respect of power, starting torque and time period is most important and mandatory (*see* **5** 'Selection' from Section 1 of Part 2 of this code).

9.4 Critical Load

a) illumination of escape routes,
b) illumination of emergency services control rooms;
c) sign boardson escape routes;
d) Fire lifts;
e) Fire Alarm system;
f) Public Address system;
g) Signalling and Control cabling;
h) Ventilation, Pressurization and smoke venting and its ancillary systems;
j) Security systems-access control; and
k) any other system in relation with fire prevention and life safety/rescue operation.

9.5 Standby Generating Set

9.5.1 It is recommended that the standby generating set and allied fuel storage tank shall be located away from building, near fire pumping station or other convenient location to handle operation during the situation of emergency. If located within building the room shall have 4 hours fire rating.

9.5.2 It shall have capacity to bear starting torque of firefighting machinery.

9.5.3 Critical load within building may be supplied from this generating set or a separate set of suitable capacity when a fire pumping station has been provided with an alternate source of electrical supply from separate feeder by supplier.

NOTE — In some cases main fire pump may have an alternate arrangement of diesel engine in such cases capacity of generating set will be reduced considerably.

9.5.4 Generating set shall be operated by AMF panel.

9.5.5 Maintenance schedule shall be strictly followed. During fire drills full load testing shall be done. Adequate quantity of fuel shall always be available.

9.6 UPS

9.6.1 *Need*

It is recommended to make provision of UPS to take care of critical load at least for initial critical time until another backup supply arrangement starts.

9.6.2 *Location and Safety Provisions*

Location and safety provisions shall be such that the UPS and battery room will not get affected during the time of fire/emergency.

9.6.3 *Batteries and Fire Hazards*

Fires initiated at UPS system are increasing. Selection of type of batteries (VLA/VRLA/Li-I) and observance of related safety measures, improper arrangement for storage of battery bank, inadequate ventilation, lapses in maintenance, over use after service life are common causes of initiating fire. Utmost care shall be taken in respect with safety measures related to UPS systems.

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10 FIRE SAFETY

10.1 Prevention – Detection – Fight

Instances of Fires in buildings are quite often. After initial ignition oxygen and fuel (could also be material lying around) are always available. Therefore where people live/work there is risk of fire. Preventive measures to eliminate, avoid initiation of fire must be in place. Fire must be detected very fast and subsequently firefighting measures be implemented immediately to mitigate consequential damages.

10.2 Norms

Fire Prevention and Life Safety related measures for Electrical Installation as mentioned under CEA (measures relating to Safety and Electrical Supply) Regulations 2010 with latest amendments, NBC 2016, IS 1646 and IS 3034 shall be observed.

11 LIGHTNING PROTECTION

Provisions of lightning protection of multi-storied buildings shall be made in conformity with Part 1/Sec 19 of this Code and IS/IEC 62305 series. Routing of down conductors shall not be through electrical service shafts. Earthing pits shall have required safe distance from other underground utility services.

12 BUILDING MANAGEMENT SYSTEM

It is recommended to provide building management system (BMS) for buildings above 70 m height, which shall be flexibly adaptable to future requirements to take care of:

a) Common facilities of heating, ventilation, and air-conditioning;
b) Fire detection system;
c) Fire fighting system;
d) Public address/communication system;
e) Display messages;
f) Access control;
g) Intrusion detection;
h) Surveillance system CCTV;
j) Power supply;
k) Measures related to energy conservation;
m) Building data; and
n) Integration of third party systems.

13 SHARING OF RESPONSIBILITIES

In multi-storeyed buildings it is joint responsibility of:

a) supplier of electricity;
b) building management committee/common service provider;
c) user/occupant; and
d) promoter/developer of building.

to prevent all possibilities which may lead to disaster.

Any lapse from either of above is liable to imperil life and property of all other occupants in the building.

13.1 Supplier of Electricity

In multistoreyed building following persons/agencies/service providers are responsible to the extent of portion of electrical installation owned/installed/provided/maintained by them, it is responsibility and also statutory obligation for the supplier of electricity to maintain installation belonging to him ‘up to the point of supply’ in safe condition. Make provision to isolate complete supply of building (*see* **7.3.12**).

13.2 Management Committee/Service Provider

It shall be a responsibility of the owner in case of individual ownership or Building Management Committee to appoint service provider to maintain and upkeep all general and emergency services, Lifts, BMS with proper

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surveillance. Get the Electrical Installation inspected and certified once in a year for safety from authorised person; Chartered Electrical Safety Engineer or Electrical Inspector. Get the Lifts inspected from Lift Inspector. Get the Fire and Life Safety systems inspected once in 6 months or as per the obligations set by Local Body/statutory provisions, carryout fire drills. It is obligatory to comply if the remarks are raised by an authority. Care shall be taken that no harm is caused to supplier's installation within the premises of building. All the related documents shall be properly maintained as record and produced to authority as and when required.

13.3 Individual Owner/Occupier

Owner/occupier is responsible to keep his individual electrical installation in safe condition so that it will not initiate fire. He shall get his electrical installation tested atleast once in five years from the authorised person; Electrical Inspector or Chartered Electrical Safety Engineer.

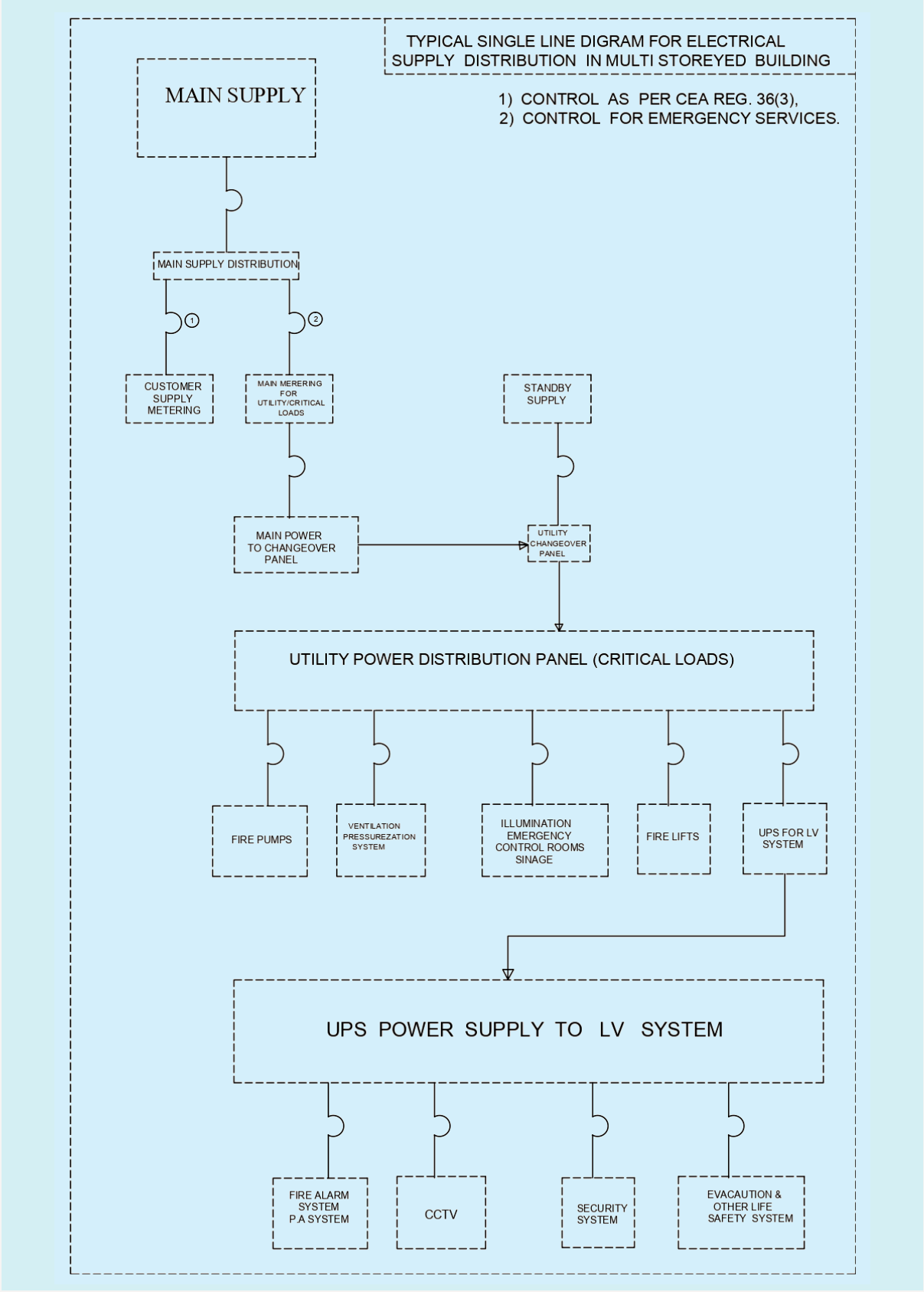
13.4 Promoter/Developer

Promoter/developer of building shall be responsible to check compliance with statutory provisions in respect of portion of electrical installation done under his scope and handed over to the owner/prospective buyer. Handing over shall be done with all necessary documents like test reports, approvals, certificates, guarantees, warranties, service contracts and also set of related documents made mandatory as per Rules/Regulations under *Real Estate Regulatory Act*. Such documents shall also contain list of responsibilities, liabilities to be taken over.

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ANNEX A

(*Clause* 7.3.12)



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NATIONAL ELECTRICAL CODE OF INDIA

PART 4 ELECTRICAL INSTALLATIONS IN INDUSTRIAL BUILDINGS

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PART 4 ELECTRICAL INSTALLATIONS IN INDUSTRIAL BUILDINGS

FOREWORD

Electrical installation in industrial buildings requires special attention in design with a basic consideration for 'safety at work-places', quality and continuity of supply, energy conservation.

The layout of electrical installation should facilitate maintenance with ease and free access. Distribution shall be designed so that fault localization is possible targeting lowest down time.

Keeping in view the tariff structures depending on Time of Day (ToD), as also an economic necessity; conserving power, maintaining power factor nearest to unity, limiting harmonic effects shall be considered as important aspects.

For reliability and continuity of supply for essential/continuous operations, standby and emergency supply sources/networks shall be designed.

Locations in industrial buildings which are by their nature hazardous, require special treatment in respect of design of electrical installations therein. Such special rules for hazardous areas are covered in Part 7 of the Code and these shall be complied with in addition to the general rules specified in that Part.

In **4** of this Part, an attempt has been made to classify industrial installations depending on the specified criteria therein. Such a classification, it is hoped would help identify the specific nature of each industry and the locations therein, assisting the design engineer in the choice of equipment and methods of installation.

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1 SCOPE

1.1 This Part of the Code (Part 4) covers the guidelines for design and construction of electrical installations in industrial buildings.

1.2 This Part does not cover specific areas in industrial sites, such as office buildings, workers rest rooms, medical facilities, canteen annexe, etc, for which requirements stipulated in the relevant sections of Part 3 of the Code apply.

1.3 This Part also does not cover locations in industrial sites that are by nature hazardous for which the provisions of Part 7 of the Code apply.

2 REFERENCES

The standards listed in Annex A contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 TERMINOLOGY

For the purpose of this standard the definitions given in Part 1/Sec 2 of the Code and the following shall apply:

3.1 Pollution — Any condition of foreign matter, solid, liquid or gaseous (ionized gases), that may affect dielectric strength or surface resistivity.

3.2 Pollution Degree (of Environmental Conditions) — Conventional number based on the amount of conductive or hygroscopic dust, ionized gas or salt and on the relative humidity and its frequency of occurrence, resulting in hygroscopic absorption or condensation of moisture leading to reduction in dielectric strength and/or surface resistivity.

4 CLASSIFICATION OF INDUSTRIAL BUILDINGS

Industry by definition includes manufacturing, processing, service sectors under which IT sector is also considered as Industry. However, for the purpose of this section industry basically include any building or part of building or structure, in which products or materials of all kinds and properties are stored, fabricated, assembled, manufactured or processes. For example, assembly plants, laboratories, dry cleaning plants, pumping stations, refineries, dairies, saw mills, chemical plants, workshops, distilleries, steel plants, etc.

Industrial installations are of various types. Single industrial site may comprise electrical loads of varying types and requirements. Classification of Industries is based on three criteria as given in **4.1** to **4.3**.

4.1 Classification Based on Fire Safety

4.1.1 Industrial buildings are classified into Group G from the fire safety point of view in SP 7. Buildings under Group G are further subdivided as follows:

a) *Subdivision G-1 — Buildings used for low hazard industries* — Includes any building in which the contents are of such low combustibility and the industrial processes or operations conducted therein are of such a nature that there are no possibilities for any self-propagating fire to occur and the only consequent danger to life and property may arise from panic, fumes or smoke, or fire from some external source.

b) *Subdivision G-2 — Buildings used for moderate hazard industries* — Includes any building in which the contents or industrial processes of operations conducted therein are liable to give rise to a fire which will burn with moderate rapidity and give off a considerable volume of smoke but from which neither toxic fumes nor explosions are to be feared in the event of fire.

c) *Subdivision G-3 — Buildings used for high hazard industries* — Includes any building in which the contents or industrial processes or operations conducted therein are liable to give rise to a fire which will burn with extreme rapidity or from which poisonous fumes or explosions are to be feared in the event of fire.

NOTE — SP 7 includes Group J buildings for such location where storage, handling, manufacture or processing of highly combustible or explosive materials or products are being carried out. Such installations including such high hazard locations in Group G classification shall comply with the special rules of Part 7 of the Code.

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4.1.2 Typical list of industries for different class of fire hazard are given in Annex B.

4.2 Classification Based on Power Consumption

Industrial buildings may also be classified depending on the quantum of electric power requirements for its services as given in Table 1.

Loads within the industrial site could be divided depending on their nature and size. For guidance, the classification given in Table 2 shall be referred to.

4.3 Classification Based on Pollution

For the propose of evaluating creepage distances and clearances, the following four degrees of pollution in the micro-environment are established:

a) *Pollution degree 1* — No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.

b) *Pollution degree 2* — only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.

c) *Pollution degree 3* — Conductive pollution occurs, or dry non-conductive pollution occurs which becomes conductive due to condensation — which is to be expected.

d) *Pollution degree 4* — Continuous conductivity occurs due to conductive dust, rain or other wet conditions.

NOTES

1 Clearances and creepage distances according to the different pollution degrees are given in Tables 13 and 15 of IS/IEC 60947-1. Unless otherwise stated by the relevant product standard, equipment for industrial applications is generally for use in pollution degree 3 environment. However, other pollution degrees may be considered to apply depending upon applications or the micro-environment.

a) The pollution degree of the micro-environment for the equipment may be influenced by installation in an enclosure. Means may be provided to reduce pollution at the insulation under consideration by effective use of enclosures, encapsulation or hermetic sealing. Such means to reduce pollution may not be effective when the equipment is subject to condensation or if, in normal operation, it generates pollutants itself.

b) Pollution will become conductive in the presence of humidity. Pollution caused by contaminated water, soot, metal or carbon dust is inherently conductive. Small clearances can be bridged completely by solid particles, dust and water and therefore minimum clearances are specified where pollution may be present in the micro-environment.

Table 1 Classification Based on Power Consumption

(*Clause* 4.2)

Sl No.	Description[1)]	Average Power Requirement	Examples
(1)	(2)	(3)	(4)
i)	Light industries	Up to 50 kVA	Hosiery, tailoring and jewellery
ii)	Average industries	Above 50 kVA up to 2 000 kVA	Machinery, engine fitting, motor cars, aircraft, light pressings, furniture, pottery, glass, tobacco, electrical manufacturing and textile (*see* Note)
iii)	Heavy industries	Above 2 000 kVA	Heavy electrical equipment, rolling mills, structural steel works, tube making, foundries, locomotives, ship-building and repairing, chemical factories, factories for metal extraction from ores, etc.

NOTE — Average factory installations are set apart from heavy industries in that the former has no conditions requiring specialized or exceptional treatment.

[1)] Terminology based on IS 732. Where different degrees of hazard occupancy exist in different parts of building, the most hazardous of those shall govern the classification for the purpose.

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Table 2 Load Groups in Industrial Buildings

(*Clause* 4.2)

Sl No.	Groups	Type to Load	Examples	Corrected Power Factor
(1)	(2)	(3)	(4)	(5)
i)	1	Small and large loads fairly evenly distributed over the whole area and loaded constantly during the working day (precision mechanical engineering)	Repair shop, automatic lathe, workshop, spinning mill, weaving mill	≥ 0.9
ii)	2	Loads evenly distributed over the whole area, but varying loads and with peak load at different times (for example, metal working industry)	Tool making	do
			Press shop	do
			Machine shop	do
			Welding shop	do
iii)	3	Loads having very high power requirement in conjunction with smaller loads of negligible size compared to the total load (for example, raw material, industry)	Heat treatment shop, steel works, rolling mills	do

5 GENERAL CHARACTERISTICS OF INDUSTRIAL BUILDINGS

General guidelines on the assessment of characteristics of installations in buildings are given in (Part 1/Sec 8) of the Code. For the purposes of installations falling under the scope of this Part 4, the characteristics given below shall apply.

5.1 Environment

The following environmental factors shall apply to industrial installations:

Environment	*Characteristics*	*Remarks*
(1)	(2)	(3)
Presence of water	Presence of water negligible, or possibilities of free falling drops or sprays, moisture	Depends on the location. For further details *see* (Part 1/Sec 8) of the Code
Presence of foreign solid bodies	These conditions include possibilities of presence of foreign solid bodies of various sizes likely to affect electrical equipment	Depends on the location. For further details *see* (Part 1/Sec 8) of the Code
Presence of corrosive polluting substances	Atmospheric where the presence of corrosive or polluting substances is significant	Industrial installations, situated by the sea, chemical works, cement works where the pollution arises due to abrasive, insulating or conducting
	Intermittent or accidental subjection to corrosive or polluting chemical substances being used or produced	Dust factory laboratories boiler rooms, etc.
	Continuous pollution	Chemical works
Mechanical stresses	Impact and vibration of low severity impact/ vibration of high severity	Household and similar conditions industrial installations subject to severe conditions
Seismic effect and lightning	—	Depends on the location of the buildings

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Environment	*Characteristics*	*Remarks*
(1)	(2)	(3)
Contact of persons with earth potential	Persons are frequently in touch with extraneous conductive parts or stand on conducting surfaces Persons are in permanent contact with metallic surroundings and for whom the possibility of interrupting contact is limited	Locations with extraneous conducting parts, either numerous or large area metallic surrounding, such as boilers and tanks
Conditions of evacuation	Low density occupation, easy conditions of evacuation	This category applies to buildings of normal or low height
Nature of processed or stored material	Existence of fire-risks, where there is manufacturing, processing or storage of flammable materials, including presence of dust/smoke	Wood-working shop, paper factories, textile mills, etc
	Processing or storage of low-flash-point materials including presence of explosive dust	Oil refineries, hydrocarbon stores

5.2 Compatibility

In industrial installations, an assessment shall also be made of any characteristics of equipment likely to have harmful effects upon other equipment or other services (*see* Part 1/Sec 8 of the Code).

5.3 Maintainability

Assessment shall also be made of the frequency and quality of maintenance of the installation (*see* Part 1/Sec 8 of the Code).

6 SUPPLY CHARACTERISTICS AND PARAMETERS

6.0 General

The arrangement of the electrical system in industrial plants and the selection of electrical equipment depends largely on the type of manufacturing process, the reliability of supply and adequate reserve of electrical capacity are the most important factors to avoid interruption of supply.

All electrical installation shall be suitable for the voltage and frequency of supply available.

Depending on load single/three phase or higher supply voltage band may be considered. Though the use of high voltage supply entails the provision of space and the capital cost of providing a suitable transformer substation on the consumer's premises, the following advantages are gained:

a) Advantage in tariff,
b) More effective earth fault protection for heavy current circuits,
c) Elimination of interference with supplies to other consumers permitting the use of large size motors, welding plant, etc., and
d) Better control of voltage regulation and more constant supply voltage.

In very large industrial buildings where heavy electric demands occur at scattered locations, the economics of electrical distribution at high voltage from the main substation to other subsidiary transformer substations or to certain items of plant, such as large motors, furnaces, etc, should be evaluated. The relative economy attainable by use of medium or high voltage distribution and high voltage plant is a matter for expert judgement and individual assessment in the light of experience by a professionally qualified electrical engineer.

6.1 Industrial Substations

The general requirements for substation installations given in Part 2 of the Code shall apply in addition to those given below.

If the load demand is high, which may necessitate supply above 650 V or if conditions of supply of local Electric supply Company requires so, a separate substation should be set up. For an outdoor substation, general guidelines as given in Part 2 of the Code shall apply. For bringing the supply into the factory building, a separate indoor accommodation, as close as possible to the main load centre, should be provided to house the switchgear equipment.

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The supply conductors should preferably be brought into the building underground to reduce the possibility of interruption of power supply. The accommodation for substation equipment as well as for main distribution panel shall be properly chosen to prevent access by any unauthorized person. It shall be provided with proper ventilation and lighting. In cases where the load currents are high (400 A and above) and the transformers are located just outside the building, a busbar trunking system may be desirable. These trunkings should, however, be straight and short as far as possible.

6.1.1 *Location of Transformers and Switchgear*

Location of transformer shall preferably at load centre subject restrictions related hazards such as fire. Special attention shall be given to mandatory provisions related to oil filled transformers. Use of K class insulating liquids having fire point >300°C may be considered.

Requirement of indoor or outdoor transformer sub-station may depend on site, type of industry, environmental conditions and other factors of external influences. Location of control switchgears its accessibility from the point of view of operation shall be precisely designed.

Protection on primary and secondary side of transformer shall conform requirements mandated under CEA (Measures related to Safety and Electric Supply) Regulations, 2010 (latest amended version).

Restricted areas shall be precisely marked and suitably locked so that unauthorised person shall not have an access within.

6.1.2 For small substations up to 1 600 kVA capacity, it is also possible to locate the substation at the load centre, without a separate room. This yields considerable economies in cost. In such cases, the transformer shall be of dry type.

6.2 Distribution of Power

6.2.1 From the point of supply, power is distributed to loads in steps depending on quantum of load and expanse. Main control panel, sub-distribution and local distributions panels shall have appropriate control switchgears to isolate and break supply as desired. Settings shall be done with appropriate discrimination to maintain sequence of tripping. Local isolation in case of fault shall be important aspect of design.

6.2.2 Electrical panels/switch-boards may be floor or wall mounted and designed conforming IS/IEC 61439. Access routes shall always be maintained free without hindrances. Clear space around/arc-flash distances as mentioned under Part 1 Section 22 shall be maintained. Provision of separate room and adequate ventilation/ positive pressure may be necessary to protect panels from external influences like dust, corrosive smokes, etc.

Switch-boards shall be so designed and installed so that provisions considering possibilities of internal arc fault are adequate and tested (IEC/TR 61641). Where necessary, internal arc-fault mitigation system (IAMS) may be adopted.

6.2.3 Cables, bus-duct routes shall be well planned and maintained considering risk factors. Cables at difference voltage levels should be laid with separation at least 250 mm and clearly identified. Cables at voltages above 1 000 V should be laid at the lowest level in trenches, and at the highest level on walls. Use of cable ladder, trey helps structured cabling work. Earth continuity shall be properly maintained in such work. All entry points shall be properly sealed with fire resistant material. Method of construction shall be as per IS 1255.

6.2.4 All switchgear equipment used in industrial installations shall have appropriate ingress protection. selection shall also be done considering appropriate range and setting facility of overload, short-circuit currents and other add-on protections. All switchgear equipment used in industrial installations shall be metal enclosed. Switchgear shall not be mounted on woodwork.

6.2.5 In certain installations where supply is from remote transformer substations, it may be necessary to protect main circuits with circuit-breakers operated by earth leakage trips, in order to ensure effective earth fault protection.

6.2.6 Where large electric motors, furnaces or other heavy electrical equipment is installed, the main circuits shall be protected by circuit-breakers or contactors of air-break or oil-immersed type fitted with suitable instantaneous and time delay over current devices together with earth leakage and back-up protection where necessary.

6.2.7 It may be necessary to provide for connection of capacitors for power-factor correction; and when capacitors are to be installed advice of capacitor and switchgear manufacturers shall be sought.

6.2.8 Sufficient additional space shall be provided for modifications, alterations, anticipated future extensions.

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6.3 Wiring System

The selection of a wiring system to be adopted in a factory shall depend upon the factors enumerated in Part 1/Sec 9 of the Code. The wiring system available for general use are listed in Annex C. Selection from a group of alternative systems shall be made in accordance with Annex C, keeping in view the points mentioned under **6.3.1**.

6.3.1 Design and selection of wiring system and material shall be done considering:

a) Situation, such as location, structure, etc.;
b) External influences, such as climatic conditions, environment, etc.;
c) Hazard classification;
d) Scope for modifications, future expansions. For example, overhead busbar trunking with tap-offs facilitates modification in machine shops;
e) Compatibility to face emergency situation; and
f) Type and class of operators, users, occupants.

6.3.2 Electrical installation for lifts, hoists shall be done in consultation with the manufacturer and circuit supplying lift equipment shall distinct and separate.

6.4 Earthing in Industrial Premises

Earth and earthing system shall conform IS 3043 and Part 1/Sec 18 of this code. Schematic drawing of earthing system shall be prepared and updated version be maintained.

6.4.1 In factories and workshops all metal conduits, trunking, cable sheaths, switchgear, distribution boards, starters, motors and all exposed conductive parts and extraneous conductive parts shall be bonded together and connected to earth system efficiently.

6.4.2 *Earth Electrodes*

Selection, number and location(s) of Earth electrode(s) shall be as per soil resistivity, design requirement in respect of limiting value of earth fault loop impedance. In case of multiple earth electrodes grid may be formed. System shall be so designed that testing of individual earth electrode is possible and resistance shall be such to conform degree of shock protection and facilitate operation of protective systems within the set duration.

6.4.3 *Earth-continuity Conductor*

6.4.3.1 *Earth-continuity conductors and earth wires not contained in the cables*

The size of the earth-continuity conductors should correlate both in magnitude and duration adequate to accept ground fault current to suite over current protective system, without creating adverse thermal effect to result in to fire hazard. For phase conductor of size up to 16 mm^2, minimum size of earth-continuity conductors shall equal to that of phase conductor (same metal), for above 16mm^2 and up to 35 mm^2, shall be 16 mm^2 and for above 35mm^2size shall be calculated as per clause 17.2.2.1 of IS 3043. It shall be noted that rate of corrosion of steel in soil is six times as fast as copper. To prevent corrosion of steel zinc coating of minimum 150 microns shall be done.

6.4.3.2 *Earth-continuity conductors and earth wires contained in the cables*

For flexible cables, the size of the earth-continuity conductors should be equal to the size of the current-carrying conductors and for metal sheathed, when used as earth continuity conductor, every joint shall of capacity not less than current carrying capacity of metal sheath.

Conduits may be used as earth-continuity conductors provided they are permanently and securely connected to the earth system. However, where by nature of the process, metal conduits cannot be used as earth-continuity conductor on account of corrosion, etc, the tough rubber or PVC sheathed cables may be used in which case they shall incorporate an earth-continuity conductor. Flexible conduits shall not be used as earth-continuity conductors. A separate earth wire shall be provided either inside or outside the flexible conduits which shall be connected by means of earth clips to the earth system at one end and to the equipment at the other end.

6.4.4 *Earth Leakage Protection*

Use residual current operating devices (RCDs) shall be made to prevent earth leakages exceeding limiting values set for direct and indirect contacts.

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RCDs having sensitivity 30mA or less gives protection against direct contact and those above 30 mA are intended to give protection against indirect contact. RCDs 300 mA are recommended for risk against fire arising due to leakage currents.

Some degree of discrimination may, in certain cases, be introduced with advantage by providing the delay in the operation of an earth-leakage trip, so that earth faults on smaller subsidiary circuits protected by fuses have time to clear and prevent the opening of the circuit-breaker, controlling a larger part of the installation.

6.4.5 *Earthing of Portable Appliances and Tools*

Good electrical continuity between the body of a portable appliance and the earth-continuity conductor shall always be maintained.

It shall be ascertained that the fixed wiring at the appliance inlet terminals has been done correctly and in accordance with relevant Indian Standard.

A single pole switch shall not be connected in the earth conductor.

No twisted or taped joints shall be used in earth wires.

Additional security may be obtained by arranging the earth-continuity conductor in the flexible cable between the socket outlet and the portable appliance in the form of a loop through which a light circulating current provided by a small low-voltage transformer is passed when the appliance is in use. Any discontinuity in this loop will interrupt the circulating current and can thus be caused to operate a relay and disconnect the supply from the portable appliance.

6.4.6 *Earthing of Electrically Driven Machine Tools*

In all types of machine tools, the body of all motors and bed plate of the machine shall be earthed at two places by means of a strip or conductors of adequate cross-sectional area. The strip or conductor shall be securely fastened to the bed plate by means of bolts.

6.4.7 *Earthing of Equipment*

All components of electric arc welding equipment shall be effectively bonded and connected to earth. The transformers and separate regulators forming multi-operator sets and capacitors for power factor correction, if used, shall be included in the bonding.

All terminals on the output side of a motor generator set shall be insulated from the car case and control panel, as the generator is not connected electrically to a motor and therefore the welding circuit is electrically separate from the supply circuit including the earth.

In case of transformer sets, which for welding purpose are double wound, an ‘earth and work’ terminal shall be provided. In single phase sets this terminal shall be connected to one end of the secondary winding and in case of three-phase sets this shall be connected to the neutral point of the secondary winding.

6.4.8 *Earthing of Industrial Electronic Apparatus*

The earthing of these apparatus shall follow normal practice, but attention shall be paid to the points discussed below.

For any industrial electronic apparatus, which incorporates small capacitors connected between the supply and the metal case of the instrument to cut down interference, capacitor shall be securely earthed.

When an oscilloscope is being used to examine the wave-form of a high frequency source, the oscilloscope shall be earthed by a conductor entirely separate from that used by the source of high frequency power. However, when an oscilloscope is being used on a circuit where the negative is above earth potential and also connected to its metallic case, the earthing of the oscilloscope is not possible. Precautions shall be taken that in such a case the oscilloscope is suitably protected from other apparatus.

High frequency induction heating apparatus shall be earthed by means of separate earth wire by as direct a route as possible.

Dielectric loss heating equipment work at frequencies between 10 MHz to 60 MHz according to its use. These should not be directly earthed. At 30 MHz, for example, a quarter wavelength is nearly 250 cm and an earth wire of this length or odd multiples of it is capable of being at earth potential at one end but several hundred volts at the other end. This is due to the presence of standing waves on the earth conductors which besides being dangerous

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can result in energy being radiated to the detriment of communication services. In such a case it is recommended to mount the equipment on a large sheet of copper or copper gauze, the earth conductor being connected to it at several points.

In case where direct earthing may prove harmful rather than provide safety, for example, high frequency and mains frequency coreless induction furnaces, special precautions are necessary. The metal of the furnace charge is earthed by electrodes connected at the bottom of the charge, and the furnace coils are connected to the mains supply but are unearthed. A relay is connected by a detection circuit which itself is earthed to the coils. The object is to prevent dangerous break-through of hot metal through the furnace lining, the earth detection circuit giving a continuous review of the conditions for the furnace lining. When leakage current attains a certain set maximum it becomes necessary to take the furnace out of service and to re-line.

7 EMERGENCY/STANDBY POWER SUPPLIES

The provisions of Part 2 of the Code shall apply.

8 SYSTEM PROTECTION

8.1 Protection of Circuits

8.1.1 Appropriate protection shall be provided at switch-boards and distribution boards for all circuits and sub-circuits against overcurrent and earth faults according to IS 732, and Part 1 of this code. The protective apparatus shall be capable of interrupting any short-circuit current that may occur, without danger. The ratings and settings of fuses, circuit breakers and the protective devices shall be coordinated to afford selectivity in operation where necessary.

Where circuit-breakers are used for protection of a main circuit and of the sub-circuits derived therefrom, discrimination in operation may be achieved by adjusting the protective devices of the sub-main circuits to operate at lower current settings and shorter time-lag than the main circuit-breaker.

Where HRC type fuses are used for backup protection of circuit-breakers, or where HRC fuses are used for protection of main circuits and circuit-breakers for the protection of sub-circuits derived therefrom, in the event of short circuits exceeding the breaking capacity of the circuit-breakers, the HRC fuses shall operate earlier than the circuit-breakers; but for smaller overloads within the breaking capacity of the circuit-breakers, the circuit-breakers shall operate earlier than the HRC fuse.

If re-wireable type fuses are used to protect sub-circuits derived form a main circuit protected by HRC type fuses, the main circuit fuse shall normally blow in the event of a short-circuit or earth fault occurring on a sub-circuit, although discrimination may be achieved in respect of overload currents. The use of re-wireable fuses is restricted to the circuits with short-circuit level of 4 kA; for higher level either cartridge or HRC fuses/Circuit breakers shall be used.

Provision shall also be made for control of general lighting and other emergency services through separate main circuits and distribution boards from the power circuits.

If necessary, independent source of supply for emergency service in particular installations may be provided as supply to DG.

8.1.2 *Overvoltage Protection*

Provisions of 4.5 of IS 732 shall apply.

Surge protective devices may be provided at the incomers of the sub distribution boards. Building should be protected by suitable lightning and surge protectors/arresters.

Additional overvoltage protection for equipment used in critical for the process should be considered (example,of such equipment could be PLC, control and monitoring system).

8.2 Fire-safety Requirements

Besides fire-fighting equipment, the fire detection and extinguishing systems, as recommended in Part 4 of SP 7 shall be followed.

Reference is also drawn to IS 1646 and clause 4.3 of IS 732 regarding rules and regulations relating to electrical installations from the point of fire safety. Annex D covers specific requirements for fire safety for representative industries.

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9 BUILDING SERVICES

9.1 Lighting

Industrial lighting encompasses seeing tasks, operating conditions and economy. With each of the various visual task conditions, lighting should be suitable for adequate visibility considering lux level, Colour Rendering Index (CRI), Correlated Colour Temperature (CCT), Glare Index, etc. Physical hazards exist in many manufacturing processes; therefore, lighting contribute to the utmost as a safety factor in preventing accidents. The speed of many manufacturing operations might also be hampered due to poor lighting. The general considerations for design of lighting in industrial areas are enumerated in IS 6665 (*see* also SP 72).

9.1.1 *Equipment for Lighting*

The choice of light sources and luminaries shall be governed by the guidelines given in IS 6665. The recommended values of illumination and limiting values of glare index are given in Annex E for guidance. For additional information, National Lighting Code, SP 72 may also be referred.

9.1.2 *Energy Conservation*

From the point of view of Energy Conservation Consideration shall be given to efficacy of lighting fixture (lumen output/watt).

9.2 Air-conditioning, Heating and Ventilation

The electrical installation meant for the services, such as air-conditioning heating and ventilation in industrial buildings shall conform to the requirements of respective standards. The specific needs of individual locations requiring these services in each factory shall be ascertained in consultation with the concerned personnel before designing the electrical system. Reference should be made to the guidelines given in SP 7.

9.3 Lifts

9.3.1 The general rules laid down in Part 1 of the Code shall apply regarding lift installations. However, the design of lifts in industrial buildings shall consider the following requirements:

a) Occupant load — The occupant load expressed in terms of gross area in m^2/person shall be 10 for industrial buildings.

b) Car-speed for goods lifts — These shall be asper relevant standards.

9.3.2 The location of lifts in factories, warehouses and similar buildings should be planned to suit the progressive movement of goods through the buildings having regard to the nature of processes carried out, position of loading platform, railway sidings, etc. The placing of a lift in a fume or dust laden atmosphere, or where it may be exposed to extreme temperatures shall be avoided. Where it is impossible to avoid extreme environmental conditions. The selection of electrical equipment shall be such that they are suitable to meet the conditions involved and shall be installed in suitable distribution board with required IP protection. Each lift shall be protected by an RCCB.

10 MISCELLANEOUS/SPECIAL PROVISIONS

10.1 Control of Static Electricity

IS 7689 shall be referred regarding recommendations for controlling static electricity generated incidentally by processes in industries which may pose a hazard or inconvenience. Specific control methods are also given for some industries therein.

10.2 Safety in Electro-heat Installations

Industrial processes include in many instances, electro-heat installations, such as:

a) Arc furnaces;

b) Induction furnaces;

c) Appliances for direct and indirect resistance heating;

d) Medium and high frequency induction heating, radio frequency heating and dielectric heating appliances;

e) Infra-red radiation heating appliances; and

f) Microwave heating.

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For safety requirements in such electro-heat installations reference shall be made to IS 9080 (Parts 2 and 4) and IS/IEC 519 Part 1, IS/IEC 519 Part 3, IS/IEC 519 Part 5 and IS/IEC 519 Part 9).

11 ENERGY EFFICIENCY ASPECT

11.1 The provisions of Part 1/Sec 21 of this code shall apply.

11.2 Energy Management System

For heavy industries as defined in Table 1 in addition to provision of (Part 1/Sec 20) and energy conservation code, an energy management system monitoring and recording power consumption, but also all relevant electrical parameters in all critical part of the electrical installation should be considered. Such energy management system should provide the following function:

a) Produce energy efficiency reporting;
b) Understand energy usage and find energy waste;
c) Remote report the status and remote control of the electrical installation;
d) Alarm in case of event in the electrical installation, such as overload, short-circuit, power interruption; and
e) Capture, analyze and understand power quality disturbances.

11.3 Power Factor Compensation

The provisions of (Part 1/Sec 20) of the Code shall apply. For specific guidance for installations covered by this Part (*see* Annex F).

11.4 Harmonics Monitoring and Filtering

Where electronic converters/nonlinear loads, such as variable speed drive, rectifiers, switch mode power supply or similar are a significant part of the total load (>25 percent) measurement of harmonics current and voltage at incomer is recommended.

Wherever necessary to control the harmonics within permissible limits, passive/active filters may be used.

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ANNEX A

(*Clause* 2)

IS No.	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
1646 : 2015	Fire safety of buildings (general): Electrical installations — Code of practice (*third revision*)
2726 : 1988	Code of practice for fire safety of industrial buildings: Cotton ginning and pressing (including cotton seed de-lintering) factories
3058 : 1990	Code of practice for fire safety of industrial buildings: Viscose rayon yarn and/or staple fibre plants
3079 : 1990	Code of practice for fire safety of industrial buildings: Cotton textile mills
3594 : 1991	Code of practice for fire safety of industrial buildings: General storage and warehousing including cold storage
3595 : 2002	Code of practice for fire safety of Industrial buildings: Coal pulverisers and associated Equipment
3836 : 2000	Fire safety of industrial buildings — Jute mills — Code of practice
4226 : 1988	Code of practice for fire safety of industrial building: Aluminium/magnesium powder factories
4886 : 1991	Code of practice for fire safety of industrial buildings: Tea factories
6329 : 2000	Code of practice for fire safety of industrial buildings — Saw mills and wood works
6665 : 1972	Code of practice for industrial lighting
7689 : 1989	Guide for the control of undesirable static electricity
9109 : 2000	Fire safety of industrial buildings — Paint and varnish factories — Code of practice
9080 (Part 2/Sec 2) : 1980	Safety requirements in electro-heat installations: Part 2 Particular requirements for resistance heating equipment, Section 2 Protection in indirect resistance heating installations
9080 (Part 2/Sec 4) : 1981	Safety requirements in electro-heat installations: Part 2 Particular requirements for resistance heating equipment, Section 4 Protection in installations used for drying varnishes and other similar products
IS/IEC 519-1 : 1984	Safety in electro-heat installation: Part 1 General requirements
IS/ IEC 519-3 : 1988	Safety in electro-heat installation: Part 3 Particular requirements for induction and conduction heating and induction melting installations
IS/IEC 519-5 : 1980	Safety in electroheat installation: Part 5 Specification for safety in plasma installation
IS/IEC 519-9 : 1987	Safety in electroheat installations: Part 9 Particular requirements for high-frequency dielectric heating Installations
IS\IEC 60947-1 : 2007	Specification for low-voltage switchgear and controlgear: Part 1 General rules (*first revision*)
SP 7 : 2016	National Building Code of India
SP 72 : 2010	National Lighting Code
IS/IEC 61439	Low-voltage switchgear and controlgear assemblies

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ANNEX B

(*Clause* 4.1.2)

EXAMPLES OF INDUSTRIES BASED ON FIRE-SAFETY

B-l The following is a representative list of industries classified according to the degree of fire hazard enumerated in **4.1.1**:

a) *Low Hazard Industries*

Abrasive manufacturing premises Aerated water factories

Agarbatti manufacturing premises Aluminium copper and zinc factories

Asbestos steam packing and lagging manufacturers

Battery manufacturers Bone mills

Breweries Canning factories

Carbon dioxide plants Cardamomefactories Cement factories

Cement and/or asbestos or concrete products manufacturing premises

Ceramic and crockery factories Clay works

Clock and watch manufacturing premises Confectionery manufacturers

Electric generating houses

Electric lamps and fluorescent tube manufacturers

Electronic goods manufacturing premises Electroplating workshops

Engineering workshops

Fruit products and condiment factories Gold thread factories/gilding factories Glass factories

Gum and glue factories

Ice candy and ice cream manufacturing premises

Ice factories

Ink factories (excluding printing inks) Milk pasteurising plants and dairy farms Mica products manufacturing premises Potteries/tiles and brick works

Rice mills

Refractories works and firebrick kilns Salt crushing factories and refineries

Silicate (other than sodium silicate) factories Soap and detergent factories

Sugar candy manufacturers

Sugar factories

Tanneries

Tea colouring factories

Umbrella factories

Vermicelli factories

Wire drawing works

b) *Moderate Hazard*

Aeronaut/betelnut factories

Atta and cereal grinding premises Bakeries and/or biscuit factories Beedi factories

Book binders and paper cutting premises Book sellers and stationers' shops

Boot and shoe factories and other leather goods factories

Boat builders and ship repairing docks Button factories

Candle works

Canvas sheet manufacturers Cardboard box manufacturers Carbon paper manufacturing premises Carpet and durries factories Carpenter's workshops

Camphor boiling premises

Cashew nut factories (using open fire) Cloth processing works

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Coffee curing premises
Coffee roasting and grinding works Colour/dyes mixing and/or blending factories Coir factories
Cork factories
Cork stopper and other cork products manufacturing premises
Collieries
Chemical manufacturers Cotton mills
Dyeing and dry-cleaning works
Electric wire and cable manufacturing premises
Enamel factories
Essential oil distillation plants Flour mills
Garment makers
Ghee manufacturing premises Ginning and pressing factories
Grains and/or seeds disintegrating factories Grease manufacturing works
Gunning and pressing factories Hat and topee factories Hosiery factories
Incandescent gas mantle manufacturers Jute mills and jute presses
Mineral oil blending and processing works Mutton tallow manufacturers
Manure and/or fertilizer works (blending, mixing and granulating only)
Mattresses and pillow making premises Oxygen plants
Paper mills Pencil factories
Plastic goods manufacturers Printing press premises
Pulverizing and crushing mills (hazardous materials)
Rice mills Rope factories
Rubber goods manufacturers Shellac factories
Spray painting works Starch factories
Synthetic fibre manufacturing premises Tea factories
Thermal power stations
Tobacco (chewing), zarda, kimam and pan masala making premises
Tobacco grinding and crushing and snuff manufacturing premises
Tobacco curing and redrying factories Tobacco pressing works
Upholsterers Weaving factories Woollen mills
Wool cleaning/pressing factories Yarn gassing plants.

c) *High Hazard*

Acetylene plants
Alcohol distillers
Aluminium and magnesium powder plants Bituminised paper/hessian cloth manufacturing premises
Bobbin factories
Cinematograph film production studies Calcium carbide plants
Cotton waste factories
Coal/coke/charcoal ball and briquettes factories
Celluloid goods manufacturers Cigarette filter manufacturers
Cotton seed cleaning or deliniting premises Duplicating and stencil paper manufacturers Fertilizer plants
Explosive manufacturers Fireworks factories
Foam plastics and foam rubber goods manufacturers
Grass, hay, fodder and *bhoosa* (chaff) pressing factories
Match factories Oil mills

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Oil extraction plants

Oil and leather cloth factories

Paint (including nitrocellulose paints) and varnish factories

Petrochemical plants

Plywood factories

Printing ink manufacturers

Resin and lamp black manufacturers Rubber substitute manufacturers Surgical cotton manufacturers

Tar distilleries

Tar felt manufacturing premises Tarpauplin and canvas proofing factories

Timber and woodworkers' premises

Tin printers (where more than 50 percent of floor area is occupied as engineering workshop this may be taken as moderate hazard risk)

Terpentino distilleries

Tyre retreading and resoling factories Woodmeal manufacturers

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ANNEX C

(*Clause* 6.3)

SELECTION OF WIRING SYSTEMS

C-1 WIRING SYSTEMS FOR GENERAL APPLICATION

a) Bare solid or tubular conductors supported on insulators in metal or incombustible structural ducts or chases (main connections) or Busbar trunking system

b) Tough rubber-sheathed or PVC-sheathed cables protected as necessary against mechanical damage, say, buried in plaster or installed in concrete ducts.

NOTE — Polythene-insulated PVC-sheathed cable provides an alternative having the advantage of high insulation-resistance.

c) Elastomer-insulated braided and compounded or PVC-insulated cable installed in heavy-gauge screwed conduit.

NOTE — The use of galvanized conduit and PVC-insulated cable is to be preferred where the situation may be damp or long life is required.

d) Elastomer-insulated braided and compounded or PVC-insulated cable installed in light-gauge steel conduit with lug grip.

e) Elastomer-insulated braided and compounded or PVC-insulated cable installed in PVC or other insulated conduit and provided with a bare copper or copper-alloy earth-continuity conductor as necessary.

f) Grid suspension wiring system comprising elastomer-insulated or PVC insulated cables laid around a galvanized steel catenary wire, braided overall or otherwise protected to withstand corrosive conditions where necessary.

g) Elastomer-insulated braided and compounded or PVC-insulated cable installed in metal trunking or ducts.

NOTE — Incombustible insulated trunking and ducts provide an alternative and where these are used a bare copper or copper-alloy earth-continuity conductor may be required.

h) Elastomer-insulated braided and compounded or, with appropriate protection where cable passes through floors or walls.

j) Elastomer-insulated lead-alloy-sheathed cables incorporating an earth continuity conductor or protected as necessary against mechanical damage and corrosion.

k) Elastomer-insulated aluminium-sheathed cable.

NOTE — Where a lead-sheathed cable has plumbed joints a separate earth-continuity conductor may not be required.

m) Mineral-insulated metal-sheathed cable with or without protective sheathing with suitable watertight glands.

C-2 ADDITIONAL WIRING SYSTEMS PARTICULARLY SUITABLE FOR USE IN FACTORIES AND THE LIKE

a) PVC-insulated and steel tape or wire armoured, and PVC-sheathed cable buried directly in the ground or used in special conditions.

b) PVC-insulated steel tape or wire armoured and PVC-sheathed cable with cleat or hook suspensions.

c) PVC-insulated and PVC-sheathed cable installed in underground earthenware ducts or metal pipes.

d) PVC-insulated and PVC-sheathed cable, mounted on porcelain or in trenches or ducts, and so installed as to be protected against mechanical damage.

e) Tough rubber-sheathed or PVC-sheathed cable mounted on insulating non-hygroscopic cleats affixed to treated, teak battens by screws of corrosion-resisting material, such as Monel metal or phosphor-bronze.

f) Elastomer-insulated braided and compounded or PVC-insulated cable installed in galvanized solid-drawn screwed conduit with flameproof couplings and inspection fittings.

g) Varnished-cambric insulated, lead-alloy or aluminium-sheathed cable.

h) Elastomer-insulated, tough rubber-sheathed cable, steel wire armoured.

NOTE — Varnished cambric insulated cables without metal sheath should be used only for short connections on switchboards and the like in dry situation

j) Cross-linked polyethylene insulated thermoplastic sheathed, armoured cable.

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C-3 SELECTION OF WIRING SYSTEMS FOR FACTORIES

Wiring systems suitable for installations indifferent categories of factories are given in Table 3.

C-4 SPECIAL RESTRICTIONS

C-4.1 Even though guidance may be taken from the selection chart (*see* Table 3) for wiring systems, the following restrictions to their use apply:

Wiring System (*see* **C-1**, **C-2**)	*Restrictions*
(1)	(2)
b) and g)	If the ducts are in the form of under floor trenches then the following provisions should be observed: 1) Cables shall preferably be so mounted on non-metallic cable support or other supports and has to be at least 75 mm above the bottom. 2) Top of trenches shall be covered with chequered plates or concrete slabs, 3) In case of long trenches, it is recommended that trenches of more than 1 000 cm^2 cross-sectional area be divided by incombustible barriers at intervals not exceeding 45 m. The barriers shall be at least 50 mm in thickness and of the same height as of cable trench. The cables shall be carried through holes in the barriers, which shall be made good thereof to prevent the passage of fire beyond the barriers, 4) The combined cross-sectional area of all conductors or cables shall not as far as possible exceed 40 percent of the internal cross-sectional area of the trench, and 5) The cable trenches shall be kept free from accumulation of water, dusts and waste materials. Cable trenches shall be away from trenches of water pipe line. 6) Provide heat sensors at intermittent locations (especially in trench below switch-boards) duly integrated with Fire Alarm system of the premise.
c)	Trunking or ducting systems for cables above ground may be used with appropriate precautions as mentioned below where: 1) they are exposed to physical damage–provide protection from mechanical damages. 2) they are exposed to corrosive vapours.–Enclosing trunk/duct should be of chemical corrosion resistant material with suitable intermittent pores to allow escape of possible gas accumulation. 3) the atmosphere is likely to contain flammable gases or vapours – use of trunking/ducting not recommended. 4) the wet processes are carried out-Enclosing trunk/duct should be of corrosion resistant material/anticorrosive surface treatment with suitable sealing of the cover lining to avoid ingress of water. 5) in concealed spaces with sufficient empty space to facilitate breathing of wire's/cable's surface. It also should have service intermittent service/inspection openings at intermittent locations duly sealed to avoid any foreign object intrusion. Ordinary steel conduits shall not be permitted in areas where flammable/corrosive vapour may be present, unless it is of type conforming with wiring system (t) and shall not be permitted in locations:

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Wiring System (*see* **C-1**, **C-2**)	*Restrictions*
(1)	(2)
	1) where wiring height is less than 2.5 m above working floor level, unless protected against mechanical damage, 2) they are exposed to corrosive vapours, 3) where atmosphere is likely to contain flammable gases or vapours, 4) where wet processes are carried out, or 5) in concealed spaces. Ordinary steel conduits shall not be permitted in areas where flammable vapour may be present, unless it is of type conforming with wiring system (t) and shall not be permitted in locations: 1) where wiring height is less than 2.5 m above working floor level, unless protected against mechanical damage, 2) where ambient temperature sometimes is likely to be above 55°C or other during the year, 3) in concealed spaces of combustible construction, 4) where atmosphere is likely to contain flammable gases or vapours, or 5) where conductor operates at voltage above 650 V.
d)	It shall be permitted only where voltage is below 650 V and in locations where the atmosphere is unlikely to contain any flammable vapours or gases.
e)	Same as in case of wiring system (d). This system shall not be permitted in locations: 1) where exposed to severe physical damage 2) where exposed to corrosive vapours, 3) where wet processes are carried out, or 4) In concealed places.
h) and s)	These systems should only be permitted for voltage below 250 V and that too only if use of such system is essential.
j), m), n), p) and v)	Same as in case of wiring system (d). Armoured cables shall not be permitted in following locations unless the cable is of PVC-sheathed type, and shall not be permitted in locations exposed to corrosive fumes or vapour; and battery rooms.

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Table 3 Selection Chart for Wiring Systems for Installations in Factories

(*Clauses* C-3.1 *and* C-4.1)

Sl No.	Section of Installation	Category of Factory								
		Average Factory		Heavy Industry		Light Industry		Chemical Industry		Factories
		1st Choice	2nd Choice	1st Choice	2nd Choice	1st Choice	2nd Choice	1st Choice	2nd Choice	Involving Fire Risk
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	Main distribution at medium or low voltage								w	
		a	c	a	c	c	p	s	n	k
										w
		k	g	k	g	g	v		p	n
		w		w						
		n	r	n	r	k			q	p
						w				
						n				
		p	v	p	v	r			r	q
		q		q						t
									w	
ii)	Sub-main distribution to local istribution boards	a	g	a	g	c	h	f	b	k
									w	w
		c		c	v	f		s	q	t
		f		f		g			r	
		k		k		k				
		w		w		w				
		p		p		p				
		v		r		v				
iii)	Sub-circuit wiring	c		b	c	g	b	c		k
		f		h	f		h	f		t
		g		j	k		j	s		
		k		v						
		v								

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ANNEX D

(*Clause* 8.2)

REQUIREMENTS FOR FIRE SAFETY IN SPECIFIC INDUSTRIES

Type of Industry	*Ref. IS*	*Motors*	*Other Equipment*	*Fittings*	*Miscellaneous*
(1)	(2)	(3)	(4)	(5)	(6)
Jute spinning and weaving, jute rope, carpet making factories	3836	All motors shall be totally enclosed type and in wet locations shall be drip-proof	All equipment shall be metal clad, dust-tight	Lighting fittings shall be dust-tight	Supply shall be at < 250 V in jute godowns
Cotton ginning cotton Seed delintering and pressing factories	2726		All equipment shall be metal clad, dust-tight		
Plants making viscose rayon yarn or staple fibre or both	3058		All equipment in the xanthation disulphide plant shall comply with Part 8 of the Code	Vapour-proof lighting fittings in areas where corrosive gases are evolved	All current carrying parts, contacts liable for corrosion shall be cadmium plated
Textile mills using cotton, cotton waste regenerated cellulose, man-made fibres or any grouping of these	3079	Totally enclosed type, the cooling air for variable speed motor taken from outside the building	Metal clad and dust-tight. equipment shall be flameproof in gas singeing rooms. Stop motion devices provided on frames shall be dust-tight	Dust-tight lighting fittings at willowing, lap breaking, waste opening, mixing, blow and raising rooms	Machines for singeing yarn shall be protected to ensure that heating elements are not switched on while yarn is stationary
Places where paints and varnishes are stored or processed	9109	—	—	Wiring in steel conduits. Lighting fittings of enclosed type	Provisions shall be made for switching off the whole factory at more than one control point
Factories where powders of aluminium, magnesium and their alloys are processed or used	4226	Motors shall be Flameproof dust-protected (*see* Part 7 of the Code)	All equipment of the enclosed type	Wiring in steel conduits. Enclosed lighting fittings	Provisions shall be made for switching off the whole factory at more than one control point.

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ANNEX D (*Concluded*)

Type of Industry	*Ref. IS*	*Motors*	*Other Equipment*	*Fittings*	*Miscellaneous*
(1)	(2)	(3)	(4)	(5)	(6)
Coal pulverizing mills, as also equipment therein for power generation cole or briquette making	3595	Totally enclosed, flameproof, dust-proof (*see* Part 7 of the Code)		Lighting fittings shall be dust-tight. Only conduits; armoured or mineral insulated type of wiring	Use of flexible cables to be kept to the minimum
Tea factories	4886	Where practicable, totally enclosed type			Fan motors of dryers and withering troughs and other control equipment shall be dust proof tape
Godowns, ware-houses, outdoor storage sites forming part of industrial complexes or others; cold storage buildings	3594	Driving motors for overhead cranes totally enclosed	All switchgear equipment metal enclosed. For mains operated electrical stackers, switch and socket shall be water-tight. Flexible connection to the stacker through rubber compound sheathed trailing cable with hard cord braiding	Screwed steel conduits mineral insulated, copper or aluminium sheathed cable. Lighting fittings to be positioned not below 45 cm below roof. A clearance of not less than 75 cm to be provided from highest stacking level. Flexible lighting pendants or portable lamps not allowed	All control equipment switches, etc., outside godown where fibrous goods, flammable liquids, nitro-cellulose, fire works or explosives are stored
Saw mills, furniture factories, coach and body build works, holsteries and other wood working shops. Plywood hard-wood, woodwool, insulation boards, wood flour, etc	6329	Motors shall be totally enclosed or pipe ventilated	All equipment shall be dust-tight and where spray painting is done shall comply with Part 7 of the Code		Electrical heaters shall be metal cases, totally enclosed, immersion type or totally enclosed low temperature type with external surface below 92°C

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ANNEX E

(*Clause* 9.1.1)

RECOMMENDED VALUES OF ILLUMINATION AND LIMITING VALUES OFGLARE INDEX — INDUSTRIAL BUILDINGS

Sl No.	*Industrial Buildings and Processes Illumination, lux*	*Average*	*Limiting Glare Index*
(1)	(2)	(3)	(4)
i)	General factor areas:		
	a) Canteens	150	—
	b) Cloakrooms	100	—
	c) Entrances, corridors, stairs	100	—
ii)	Factory outdoor areas:		
	Stockyards, main entrances, exit roads, car parks, internal factory roads	20	—
iii)	Aircraft factories and maintenance hangers:		
	a) Stock parts productions	450	25
	b) Drilling, riveting, screw fastening, sheet aluminium layout and template work, wing sections, cowling welding, sub-assembly, final assembly, inspection	300	25
	c) Maintenance and repairs (Hangers)	300	25
iv)	Assembly shops:		
	a) Rough work, for example, frame assembly, assembly of heavy machinery	150	28
	b) Medium work, for example, machined parts, engine assembly, vehicle body assembly	300	25
	c) Fine work, for example, radio and telephone equipment, typewriter and office machinery assembly	700	22
	d) Very fine work, for example, assembly of very small precision mechanisms, instruments	1 500[1)]	19
v)	Bakeries:		
	a) Mixing and make-up rooms, oven rooms, wrapping rooms	150	25
	b) Decorating and icing	200	25
vi)	Boiler houses (industrial):		
	a) Coal and ash handling	100	—
	b) Boiler rooms:		
	1) Boiler fronts and operating areas	100[2)]	—
	2) Other areas Outdoor plants:	20 to 25	—
	i) Catwalks	20	—
	ii) Platforms	50	—
vii)	Bookbinding:		
	a) Pasting, punching and stitching	200	25
	b) Binding and folding; miscellaneous machines	300	22
	c) Finishing, blocking and in laying	300	22

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ANNEX E (*Continued*)

Sl No.	*Industrial Buildings and Processes Illumination, lux*	*Average*	*Limiting Glare Index*
(1)	(2)	(3)	(4)
viii)	Boot and shoe factories:		
	a) Sorting and grading	1 000[3)]	19
	b) Clicking and closing, preparatory operations	700	22
	c) Cutting table and presses, stitching	1 000	22
	d) Bottom stock preparation, lasting and bottoming, finishing	700	22
	e) Shoe rooms	700	22
ix)	Breweries and distilleries:		
	a) General working areas	150	25
	b) Brewhouse, bottling and canning plants	200	25
	c) Bottle inspection	Special lighting	—
x)	Canning and preserving factories:		
	a) Inspection of beans, rice, barley, etc	450	22
	b) Preparation: kettle areas, mechanical cleaning, dicing, trimming	300	25
	c) Canned and bottled goods: retorts	200	25
	d) High speed labelling lines	300	25
	e) Can inspection	450	—
xi)	Carpet factories:		
	a) Winding, beaming	200	25
	b) Designing, Jacquard and cutting, setting pattern, tufting, topping, cutting, hemming, fringing	450	22
	c) Weaving, mending, inspection	450	22
	Ceramics — *See* pottery and clay products		
	Chemical works:		
	a) Hand furnaces, boiling tanks, stationery driers, stationery or gravity crystalizers, mechanical driers, evaporators, filtration plants, mechanical crystallising bleaching, extractors, percolators, nitrators. electrolytic cells	150	28
	b) Controls, gauges, values, etc	100	—
	Control rooms:		
	1) Vertical control panels	200-300	19
	2) Control desks	300	19
xiv)	Chocolate and confectionery factories:		
	a) Mixing, blending, boiling	150	28
	b) Chocolate husking, winnowing, fat extraction, crushing an refining, feeding, bean cleaning, sorting, milling, cream making	200	25
	c) Hand decorating, inspection, wrapping, packing	300	22

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ANNEX E (*Continued*)

Sl No.	*Industrial Buildings and Processes Illumination, lux*	*Average*	*Limiting Glare Index*
(1)	(2)	(3)	(4)
xv)	Clothing factories:		
	a) Matching-up	450[3)]	19
	b) Cutting sewing:		
	1) Light	300	22
	2) Medium	450	22
	3) Dark	700	22
	4) Pressing	300	22
	Inspection:		
	1) Light	450	19
	2) Medium	1 000	19
	3) Dark	1 500	19
	d) Hand tailoring:		
	1) Light	450	19
	2) Medium	1 000	19
	3) Dark	1 500	19
	Collieries (surface buildings):		
	Coal preparation plant:		
	1) Working areas	150	—
	2) Other areas	100	—
	3) Picking belts	300	—
	4) Winding houses	150	—
	b) Lamp rooms:		
	1) Main areas	100	—
	2) Repair sections	150	—
	3) Weigh cabine	150	—
	c) Fan houses	100	—
xvii)	Dairies:		
	a) General working areas	200[2)]	25
	b) Bottle inspection	Special lighting	—
	c) Bottle filling	450	25
xviii)	Die sinking:		
	a) General	300	—
	b) Fine	1 000	19
xix)	Dye works:		
	a) Reception, ‘grey’ perching	700	—
	b) Wet processes	150[2)]	28
	c) Dry processes	200[2)]	28
	d) Dyers’ offices	700[3)]	19
	e) Final perching	2 000[3)]	—

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ANNEX E (*Continued*)

Sl No.	*Industrial Buildings and Processes Illumination, lux*	*Average*	*Limiting Glare Index*
(1)	(2)	(3)	(4)
xx)	Electricity generating stations: Indoor locations		
	a) Turbine halls	200	25
	b) Auxiliary equipment; battery rooms, blowers auxiliary generators, switchgear and transformer chambers	100	—
	c) Boiler houses (including operating floors) platforms, coal conveyors, pulverizers, feeders, precipitators, soot and slag blowers	70-100	—
	d) Boiler house and turbine house	100	—
	e) Basements	70	—
	f) Conveyor houses, conveyor gantries, junction towers	70-100	—
	g) Control rooms:		
	1) Vertical control panels	200-300	19
	2) Control desks	300	19
	3) Rear of control panels	150	19
	4) Switch houses	150	25
	h) Nuclear reactors and steam, raising plants:		
	1) Reactor areas, boilers, galleries	150	25
	2) Gas circulator days	150	25
	3) Reactor charge/discharge face	200	25
xxi)	Electricity generating stations: Outdoor locations		
	a) Coal unloading areas	20	—
	b) Coal storage areas	20	—
	c) Conveyors	50	—
	d) Fuel oil delivery headers	50	—
	e) Oil storage tanks	50	—
	f) Catwalks	50	—
	g) Platforms, boiler and turbine decks	50	—
	h) Transformers and outdoor switchgear	100	—
xxii)	Engraving:		
	a) Hand	1 000	19
	b) Machine (*see* Die sinking)	—	—
xxiii)	Farm buildings (dairies)		
	a) Boiler houses	50	—
	b) Milk rooms	150	25
	c) Washing and sterilizing rooms	150	25
	d) Stables	50	—
	e) Milking parlours	150	25
xxiv)	Flour mills:		
	a) Roller, purifier, sifting and packing floors	150	25
	b) Wetting tables	300	25

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ANNEX E (*Continued*)

Sl No.	*Industrial Buildings and Processes Illumination, lux*	*Average*	*Limiting Glare Index*
(1)	(2)	(3)	(4)
xxv)	Forges: General	150	28
xxvi)	Foundries:		
	a) Charging floors, tumbling cleaning, pouring, shaking out, rough moulding and rough core making	150	25
	b) Fine moulding and core making, inspection	300	25
xxvii)	Garages:		
	a) Parking areas (interior)	70	28
	b) Washing and polishing, greasing, general servicing, pits	150	28
	c) Repairs	300	25
xxviii)	Gas works:		
	a) Retort houses, oil gas plants, water gas plants, purifiers, coke screening and coke handling plants (indoor)	30-50[4)]	28
	b) Governor, meter, compressor, booster and exhauster houses	100	25
	c) Open type plants:		—
	1) Catwalks	20[4)]	—
	2) Platforms	50[4)]	—
xxix)	Gauge and tool rooms: General	700[5)]	19
xxx)	Glass works and processes:		
	a) Furnace rooms, bending, annealing lehrs	100	28
	b) Mixing rooms, forming (blowing, drawing, pressing, rolling)	150	28
	c) Cutting to size, grinding, polishing, toughening	200	25
	d) Finishing (bevelling, decorating, etching, silvering)	300	22
	e) Brilliant cutting	700	19
	Inspection:		
	1) General	200	19
	2) Fine	700	19
xxxi)	Glove making:		
	a) Pressing, knitting, sorting, cutting	300	22
	b) Sewing:		
	1) Light	300	22
	2) Medium	450	22
	3) Dark	700	22
xxxii)	Hat making		
	a) Stiffening, braiding, cleaning, refining forming, sizing, pouncing, flanging, finishing ironing	150	22
	b) Sewing:		
	1) Light	300	22
	2) Medium	450	22
	3) Dark	700	22

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ANNEX E (*Continued*)

Sl No.	*Industrial Buildings and Processes Illumination, lux*	*Average*	*Limiting Glare Index*
(1)	(2)	(3)	(4)
xxxiii)	Hosiery and knitwear:		
	a) Circular and flat knitting machines universal winders, cutting out, folding and pressing	300	22
	b) Lock stitch and overlooking machines:		
	1) Light	300	22
	2) Medium	450	22
	3) Dark	700	22
	c) Mending	1 500	19
	d) Examining and hand finishing, light, medium, dark	700	19
	e) Linking or running-on	450	19
xxxiv)	Inspection shops (Engineering)		
	a) Rough work, for example, counting, rough checking of stock parts, etc.	150	28
	b) Medium work, for example, 'Go' and 'No-go' gauges, sub-assemblies	300	25
	c) Fine work, for example, radio and telecommunication equipment, calibrated scales, precision mechanisms, instruments	700	22
	d) Very fine work, for example, gauging and inspection of small intricate parts	1 500	19
	e) Minute work, for example, very small instruments	3 000[2)]	19
xxxv)	Iron and steel works		
	a) Marshalling and outdoor stockyards	10-20	—
	b) Stairs, gangways, basements, quarries, loading docks	100	—
	c) Slab yards' melting shops, ingot stripping soaking pits, blast furnace working areas, picking and cleaning lines, mechanical plants, pump houses	100	28
	d) Mould preparation, rolling and wire mills, mills motors rooms, power blower houses	150	28
	e) Slab inspection and conditioning, cold strip mills, sheet and plate finishing, tinning, galvanizing, machine and roll shops	200	28
	f) Plate inspection	300	—
	g) Tinplate inspection	Special lighting	—
xxxvi)	Jewellery and watchmaking		
	a) Fine processes	700[1)]	19
	b) Minute processes	3 000[1)]	10
	c) Gem cutting, polishing, setting	1 500[3)]	—
	Laundries and dry cleaning works		
	a) Receiving, sorting, washing, drying, ironing (calendering), despatch	200	25
	b) Dry cleaning, bulk machine work	200	25
	c) Fine hand ironing, pressing, inspection mending, spotting	300	25

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ANNEX E (*Continued*)

Sl No.	*Industrial Buildings and Processes Illumination, lux*	*Average*	*Limiting Glare Index*
(1)	(2)	(3)	(4)
xxxix)	Leather dressing		
	a) Vats, cleaning, tanning, stretching, cutting, fleshing and stuffing	150	28
	b) Finishing, staking, splitting and scrafing	200	28
xl)	Leather working		
	a) Pressing and glazing	450	22
	b) Cutting, scarfing, sewing	700	22
	c) Grading and matching	1 000[3)]	19
xli)	Machine and fitting shops		
	a) Rough bench and machine work	150	28
	b) Medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing and polishing	300	25
	c) Fine bench and machine work, fine automatic machines, medium grinding fine buffing and polishing	700	22
xlii)	Motor vehicle plants		
	a) General sub-assemblies, chassis assembly, car assembly	300	25
	b) Final inspection	450	25
	c) Trim shops, body sub-assemblies, body assembly	300	25
	d) Spray booths	450	—
xliii)	Paint works		
	a) General automatic processes	200	25
	b) Special batch mixing	450	22
	c) Colour matching	700[3)]	19
xliv)	Paint shops and spraying booths:		
	a) Dipping, firing rough spraying	150	25
	b) Rubbing, ordinary painting, spraying and finishing	300	25
	c) Fine painting, spraying and finishing	450	25
	d) Retouching and matching	700[3)]	19
xlv)	Paper-works:		
	a) Paper and board making:		
	1) Machine houses, calendering pulp mills, preparation plants, cutting, finishing, trimming	200	25
	2) Inspection and sorting (over hauling)	300	22
	b) Paper converting processes:		
	1) Corrugated board, cartons, containers and paper sack manufacture, coating and laminating processes Type foundries:	200	25
	2) Matrix making, dressing type, hand and machine casting	200	25
	3) Front assembly, sorting	450	22
	c) Printing plants:		
	1) Machine composition, imposing stones	200	25
	2) Presses	300	25

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ANNEX E (*Continued*)

Sl No.	*Industrial Buildings and Processes Illumination, lux*	*Average*	*Limiting Glare Index*
(1)	(2)	(3)	(4)
	3) Composing room	450	19
	4) Proof reading	300	19
	Electrotyping:		
	1) Block-making, electroplating, washing, backing	200	25
	2) Moulding, finishing, routing	300	25
	d) Photo-engraving:		
	1) Block-making, etching, masking	200	25
	2) Finishing, routing	300	25
	e) Colour printing: Inspection area	700[3)]	19
	l) Rubber processing:		
	a) Fabric preparation creels	200	25
	b) Dipping, moulding, compounding calendars	150	25
	c) Tyre and tube making	200	25
xlvi)	Sheet metal works:		
	a) Benchwork, scribing, pressing, punching shearing, stamping, spinning, folding	200	25
	b) Sheet inspection	Special lighting	
xlvii)	Soap factories:		
	Kettle houses and ancillaries, glycerine evaporation and distillation, continuous indoor soap making, plants:		
	1) General areas	150	25
	2) Control panels	200-300	25
	Batch or continuous soap cooling, cutting and drying, soap milling, plodding:		
	1) General areas	150	25
	2) Control panels, key equipment	200-300	25
	Soap stamping, wrapping and packing, granules making, granules storage and handling, filling and packing granules:		
	1) General areas	150	25
	2) Control panels, machines	200-300	25
	d) Edible products processing and packing	200	25
xlviii)	Structural steel fabrication plants:		
	a) General	150	28
	b) Marking off	300	28
xliv)	Textile mills (cotton or linen):		
	Bale breaking, blowing, carding, roving, slubbing, spinning		
	a) (ordinary counts), winding, heckling, spreading, cabling	150	25
	b) Warping, slashing, dressing and dyeing, doubling (fancy), spinning (fine counts)	200	25
	c) Healding (drawing-in)	700	—

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ANNEX E (*Continued*)

Sl No.	*Industrial Buildings and Processes Illumination, lux*	*Average*	*Limiting Glare Index*
(1)	(2)	(3)	(4)
	d) Weaving:		
	1) Patterned cloths, fine counts dark	700	19
	2) Patterned cloths, fine counts light	300	19
	3) Plain 'grey' cloth	200	19
	e) Cloth inspection	700[1)]	—
lv)	Textile mills (silk or synthetics):		
	a) Soaking, fugitive tinting, conditioning or setting of twist	200	25
	b) Spinning	450	25
	Winding, twisting, rewinding and coning, quality slashing:		
	1) Light thread	200	25
	2) Dark thread	300	25
	d) Warping	300	25
	e) Healding (drawing-in)	700	—
	f) Weaving	700	19
	g) Inspection	1 000[3)]	19
lvi)	Textile mills (woollen):		
	a) Scouring, carbonizing, teasing, preparing, raising, brushing, pressing, back-washing, gilling, crabbing and blowing	150	25
	b) Blending, carding, combing (white), tentering, drying, cropping	200	25
	c) Spinning, roving, winding, warping, combing (coloured), twisting	450	25
	d) Healding (drawing-in)	700	—
	Weaving:		
	1) Fine worsteds	700	19
	2) Medium worsteds, fine woollens	450	19
	3) Heavy woollens	300	19
	f) Burling and mending	700	19
	g) Perching:		
	1) Grey	700	—
	2) Final	2 000[3)]	—
xlvii)	Textile mills (jute):		
	a) Weaving, spinning, flat, jacquard carpet looms, cop winding	200	25
	b) Yarn calender	150	25
xlviii)	Tobacco factories: All processes	300[3)]	22
lix)	Upholstering, furniture and vehicles	300	22
lx)	Warehouses and bulk stores:		
	a) Large material, loading bays	100	28
	b) Small material, racks	150	25
	c) Packing and despatch	150	25

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ANNEX E (*Concluded*)

Sl No.	*Industrial Buildings and Processes Illumination, lux*	*Average*	*Limiting Glare Index*
(1)	(2)	(3)	(4)
lxi)	Welding and soldering:		
	a) Gas and arc welding, rough spot welding	150	28
	b) Medium soldering, brazing and spot welding, for example, domestic hardware	300	25
	c) Fine soldering and spot welding, for example, instruments, radio set assembly	700	22
	d) Very fine soldering and spot welding, for example, radio valves	150	19
lxii)	Woodworking shops:		
	a) Rough sawing and bench work	150	22
	b) Sizing, planning, rough sanding, medium machine, and bench work, gluing, veneering, cooperage	200	22
	c) Fine bench and machine work, fine sanding and finishing	300	22
	[1] Optical aids should be used where necessary.		
	[2] Supplementary local lighting may be required for gauge glasses and instrument panels. Special attention should be paid to the colour quality of the light.		
	[3] Supplementary local lighting should be used at important points.		
	[4] Supplementary local lighting and optical aids should be used where necessary.		

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ANNEX F

(*Clause* 11.3)

POWER FACTOR IN INDUSTRIAL INSTALLATIONS

F-1 The general guidelines for power factor compensation is given in Part 1/Sec 20 of the Code. For guidance, the natural power factor for some three-phase electrical installations are given in Table 4. The recommended capacitor ratings at rated voltage, for direct connection to ac induction motor in industries are given in Table 5.

Table 4 Power Factor for Three Phase Electrical Installations

(*Clause* F-1)

Sl No.	Type of Installation	Natural Power Factor
(1)	(2)	(3)
i)	Cold storage and fisheries	0.76-0.80
ii)	Cinemas	0.78-0.80
iii)	Metal pressing	0.57-0.72
iv)	Confectionery	0.77
v)	Dyeing and printing (textile)	0.60-0.87
vi)	Plastic moulding	0.57-0.73
vii)	Film studios	0.65 to 0.74
viii)	Newspapers	0.58
ix)	Heavy engineering works	0.48-0.75
x)	Rubber extrusion and moulding	0.48
xi)	Pharmaceuticals	0.75-0.86
xii)	Oil and paint manufacturing	0.51-0.69
xiii)	Silk mills	0.58-0.68
xiv)	Biscuit factory	0.60
xv)	Printing press	0.65-0.75
xvi)	Food products	0.63
xvii)	Laundries	0.92
xviii)	Flour mills	0.61
xix)	Gas works	0.87
xx)	Textile mills	0.86
xxi)	Oil mills	0.51-0.59
xxii)	Woolen mills	0.70
xxiii)	Potteries	0.61
xxiv)	Cigarette manufacturing	0.80
xxv)	Cotton press	0.63-0.68
xxvi)	Foundries	0.59
xxvii)	Tiles and mosaic	0.61
xxviii)	Structural engineering	0.53-0.68
xxix)	Chemicals	0.72-0.87
xxx)	Municipal pumping stations	0.65-0.75
xxxi)	Oil terminals	0.64-0.83
xxxii)	Telephone exchange	0.66-0.80
xxxiii)	Rolling mills	0.72-0.60
xxxiv)	Irrigation pumps	0.52-0.70

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Table 5 Capacitor Ratings at Rated Voltage

(*Clause* F-1)

Rated Output of Motors kW	Capacitor Rating in kVAR for Motor Speed					
	3 000 rev/min	1 500 rev/min	1 000 rev/min	750 rev/min	600 rev/min	500 rev/min
(1)	(2)	(3)	(4)	(5)	(6)	(7)
2.25	1	1	1.5	2	2.5	2.5
3.7	2	2	2.5	3.5	4	4
5.7	2.5	3	3.5	4.5	5	5.5
7.5	3	4	4.5	5.5	6	6.5
11.2	4	5	6	7.5	8.5	9
15	5	6	7	9	11	12
18.7	6	7	9	10.5	13	14.5
22.5	7	8	10	12	15	17
37	11	12.5	16	18	23	25
57	16	17	21	23	29	32
75	21	23	26	28	35	40
102	31	33	36	38	48	55
150	40	42	45	47	60	67
187	46	50	53	55	68	76

NOTES

1 The reference to speed of motor has been made since the manufacturers provide information on that basis.

2 The capacitive current supplied by condensers directly across induction motor terminals should not exceed the magnetizing current of the induction motors, to guard against excess transient torques and over-voltages.

3 Should a consumer desire to improve the power factor beyond a value which is limited by considerations of magnetizing kVAR of the motor as stated in Note 2, then he may install the calculated capacitor kVAR as a separate circuit with its independent control-gear.

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PART 5 OUTDOOR INSTALLATIONS

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PART 5 OUTDOOR INSTALLATIONS

FOREWORD

As compared to the various types of indoor installations covered in other Parts of this Code, outdoor installations are distinct in nature by virtue of their being exposed to moderate to heavy environmental conditions. In addition, electric power in outdoor installations is normally utilized for specific purposes, such as lighting or for meeting the needs of heavy machinery (for example, open cast mines). In the case of the latter, the duties would be more onerous than those normally encountered in indoor situations, thereby calling for special considerations in their design.

Keeping the above in view, Part 5 of this Code deals with installations erected outdoor. Some outdoor installations are erected to serve for a small duration of time after which they are meant to be dismantled. Such installations are called temporary installation. For convenience, and keeping other aspects of safety provisions in view, this duration is defined as not exceeding six months. Permanent outdoor installations are those which are generally in use for longer periods of time. This Part 5 of this Code basically deals with these two types of outdoor installations.

Part 5 consists of the following sections:

Section 1 Public Lighting Installations

Section 2 Temporary Outdoor Installations

Section 3 Permanent Outdoor Installations

Even though installations for lighting of public thoroughfares are permanent in nature, they are dealt with separately in Section 1.

It may, however, be noted that small outdoor locations around building installations (for example, gardens around hotel installations or storage yards in industries) do not fall under the scope of Part 5. For requirements, pertaining to this, reference should be made to relevant parts of this Code.

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SECTION 1 PUBLIC LIGHTING INSTALLATIONS

FOREWORD

One of the most common forms of permanent outdoor installations is the public lighting installations intended for lighting of public thoroughfares. With the availability of variety of light sources for such installations and the need for proper illumination of a variety of traffic routes and city centres, it has been found necessary to lay down guidelines for designing on efficient and economical lighting installation. This Section of this Code is intended to cover general principles governing the lighting of public thoroughfares and to lay down recommendations on the quantity and quality of lighting to be provided. The actual details of design would entirely depend on the local circumstances.

The requirements given in this Section are, as far as, practicably aligned with the recommendations of the International Commission on Illumination (CIE) modified to suit the local conditions and regulations.

1 SCOPE

1.1 This Section of the Code (Part 5/Sec 1) covers requirements of public lighting installations to provide guidance to those concerned with the preparation of public lighting schemes, their installation and maintenance (*see* also SP 72).

1.2 This Section deals only with electric lighting sources and does not include gas or other types of lighting.

1.3 This Section also does not cover exterior lighting installations, such as those which apply for parks, shopping enclaves, flood lighting of routes and structures of architectural importance, etc.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No.	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
SP 72 : 2010	National Lighting Code
1885 (Part 16/Sec 2) : 1968	Electrotechnical vocabulary: Part 16 Lighting, Section 2 General illumination lighting fittings and lighting for traffic and signalling
1944 (Parts 1 and 2) : 1970	Code of practice for lighting of public thorough fares:
	Part 1 General principles
	Part 2 Lighting for traffic routes (Groups A1, A2, B1 and B2) (*first revision*)
1944 (Part 5) : 1981	Code of practice for lighting of public thoroughfares: Part 5 Lighting of grade separated junctions, bridges, and elevated road (Group D)
1944 (Part 6) : 1981	Code of practice for lighting of public thoroughfares: Part 6 Lighting for town and city centres and areas of civic importance (Group E)

3 TERMINOLOGY

For the purpose of this Section, the following terms together with those provided in IS 1885 (Part 16/Sec 2) shall apply.

3.1 Terms Relating to Highways

3.1.1 *Highway* — A way for the passage of vehicular traffic over which such traffic may lawfully pass.

3.1.2 *Layout* — All those physical features of a high way other than the surfacing of the carriage way, which must be considered in planning a lighting installation.

3.1.3 *Carriageway* — That portion of a highway intended primarily for vehicular traffic.

3.1.4 *Dual Carriageway* — A layout of the separated carriageways, each reserved for traffic in one direction only.

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3.1.5 *Central Reserve* — A longitudinal space dividing a dual carriageway.

3.1.6 *Service Road* — A subsidiary road between principle road and buildings or properties facing thereon or a parallel road to the principal road and giving access to the premises and connected only at selected points with the principle road.

3.1.7 *Cycle Track* — A way or part of a highway for use by pedal cycles only.

3.1.8 *Footway* — That portion of a road reserved exclusively for pedestrians.

3.1.9 *Verge* — The unpaved area flanking a carriageway, forming part of the highway and substantially at the same level as the carriageway.

3.1.10 *Shoulder* — A strip of highway adjacent to and level with the main carriageway to provide an opportunity for vehicles to leave the carriageway in an emergency.

3.1.11 *Refuge* — A raised platform or a guarded area so sited in the carriageway as to divide the streams of traffic and to provide a safety area for pedestrians.

3.1.12 *Kerb* — A border of stone, concrete or other rigid material formed at the edge of a carriageway.

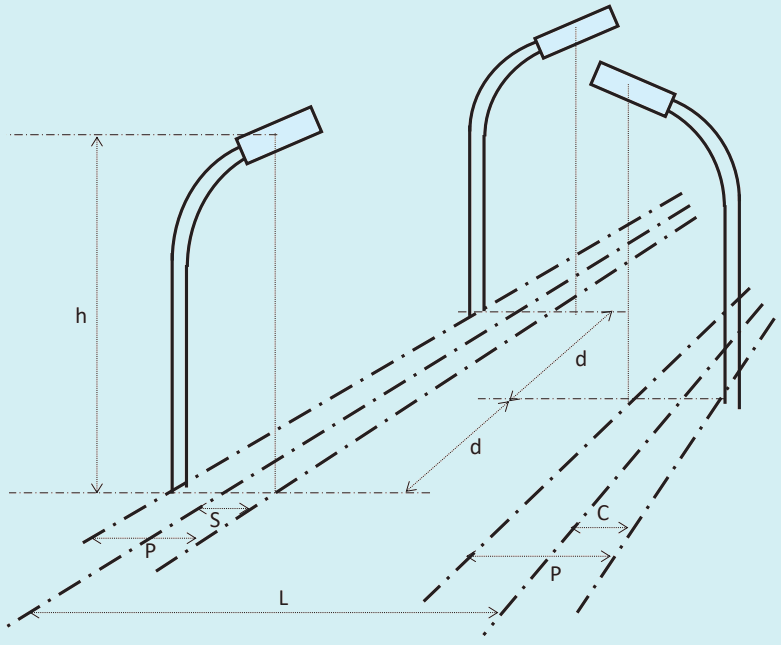
3.2 Terms Relating to Lighting Installation

3.2.1 *Lighting Installation* — The whole of the equipment provided for lighting the highway comprising the lamps, luminaires, means of support and electrical and other auxiliaries.

3.2.2 *Lighting System* — An array of luminaires having a characteristic light distribution sited in a manner concordant with this distribution (lighting systems are commonly designated by the name of the characteristic light distribution, for example, cut-off, semi-cut-off, etc.).

3.2.3 *Luminaire* — A housing for one or more lamps, comprising a body and any refractor, reflector, diffuser, or enclosure associated with the lamp(s).

3.2.4 *Outreach* — The distance measured horizontally between the centre of the column or wall face and the centre of a luminaire (*see* Fig. 1).



Key

p = outreach, h = mounting height of luminaires, s = overhang, L = width of the carriage way d – Spacing, c = clearance

FIG. 1 SITING OF LUMINAIRES CHARACTERISTIC DIMENSIONS

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3.2.5 *Overhang* — The distance measured horizontally between the centre of a luminaire mounted on a bracket and the adjacent edge of the carriageway (*see* Fig. 1).

3.2.6 *Mounting Height* — The vertical distance between the centre of the luminaire and the surface of the carriage (*see* Fig. 1).

3.2.7 *Spacing* — The distance, measured along the centre line of the carriageway, between successive luminaires in an installation (*see* Fig. 1).

NOTE — In a staggered arrangement, the distance is measured, along the centre line of the carriageway, between a luminaire on one side of the carriageway and the next luminaire, which is on the other side of the carriage. It is not the distance measured on the diagonal joining them, nor the distance between successive luminaires on the same side of the carriageway.

3.2.8 *Span* — That part of the highway lying between successive luminaires in an installation.

3.2.9 *Width of Carriageway* — The distance between kerb lines measured at right angles to the length of the carriage way (*see* Fig. 1).

3.2.10 *Arrangement* — The pattern according to which luminaires are sited on plan, for example, staggered, axial, opposite.

3.2.11 *Geometry* (*of a Lighting System*) — The inter related linear dimensions and characteristics of the system, namely the spacing, mounting height, width, overhang and arrangement.

3.3 Photometric Terms

3.3.1 *Luminous Flux* — The light given by a light source or a luminaire or received by a surface irrespective of the directions in which it is distributed. The unit of the luminous flux is lumen (l m).

3.3.2 *Lower Hemispherical Flux or Downward Flux* — The luminous flux emitted by a luminaire in all directions below the horizontal.

3.3.3 *Luminous Intensity* — The quantity which describes the light-giving power of a luminaire in any direction. The unit of luminous intensity is Candela (cd).

3.3.4 *Illumination* — The luminous flux incident on a surface per unit area. The unit of illumination is lumen per square metre (lux).

3.3.5 *Luminance* (*at a Point of Surface and in a Given Direction*) — The luminous intensity per unit projected area of a surface. If a very small portion of a surface has an intensity *I* in a particular direction and its orthogonal projection (that is, its projection on a plane perpendicular to the given direction) has an area *D*, the luminance in this direction is *I/D* candelas per unit area. The usual unit is candela per square metre (cd/m^2).

3.3.6 *Luminosity* — The attribute of visual sensation according to which an area appears to emit more or less light. It is sometimes called brightness.

NOTE — Luminosity is the visual sensation which correlates approximately with the photometric quantity ‘luminance’.

3.3.7 *Light Output* — The luminous flux emitted by a luminaire.

3.3.8 *Light Distribution* — The distribution of luminous intensity from a luminaire in various directions in space.

3.3.9 *Symmetrical* (*Converse Asymmetrical*) *Distribution* — A distribution of luminous intensity which is substantially symmetrical (conversely asymmetrical) about the vertical axis of the luminaire.

3.3.10 *Axial* (*Converse Non-axial*) *Distribution* — An asymmetrical distribution in which the directions of maximum luminous intensity lie (do not lie) in vertical planes substantially parallel to the axis of the carriageway.

3.3.11 *Peak Intensity Ratio* — The ratio of the maximum intensity to the mean hemispherical intensity of the light emitted below the horizontal.

3.3.12 *Mean Hemispherical Intensity* — The downward flux divided by 6.28 (2π) (this is the average intensity in the lower hemisphere).

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3.3.13 *Intensity Ratio* (*in a Particular Direction*) — The ratio of an actual intensity from the luminaire (in a particular direction) to the mean hemispherical intensity.

3.3.14 *Beam* — The portion of the light output of the luminaire contained by the solid angle subtended at the effective centre of the luminaire containing the maximum intensity, but no intensity less than 90 percent of the maximum intensity.

3.3.15 *Beam Centre* — A direction midway between the directions for which the intensity is 90 percent of the maximum in a vertical plane through the maximum and on a conical surface through the maximum.

3.3.16 *Isocandela Curve* — A curve traced on an imaginary sphere with a source at its centre and joining all the points corresponding to those directions in which the luminous intensity is the same or a plane projection of this curve.

3.3.17 *Isocandela Diagram* — An array of Isocandela curves.

3.3.18 *Polar Curve* — Curve of light distribution using polar co-ordinates.

3.4 Terms Relating to Luminaires

3.4.1 *Street Lighting Luminaire* — A housing for a light source or sources, together with any refractor, reflector, dispersive surround or other enclosure which may be associated with the source in order to modify the light distribution in a desired manner and protect the light from weather conditions and insects and/or for the sake of appearance, brightness and other lighting characteristic the source.

3.4.2 *Cut-off Luminaire* — Luminaire employing the technique used for concealing lamps and surfaces of high luminance from direct view in order to reduce glare.

3.4.3 *Semi-cut-off Luminaire* — Luminaire employing the technique for concealing lamps and surfaces of high luminance from direct view in order to reduce glare but to a lesser degree than cut-off luminaire.

3.4.4 *Integral Luminaire* — Luminaire with all its accessories, such as ballasts, starters, igniters, capacitors, etc. However, integrally with the body of the luminaire.

3.4.5 *Post Top Luminaire* — Luminaire with arrangement for mounting the same symmetrically on the top of the column.

4 CLASSIFICATION

Ideally, both from the points of view of traffic safety and comfort, a high standard of lighting is advisable on all roads. The system of lighting, from good engineering point of view as well as economy should take into account all the relevant factors, such as the presence of factories, places of public resort, character of the street (whether a shopping area or a ring-road in non-built-up area), aesthetic considerations, the properties of the carriageway surface, the existence of lumps, bends or long straight stretches and over hanging trees, probable particle contamination in air due to road ambient conditions effecting out of smoke/smog/fog/vehicle exhaust.

4.1 The classification of lighting installations in public thorough fares given in **4.2** is based on volume, speed and composition of the traffic using them. It is left to the local engineer to decide upon the category of the lighting for the given road. Further, amplification of the types of thoroughfares can be had from Annex A, wherein description of terms is given for guidance.

4.2 Types of Roads

For the purposes of this Section, roads are classified as given in Table 1.

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Table 1 Road Classification

(*Clause* 4.2)

Sl No.	Group [as in IS : 1944 (Part 1 and 2)]	Description
(1)	(2)	(3)
i)	A	Main Roads.
	A1	Very important routes with rapid and dense traffic where safety, speed of traffic and comfort to drivers are the only consideration.
	A2	Other main roads with considerable mixed traffic like main city streets, arterial roads, etc.
ii)	B	Secondary roads — Roads which do not require lighting up to Group A standard.
	B1	Secondary roads of considerable traffic such as principal local traffic routes, shopping streets, etc.
	B2	Secondary roads with comparatively light traffic.
iii)	C	Residential and unclassified roads. These are roads not included in Groups A and B.
iv)	D	Grade separated junctions, bridges, and elevated roads (*see* Note 2).
v)	E	Town and city centers and areas of civic importance (*see* Note 2).
vi)	F	Roads with special requirements (*see* Note 3).
vii)	G	Tunnels (roads underground).

NOTES

1 For the purposes of lighting installations, bridges are classified short or long when their lengths are less than or greater than 60 m.

2 Such areas are set apart since their standard of lighting is different from and higher than that described for other groups. Group E also includes important shopping streets, boulevards, promenades, and such other places which are the focus of special activities after dark.

3 Group F includes roads in the vicinity of aerodromes, railways, docks, and navigable waterways; where special lighting requirements are to be met in addition to compliance with general principles.

5 GENERAL PRINCIPLES

5.1 Aims of Public Lighting Installations

5.1.1 *Main Roads*

The aim of public lighting along main roads, bridges and flyovers (Groups A, B and D) is to permit users of the roads at night to move about with greatest possible safety and comfort so that the traffic capacity of the road at night is as much equal to that planned for daytime as possible. Towards this, end consideration has to be given designing the lighting on road junctions and pedestrian crossings so that these can be easily identified by the drivers.

5.1.2 *Roads in Residential Areas*

The principle aim of public lighting along roads in residential areas (Group C) is to provide light along the stretch of carriage way and footpath for safety and comfort of road users mainly the pedestrians; consideration has to be given to ensure that the lighting is soft and does not cause glare.

5.1.3 *Roads in City Centres*

The main consideration while designing the lighting in city centres (Group E) is proper illumination of footpaths for pedestrians, besides the comfort of the drivers. Also, care is required to easily identify flow of traffic and road dividers, islands, roundabouts, etc.

5.1.4 *Roads with Special Requirements (Group F)*

Separate considerations are required to be given for each of the following:

a) *Airports*

The main consideration in designing lighting of roads in the vicinity of airports is to ensure that under no circumstances, would a pilot mistake the stretch of the road as airport landing strip/runway/taxiway on airport

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at night time. Also the pattern of luminaire siting and colour of light source should no way resemble/match the runway. Also, the lamps should not cause glare to the pilot either while taking off or more specifically while landing, which may interfere with his/her judgement.

b) *Railways and docks*

The driver of the railway is required to observe a number of signal should the tracks in the course of his work. It is necessary that none of the street lamps either glare to the driver or is mistaken by the driver for track signals due to/form/shape/colour of the light. Similar considerations are applicable to navigators in the vicinity of docks.

5.2 Principles of Vision in Public Lighting

Though public lighting has to satisfy both drivers and pedestrians, it is in practice requirements of the drivers which are more stringent. The following principles are considered essential [*see* also IS 1944 (Parts 1 and 2)].

5.2.1 *Requirements of Drivers*

These are as follows:

a) Visibility of the whole of the road and its details, such as entry of side-roads, intersecting roads traffic signs, etc.;
b) Visual guidance on the alignment of the road;
c) Clear visibility of objects in time;
d) Good seeing condition by silhouette vision;
e) Continuity and uniformity of lighting; and
f) General or special lighting of signs.

5.2.2 *Visual Field of the Driver*

The visual field of the driver comprises, in order of decreasing importance:

a) The carriageway;
b) The surrounds around /along the road, including signs; and
c) The sky, including the bright luminaires.

5.2.3 *Visibility*

The phenomenon of visibility is directly related to contrast. Good contrast should always be produced:

a) Between the carriageway and all objects which indicate its boundaries; and
b) Between any obstacles which may be present and the background against which it appears; since the characteristics of the obstacles may vary over a very wide range, any factor which tends to increase contrast should be exploited.

5.2.4 *Glare and Visual Comfort*

Glare in public lighting is generally caused by the luminaires. Other factors that can lead to glare are presence of undesirable large surface of high reflection factor, specular surfaces, excessively bright shop windows, advertisement signs or road direction signs.

5.3 Criteria of Quality

The following four factors contribute to the fundamental criteria of quality of public lighting:

a) Level of luminance,
b) Uniformity of luminance,
c) Limitation of glare,
d) Optical guidance, and
e) Atmospheric pollution due to season/traffic.

5.3.1 *Level of Luminance*

The level of luminance should be adequate to provide visibility which guarantee for the user a maximum of safety and sufficient visual comfort. It is obvious that it is the road surface luminance rather than the illumination level which provides for an accurate measure of the effective light in a street lighting installation. However, with

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the present state of technique and the knowledge of reflection properties of road surfaces, the calculation and measurement of luminance are likely to present difficulties. Reference may be made to **8.2** regarding illumination values to be provided on the road surfaces.

5.3.2 *Uniformity of Luminance*

This provides visual comfort for the driver.

5.3.3 *Limitation of Glare*

It is required to control the glare caused due to luminaires at a value which keeps the visual discomfort below an acceptable level.

5.3.4 *Visual Guidance*

A good visual guidance is required especially in long stretches of the road and even more on complicated intersections, roundabouts, etc. Most of the long-range guidance is offered by the luminaires.

6 DESIGN

6.1 Lighting Layout of Roads

The design, spacing and column heights are governed by the road-width and the classification of the roads. Typical layouts for various road width are given in Table 2. (*See* also Fig. 2.)

Table 2 Classification of Roads and Recommended Arrangement of Columns

(*Clause* 6.1)

Sl No.	Width of Carriage Way (*m*)	Group	Arrangement as in Fig.	Column Height *H (m)*	Spacing *S*
(1)	(2)	(3)	(4)	(5)	(6)
i)	24	A1	2F	9-14	2.5-3.0 *H*
ii)		A2	2E	9	2.5 *H*
iii)	18-20	A1	2D	9-14	2.5-3.0 *H*
iv)			2C	9	2.5 *H*
v)		A2	2D	9	2.5 *H*
vi)			2C	9	2.5 *H*
vii)		B1	2C	9	3.0 *H*
viii)	12	A2	2C	9	2.5 *H*
ix)		B1	2C	9	3.0 *H*
x)		B2	2B	9	3.0 *H*
xi)		C	2B	9	2.0 *H*
xii)	9	B2	2B	9	3.0 *H*
xiii)		C	2B	7	3.5 *H*
xiv)	6	C	2A	7	3.5 *H*

6.2 Lighting Layout of Flyovers

The design and column heights on flyovers are governed by the layout of flyovers, height above normal ground level and the width of the low-level roads. The spacing may be governed by the structural design of the flyovers. The layout of typical flyovers is given in Fig. 3A to 3D.

6.2.1 The layout with recommended arrangements, column heights and spacing for various road widths on flyover are given in the Table 3.

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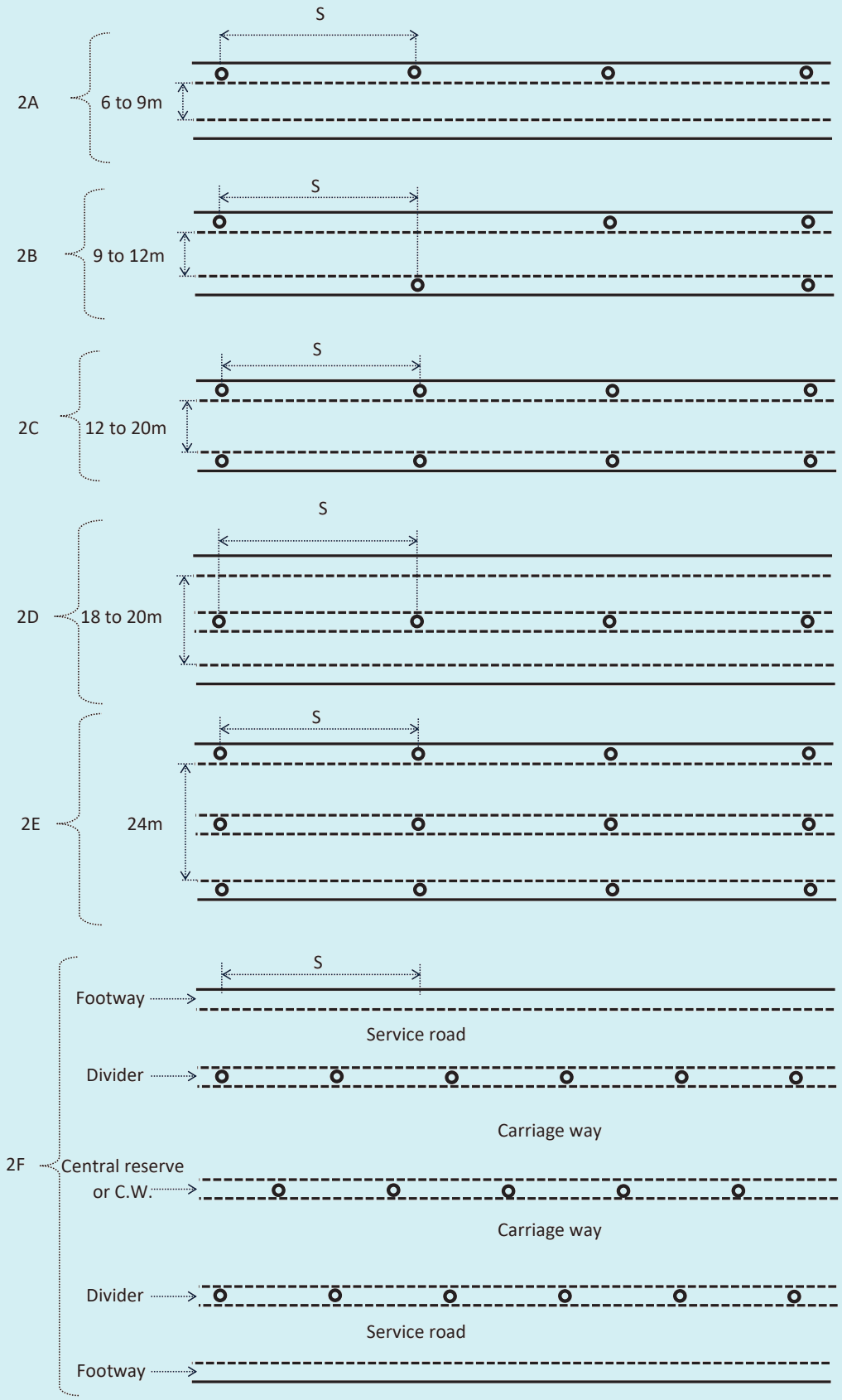
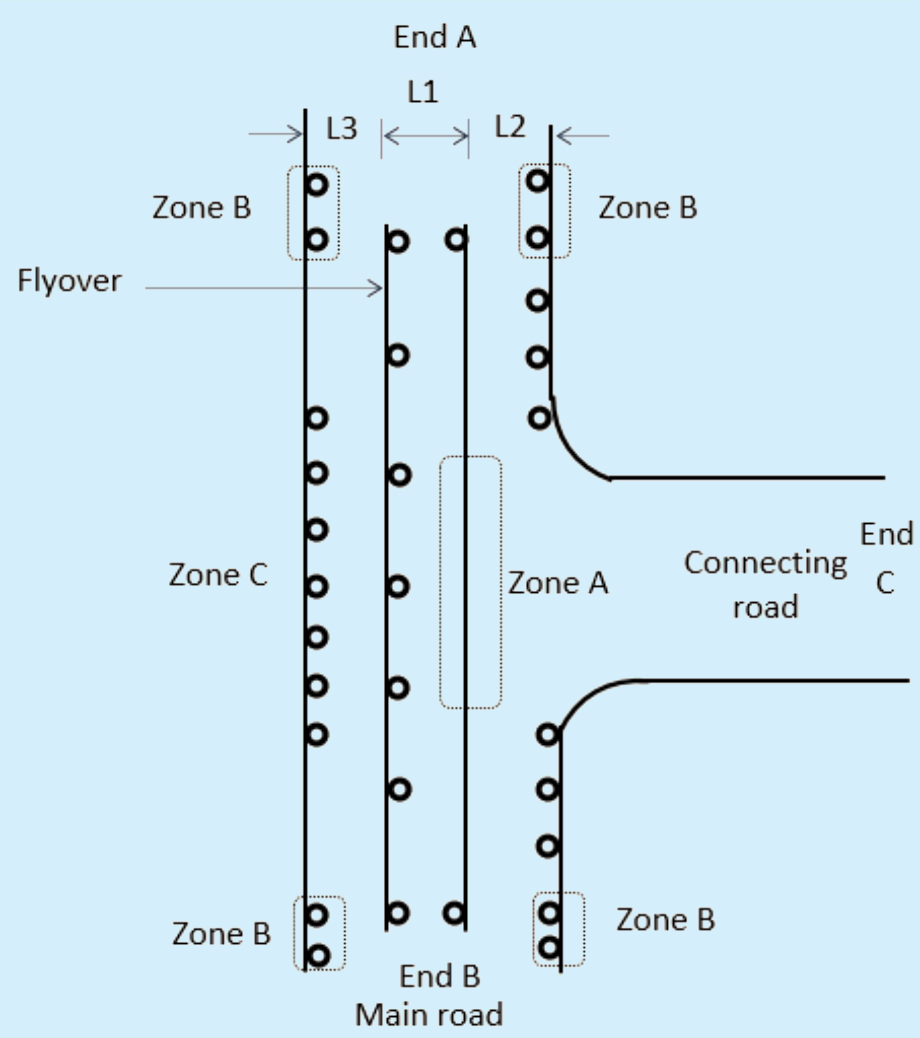


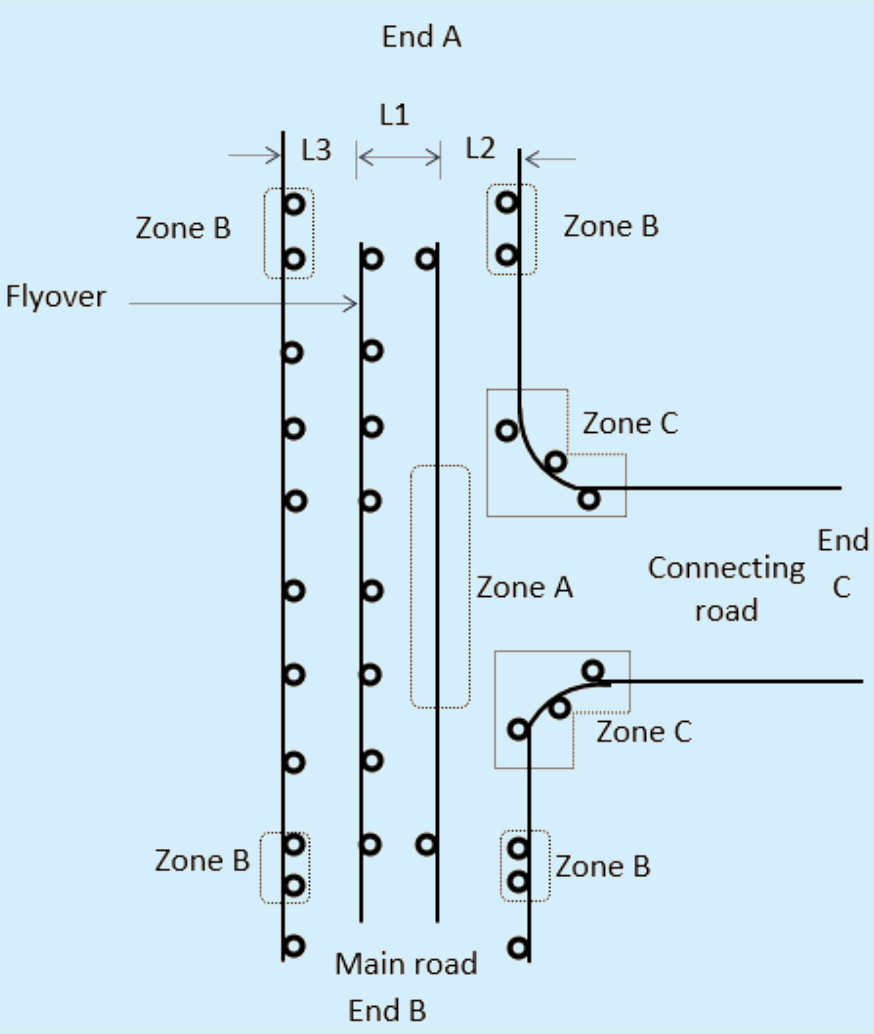
FIG. 2 STANDARD LAYOUTS FOR ROADS (SIX ALTERNATIVES)

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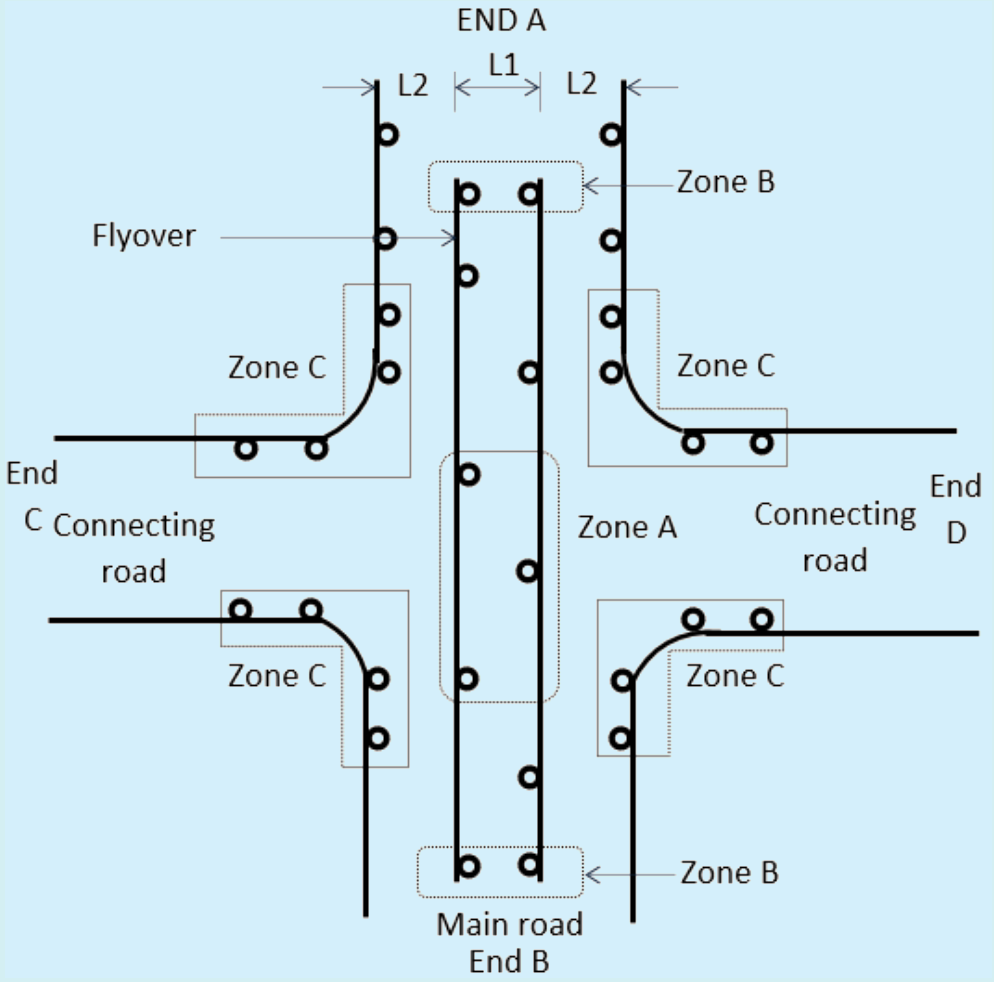
3A

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3B

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3C

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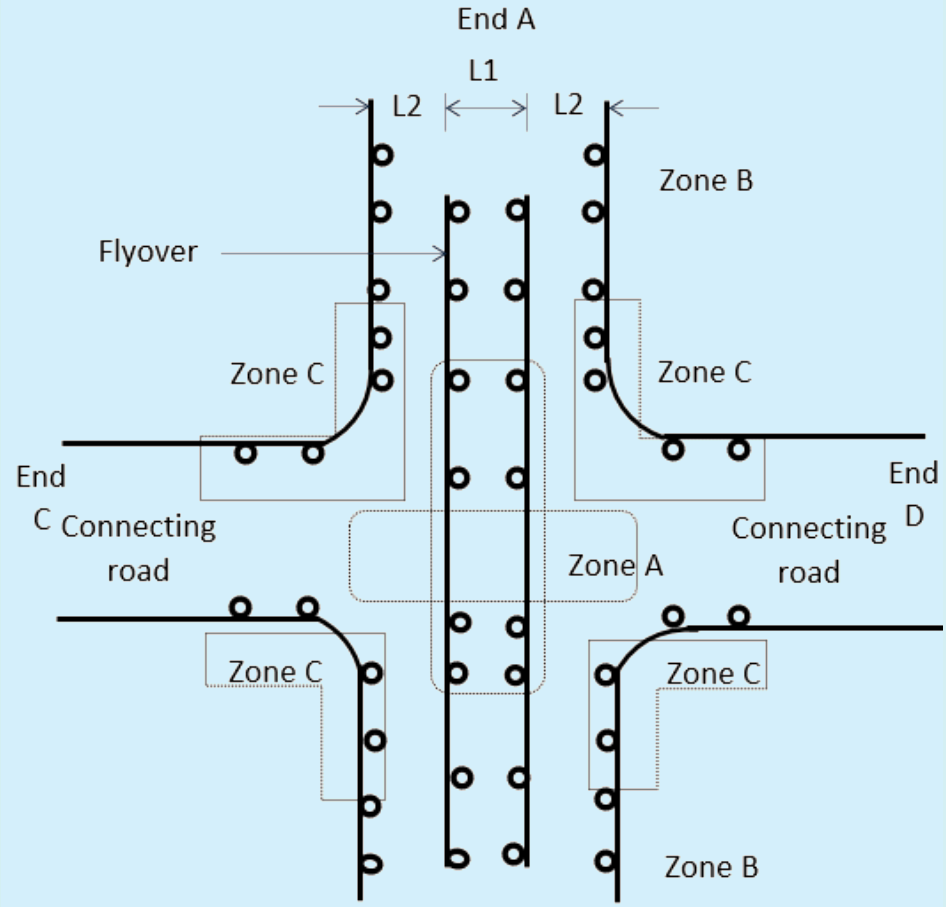


FIG. 3 STANDARD LAYOUTS FOR FLYOVERS (FOUR ALTERNATIVES)

Table 3 Recommended Arrangement of Columns on Flyovers

(*Clause* 6.2.1)

Sl No.	Width of Carriage Way (*m*)	Group	Arrangement as in Fig.	ColumnHeight $H^{1)}$ *(m)*	Spacing *S*
(1)	(2)	(3)	(4)	(5)	(6)
i)	12	D	3C	9	2-2.5 *H*
ii)		D	3B	9	2 *H*
iii)	9	D	3A	9	2 *H*

[1)] Above the flyover road level.

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6.2.2 The layouts with recommended arrangements, column heights and spacing for various road widths of low-level road are given in Table 4.

Table 4 Recommended Arrangement of Columns on Flyovers (Low Level Roads)

(*Clause* 6.2.2)

Sl No.	Width of Carriage Way (*m*)	Group	Arrangement as in Fig.	Column Height $H^{1)}$ (*m*)	Spacing *S*
(1)	(2)	(3)	(4)	(5)	(6)
i)	Over 20	D	3C	9	2.5 *H*
ii)	10 - 20	D	3D	14	1.5 *H*
iii)	Upto 10	D	3A	9	2.5 *H*

[1)] Above low-level road

6.3 Junctions

Spacing of columns at the junction should be 50 to 75 percent of the normal spacing of columns on the main roads. These columns may be installed on the traffic islands located at the junctions.

6.3.1 The level of illumination at the junction should be substantially higher than the nearby roads. The junctions may be lighted by either of the following methods:

a) *Higher level of illumination* — In case this scheme is adopted, the level of illuminations should be 150 percent of that of the roads.

b) *Change in height of columns* — The size of columns adopted at the junction should be higher than those adopted on roads. Recommended sizes are given in Table 5.

c) *Change in the colour of the light source* — In case the main road and the junction is lit by LED lamp then colour of light of these locations should differ from each other.

Table 5 Recommended Variation in Height of Columns of Junctions

[*Clause* 6.3.1 (b)]

Sl No.	Height of Columns on Roads	Recommended Height of Columns at Junctions
(1)	(2)	(3)
i)	7	9
ii)	9	14
iii)	14	High mast

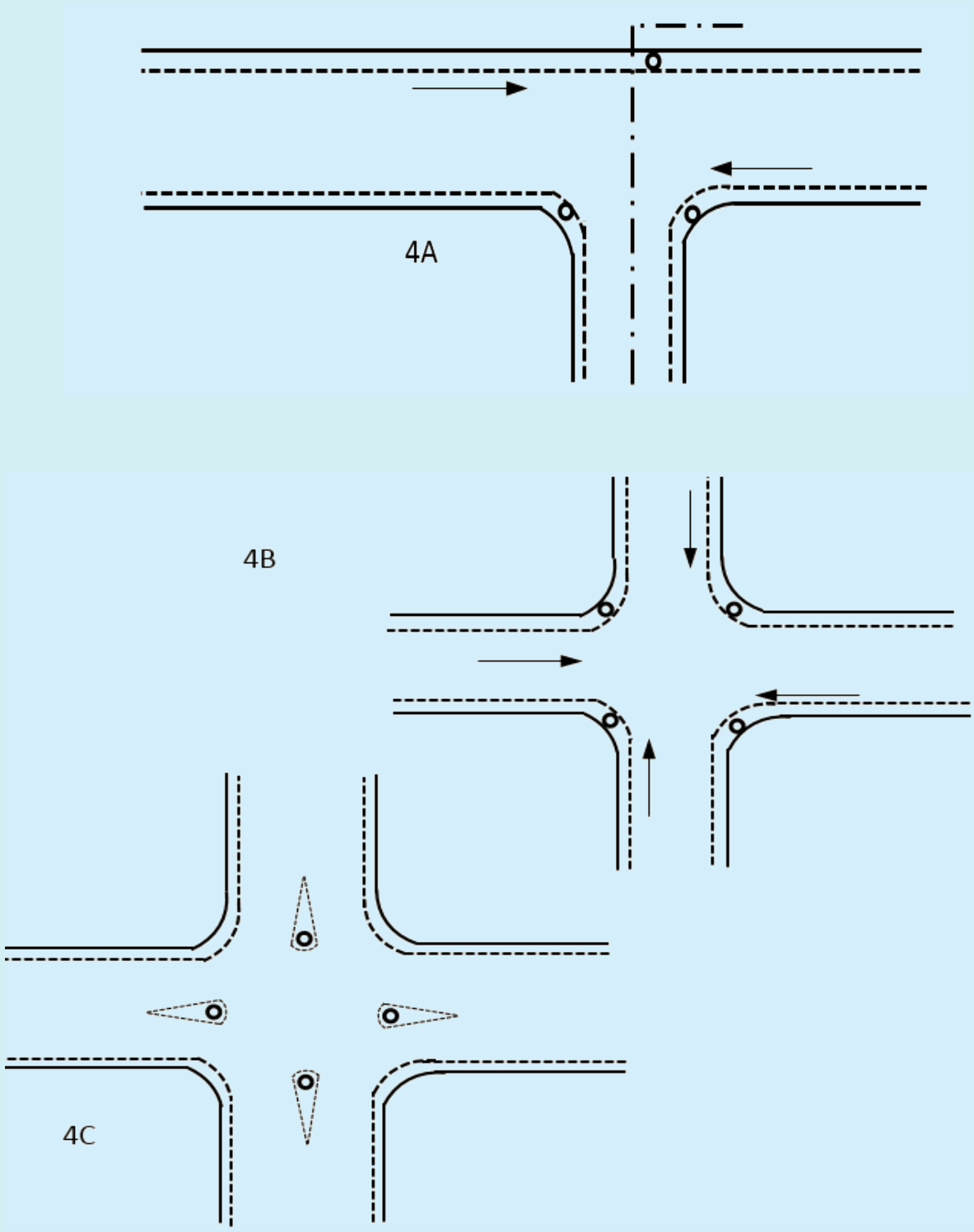
6.3.2 The different types of junctions commonly encountered are discussed below in details as they require special consideration:

a) *Simple two road junction* — This type of junction should be illuminated by locating the columns in such configuration that the junction is noticed by fast moving traffic from considerably far away distance in order to manoeuvre the vehicle better. The design would depend upon existence of traffic islands at the junctions. Typical layouts of such junctions are shown in Fig. 4A to Fig. 4C.

b) *Junction of two major roads* — These junctions would generally be provided with traffic island at suitable locations to regulate flow of traffic. The lighting columns could be located in the islands to advantage. However, if the junctions are too wide or the islands do not permit planting of poles within the desired spacing, special considerations are required. Typical layouts of such junctions are shown in Fig. 5A to 5C.

c) *Multiple road junctions* — The lighting of multiple road junction would depend upon the geographical layout of the roads, the width of the various roads and most important, the traffic conditions. At such junctions invariably entry for traffic may not be permitted on all the roads. Similarly, the traffic islands design would change from location to location. Special consideration will have to be given to the design of lighting of such junction. Typical layouts of such junctions are shown in Fig. 6A to 6D.

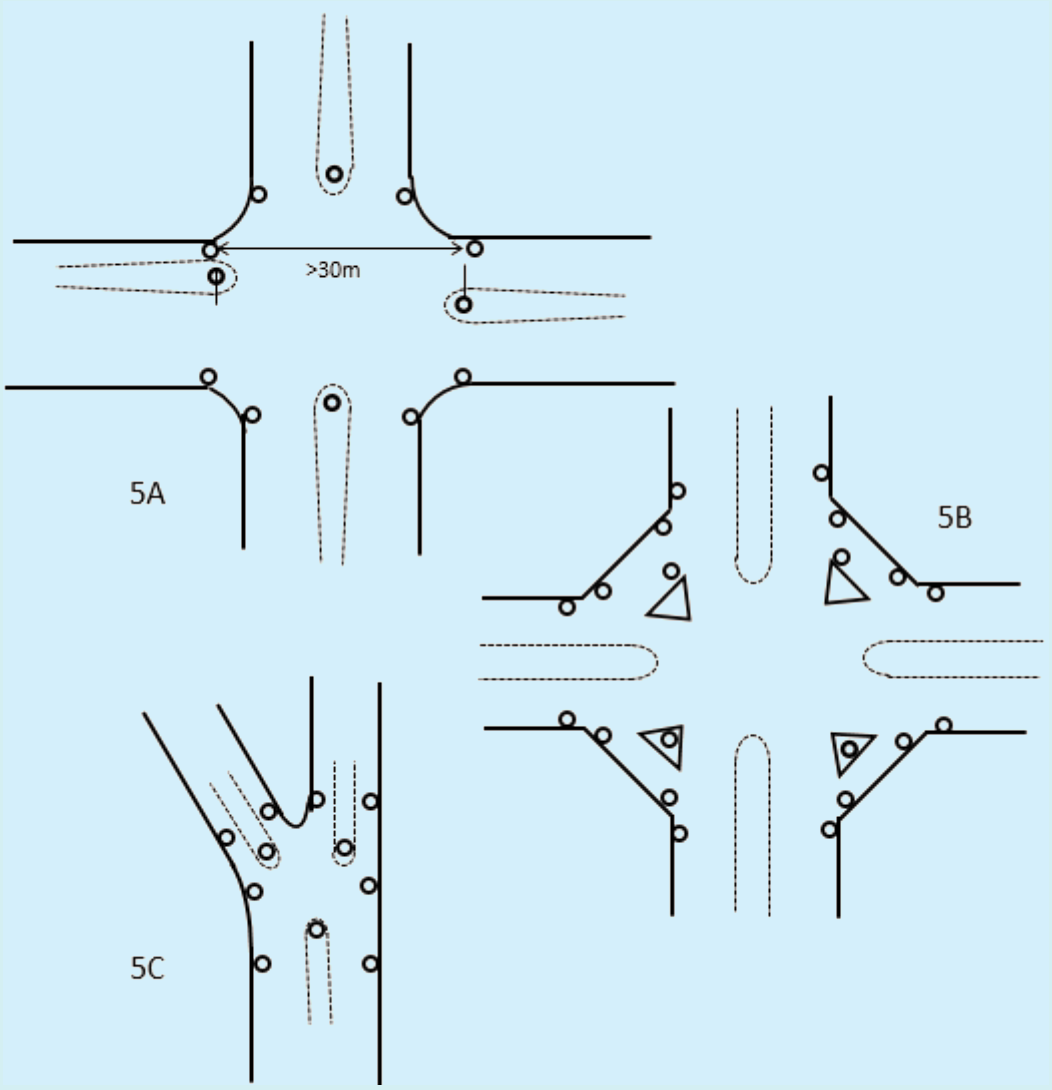
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o = Locations of Columns

FIG. 4 SIMPLE TWO ROAD JUNCTIONS (THREE ALTERNATIVES)

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o = Locations of Columns

FIG. 5 JUNCTION OF TWO MAJOR ROADS (THREE ALTERNATIVES)

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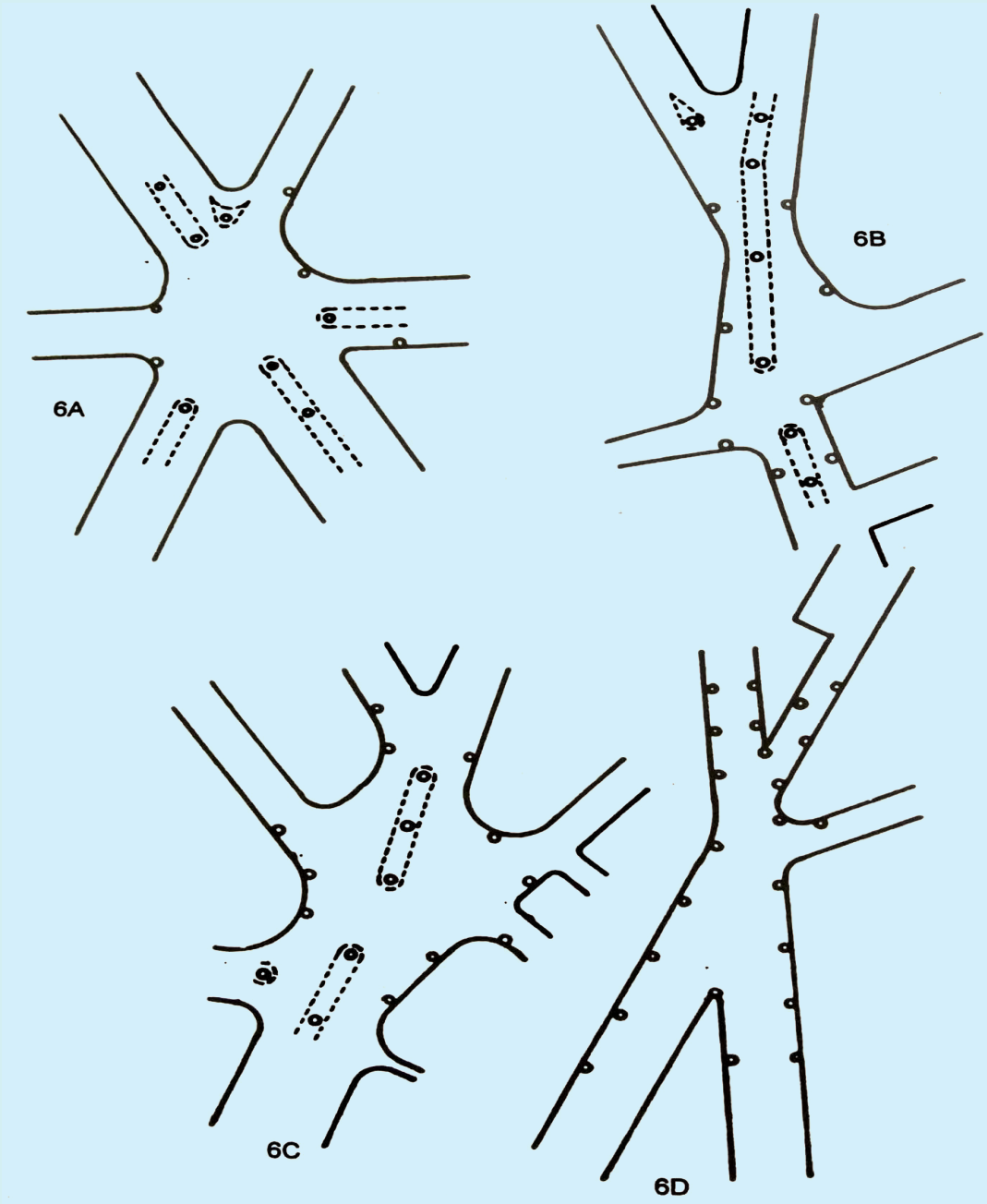


FIG. 6 MULTIPLE ROAD JUNCTIONS (FOUR ALTERNATIVES)

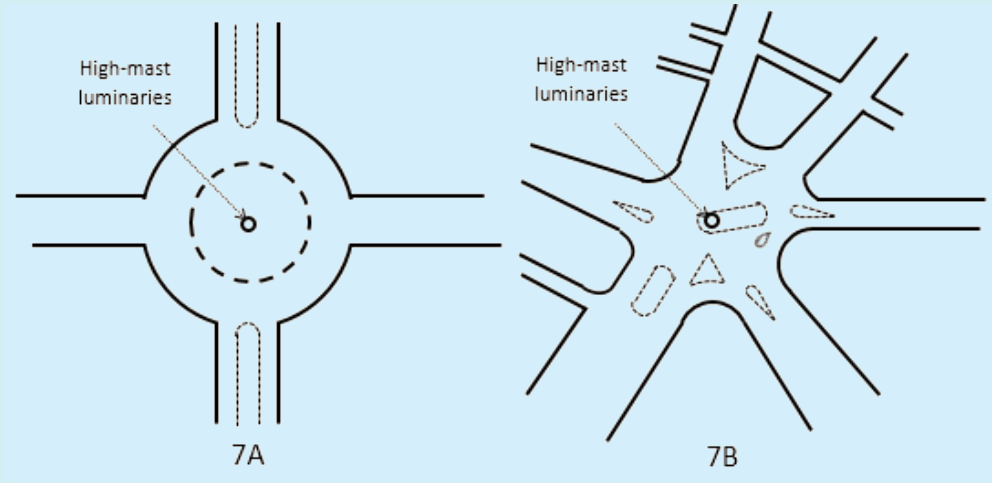
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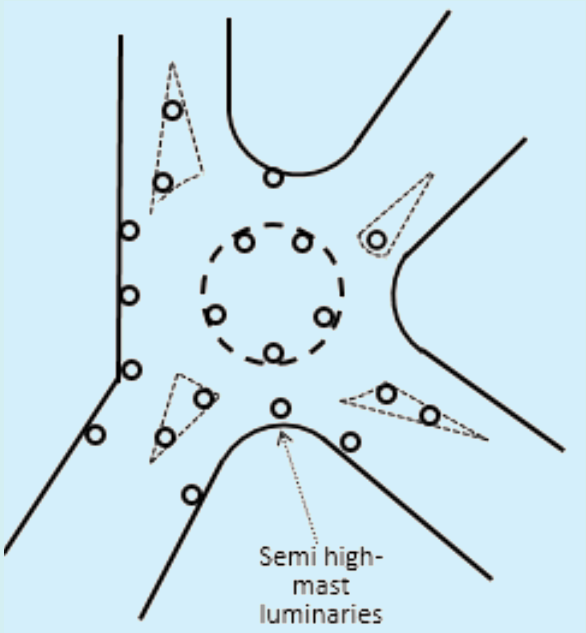
6.4 Roundabouts

Multiple road junctions with roundabouts are much easier to design as a definite central roundabout is available to locate the columns. Two types of roundabouts are discussed below:

a) *Islands which are clear or have only parking lots* — The lighting of these could be advantageously achieved by use of high mast as given in Fig. 7A and 7B or semi-high mast lighting as in Fig. 7C and Fig. 7D.

b) *Islands which have gardens or other construction which would be obstruction to line of vision of traffic* — The lighting of these could be either by semi-high mast as in Fig. 8A or conventional lighting as in Fig. 8B and 8C.





7 C

FIG. 7 USE OF HIGH MAST, SEMI-HIGH — MAST LUMINAIRES IN ROUNDABOUTS (FOUR ALTERNATE) (*Continued*)

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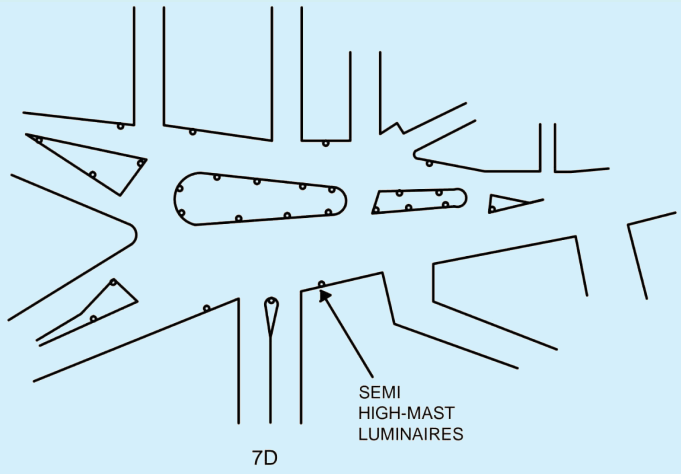


FIG. 7 USE OF HIGH MAST, SEMI-HIGH — MAST LUMINAIRES IN ROUNDABOUTS (FOUR ALTERNATE) (*Concluded*)

6.5 Road Lighting in the Vicinity of Aerodrome

6.5.1 *General Requirements*

When a proposed road lighting scheme is within 5 km of the boundary of an aerodrome it is essential that appropriate aviation authority is consulted regarding any restrictions and precautions to be observed that may be necessary.

6.5.2 The aviation authority may have a specific interest in the pattern of the layout, the mounting height, the colour and intensity, distribution of light emitted above the horizontal so that lighting installation appears distinctly different/dissimilar in light colour/pattern/placement in order not to pose/present any danger due to confusion of navigated airborne objects. The following points should, therefore, be kept in view while designing lighting scheme in the vicinity of the aerodromes:

a) The light provided in the vicinity of an aerodrome shall be properly screened to avoid any glare/upward luminance which may otherwise endanger safety of an aircraft arriving and departing from an aerodrome.
b) Lights mounted on the electric poles/pylons shall not cause an obstruction to the arriving and departing aircraft from an aerodrome in terms of obstacle limitation specified by theairport authorities.
c) It is particularly important to ensure that lighting of the road cannot ever be confused with the ground lighting of the flight paths by the pilots. Following conditions should be ensured:
    1) In case roads are not parallel to landing strips:
        i) Uniform design and spacing of columns is not recommended.
        ii) Arrangement of mounting columns on opposite as in Fig. 2C, 2E is not recommended.
    2) In case roads within airport boundaries are parallel to landing strips, no lighting should be provided on the stretch of such parallel road near the landing strip.

6.6 Road Lighting in Vicinity of Railways, Docks and Navigable Waterways

In lighting for roads in the vicinity of railways, docks and navigable waterways, because of the colour of the light source may interfere with the proper recognition of signal system, it is essential that this interference is avoided, but local conditions vary so widely that it is not possible to lay down any rigid code applicable to all circumstances.

6.6.1 *Requirements*

The following requirements are likely to apply in all places where roads are so located that their lighting installation may affect the operation of railways, docks and navigable waterways.

6.6.2 *Consultations*

It is essential that prior consultation is made with the appropriate authorities regarding any special provision that may be necessary. These provisions should be met in a way that is mutually acceptable so that they may be incorporated at the design stage.

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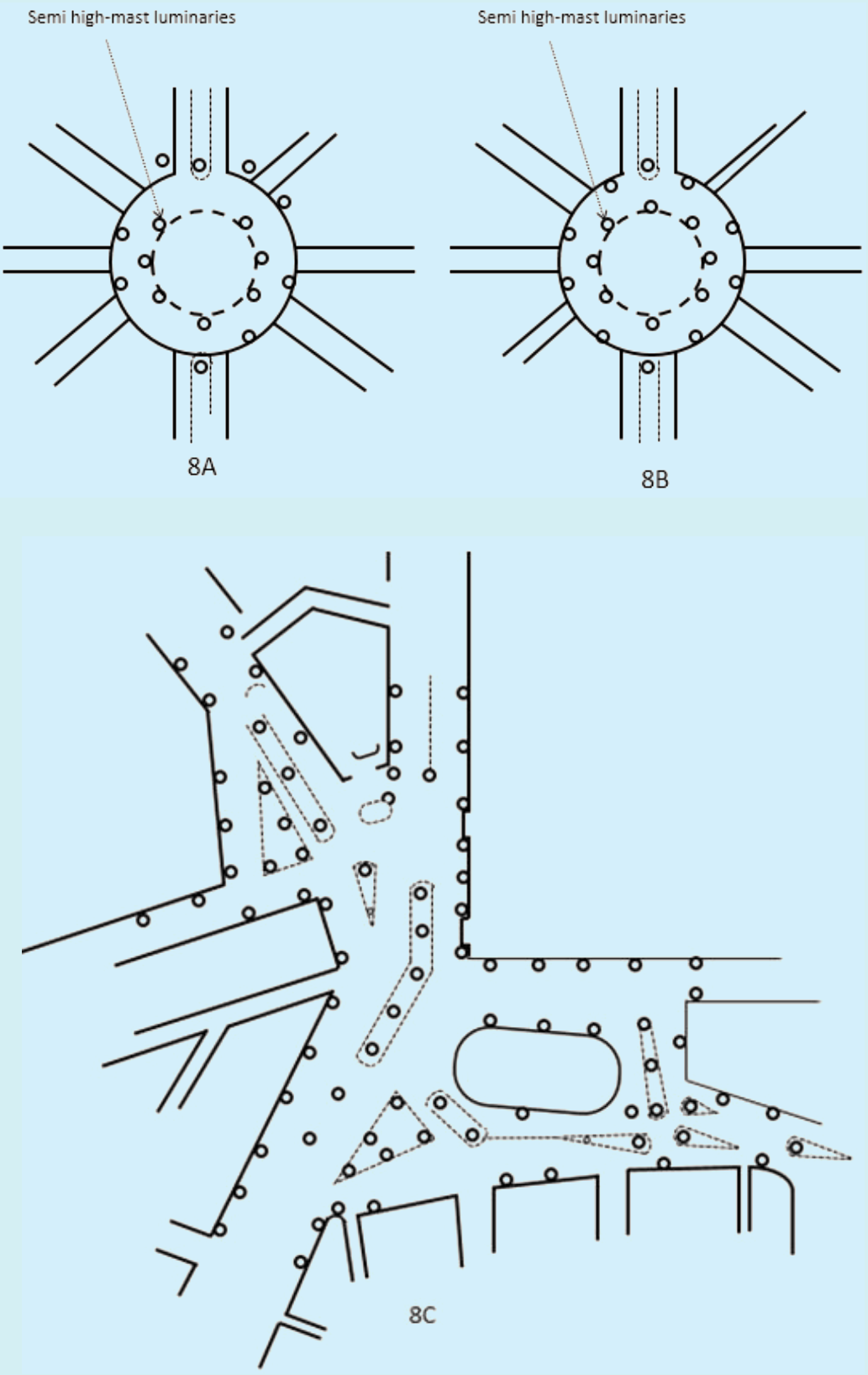


FIG. 8 USE OF SEMI-MAST OR CONVENTIONAL LIGHTING IN ROUNDABOUTS (THREE ALTERNATIVES)

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6.6.3 *Colour*

Where any form of road lighting is employed there is a risk of confusion with signal light. This may necessitate careful selection of light source, siting of luminaires or the use of appropriate screened luminaire at certain points and heights.

6.6.4 *Glare and Masking*

The position of individual light source on the road may fall in line with signal lights and even when fairly remote may mask them or make them difficult to recognise or may hamper the vision because of glare. If these cannot be avoided by re-siting, it may be necessary to employ screening to obviate the interference even though the colour of the light source is not objectionable.

6.6.5 *Screening*

In all cases where screening of a light source is required, this should preferably be achieved by means of properly designed luminaires and not by addition of unsightly screens to normal luminaires.

6.6.6 *Siting*

If the road is bordered by water (lake, river or canal) and if the lighting is single sided, it is recommended that the columns be sited, if possible, on the waterside.

6.6.7 *Penetration*

Selected luminaire should have high ability to penetrate the vicinity under lighting during rainy/stormy/dusty/foggy/smoggy atmosphere at any time of day/night.

7 SELECTION OF EQUIPMENT

7.1 Electric Light Sources

The choice of source for public lighting is guided by the following considerations:

a) Luminous flux,
b) Economy (determined by lumens/watt and life),
c) Dimensions of the light sources, and
d) Colour characteristics.

7.1.1 *The sources normally used in public lighting are:*

a) LED lamps,
b) Sodium vapour lamps,
c) Metal-halide lamps, and
d) High pressure sodium vapour lamps.

7.1.1.1 *LED lamps*

These lamps are the most improved version of a light source with efficacy to the order of 100-140 lm/W with better colour rendering as well as colour changing capability. It is the most energy efficient and satisfactory solution as off now for operational economy. Also, luminaires can be made more compact due to variety in placement of LED formations making dimensions of these lamps flexible. It also has superior light control for specific applications.

7.1.1.2 *Sodium vapour lamps*

The use of sodium lamps is convenient when colour rendering is not important and when a high luminous efficacy is desired. Their colour is sometimes useful to provide visual guidance. It is also particularly suitable under foggy conditions. However, now a days these lamps are getting obsolete due to introduction of LED lamps which are widely used due to energy saving drive promoted by Government.

7.1.1.3 *Metal halide lamps*

These lamps are improved versions of HPMV lamps and having very much higher efficiencies in the order of 80 lm/W combined with good colour characteristics. However, now a days, these lamps are getting obsolete due to introduction of LED lamps which are widely used due to energy saving drive promoted by Government.

7.1.1.4 *High pressure sodium vapour lamps*

These lamps are improved versions of sodium vapour with efficiency of the order of to 100 lm/W with colour rendering satisfactory and of dimensions suited to fittings of small size and accurate light control. However, now

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a days, these lamps are getting obsolete due to introduction of LED lamps which are widely used due to energy saving drive promoted by Government.

7.2 Luminaires

The luminaire has double role of protecting the light source from the weather and redistributing the luminous flux of the source. In the choice of the luminaire the following points should be considered:

a) Nature and power of the source or sources;
b) Nature of the optical arrangements and the light distribution which they provide;
c) Light output ratio;
d) Whether the luminaire is open or closed type;
e) Resistance to heat, soiling, and corrosion;
f) Protection against collection of dust and insects;
g) Resistance to atmospheric conditions;
h) Ease of installation and maintenance;
j) Presence or absence of auxiliaries;
k) Fixing arrangements, the weight and area exposed to wind pressure; and
m) Ability to dissipate the heat generated by light source and control gear.

The influence of all these factors varies according to local circumstances and it is difficult to recommend one solution rather than another, but the attention of lighting designers may be drawn to the fact that the most economical installation can be achieved only by the choice of the most suitable luminaire, selected according to the relative importance of the above mentioned factors. There is, however, one essential characteristic of luminaires the choice of which directly influences the quality of the lighting, that is, the general form of its distribution curves of luminous intensity particularly in directions near the usual directions of vision.

7.2.1 The following general forms of light distribution are considered according to the degree of glare which is acceptable:

a) Post top integral luminaires,
b) Post top non-integral luminaires,
c) Cut-off integral luminaires,
d) Cut-off non-integral luminaires,
e) Semi-cut-off integral.
f) Non-cut-off tubular luminaires, and
g) Flood-lighting luminaires.

7.2.1.1 *Cut-off luminaire*

A luminaire whose light distribution is characterised by a rapid reduction of luminous intensity in the region between 80° and the horizontal. The intensity at the horizontal should not exceed 10 cd per 1 000 lm of flux from the light sources and the intensity at 80° is of the order of 30 cd per 1 000 lm. The direction of the maximum intensity may vary but should be below 65°. The principal advantage of the cut-off system is the reduction of glare and its use is favoured under the following conditions:

a) Matt carriageway surfaces;
b) Absence of buildings;
c) Presence of large trees;
d) Long straight sections;
e) Slight humps, bridges; and
f) Few intersections and obstructions.

7.2.1.2 *Semi-cut-off luminaire*

A luminaire whose light distribution is characterised by a less severe reduction in the intensity in the region 80° to 90°. The intensity at the horizontal should not exceed 50 cd per 1 000 lm of flux from the light sources (*see* Note) and the intensity at 80° is of the order of 1 000 cd per 1 000 lm. The direction of the maximum intensity may vary

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but should be below 75°. The principal advantage of the semi-cut-off system is a greater flexibility in siting, and its use is favoured under the following conditions:

a) Smooth carriageway surfaces;
b) Buildings close to carriageway, especially those of architectural interest; and
c) Many intersections and obstructions.

NOTE — Subject to a maximum value of 1 000 cd whatever is the luminous flux emitted.

7.2.1.3 *Non-cut-off luminaire*

A luminaire whose luminous intensity in directions making an angle equal to or greater than 80° from the downward vertical is not reduced materially and the intensity of which at the horizontal may exceed the values specified for the semi-cut-off distribution, but should not nevertheless exceed 1 000 cd. Non-cut-off luminaires are permissible only when a certain amount of glare may be accepted and when the luminaires are of large size and of reduced brightness. In certain cases, they have some advantages in increasing the illumination of facades.

7.2.1.4 *Inclination*

Attention should be given to the inclination of luminaires. An upward inclination which is generally called for reasons of aesthetics should be employed with care. Too great an inclination of the luminaire may modify, particularly in certain directions, the cut off qualities of the luminaires and in certain situations (for example, when there are roads at several levels, bends, roundabouts, etc.) this inclination may lead to unexpected glare.

8 GUIDELINES FOR SPECIFIC LOCATIONS

8.1 Several factors contribute to good public lighting and those are enumerated for guidance in various parts of IS 1944 series. Recommendations are made on the various components of design of public lighting installations and those require detailed calculations of the level and uniformity of illumination on the road surface and of glare. Several criteria may not be satisfied for want of data, such as characteristics of surface, etc. To get some idea of the extent to which the installation would perform, it may be preferable to make a mock-up installation of a few luminaires on a stretch of road to be lighted.

8.2 Tables 6, 7 and 8 give a summary of recommendations on the various types of thoroughfares. These shall be used as ready reckoners, though for a detailed guidance reference should be made to the relevant part of IS 1944.

NOTE — Recommendations for Groups C, F and G lighting gear are under consideration.

Table 6 Lighting Installation in Group A and B Roads

(*Clause* 8.2)

Sl No	Description	Group A1	Group A2	Group B2	Group B2
(1)	(2)	(3)	(4)	(5)	(6)
i)	Average level of illumination on road surface, lux	30	15	8	4
ii)	Ratio minimum/average illumination ratio	0.4	0.4	0.3	0.3
iii)	Transverse variation of illumination, percent	33	33	20	20
iv)	Preferred Type of luminaire:	Cut-off	Cut-off	Cut-off or semi cut-off	Cut-off or semi cut-off
	Permitted	Semi-cut-off	Semi cut-off	Non cut-off	Non cut-off
v)	Mounting height, m	9-10	9-10	7.5-9	7.5-9
vi)	Maximum spacing of luminaire/height ratio	Cut-off = 3		Cut-off = 3	
		Semi-cut-off = 3.5		Semi-cut-off = 3.5	
				Non-cut-off = 4	

NOTES

1 In Group A lighting, the level and uniformity of illumination shall be as high as possible and the glare strictly reduced.

2 In Group B lighting, greater tolerances on uniformity and glare are admitted, which may be justified by the character of the roads and by the presence of facades.

3 Mounting heights less than 7.5 m are undesirable except in special cases, such as lighting of residential roads or roads bordered by trees.

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Table 7 Lighting Installations in Group D Roads

(*Clause* 8.2)

Sl No.		Description	Remarks
(1)		(2)	(3)
i)	A	*Grade Separated Junctions*	
		1 Lighting by conventional street lighting technique Complex junctions:	
		a) General principles	*See* IS 1944 (Parts 1 and 2)
		b) Mounting height, m	10-12
		c) Luminaire	cut-off
		d) Light sources	LED or HPSV lamps
		2 Lighting by high-mast lighting	
		a) Minimum service level value (lux)	30
		b) Uniformity ratio (avg)	0.4
		c) Height of masts, m	Not less than 20
		d) Choice of luminaire	*see* IS 1944 (Parts 1 and 2)
ii)	B	*Bridges*	
		1 Short bridges (<60 m)	Normal street lighting techniques with minor adjustments [*see* IS 1944 (Part 5)]
		2 Long bridges (> 60 m)	*See* IS 1944 (Part 5)
		3 Bridges of historical importance	Special considerations apply
		4 Parapet lighting	
		a) Mounting height, m	Not greater than 1
		b) Separation between rows of lighting, m	Not greater than 12
		c) Choice of lamps	LED, HPSV lamps or other linear sources of luminance weatherproof, dustproof, vermin proof, robust
		5 Footbridges	
		a) Illumination, lux	Not less than 6
iii)	C	*Elevated Roads*	
		a) General lighting	Like heavy traffic roads
		b) Choice of luminaire	Cut-off

9 POWER INSTALLATION REQUIREMENTS

9.1 The electrical design aspects of public lighting installations not only consider the illumination principles, but also economic considerations giving allowance for cost of electrical control units, cable ducts, switching, etc.

9.1.1 *Lamps and Luminaires*

All lamps and luminaires and other fittings used in public lighting installations shall conform to the relevant Indian Standards.

9.2 Cables

9.2.1 Underground cables shall be laid for power supply to the streetlamps. For roads under Groups A, B and D, separate mains shall be laid for group control of lamps on these roads. The street lighting cables shall be terminated in separate junction boxes or street lighting pillars. The pillars shall be provided with electrically operated contactors of suitable current rating. Auxiliary terminals of these contactors could provide facility of return indication in case of supervisory remote control. In addition, as an alternative to this, it should have programmable timers to facilitate automatic time-based switching control depending on seasonal variations

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in sunrise/sunset. The contactor circuits shall be provided with externally mounted switches for local manual operation. A typical street lighting pillar with control circuit is shown in Fig. 12.

9.2.2 The cable circuits for each section of the roads shall be so designed as to prevent important section of the roads from being completely off in case of a fault on the underground cables. For roads under Groups A1, A2 and D, each stretch of road shall be lit by two independent circuits, preferably emanating from two separate street lighting pillars.

For junctions also, the lamps shall be divided into at least two circuits in such a way that in case of fault on one circuit the entire junction or a section of it does not become completely dark.

Table 8 Lighting Installations in Group E Roads

(*Clause* 8.2)

Sl No.	Description	Remarks
(1)	(2)	(3)
i)	*Main squares* [*see* IS 1944 (Part 6)]:	
	1) Average level of illumination, lux	20
	2) Mounting height, m	10-15
ii)	*Shopping streets/promenades*	Special considerations
iii)	*Pedestrian precincts*	
	1) Average horizontal illuminance (footway level), lux	20
	2) Average horizontal illuminance (under canopies), lux	50
	3) Mounting height, m	5-6
	4) Luminaires	Special considerations
iv)	*Public car parks* (*above ground*)	
	1) Average horizontal illuminance, lux	10
	2) Luminaires preferred	Floodlight luminaries on high masts
v)	*Pedestrian stairways/footbridges*	
	1) Average level of illuminance (surface of footbridge), lux	6
	2) Average level of illuminance (sub-ways), lux	10

9.2.3 In case of roads in groups A, B and D, the cables shall preferably be terminated into the column junction boxes by looping rather than 'T' joints using appropriate type of terminal block/connector strip with terminal protection shroud.

9.2.4 Underground cables of suitable sizes should be utilised for the purpose of control. The recommended sizes of the cables for various installations are shown in Table 9.

Table 9 Recommended Types and Sizes of Cables

(*Clause* 9.2.4)

Sl No.	Round Group	Preferred Size of Cables (sq.mm.)	Type of Cables	Max. No. of Luminaries to be Looped per Circuit	Max Length of Cable per Circuit
(1)	(2)	(3)	(4)	(5)	(6)
i)	A1	4 to 25	3-phase, 4-core	The maximum no of luminaries and maximum length shall be selected subject to a maximum allowed voltage drop of 6 percent	
ii)	A2		3-phase, 4-core		
iii)	B1		3-phase, 4-core		
iv)	B2	Up to 10 sq mm copper and higher sizes aluminum	1-phase/3-phase, 4-core		
v)	C		1-phase/3-phase, 4-core		
vi)	D		3-phase, 4-core		

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Special care shall be taken in Neutral conductor in order to avoid temporary over voltage due to loss of neutral.

Up to 6/10 mm^2 cables with copper conductor are recommended and higher sizes, cables with aluminium conductors are preferred.

9.2.5 The distribution board with suitable sized contactors with independent MCB's shall be provided for each phase. The contactors shall be controlled by electrically operated switches mounted for external manual/local operation.

9.2.6 Safety against electrocution shall be ensured by installing protective device as:

a) Type and rating of MCB is selected considering, a fault at the final light shall ensure automatic disconnection of the MCB. The fault loop impedance shall be lower enough to enable automatic disconnection in case a TN network is used.

b) If this condition in Sl. No. (1) cannot be fulfilled, every circuit shall be protected by an RCBO with a residual current not larger than 30 mA.

9.2.7 Street lights in gardens, parks and inside housing colonies shall be supplied from RCBO with a residual current not larger than 30 mA.

9.3 Power Supply

The supply to the streetlights may be either through overhead wires or underground cables. The supply to lamps on roads under Groups A, B and D, should preferably be by underground cables laid specially for street lighting purposes. In case overhead wires are employed these should also be suitable for street lighting purposes.

The following power supply configurations is provided for information.

9.3.1 *TN-S System with MCB of Suitable Rating and RCD Not Larger than 30 mA at Distribution Board (DB)*

Safety is achieved by automatic disconnection of supply during fault. 3 phase, Neutral and earth conductor starts from the DB, runs up to the last light as shown in Fig. 9.

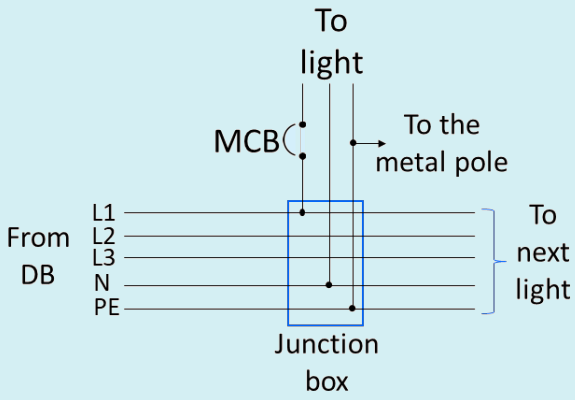


FIG. 9 STREET LIGHTING PILLAR - TN-S SYSTEM

9.3.2. *TN-C-S System with MCB of Suitable Rating and RCD Not Larger than 30 mA*

Safety is achieved by automatic disconnection of supply during fault. 3 phase and combined neutral and protective earth conductor starts from the DB, runs up to the last light as shown in Fig. 10. No need of a separate earth conductor. However, neutral and earth shall be combined in the junction box as shown in Fig. 10. RCD's at DB are not effective in this system. In case of any neutral disconnection, TOV will be limited in this system.

Since RCD's at DB are not effective, the system shall be implemented with careful measurement of fault loop impedance and automatic disconnection. The outgoing MCB at the DB shall ensure automatic disconnection in case of a fault.

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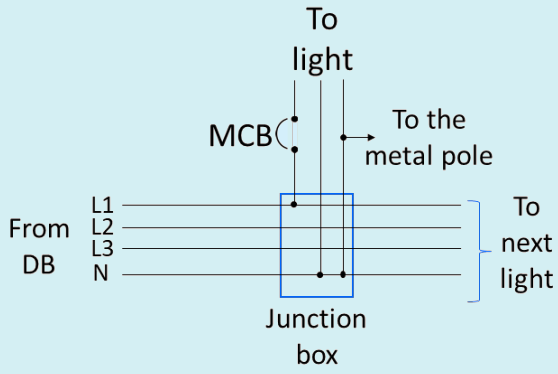


FIG. 10 STREET LIGHTING PILLAR - TN-C-S SYSTEM

9.3.3 *IT System*

An isolation transformer is installed for the lightning circuit. Output side of the isolation transformer is unearthed. Line and neutral conductor are completely isolated form earth. *See* Fig. 11. An insulation monitoring device shall be provided to indicate the occurrence of a first fault from a live part to exposed conductive parts or to earth. Insulation monitoring devices are mandatory. Automatic disconnection during first fault is not necessary. However, the fault shall be rectified as fast as possible. For further information on IT system, refer 4.2.11.6.3 of IS 732.

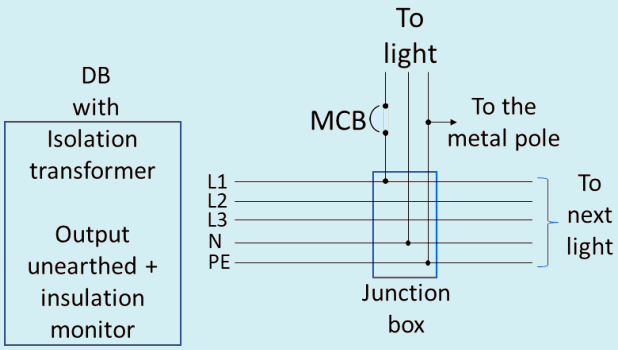


FIG. 11 STREET LIGHTING PILLAR - IT SYSTEM

9.4 Control of Street Lighting Installations

9.4.1 The contactors may be provided with additional circuitry for remote/automatic control. Following schemes for remote control are recommended:

a) *Special Relay Control* — This may be achieved by special control cables laid up to the street lighting. Special relays operated by normal supply or electronic impulses may be provided. This scheme enables return indication of the operation by auxiliary contacts of the contactors.

b) *Ripple Control* — This may be achieved by injecting audio frequency impulse through suitable power supply network and installing suitable sensors at control points.

9.4.2 *Automatic Control*

The contactors may, alternately, be controlled automatically by use of auto-control devices. The following controls are recommended:

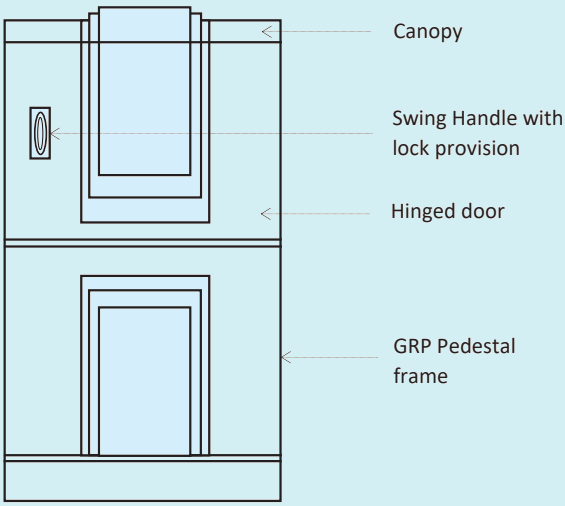
a) *Photoelectric Control* — This may be achieved by installing suitably mounted photoelectric switches near the control points. The photoelectric switch shall be mounted so as to be free the glare caused by headlights of motor vehicles and protected from the weather.

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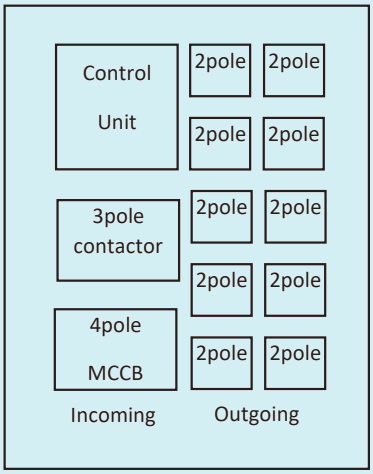
b) *Time Switches* — The local electrically operated contractors may be controlled through time switches. The time switches may be manually spring would or electrically operated. In case of electrical operation, the time switches should be of electrically wound mechanically operated variety so as to prevent their being affected by variations in supply. However, these would need to be regulated from time to time due to seasonal variations.

c) *Electronic Control Switches* — It should be possible to install pre-programmed electronic micro-processors, with one-year seasonal variations. These could be installed for each individual lamp. With suitable design these could also be utilised to switch off unwanted lights after peak traffic hours are over.

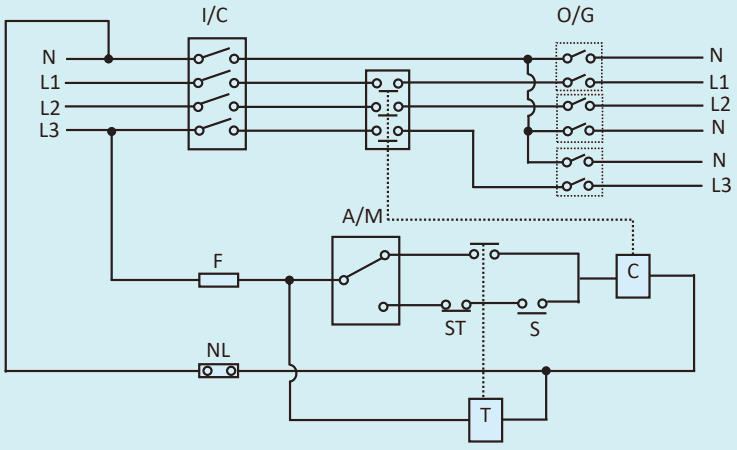
d) *Intelligent Digital Control Module* — This may be achieved by introducing microprocessor based programmable control module wired /unwired (Sim card based) which can provide various control options depending on traffic density (Public/vehicle), natural light, on the spot atmospheric conditions, etc.



12A Typical street lighting



12B Inside layout



Streetlights

I/C - Incoming MCCB 4P
C - Contactor 3P
T - Timer (Digital)
O/G - Outgoing RCBO 2P
F - Fuse
NL - Neutral link
A/M - Auto/Manual selector switch
ST - Stop push button
S - Start push button

12C Typical Contactor Wiring for Remote/Automatic

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9.4.3 *Black-out Control*

Black-out control may be required to be adopted in case of war in vulnerable areas. This could be achieved by either of the following schemes:

a) *Remote Control* — Special control cables are laid (alternatively, use of telephone cables) to give control impulse to group control points. The control could then be utilised to switch off the lamps instantaneously on demand by civil defence authorities.

b) *Ripple Control* — In case special control cables are not available, ripple control equipment could be used with suitable sensing devices at the control points. When the need arises, the entire area could be switched off by ripple control impulse.

c) *UHF Control* — Electronic relays responding to pre-determined control frequency could be installed at each switching point. This could be programmed to switch off on demand by a pre- determined control frequency signal.

9.4.4 *Brown-out Control*

Brown-out control is necessary in vulnerable cities with heavy vehicular traffic at the time of war, where complete black-out is not practicable. Even in such cases, complete black-out would be necessary at the time of possible air raids. Following alternatives for brown-out control are recommended:

a) *Voltage Control* — This could be advantageously adopted in areas where the source of lighting is filament lamp. Applying reduced voltage to such lamps would automatically reduce the illumination to any desired level. In case of discharge lamps, this scheme would not be suitable.

b) *Ripple Control* — In case ripple control is adopted, it would be possible to programme alternate (or any other combination) lamps to respond to specified ripple control signals. In case of necessity, brown-out could be affected by switching off alternate lamps and complete black-out by switching off all the lamps.

c) *Multiple Lamp Luminaires* — On main roads, the luminaires adopted could have two or more lamps, each controlled either by different phase or by separate ripple control signals. In case of necessity, either one or two phases could be switched off, or alternately alternate lamps be switched off by suitable ripple control signals.

d) *Replacement of Lamps* — In case of prolonged brown-out operations, the wattage of the lamps could be reduced by replacing the same with lower wattage lamps. This, though could not be achieved on short notice is recommended in case of prolonged operations.

e) Microprocessor based intelligent wired/unwired (sim card based) control.

10 MISCELLANEOUS CONSIDERATIONS

10.1 Aesthetics

The aesthetics of a lighting installation are principally judged by day. Half of the time, the lighting installation serves no useful purpose; an attractive or at least a non-disturbing daytime appearance which harmonises well with the surroundings is, therefore, of great importance. Aesthetic considerations should relate to the unit formed by the luminaire and its support and the situation in which it is placed.

Firstly, the unit formed by the luminaire and its support should be considered. Secondly, the siting of the luminaires in the scene may lead to unpleasant effects even if the luminaires themselves considered in isolation, are aesthetic.

There are no simple or universal rules for aesthetically satisfactory design and layout since every city, town and village has its own character and what may look well in one place may be incongruous in another.

The points of general application are:

a) Design and siting;

b) Columns and surroundings;

c) Size and type of luminaire;

d) Form of bracket;

e) Assembly of column, bracket and luminaire;

f) Arrays of luminaires; and

g) Material and colour.

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10.2 Lighting Columns as Hazards

A motor vehicle involved in an accident frequently leaves the carriageway and the probability of this happening increases with the speed of the vehicle. If the vehicle collides with a lighting column the severity of injuries to the occupants is likely to be increased. There is evidence to suggest that the number of such collisions decreases with the increase of distance of the column from the edge of the carriageway.

Normally the clearance between column and carriageway should be at least 1.5 m. Where there is a footway close to the carriageway, the column should be sited behind the footway. In exceptional cases, a smaller clearance may be used.

If possible, the column itself can be provided with reflective coating up to 1.5-2 m from ground in order to achieve enhanced visual presence in dusty/dim atmosphere.

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ANNEX A

(*Clause* 4.1)

TYPES OF ROADS

Sl No.	Term	Description of Type of Road
(1)	(2)	(3)
i)	Road	A general term denoting any public way for purposes of vehicular traffic
ii)	Street	A road which has become partly or wholly defined by buildings along one or both frontages
iii)	Motorway	A road reserved for motor traffic, accessible only from interchanges and on which stopping, and parking are prohibited. Roads of this type should have two or several separate and one-way carriageways
iv)	Express road	A road like, but lacking some feature of a motorway, for example: a) not dual carriageway; b) not fully access-controlled; and c) not all intersections grade- separated.
v)	All-purpose road	Road usable by all traffic (including pedestrians and cyclists); Used to distinguish other roads from motorways
vi)	Trunk road/Major road	A main route in the through communication system of a country
vii)	Minor road	A road which has, or to which is assigned, a lesser traffic value than that of a major road
viii)	Ring road	A road round an urban area enabling traffic to avoid the urban center
ix)	Radial road	A road providing direct communication between the center of an urban area and the outer districts
x)	Commercial street	Street with frontages comprising a high proportion of commercial premises (usually unlit at night), and with a high proportion of heavy goods vehicles in the traffic stream
xi)	Shopping street	Street with frontages comprising a high proportion of shops or other premises which may be lit at night and with heavy pedestrian (and possibly pedal cycle) traffic
xii)	Resident street	Street with most frontages comprising private houses
xiii)	Collector road/Distributor road	A link between the radial or ring roads and the local access streets
xiv)	Local street	Street giving direct access to buildings and land with a minimum of through traffic
xv)	Service road	A subsidiary road between principle road and buildings or properties facing thereon or a parallel road to the principal road and giving access to the premises and connected only at selected points with the principle road
xvi)	Footway	That portion of a road reserved exclusively for pedestrians
xvii)	Cycle track	A way, or part of a road, reserved for use only by bicycles

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SECTION 2 TEMPORARY OUTDOOR INSTALLATIONS

FOREWORD

Electrical installations are often required to be designed and erected for use for short periods of time ranging from a few hours to few months and are connected to the supply source in open ground. Such installations are generally unprotected from environmental hazards as compared to installations in buildings.

The major risks in the use of power in such installation arise from short circuit resulting in fire accidents and exposure to live wire resulting in shock. It is, therefore, imperative to lay down the necessary precautions to be observed for such installations from the point of view of safety.

Temporary installations covered in this section are enumerated in **5** and are classified based on the duration of their existence in use. It may be noted that this section basically intends to lay down additional safety measures to be adopted in the design of temporary installations, and the general guidelines for outdoor installations under heavy conditions from the point of view of selection and use of equipment given in Part 5/Sec 3 shall also be referred to.

1 SCOPE

This Section of the Code (Part 5/Sec 2) covers the requirements for outdoor electrical installations of temporary use.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No./International Publications	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
3043 : 2018	Code of practice for earthing (*second revision*)
5613 (Part 1/Sec 1) : 1985	Code of practice for design, installation, and maintenance of overhead powerlines: Part 1 Lines up to and including 11 kV, Section 1 Design (*first revision*)
5613 (Part 1/Sec 2) : 1985	Code of practice for design, installation, and maintenance of overhead power lines: Part 1 Lines up to and including 11 kV, Section 2 Installation, and maintenance (*first revision*)
SP 7 : 2016	National Building Code of India
IS/IEC 60309-1 : 2002	Plugs, socket-outlets and couplers for Industrial purposes: Part 1 General requirements (*first revision*)
IS/IEC 60309-2 : 2002	Plugs, socket-outlets and couplers for Industrial purposes: Part 2 Dimensional interchangeability requirements for pin and contact-tube accessories (*first revision*)
IS/IEC 61439	Low-Voltage Switchgear and Controlgear Assemblies

3 TERMINOLOGY

For the purpose of this Section 2, the following definitions in addition to those given in Part 1/Sec 2 of this Code shall apply.

3.1 Temporary Installations (Outdoor) — An electrical installation open to sky or partially covered, intended to be used for a temporary period not exceeding 6 months.

NOTE — In special cases, the guidelines specified in this Section shall be applicable for longer durations subject to fresh inspection and tests with the prior approval of the supply authority (*see* also **9.3**).

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4 CLASSIFICATION

4.1 The temporary outdoor electrical installations covered in this Section are those intended for the following purposes:

a) *Temporary installations for durations not exceeding* 6 *months* — Outdoor installations open to sky or partially covered, erected in the vicinity of construction sites solely for the purposes of supplying the electrical needs of building construction work such as lighting and power loads.

NOTES

1 Construction site installations for very long periods of times, where the equipments are quite similar to those in heavy conditions shall conform to the requirements in Part 5/Sec 3 of this Code.

2 Construction site installations are those which include sites where the following are carried out:

a) Construction of new building.

b) Works of repair, alternation, extension, or demolition of existing buildings; and

c) Public engineering works. The construction site installations are also characterised by frequent modifications.

b) *Temporary installations for durations not exceeding* 45 *days* — These include large loads such as for exhibitions, fairs, etc.

NOTE — Exhibition or fair site lighting installations of the permanent type shall conform to the requirements specified in Part 5/Section 1 of this Code.

c) *Temporary installations for durations not exceeding* 7 *days* — These include installations site of temporary nature intended for a weeklong public function or outdoor lighting installations of buildings and parts in view of festival and other reasons.

d) *Temporary installations for durations not exceeding* 24 *h* — These include temporary installations which cater to loads for the purposes of marriages, reception, religious and other public function, etc.

5 GENERAL CHARACTERISTICS OF TEMPORARY INSTALLATIONS

General guidelines on the assessment of characteristics of installations in buildings are given in Part 1/Sec 8 of this Code. For the purposes of installations falling under the scope of this section, the characteristics defined below generally apply.

5.1 Environment

The following environmental factors shall apply to temporary outdoor installations:

Sl No.	Environment	Characteristics	Remarks
(1)	(2)	(3)	(4)
i)	Presence of water	Possibility of splashes from any direction	External lighting fittings, construction site equipment, etc.
ii)		Possibility of jets of water in any direction partial or total covering by water	Temporary installations in parts
iii)	Presence of foreign solid bodies	Presence of small objects	
iv)		Presence of dust in significant quantity	
v)	Impact	High severity	Construction demolition sites
vi)	Vibrations	Medium severity	Constructions, demolitions sites
vii)	Presence of flora/mould growth	No harmful hazard	
viii)	Presence of fauna	Hazard from fauna (insects, birds, small animals)	
ix)	Solar radiation	Solar radiation of harmful intensity and/or duration	
x)	Seismic effects	—	Depends on the location of the installation
xi)	Lightning	Hazard from exposure of equipment	Generally applicable for installations located outdoors

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5.2 Utilization

The following factors of utilization apply:

Sl No.	Utilization	Characteristics	Remarks
(1)	(2)	(3)	(4)
i)	Capability of persons	Uninstructed persons	Majority of occupants say in an exhibition's circus fair
ii)		Instructed persons adequately advised or supervised by skilled persons	Applies to operating staff
iii)	Contact of persons with earth potential	Frequent	Construction sites
iv)	Conditions of evacuation during emergency	Low density occupation easy conditions of evacuation	Small gatherings, such as for marriages and similar functions
v)		High density occupation, difficult conditions of evacuation	Circus, large public gatherings inside an enclosure, etc.
vi)	Nature of processed	Fire risk	*Shamianahs*, tents
vii)	Construction of structure	Combustible	The nature of construction materials used in temporary installations may be combustible. Such as wooden cloth structures in tents
viii)		Structural design flexible or unstable	Structures which are weak or subject to movement, such as tents, removable partitions etc.

6 GENERAL REQUIREMENTS FOR TEMPORARY OUTDOOR INSTALLATIONS

6.1 Temporary installation shall in general conform to the requirements stipulated in the relevant Section of Part 1 of this Code, in respect wiring of circuits, location and installation of equipment, etc. Additional requirements are given in **7** ***(see also*** SP 7).

6.2 If the equipment used in temporary and provisional places of work in the open, such as building sites are similar to those used in surface mining applications, reference shall be made to the guidelines contained in Part 5/Sec 3 of this Code.

7 ADDITIONAL REQUIREMENTS FOR TEMPORARY OUTDOOR INSTALLATIONS

7.1 Supply Intake Arrangements

The type of outdoor installations will depend on the magnitude and duration of the installation. Depending on the availability of spare capacity, of the existing distribution system, the supply intake arrangements could be through either of the following:

a) A HV feeder,
b) A HV feeder and step-down transformer,
c) LV SERVICE LINE (SINGLE/THREE PHASE), or
d) A tapping form one of the existing service connection.

One construction site may be served by several sources of supply, including fixed or mobile power generators. All the circuits supplied from the same point of supply comprise one installation and it is important to clearly differentiate them; in particular, a single distribution point, cabinet or distribution board shall consist of only components belonging to one and the same installation except for circuits for standby supplies, signalling or control.

7.1.1 *Commissioning of Substation*

In case the loads at construction sites or to exhibitions, circuses, etc, are large and the power supply authority has no network in the vicinity of the temporary installation that could be utilised then it would be necessary to

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establish a temporary substation where the switchgear and transformer can be installed. The substation site shall be so selected that it is as close to the load centre as possible.

The power supply authority's line should be brought up to the substation in a separate enclosure. If overhead line is laid up to the temporary substation, then the supporting poles, conductors, materials of the line, insulation and the method of stringing the conductors and the mechanical strength of the line as a whole shall conform to the relevant provisions of IS 5613 (Part 1/Sec 1) and IS 5613 (Part 1/Sec 2). In case supply at voltages above 650 V is required, a suitable enclosure to install the switchgear and the metering arrangement shall also be erected.

7.1.2 *Power Distribution*

7.1.2.1 At the origin of each installation a unit containing the main control gear and the principal protective device shall be provided. Incoming OCPD shall be installed in an earthed metallic enclosure and as close to the metering point as possible (*see also* **7.2.1.1**). The fault loop impedance and the prospective fault current at the origin of installation shall be measured. Type and rating and the OCPD shall be selected based on this measurement in order to ensure automatic disconnection with in the time specified in IS 3043 and IS 732.

7.1.2.2 Means of emergency switching shall be provided so as to completely isolate the supply in case of emergency.

7.1.2.3 The enclosure or the distribution board in which the main switch is installed shall be such that the equipment within shall be unaffected by the environmental conditions (*see* **5.1**). A double insulated installation with higher degree of Ingress protection shall be preferred.

7.1.2.4 The main switch on the installation shall be connected to the point of supply by means of an armoured cable or insulated wires and the termination of this cable shall be adequately protected from rainwater.

7.1.2.5 The main requiring handle for operation (generally above 100A) shall be located at a height not exceeding 1.5 m. To remain accessible during emergencies and for ease of operation. The main switch operated by toggle/rocker type action can be located up to 2 m of height. However, no switch should be located below 450 mm from floor/ground level in order to provide operational ease and to avert probable contact with splashing drops water/liquid bouncing repelling from ground / spread on floor for cleaning purpose/spillage.

7.1.2.6 The cable shall be laid either underground or supported in the air. Precautions shall be taken to ensure that this cable when laid underground is done so with the same meticulous care as is, done for a permanent installation. In case the cable passes underneath the passages, it shall be laid in whole or split pipes. When laid over ground, the cables shall either be cleated with saddles of proper size along the walls of a permanent structure if available, or alternatively, it shall be supported on rigid poles. The height of the cable shall not be less than 2 m when run inside the compound and at least 5 m when run along or across road. Crossing of the road shall preferably be avoided. An independent earthing shall be established inside the installation premises. In case overhead wires are used in the installation they should conform to the relevant Indian Standards mentioned in **7.1.1**.

7.1.2.7 In selecting the equipment and cables, the ratings hall be decided taking the environmental conditions into account.

7.1.2.8 The supply intake point shall be placed outside the periphery of area which is accessible to the public.

7.1.2.9 In cities, towns, and thickly populated localities, it is advisable to wire up the installation with insulated wires including for main circuits in open compounds or running along or across roads. For main circuits, cables shall be used, preferably laid underground. Alternatively, they shall be cleated along the walls of structures with proper saddles. When laid underground, the cable shall be laid at a depth of 900 mm, covered with sand, bricks and earth for providing mechanical protection.

7.1.2.10 For temporary installations in cities and towns for purposes described under **4.1**(b), (c) and (d), bare conductors shall not be used. Only in the case of load for purposes mentioned under **4.1**(a) especially outside cities and town bare conductors are permitted.

7.1.2.11 *In cities and towns, if the premises where temporary electric supply required is isolated, then:*

a) Mixed wiring of insulated and bare conductor — overhead wiring, and

b) Mixed wiring partly underground and partly overhead may be used.

In such an event, the underground part of the installation and the overhead part of the installation shall separately conform to the requirements as mentioned in this Section.

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7.1.2.12 TN-S type earthing shall be installed. For a three-phase application, a 5 wire system, where the 5th wire act as protective earth conductor shall be used from the main switch board up to the last electrical apparatus.

7.2 Control of Circuits

7.2.1 *Main Circuit*

7.2.1.1 A device shall be provided on the incoming cable to each supply unit and each distribution unit for switching and isolating. With this type of arrangement, it shall be possible to switch off the supply at the intake point or at the distribution point.

7.2.1.2 The main switch shall be adequately protected from ingress of water. The incoming and outgoing cable/wires of the main switch shall be firmly supported so that cable and wire ends connected to the main switch shall not be subjected to any mechanical force, transmitted to it from any portion of the cables and wires.

7.2.1.3 The main switch shall be installed on a firm and vertical surface, which can withstand the mechanical vibrations created at the installation site as well as the wind pressure at the location.

7.2.1.4 There shall be adequate ventilation in the room where main switches are installed and there shall be operational space around the switch in accordance with good practice. The switch room shall be accessible at any time of the day or night to authorised persons.

7.2.2 *Sub-circuit*

7.2.2.1 On large temporary installations like those on construction sites, at exhibitions, circuses, etc, the outgoing end of the main switch shall be connected to bus bar of adequate size and various sub-circuits shall be connected to this bus bar through double or triple pole switches, depending upon whether they are single phase or 3 phase circuits. The switches shall be mounted on a firm support and shall be at a height between 1 m and 2 m from the floor level. The sub circuit switch shall be so spaced that there shall be a minimum clear distance of 60 mm between the switches for ease of operation.

7.2.2.2 The outgoing wires from the sub-circuits witches inside the enclosure shall be cleated firmly on wooden battens or taken through conduits which are fixed by means of saddles to the masonry wall or wooden partition wall. The lead wires connected to the sub circuits switches shall be suitably supported on wall with clips and shall not be left hanging. Spans more than 2 m shall have guide wire support.

7.2.2.3 The distribution boards the sub-circuits shall be at an accessible height but not less than 1 m. The distribution boards shall be fixed on firm supports or on pole firmly planted in the ground.

7.2.2.4 Taped joints shall not be used at heights less than 3 m. The taped joints shall be properly supported and preferably clamped on either side of the joint so that the joint is not subject to a strain. For series lights used for decorative purposes, no taped joint shall be used.

7.2.2.5 A broken bulb of a lamp in a series circuit is a risk and therefore series lamps shall not be strung or hung at heights less than 3 m. A defective series lamp shall not be allowed to remain in its position and shall be immediately removed.

7.2.2.6 *Installation at Construction Sites*

The entire area where the temporary supply will be used, shall be indicated beforehand and in case the electric supply is required at construction site for pipelines, then a drawing may also be given to the electric supply authority. On this drawing, various points from where different appliances/equipment are intended to be used, may also be indicated. All switches, sockets and fixed appliances shall be protected from rain by enclosing these in cubicles. Sub-circuit distribution board shall be installed, at a place where it is safe from atmospheric conditions. If such a place is not available, the distribution board shall be placed in a cubicle. In a 3-phase circuit, the loads on the 3 phases shall be balanced. At the point of supply, the load on the neutral shall not be more than 20 percent of the computed value of the load in the phases.

7.2.3 *Earthing*

7.2.3.1 All appliances and equipment on temporary installation shall be connected to TN-S system consisting of 5 wires. The 5th wire shall be used the protective earth conductor. Wherever armoured cables are used, the armouring shall be connected to earthing arrangement of power supply Authority. All exposed and extraneous

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conductive parts shall be earthed to the protective earth conductor in such a way that the maximum expected fault voltage is less than 32 volts.

7.2.3.2 For local earthing, the earth electrode shall be buried near the supply intake point. The earth continuity wire shall be bare round conductors/strips and shall be a single core insulated wire and shall be connected to the local earth plate and taken along the cable connecting the supply intake point and the main switch in the installation. The connection from this earth continuity wire shall be taken to various sub distribution boards and terminated on a bus bar. All appliances and equipment connected to sub distribution board shall get their duplicate earth connection from the earth continuity bus bar on the sub distribution board.

8 PROTECTION AND SAFETY

8.1 The installation shall be protected against overload, short circuit and earth leakage by suitable protective devices.

8.2 At the mains incoming the protective earth conductor and the Neutral of the supply system shall be interconnected. If this connection is not allowed by the power supplier, a residual current device (RCCB or CBCT with relay) with a residual current not higher than 30 mA shall be installed at the origin of installation.

8.3 The fault loop impedance at the origin and sub circuits shall be lesser to allow disconnection of supply. This shall be measured to ensure automatic disconnection of supply during fault.

8.4 Temporary supply is generally used at public places and for public functions and, therefore, extreme care shall be taken to ensure that there is no risk of any type of hazard either from electrical shock or fire. No flammable material shall be stored near the service intake point or the operational area of electrical equipment or appliances. For large public functions, exhibitions, etc., suitable fire extinguishers shall be kept at the supply intake point and near the main switch of the installation.

8.5 In construction sites, protection of persons against indirect contact shall be assured by automatic disconnection of supply appropriate to the system of earthing. Socket outlet shall either be protected by residual current devices having operating current not exceeding 30 mA or be supplied by safety extra low voltage or electrical separation of circuit each socket outlet being supplied by a separate transformer.

8.6 All temporary and portable DB’s shall be of double insulated type.

8.7 Plugs, sockets and couplers used shall be of industrial grade confirming to IS/IEC 60309 (Parts 1 and 2). All outdoor sockets shall be of IP 67. Supplies to emergency services shall be fed from sockets having interlock facility to limit unauthorised use.

9 TESTING AND COMMISSIONING

9.1 Supply to all temporary installations should be connected by a specific date for the user and therefore, the installation work meant for types of installations in **4.1**(a), (b) and (c) shall be ready at least 24 h prior to connection of supply, so as to properly test the installation and find the loads in different sub-circuits. In the case of installation described in **4.1**(c), there should be a period of at least 6 h after completion of the work and prior to connecting supply for the purpose of testing the installation and visual inspection.

9.2 The various tests on the installation shall be carried out as laid down in Part 1/Section 14 and Part 3 of this Code.

9.3 When the specified duration of use of the installation as defined in **3.1** is required to be extended beyond the stipulated period of 6 months, the guidelines specified in this Section shall be applicable subject to fresh inspection and tests as above, with the prior approval of the supply authority.

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SECTION 3 PERMANENT OUTDOOR INSTALLATIONS

FOREWORD

Outdoor installations of the permanent nature require special treatment as compared to temporary installations of short durations (less than 6 months) primarily owing to the continuous exposure of the former installation and equipment forming part of it, to heavy conditions of service at site. The design and selection of equipment and components must take into consideration the expected loading, operating characteristics, and cycle duty, as well as the special and arduous environmental, operational, transportation and storage conditions.

This Part and Section of the Code attempts to cover the general requirements applicable to equipment and auxiliaries for a variety of permanent outdoor site installations which are enumerated in **4**. It is intended to provide necessary guidelines for such installations in this Section for the purposes of the practicing engineers and the relevant authorities.

The general characteristics of permanent outdoor installations are enumerated in **5**. The object of this Section is to set out the guiding principles to ensure the safety of persons, livestock, property, and the proper functioning.

In the preparation of this Section, considerable assistance has been derived from IEC 60621: 1987 ‘Electrical installations for outdoor sites under heavy conditions including open-cast mines and quarries’, issued by the International Electrotechnical Commission.

1 SCOPE

1.1 This section of this Code (Part 5/Sec 3) covers requirements for permanent outdoor installations, for operations of equipment and machinery therein used for the purposes, such as:

a) Winning, stacking and primary processing;
b) Secondary processing;
c) Transport conveying;
d) Associated pumping and water supply systems;
e) Haulage trucks;
f) Power generating and distribution systems;
g) Control, signal supervisory and communication system; and
h) Ancillaries.

1.2 This Section does not cover temporary and provisional places of work of durations less than 6 months for which reference shall be made to Part 5/Sec 2 of this Code.

NOTE — However, this Section shall be applicable to building sites and earth-moving sites as far as the equipment used therein are like those used in surface mining application.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

IS No.	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
1255 : 1983	Code of practice for installation and maintenance of power cables up to and including 33 kV (*second revision*)
10028 (Part 2) : 1981	Code of practice for selection, installation, and maintenance of transformers: Part 2 Installation
IS/IEC 60309-1 : 2002	Plugs, socket-outlets and couplers for Industrial purposes: Part 1 General requirements (*first revision*)
IS/IEC 60309-2 : 2002	Plugs, socket-outlets and couplers for Industrial purposes: Part 2 Dimensional interchangeability requirements for pin and contact-tube accessories (*first revision*)
IS/IEC 60947-1 : 2007	Low voltage switchgear and control gear: Part 1 General rules (*first revision*)

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3 TERMINOLOGY

For the purpose of this Section, the definitions given in Part 1 along with the following shall apply:

3.1 Operations (Electrical) — The process of performing work through the controlled application of electrical power. This process includes:

a) Operating — Which means, switching, adjusting, controlling and supervision, and
b) Servicing — which means maintenance, alterations, removal of faults and testing.

3.2 Operating Area — An area accessible to operating personnel in the normal performance of their duties.

3.3 Electrical Operating Area — An area accessible only by the opening of a door or the removal of a barrier. The area shall be clearly and visibly marked by appropriate signs.

3.4 Closed Electrical Operating Area — An area accessible only through the use of a tool or key the area shall be clearly and visibly marked by appropriate signs.

3.5 Working Level (Bench) — That part of an open-cut mine or quarry on which machinery and/or rolling stock are in operation. The working level and/or working area may change location with the progress of operations.

3.6 Winning and Stacking Machinery — Winning and stacking machines are used in the process of uncovering or detaching materials from the earth's surface or stacking such material. These machines are designed to be able to change location according to operational requirements. They include the following:

a) Excavators, namely: bucket-wheel excavators, bucket-chain excavators, draglines, shovels and other excavators, reclaimers, ditch bunker loaders, etc.;
b) Spreaders and stackers;
c) Mobile conveyor bridges;
d) Mobile conveyors, including tripper carriages;
e) Loading stations, including hoppers and surge bins;
f) Floating dredgers; and
g) Mobile electric drills.

3.7 Transport Conveying System — A movable or stationary mechanical item of plant designed for the conveying of materials continuously from one location to another.

They include the following:

a) Belt conveyors,
b) Chain conveyors,
c) Bucket conveyors,
d) Paddle or scraper conveyors,
e) Screw conveyors, and
f) Hydraulic conveyors systems.

3.8 Primary Processing Machinery — Any machinery necessary to prepare material won from the earth prior to its transport to the final processing or utilization areas.

3.9 Secondary Processing Machinery — Any machinery necessary to process at a point remote from the open cut or quarry, material won from the earth.

3.10 Fixed Apparatus — An apparatus or assembly of apparatus which is permanently installed in a determined place and which is not normally moved during or between periods of use.

3.11 Portable Apparatus — An apparatus or assembly of apparatus intended to be normally held in the hand during use and which can be carried by a person.

NOTE — Cables are not included as part of apparatus.

3.12 Mobile Apparatus — An apparatus or assembly of apparatus which is too heavy to be portable, but which is capable of being moved without discontinuity of electric power during use.

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3.13 Movable Apparatus — An apparatus or assembly of apparatus which is too heavy to be portable, but which is moved between periods of use, with its electric power source disconnected.

3.14 Haulage Truck — An electrically powered vehicle usually operating on rubber tyres used for transport of materials and which may have a self-contained or external power supply.

3.15 Movable Railway System — A railway system which is designed to be movable to another location without dismantling.

3.16 Self-Contained Power Supply — An electrical installation in which the generation and utilization plants are housed within the same structure.

3.17 External Power Supply — An electrical installation in which the generation and utilization plants are not housed within the same structure.

3.18 Exposed Conductive Part — A conductive part which can be touched readily, and which normally is not live but which may become live under fault conditions.

NOTE — Typical exposed conductive parts are walls of enclosures, operating handles, etc.

3.19 Earthable Point — That point of the power system, for example, of the transformer and/or generator, which would be connected to earth if the system were to be earthed.

NOTE — The earth able point may be the neutral point depending on the type of power system.

3.20 Insulation Monitoring and Warning Device — A device which causes a signal to be given in the event of reduced insulation resistance to earth.

3.21 Movable Distribution Cable — An insulated cable that may be moved from time to time according to the operation without necessarily following the movements of the machinery.

3.22 Drum Cable — An insulated cable specially designed to be frequently reeled on and off a cable drum or reeler mounted on a mobile machine.

3.23 Trailing Cable — An insulated cable specially designed to be towed by a mobile machine.

3.24 Overhead Traction (Trolley) Wire — An electric line having bare conductors used for supplying vehicles (for example, locomotives) by means of a collector or pantograph.

3.25 Overhead Traction Distribution Line (Feeder) - An electric line having bare conductors used for the interconnecting line between the power source and traction wire.

3.26 Overhead Collector Wire — An electric line used for supplying moving machinery, such as are claimer, by means of a collector.

3.27 Overhead Distribution Line (Feeder) — An interconnecting electric line between distribution substation and load point.

3.28 Return Conductors — Conductors (which maybe rails) used for carrying the return current.

3.29 Safety Circuits and Devices — Circuits and devices designed to prevent danger to personnel or livestock and damage to plant in the event of abnormal or unintentional operation.

4 TYPES OF PERMANENT OUTDOOR INSTALLATIONS

The types of permanent outdoor installations covered by this Section are given in **4.1**. The general characteristics and service conditions enumerated in **5.1** cannot be made uniformly applicable to all such installations. Depending on the site conditions and the nature of the operation involved, a judicious estimate must be made of the environmental factors that influence the performance of the installation.

4.1 The following are the types of permanent outdoor installations covered by this Section:

a) *Open-cut or open-cast mine* — An open-air site for the extraction of materials or minerals, such as coal, bauxite, iron-ore, etc.

NOTE — Underground mines are excluded from the scope of this Section. However, surface installations of underground mines are covered by this Section, to the extent that the operations therein are identical with those described in **1.1**.

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b) *Quarry* — An open-air site for the extraction of materials such as limestone, gravel, clay, etc.

c) *Dockyards* — Includes loading and unloading areas, container terminal, railway yards, repair docks, passenger berths, jetty is, etc.

d) *Airport aprons* — A defined area on a land aerodrome, intended to accommodate aircraft for the purposes of loading and unloading passengers, mail or cargo, refuelling parking, or maintenance.

e) *Railway marshalling yards* — A yard with facilities for receiving classifying and dispatching railway rolling stock.

5 GENERAL CHARACTERISTICS OF PERMANENT OUTDOOR INSTALLATIONS

The design and the selection of components shall be based on expected loading, operating characteristics and cyclic duty taking into consideration the protection required in special and arduous environmental, operational, transportation and storage conditions.

5.1 Some of these conditions, are listed below which may differ from their normal values:

a) Altitude;

b) Low and/or high ambient temperature;

c) Supply voltage variations;

d) Supply frequency variations;

e) Insecure power supply and transients;

f) High or low humidity;

g) Environment (dust, wind pressure, marine atmosphere, etc.);

h) Flammable and/or explosive material/or atmosphere;

j) Vermin, including rodents or other small animals;

k) Localities prone to natural calamities; and

m) Ecological impact.

6 RULES FOR EQUIPMENT AND AUXILIARIES

6.0 General

6.0.1 *Exchange of Information*

Before ordering electrical equipment for outdoor sites, information regarding the duties, location, and installation conditions under which they would operate, should be gathered by the engineers responsible for their procurement, installation and maintenance so that the electrical equipment or apparatus is procured to suit those conditions. Necessity for special measures may be decided in consultation with all concerned.

6.0.2 *Relevant Standards*

The electrical specifications of all components shall be not less than that required by the relevant Indian Standard.

6.0.3 *Materials*

Materials used in component construction shall be appropriate for the environmental conditions, including temperature, altitude, moisture, etc.

6.0.4 *Protection*

Protection shall be provided against damage and/or overheating during normal operation or in expected fault conditions.

6.0.5 *Operating Conditions*

Components shall be designed to meet such conditions as vibration, acceleration, deceleration, slewing and angles of inclination (tilting and mounting) which may occur under expected operational conditions.

6.0.6 *Site Conditions*

Components shall be installed so that design features, such as cooling systems shall not be impaired by external factors such as position, blocking of ventilation ducts, hostile environment, etc.

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6.0.7 *Combustible Materials*

If combustible material (for example, gas, dust or liquid) is present in such quantity as to create a hazard and contact is possible between any exposed part of the component and the combustible material, the temperature of the exposed part shall not exceed the limits specified in Part 7 of this Code.

6.0.8 *Noise Limitations*

Consideration shall be given in the design to limit the noise level in accordance with local rules.

6.1 Selection of Equipment and Ancillaries

6.1.1 *Rotating Machines*

Rotating machines used in applications where high acceleration, over speed, reversing or braking may be employed shall be so selected that they are capable of withstanding the expected stresses on parts, such as rotor windings or cages, stators, stator end windings, shafts and couplings, rotating machines shall be so located or guarded to prevent inadvertent contact with moving parts.

6.1.2 *Transformers*

Transformers shall be so selected that:

a) the bracing of the core, coils, internal leads and the tank of transformers on mobile and movable installations are capable of withstanding vibrations;
b) they are totally enclosed; and
c) dry type transformers including cooling system are protected against harmful ingress of dust.

The following additional protective measures are suggested for fire:

a) Use of dry type transformers,
b) Use of flame-retardant cooling medium, and
c) Protective measures as specified in IS 10028 (Part 2) for transformers with flammable cooling medium. Adequate precautions shall be taken to prevent spillage of the cooling medium causing pollution.

6.1.3 *Static Converters*

The following precautions are recommended:

a) Protection against harmful effects of overvoltage, and transient over-voltage;
b) Protection against interference with communication or electrical control equipment;
c) Protection against spurious operation due to electrical coupling with other apparatus;
d) Protection from EMI;
e) Feedback supervision, where necessary; and
f) Measures to limit harmonics.

6.1.4 *Switching Devices*

The following measures are recommended for switching devices for outdoor sites:

a) Selection of proper design that no unintentional switching may be caused under expected operational and risk conditions;
b) Ensuring, where required suitable means to enable isolators to be locked;
c) Suitable labelling of switching devices which are not meant for interrupting load or fault currents; and
d) Suitable installation precautions to prevent hazards to personnel from electric areas, automatic movement of the mechanism, etc.

6.1.5 *Cables*

6.1.5.1 *Phase conductors*

Selection of phase conductor size should take into consideration the expected load current, short-circuit current and duration of fault, voltage drop, and the mechanical strength required for the expected method of handling. The voltage drop should be calculated for both starting and maximum load conditions. Where supplying cyclic loads, the current-carrying capacity should be based on the long time (for example, 10 min) rms current expected.

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6.1.5.2 *Protective conductor*

All multicore cables of the movable distribution, drum, and trailing types shall contain a protective conductor. In high voltage systems, special measures shall be taken to guard against deterioration of the earthing circuit. This may be achieved by either:

a) Frequent measurement of continuity of the conductors once in 2 months, or
b) Cables should be specially designed and used in accordance with the requirements of relevant Indian Standard whether they are used on a drum.

The protective conductor may be in the form of core(s) and/or screen(s).

For certain classes of movable distribution cables, the armouring may, subject to the requirements of **6.1.5.3**, form the protective conductor.

6.1.5.3 *Armouring as protective conductor*

Where the cross-sectional area of a single composite strand of the armouring is greater than 6 mm^2, the metallic armouring of a movable distribution cable maybe used as a protective conductor provided that the security against breakage of the armouring (taking into account strength, elongation, lay, etc.) is at least equal to that of all the conductors; and provided that the armour conductivity is at least equal to that of a protective conductor of the required nominal cross-sectional area which would otherwise be required.

6.1.5.4 *Limiting temperatures under short circuit*

Cables shall be selected to ensure that the maximum allowable conductor temperature, considering the type of insulation, is not exceeded under expected short-circuit fault conditions.

6.1.5.5 *Protection against partial discharge*

For flexible cables having nominal voltages greater than 3.8/6.6 kV, measures shall be provided to minimize internal partial discharge or to render such effects harmless (for example, field gradient control). Suitable protective measures shall be applied to reduce the touch and step voltages. Such measures may consist of:

a) Metallic screens, or
b) Substantial semi-conductive elements in contact with the protective conductor.

6.1.5.6 *Semi-conducting layers*

Where cables are fitted with substantial longitudinal semi conducting layers for the purpose of providing a current path to the protective conductor in the event of a fault, the resistance between the semi conducting element and the protective conductor should be tested to ensure that it is suitable to carry the prospective fault current.

6.1.5.7 *Provision of screens and/or armouring for cables above 1 000 V*

Where flexible cables are handled manually while energized, they shall have metallic screens and/or armouring or shall be provided with conducting elastomeric screens of substantial cross-sectional area and so placed as to limit the touch and step voltages that may arise in the event of a cable fault. In cases where cables are handled only by means of special insulated tools, these requirements shall apply only for voltages above 3.8/6.6 kV.

6.1.5.8 *Identification of protective conductor*

Unless otherwise required, the following applies:

a) For cables rated at up to and including 1 000 V, in which the protective conductor is insulated, such insulation, or outer taping, shall be distinctly and indelibly coloured green and yellow also (*see* Part 1/Sec 4 of this Code) over its whole length so that in any 15 mm length one of these colours shall cover at least 30 percent and not more than 70 percent of the surface, the other colour covering the remainder of the surface; and
b) For cables rated at above 1 000 V, in which the protective conductor is insulated, such insulation or outer taping shall at least be identified at each end by the green/yellow colour combination applied in accordance with the foregoing paragraph. Suitable supplementary identification may also be used.

6.1.5.9 *Partial discharge performance*

For cables rated at above 3.8/6.6 kV each production length (minimum length 150 m) of movable distribution cable, drum cable and trailing cable shall be tested by the cable manufacturer for partial discharge.

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6.1.5.10 *Terminations of flexible cables*

Flexible cables shall be terminated in such a way that their ends are not under stress or under tension effects, and that excessive bending and compressing are avoided.

6.1.5.11 *Power cable twist limitation*

Where the normal mode of operation of the machine requires in frequent rotation through an arc of up to 360º in either direction, the distance between the clamping supports of the cable shall be not less than 50 times the largest cable diameter in the cable run.

Where cables designed especially for this purpose are used, the above ratios may be reduced to 25 and 50 times respectively.

6.1.5.12 *Sheathing*

Cables may be laid directly on or in the ground provided that the outer sheath is designed for the operating conditions.

Cables having extruded metallic sheaths, for example, cables with lead alloy or aluminium sheaths or mineral insulated metal-sheathed cables, shall not be used where fatigue may occur, due to vibration, frequent handling, or ground movement.

6.1.5.13 *Segregation of power and control cores*

a) *Single-core cables* — Single-core cables which are installed in a common duct, conduit or sleeving may be used for several circuits, both power and control.

   All such cables (except bare earthing conductors) shall be insulated for the maximum voltage applied to any cable in the duct, conduit, or sleeving.

   When using single-core cables for alternating current circuits, all conductors of a given circuit shall follow the same magnetic path to neutralize the resultant magnetic flux.

b) *Multicore cables* — For voltages up to and including 1 000 V, multicore cables may be used for several circuits, both power and control. For voltages above 1 000 V, the only control core(s) which may be included in a multicore cable, shall be the earth continuity check pilot.

   Multicore cables containing power and control cores shall comply with the following requirement as appropriate:

   1) Any cable containing pilot, control and, supervisory cores shall have such cores insulated from all other conducting elements of the cable.
   2) Cables operating at above 1 000 V in an unearthed system shall have either metallic screens or individual conductive rubber screens separating the power cores from the pilot core(s).
   3) Cables operating at above 1 000 V in an earthed system shall have metallic screens separating the power cores from the pilot core(s); and
   4) Cables operating at up to and including 1 000 V shall have pilot, control or supervisory cores separated from power cores by conductive rubber screens if on an unearthed system or metallic screens if on an earthed system. Alternatively, for either system, the pilot, control, or supervisory cores shall be insulated to a voltage level equal to that of the power cores.

c) *Composite multicore cables on reeling drums* — Multicore cable which contain power, pilot, control, or supervisory cores may be used for reeling drum applications, subject to the voltage limitations given in (b) above provided that the cable is specially designed for such reeling duty.

6.1.5.14 *Separation of cables in racks*

Where power and control cables, multicore and single core are used on a common rack, tray or duct, the degree of mutual interference shall be considered.

6.1.5.15 *Bending radius for flexible cables over 25 mm diameter*

The recommended minimum bending radius for flexible cables during installation and handling in service is six times the cable diameter for cable not constructed in accordance with **6.1.5.5**(a) or (b), and eight times the cable diameter for cables which are constructed in accordance with **6.1.5.5**(a) or (b).

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6.1.6 *Cable Connectors*

6.1.6.1 *Use of plug/socket connectors*

Plug and socket connectors used at voltages up to and including 1 000 V shall be of industrial type as per IS/IEC 60309 (Parts 1 and 2). Power supplies to emergency and safety services connected form sockets shall have an interlock facility to avoid unauthorised disconnection.

Where plug and socket connectors are used at voltages above 1 000 V, measures shall be taken to prevent the plug from being engaged with, or disengaged from, the socket while the circuit is energized. The measures shall consist of one or both of the following:

a) The provision of isolating switches which are interlocked with the plug/socket to prevent connection or disconnection while the circuit is energized and to prevent switching the circuit when the plug/socket connection is incomplete.

b) The provision of protective conductor monitoring by means of either a pilot core, by high frequency monitoring, or by other means.

NOTE — The measures under (b) are intended as a safety feature and should not be used for normal isolation purposes.

6.1.6.2 *Use of bolted plug/socket connectors and bolted connections*

Where bolted plug/socket connectors or bolted connections are used, interlocking is not required provided suitable and adequate operational procedures are implemented.

6.1.7 *Control Circuits and Control Devices*

Control circuits and control devices shall not automatically reset after tripping unless resetting of the control device either does not cause automatic restarting of the device or there is no hazard to personnel created by automatic restarting or fire.

For unearthed control circuits, measures shall be taken to limit the leakage and capacitance currents that they shall not exceed 70 per cent of the drop-out currents.

For unearthed control devices, an insulation monitoring device shall also be provided for safety.

6.1.8 *Safety Circuits and Safety Devices*

Any safety circuits shall incorporate fail-safe principle as far as reasonably possible. Some of the principles suggested are:

a) Closed circuit principle,

b) Proving function operation principle, and

c) Fail-safe principles with solid state switching devices.

7 GENERAL RULES FOR PROTECTION IN OUTDOOR INSTALLATIONS

The general rules for protection for electrical installation inside buildings, as enumerated in Part 1/Sec 22 of this Code are applicable for outdoor installations of permanent nature covered by the scope of this Section. The additional requirements applicable for permanent outdoor installations are given in the following clauses.

7.1 Protection against Direct Contact

7.1.1 *Complete Protection by Means of Barriers or Enclosures*

7.1.1.1 The minimum electrical clearances in air between field installed bare conductors and between such conductors and earthed parts (such as barriers and enclosures) shall be in accordance with Table 1 or 2.

NOTES

1 These tables need not apply within electrical apparatus wiring devices or manufactured assemblies nor when the installation is covered by other sections of this Code.

2 Tables 1 and 2 take into consideration the fact that the system voltage may vary up to 20 per cent from the rated operating voltage.

3 Tables 1 and 2 may be used to indicate clearance distances between conductors and earth in a TN or TT system by using the phase-to-earth voltage.

4 These minimum clearance distances in Tables 1 and 2 do not take into consideration such factors as creep age distances, different voltage levels in the same area nor extreme environmental conditions, etc.

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7.1.1.2 All live parts shall be inside enclosures or behind barriers providing at least the degrees of protection in accordance with Table 3.

7.1.1.3 Barriers and enclosures shall be firmly secured in place, and taking into account their nature, size and arrangement, they shall have sufficient stability and durability to resist the strains and stresses likely to occur in outdoor conditions.

7.1.1.4 Where access to the installation is necessary by removal of barriers, opening of enclosures, etc., these shall:

a) Necessitate the use of key or tool;
b) Involve provision of an interlocking device such that the removal, opening or withdrawal without the use of a key or tool necessitates previous switching off of all live parts; or
c) Ensure automatic disconnection when removal, opening or withdrawal without the use of a key or tool is attempted.

7.1.2 *Partial Protection by Placing Live Parts out of Reach (see Table 3)*

7.1.3 *Partial Protection by the Provision of Obstacles (see Table 3)*

7.2 Protection against Indirect Contact

7.2.1 The provisions of Part 1/Sec 7 of this Code shall apply.

8 REQUIREMENTS FOR PERMANENT OUTDOOR INSTALLATIONS

8.1 Winning, Stacking and Primary Processing Machinery

8.1.1 *Mounting of Components*

For the mounting of motors, limit switches, sockets, etc., special protective connections to the structural parts of the installation are not required if the connecting surfaces between the electrical equipment housing and structural parts provide an adequate conducting area. In such cases, the normal mounting bolt or screw connection is adequate. This is also applicable for the mounting of all types of electrical equipment in cubicles, termination boxes, etc. Where the equipment is required to operate under corrosive atmospheric conditions or extreme vibrating conditions, a separate protective conductor shall be connected to motors, limit switches, etc.

8.1.2 *Off-Board Mobile and Movable Auxiliary Equipment*

For mobile and movable off-board auxiliary equipment (such as welding equipment, vulcanising transformers, etc.) where the protective conductor is not monitored nor visible, a visible main equipotential bonding conductor shall be provided between such auxiliary equipment and plant.

8.1.3 *Insulation Monitoring Device for IT Systems*

In the case of an IT system, an insulation monitoring device is not required for power circuits which are supplied by a power source from within the machine, such as by a transformer having electrical isolated windings or by a generator or storage battery.

Table 1 Clearance Distances for Indoor Installations

(*Clause* 7.1.1.1)

Sl No.										
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	Maximum rms value of rated operating voltage, kV	1	3	6	10	20	30	45	60	110
ii)	Minimum distance for installations subject to over voltages, mm	40	65	90	115	215	325	520	700	1 100
iii)	Minimum distance for installations protected against over voltages or connected to cables, mm	40	60	70	90	160	270	380	520	950

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Table 2 Clearance Distances for Outdoor Installations

(*Clause* 7.1.1.1)

Sl No.									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Maximum rms value of rated operating voltage, kV	10	20	30	45	60	110	150	220
ii)	Minimum distance for installations subject to over voltages, mm	150	215	325	520	700	1 100	1 550	2 200
iii)	Minimum distance for installations protected against over voltages or connected to cables, mm	150	160	270	380	520	950	1 350	1 850

Table 3 Minimum Protection Against Direct Contact by Barriers or Enclosures (Applicable to Live Parts Only)

(*Clauses* 7.1.1.2, 7.1.2 *and* 7.1.3)

Sl No.	Voltage Band (a.c.)	Within Operating Areas	Within Electrical Operating Areas	Within Closed Electrical Operating Areas
(1)	(2)	(3)	(4)	(5)
i)	$50 < U < 1\,000$ V *See* Note 1	Complete protection IP2X[1)] or IP4X for top surfaces or barriers or enclosures which are readily accessible. This applies to those parts of enclosures which might serve as a standing surface	Partial protection IP1X[1)] if $U \leq 660$ V or no simultaneously accessible parts at different voltages are situated within arm's reach Complete protection IP2X if $U > 600$ V or IP4X if $U > 660$ V for top surfaces or barriers or enclosures which are readily accessible This applies to those parts of enclosures which might serve as a standing surface	No protection IP0X if $U \leq 660$ V Partial protection IP0X if $U > 660$ V or no simultaneously accessible parts at different voltages are situated within arm's reach
ii)	$U > 1\,000$ V	Complete protection IP5X within arm's reach Partial protection IP2X beyond arm's reach	Complete protectionIP5X[1)] within arm's reach Partial protection IP1X[1)] beyond arm's reach	Partial protection IP1X[1)]

NOTES

1 Key:

U = rated voltage of the installation between lines.

[1)] = For electrical operating areas and closed electrical operating areas, protection equivalent to IP1X is also considered to be achieved by placing out of reach or by the interposition of obstacles, for example, by means of protective barriers or handrails.

2 The use of floor plug and socket connector is not precluded but such sockets shall be covered when not in use.

3 For details on IP classifications, *see* IS/IEC 60947-1. As used in the present standard, the IP classification is intended to specify only the degree of protection required to protect persons from contact with live parts. Additional protection may be required for protection from contact with moving parts or to prevent ingress of solid foreign bodies, such as dust.

4 In the case of d.c. voltages, the voltage bands in the above table may be increased in the ratio of 1 : 1.5, namely, up to 1 500 V and above.

8.1.4 *Insulation Monitoring Devices for Vulcanising Heating Platens*

In IT systems, insulation monitoring devices are not required for vulcanising heating platens where the power circuit is supplied from a transformer having electrically isolated windings.

8.1.5 *Electric Hand Tools*

Shall be protected by RCD with a residual current not more than 30 mA.

8.1.6 *Electric Hand Lamps*

Shall be protected by RCD with a residual current not more than 30 mA.

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8.1.7 *Drives*

The following recommendations apply to drives with a periodic or cyclic duty as well as to certain other drives with a continuous duty.

8.1.7.1 *Effect on voltage levels*

The effects of equipment starting and of the duty cycle on voltage levels, which may result in damage or the malfunction of equipment, shall be taken into consideration to ensure the safety of personnel and equipment.

8.1.7.2 *Supply systems*

The effect of load fluctuations on the supply system shall be considered, taking account any restrictions imposed by the electricity supplier.

8.1.8 *External Power Supply Systems*

8.1.8.1 *System design*

The supply system shall meet the requirements of cyclic or periodic loads, motor starting, and inherent a.c. motor oscillations due to transient load changes. For protection requirements, *see* **7**.

8.1.8.2 *Overcurrent protection*

Overload and short-circuit protection for transformers, cables, etc, shall take into consideration the starting requirements and cyclic nature of the load.

8.1.8.3 *Automatic reclosing or transferring*

Where regeneration may delay the operation of under voltage devices, automatic reclosing or

transferring devices should not be used in the power distribution system unless such device has sufficient time delay to allow motor disconnection, the device is fitted with ‘out of step’ protection, or the combination of supply system and motor design characteristics is, such as to permit automatic re-energisation.

8.1.8.4 *System voltage*

It is important that the equipment manufacturer and user mutually understand whether the voltage specified is under no-load or full load conditions.

8.1.9 *Self-contained Power Systems*

8.1.9.1 *System design*

The power generation systems shall meet the requirements of motor starting, regeneration, peak load, rms load and frequency stability.

8.1.9.2 *Fire protection*

Consideration should be given to the need for special and/or additional fire protection due to the fuels used (*see* **6**).

8.1.9.3 *Earthing*

When the supply of electrical energy is self-contained within stationary, mobile, or movable items of equipment and there is no external supply, such equipment need not be connected to the general mass of the earth.

8.1.9.4 *Supply to off-board equipment*

When power is supplied to off-board mobile and movable equipment conditions given in **8.1.2** are applicable.

8.1.10 *Cable Types*

Under consideration.

8.1.11 *Control Circuits and Control Devices*

8.1.11.1 *Shock vibration and voltage fluctuations*

The effect of shock, vibration or voltage fluctuations on control devices shall be taken into consideration, ensuring that safety of personnel and equipment is not endangered by inadvertent operation of control devices.

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When mechanically latched control devices are used and re-energisation following loss of supply power would endanger personnel or equipment, means shall be provided to automatically trip the latched control device on loss of supply power. The device shall also be tripped on operation of protective devices.

8.1.11.2 *Synchronous motor control*

a) *Automatic field removal* — Where synchronous motors are used to drive any part of the installation, automatic motor field removal on disconnection is required.

b) *Automatic field excitation control* — Where synchronous motors are used to drive periodic or cyclic loads, an automatic field excitation control is recommended.

c) *Power loss protection* — Where synchronous motors are used to drive loads which may be regenerative, means shall be provided to trip the motor starting switch or incoming lines witch upon loss of power supply. Frequency sensitive devices are recommended. When automatic reclosing or transferring devices are used in the distribution system, conditions given in **8.1.8.3** are applicable.

8.1.11.3 *Stop control*

The devices described in the following paragraphs shall not be used for purposes of isolation or immobilisation to allow work to be carried out on parts which would otherwise be electrically energised or moving:

a) *Stop control circuits* — The circuits of stop control and of other safety protection devices should be as simple, reliable, and direct actin gas is practical.

b) *Location of stop controls* — A stop control shall be located near each start control, except for lift call control. Additional stop controls may be provided.

c) *Locking of stop controls* — Where required, provision shall be made to guard against un authorised starting. Acceptable methods include locking of stop controls in the 'off' position or ensuring that only the person operating the stop control has access to the start control.

d) *Pull wire stop controls* — Stop controls operated by a pull wire shall be arranged so that a pull on the wire in any direction will stop the controlled equipment. The stop controls shall be of a type in which the contacts are opened by a positive mechanical action and can only be reclosed by a further mechanical action.

8.1.11.4 *Interlocking of start controls*

Where equipment can be started from more than one location, the control system shall permit operation from only one nominated location at any one time, unless start-up alarms are used, the equipment is in sight from all starting locations, or the equipment is guarded against inadvertent access.

8.1.12 *Emergency Stopping and Emergency Devices*

8.1.12.1 *Emergency stopping*

Disconnection of power or other equally effective means shall be provided for stopping the drive under emergency conditions. The power disconnect device may be a manually or remotely operated power circuit breaker, contactor, etc.

Emergency stopping can be accomplished by means other than disconnection of power, provided that such means otherwise comply with the intent of **8.1.11.3**. For example, when rotation conveners are used, disconnection of the external excitation is permitted if protection against self-excitation is provided.

8.1.12.2 *Emergency devices*

Where the cut-out devices are actuated remotely, they will be arranged as series tripping system. However, shunt tripping devices may be used providing the tripping device and its stored energy tripping supply are monitored and regularly maintained. Emergency devices may be arranged to operate simultaneously in several different circuits. Several emergency devices may be arranged in groups; each group may operate in single or multiple circuits. Where several circuits are divided the respective contact elements shall be connected in series. However, shunt tripping systems may be used providing the above-mentioned conditions are maintained. The emergency device may use remote control systems, for example, audio-frequency of time-multiplex operations, providing at least the same protective measures as for the above devices are applied to ensure positive and reliable operations. However, the simultaneous existence of two or more faults within the remote controls system need not be expected.

8.1.13 *Provision for Supply Isolation*

A means of mains supply isolation shall be provided to isolate the power circuits from the equipment or parts thereof inclusive of control and motor circuits.

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However, separate means of isolation may be provided for control circuits, which may remain energised after disconnection of power circuits, provided special measures for the safety of personnel and equipment have been implemented.

8.2 Secondary Processing Machinery

Under consideration.

8.3 Transport Conveyor Systems

8.3.1 *Mounting of Components*

For the requirements of mounting of components, **8.1.1** shall be referred.

8.3.2 *Equipotential Bonding Conductor and Conductivity of Structural Parts*

Where electrical equipment supplied at a voltage in excess of 50 V is mounted on a conveyor structure and the cable to the equipment does not include a protective conductor, an equipotential bonding conductor shall be provided to the electrical equipment unless the structural parts of the conveyor are mechanically fastened and/or electrically bonded together. The conductivity of the metallic structural parts of the conveyor and its fastenings shall be at least equal to that of the otherwise necessary equipotential bonding conductor.

8.3.3 *Off-board Mobile and Movable Auxiliary Equipment*

For the requirements of off-board mobile and movable auxiliary equipment, **8.1.2** shall be referred.

8.3.4 *Insulation Monitoring Device for IT Systems*

For the requirements of insulation monitoring device for IT systems, **8.1.3** shall be referred.

In cases where an IT system is used for reasons of continuity of supply, an insulation monitoring device shall be provided to indicate the occurrence of a first fault from a live part to exposed conductive parts or to earth. This device shall initiate an audible and/or visual signal which shall continue as long as the fault persists.

If there are both audible and visible signals, it is permissible for the audible signal to be cancelled.

NOTE — It is recommended that a first fault be eliminated with the shortest practicable delay.

8.3.5 *Insulation Monitoring Devices for Vulcanizing: Heating Platens*

For the requirements of insulation monitoring devices for vulcanizing: heating platens, **8.1.4** shall be referred.

8.3.6 *Electric Hand Tools*

For the requirements of electric hand tools, **8.1.5** shall be referred.

8.3.7 *Electric Hand Lamps*

For the requirements of electric hand lamps, **8.1.6** shall be referred.

8.3.8 *Cables*

8.3.8.1 *General*

Where cables without semi conductive sheaths, metallic screens or armouring are suspended from structures or frames of movable conveyors, such structures and frames shall be considered as extraneous conductive parts and shall be included as part of the whole plant in the design of the protective measures against indirect contact, that is, by ensuring that all metallic parts are linked together.

8.3.9 *Stop Controls*

The devices described in the following clauses shall not be used for purposes of isolation or immobilisation to allow work to be carried out on parts which would otherwise be electrically energised or moving.

8.3.9.1 *Stopping sequence*

The operation of a stop control on a conveyor shall stop that conveyor and:

a) All upstream conveyors to a controlled loading point,
b) Cause the material from all upstream conveyors to be diverted to an alternative route,

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c) Initiate braking to stop the conveyor in safe time, and

d) Prevent run-back.

On very long conveyor systems, however, the operation of a stop control within one stop zone need not stop all upstream conveyors beyond that zone, provided that the conveyor upstream of the zone is proved to be unloaded, such as by sensors.

Although the stop control may be reset automatically, restarting shall be initiated manually.

8.3.9.2 *Location of stop controls*

Stop controls shall be provided. It is recommended that stop controls be located at the head and tail ends of a conveyor and that pull wire stop controls be used along the length of the conveyor. All accessible points along the pull wire operated stop control are considered as stop controls. Where individual stop controls are used, they shall be located not more than 15 m from any accessible point along the conveyor. Stop controls shall be accessible from any side of a conveyor to which there is access.

NOTE — Manually operated stop controls may also provide the function of an emergency stop.

8.4 Pumping and Water Supply Systems

8.4.1 *Deep-well Type Pumps*

8.4.1.1 *Risers as protective conductors*

Where a continuous metallic riser pipe is fitted between the motor and the well head, no protection conductor is required between the motor and the protective conductor connected directly to the fixed riser provided that:

a) The supply cable is terminated close to the wellhead,

b) The conductivity of the metallic riser (standpipe) and the connections (couplings) shall be at least equal to the conductivity of the protective conductor which would otherwise be necessary, and

c) Personnel do not have access down the well.

8.4.1.2 *Continued operation after first earth fault*

Operation may continue after the first earth fault only when all the following conditions are met:

a) An IT system is used,

b) Personnel do not have access down the well, and

c) Equipotential bonding is provided.

NOTE — Electrically initiated explosive devices should not be stored or used in the vicinity of suchinstallations as hazards may exist due to fault currents flowing in the ground when systems continue to operate following the first earth fault.

8.4.1.3 *Equipotential bonding*

An equipotential bonding conductor shall be installed between the main earth terminals of the supply and the well head(s), where the conductor shall be connected directly to the fixed riser. Where transformers are located at the well head, their enclosures shall be connected to this bonding conductor.

The equipotential bonding conductor shall be so dimensioned that the voltage drop between any two points (of resistance value *R*) that may be contacted simultaneously shall not exceed 50 V. That is:

$$t \leq \frac{50}{K \times I_n} \text{ ohms}$$

Where, I_n (in amperes) is the rated current of the power fuses or, in the case of circuit-breakers, 0.2 times the releasing current for the instantaneous or short-time delay trip; and *K* is a multiplying factor.

NOTE — A value of K = 2.5 is suggested for the time being.

8.4.1.4 *Exemption from insulation monitoring device*

An insulation monitoring device (or earth fault detector) is not necessary.

8.4.1.5 *Double line to earth faults*

Protection shall be provided to disconnect the supply in the case of a double fault (phase-earth-phase).

A device such as one which detects a change in neutral displacement on the occurrence of the first and second earth faults, may be provided. Disconnection follows the second fault.

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9 ADDITIONAL GUIDELINES FOR INSTALLATIONS IN SPECIFIC AREAS

9.0 General

9.0.1 The requirements given in **4** to **8** are applicable to the specific areas described in this Section in so far as the operations are identical with those described.

9.0.2 Guidance from relevant experts shall be taken in respect of specific areas before installation work begins.

9.1 Lighting of Aircraft Aprons

The provisions of relevant Indian Standards shall apply.

9.2 Lighting of Ports and Harbours

The provisions of relevant Indian Standards shall apply.

9.3 Lighting Installations in Railway Marshalling Yards

9.3.1 *Classification*

9.3.1.1 The classification in respect of yard area is based on the speed and intensity of traffic both vehicular and otherwise.

a) *Multipurpose yard* — A marshalling yard with facilities for receiving, classifying and despatching vehicles to their several destinations. They also deal with traffic originating at or destined for centres.

b) *A reception yard* — A yard in which the loads of incoming trains may stand clear of running lines while waiting for their turn to be dealt with.

c) *A classification yard* — A yard in which trains are broken up on the different lines for the various directions or stations irrespective of station order, to form them into trains and prepare them for correct marshalling.

9.3.1.2 The railway yards are also classified into five main categories depending on their handling capacity and way of working:

a) *Gravity yard* — A yard where natural gradient is available. It is utilized for classification and sorting of loads. Shunting is done without engine.

b) *Hump yard* — Hump yard created by raising track levels in specified crest of 2 to 2.5 m height. Hump yards are those where shunting necks have shape of a camel hump. These yards are mechanized where wagon level crosses 2 500 wagons/day. Normally one hump handles 1 000 to 1 500 wagons/day. The number of humps can be increased depending on the workload.

c) *Flat yard* — Yards with flat shunting neck are called flat yard. It deals from 300 to 700 wagons/day. It is mostly suitable for metre gauge.

d) *A sorting yard* — This is a yard in which wagons are separated in station order and reformed into trains in special order to meet the requirements of the section ahead or any other special transportation requirements.

e) *A departure yard* — This is a yard in which loads are kept waiting for departure.

9.3.1.3 Each yard can be of anyone of the three formations based on method of construction:

a) Balloon or classification type,

b) Ladder type, and

c) Grid type.

NOTE — Yards with grid type formation are reception cum-despatch yards.

9.3.1.4 For the purpose of illumination, most important locations are ‘king points’ and ‘queen points’ and order of priority for lighting is determined accordingly.

NOTES

1 King points are the first pair of points that the wagon meets after passing over the hump summit and these divide the hump yard into two portions.

2 Queen points are the second pair of points the wagon meets on either of the two diverging lines taking off from the king points and these divide the classification lines into four sub-portions. These are two in each hump yard.

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9.3.2 Different segments (functions) of yards are:

a) Classification yard — zone-wise,
b) Sorting yard — station-wise,
c) Reception yard,
d) Despatch yard, and
e) Through goods yard.

9.3.3 *Design*

9.3.3.1 For the purpose of designing the lighting system, the recommended height of tower is 30 m.

9.3.3.2 *Selection of equipment*

a) Light sources — The following sources of light are recommended for the purpose of yard lighting:
   1) High pressure mercury vapour lamps; and
   2) High pressure sodium vapour lamps.

   Each luminaire may be provided with 2 lamps of 400 W or 1 lamps of 1 000 W.
b) Luminaires — Flood lighting types of luminaires are recommended for yard lighting installation.

9.3.3.3 Levels of illumination would depend on the type of marshalling yard. The levels given below are recommendatory:

Sl No.	Type	Minimum	Maximum	Special Location Like Shunting Neck, King Points, etc
(1)	(2)	(3)	(4)	(5)
i)	Important yard	1.2 lux	5 lux	10 lux
ii)	Small yards	0.5 lux	1.2 lux	5 lux

9.3.4 *Power Installation Requirements*

9.3.4.0 The source of electric supply shall be located at a suitable place nearest to the yard.

9.3.4.1 The power supply to the towers shall be through underground armoured cables. Minimum size of cable shall be 10 to 16 mm^2 - 4 core.

9.3.4.2 Means shall be provided to control supply to group of towers with control gear located in feeding substation/switching substation.

9.3.4.3 The cables shall be preferably terminated on column junction boxes by looping joints, rather than 'T' joint.

9.3.4.4 The junction boxes shall be provided with suitable sized contactors with independent fuses for each phase. The contactors shall be controlled by electrically operated switch mounted for external manual local operation. Laying of cables in yard, along the track and across the tracks should be done in accordance with IS 1255.

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NATIONAL ELECTRICAL CODE OF INDIA

PART 6 ELECTRICAL INSTALLATIONS IN AGRICULTURAL PREMISES

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PART 6 ELECTRICAL INSTALLATIONS IN AGRICULTURAL PREMISES

FOREWORD

This Part of the Code is primarily intended for covering the specific requirements of electrical installations in agricultural premises which include premises where livestock are present and farm produce are handled or stored. With the increase in sophistication in organizing the farm output of the country, and the use of electricity for certain essential purposes, it has been felt necessary to cover the requirements of such installations as a part of the Code.

Installations in agricultural premises are different from those covered in other Sections of the Code in that the external influences on the electrical services are quite different from those encountered elsewhere. Even though the overall power requirements for such installations would be small, the presence of livestock and other extraneous factors necessitate laying down specific requirements.

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1 SCOPE

1.1 This Part of the National Electrical Code of India (Part 6) covers requirements for the fixed electrical installations in agricultural premises excluding dwellings or similar locations situated in these premises.

1.2 This Part applies to premises where livestock are present.

NOTE — Examples of such premises are stables, cow houses, sheepfolds, stalls, hen-houses, piggeries, etc.

2 TERMINOLOGY

For the purpose of this Part, the definitions given in Part 1/Section 2 of the Code shall apply.

3 CLASSIFICATION

3.1 Installations in agricultural premises shall be broadly classified into:

a) Farm houses and agricultural processing units, and
b) Livestock houses.

3.1.1 *Farm Houses and Agricultural Processing Units*

Farm houses and agricultural processing units are premises where livestock are not normally present and are those utilized solely for the purposes of handling, processing or storing farm inputs and produce.

3.1.2 *Livestock Houses*

Livestock houses are premises where livestock are present for long periods of time during the day (such as in a dairy farm) with or without associated farm units.

3.1.2.1 Livestock houses are further classified depending on the type of climatic conditions:

a) Plain areas with moderate rainfall,
b) Arid areas and high altitude areas, and
c) Heavy rainfall areas and high rainfall humidity areas.

3.1.2.2 Livestock houses can also be classified depending on the type of animal or bird housed. For example:

Animal/Bird Housing	*Sub-classification*	
Poultry housing	Layer house Brooder house	Stationary portable
Sheepfolds	—	
(sheep and goats) piggeries	—	
horse stables or equine houses	—	
Cattle housing	Cattle sheds for average farmer (3 milk animals with their calves and pair of bullocks) Cattle sheds for rural milk producer (average of about 20 animals) Organized milk produces (130 animals) Large dairy farm (about 500 animals)	

4 GENERAL CHARACTERISTICS OF AGRICULTURAL PREMISES

General guidelines on the assessment of general characteristics of buildings are given in Part 1/Section 8. For the purpose of installations covered by this Part the conditions given below apply.

4.1 Environment

The following conditions generally apply:

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Environment	*Characteristics*	*Remarks*
(1)	(2)	(3)
Presence of water	Possibility of splashes from any direction	Locations where equipment maybe subjected to splashed water, for example external lighting fittings
	Possibility of jets of water from any direction	Locations where hose-water is used regularly
Presence of foreign solid bodies	Presence of dust in significant quantity	Applies to barns, stores and stalls
Presence of corrosive or polluting substances	a) Intermittent or accidental subjection to corrosive or polluting substances	Applies to locations in which livestock are present or fertilizers or plan protective products are stored or handled
	b) Continuously subjected to corrosive or polluting substances	
Presence of flora and/or mould growth	Harmful hazard present	—
Presence of fauna Electromagnetic influences	Harmful hazard present	Insects, birds and small animal
	Harmful presence of induced currents	

4.2 Utilization

The following conditions apply:

Utilization	*Characteristics*	*Remarks*
Electrical resistance of human body	Low to resistance due to wet conditions	—
Contact of persons with earth potential	Persons are frequently in touch with extraneous conductive parts or stand on conducting surfaces	
Conditions of evacuation during emergency	Low density occupation difficult conditions of evacuation High density occupation easy conditions of evacuation	Special precautions to be taken where animals are present
Nature of processed or stored materials	Flammable material including dust	Barns
Building design	Propagation of fire is facilitated and risks due to structural movement of structures which are weak	

5 SUPPLY CHARACTERISTICS AND PARAMETERS

5.1 Information shall be exchanged among the people concerned on the electrical needs of the premises before installation work begins. Each installation may have to cater to the services required in the subunits of the premises which depend on the type of agricultural premises as enumerated in **4**.

5.1.1 In agricultural farms the following sub-units are present:

a) Outdoor processing,
b) Indoor processing,
c) Heating/cooling,
d) Cold storage,
e) Stores, and
f) Office.

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5.1.2 In sheepfolds, the following sub-units are present:

a) Sheds, such as flock shed, ram or buck shed, sick shed, etc;
b) Sheering and store room; and
c) Shepherd house.

5.1.3 In cattle housing, the following sub-units are present:

a) Sheds for animals,
b) Milk recording and testing room,
c) Utensils room,
d) Ration room,
e) Stores, and
f) Office.

5.1.4 In meat houses and abattoirs, the following subunits are present:

a) Animal sheds before slaughter,
b) Slaughter shed,
c) Flaying, dressing and washing,
d) By-products handling,
e) Inspection,
f) Laboratory, and
g) Office.

5.2 Wiring Systems

5.2.1 Main switchgear shall not be installed:

a) within reach of livestock, or
b) in any position where access to it may be impeded by livestock.

5.2.2 Where an installation serves more than one building, it shall be possible to isolate and control the buildings individually.

5.2.3 Means of access to all live parts of switchgear and other fixed live parts where different nominal voltages exist shall be marked to indicate the voltages present.

5.2.4 *Cables*

5.2.4.1 All cables shall be placed out of reach of livestock and clear of all vehicular movement.

5.2.4.2 Where additional protection against mechanical damage to cables is required, it shall, wherever possible, be provided by the use of non-metallic materials.

5.2.4.3 Where long runs of cable must be placed along the sides of buildings, they shall wherever possible be placed on the outside of the buildings, and as high as practicable.

5.2.4.4 Where conductors or cables are carried overhead supported by buildings or by poles, the minimum height above ground shall be 6 m.

5.2.4.5 Cable couplers shall not be used in agricultural premises.

In locations accessible to, and enclosing, livestock wiring systems shall be erected so that they are inaccessible to livestock or suitably protected against mechanical damage.

Overhead lines shall be insulated.

In areas of agricultural premises, where vehicles and mobile agricultural machines are operated, the following methods of installation shall be applied:

a) Cables to be buried in the ground at a depth of at least 0.6 m with added mechanical protection;

NOTE — Where conduits are used as additional protection, they should provide a degree of protection against compression of 450 N and a normal degree of protection against impact according to IS 16205 (Part 24).

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b) Cables in arable or cultivated ground to be buried at a depth of at least 1 m; and

c) Self-supporting suspension cables to be installed at a height of at least 6 m.

NOTE — Cables buried in the ground is the preferred method of installation.

5.2.4.6 Wiring systems supplying main distribution boards at the origin of the electrical installation, if not protected by RCDs, shall be protected against mechanical damage, for example, buried in the soil or installed in separated enclosed cable trunking or ducting systems.

This requirement shall also apply to residences and other locations belonging to agricultural or horticultural premises.

5.2.4.7 Special attention shall be given to the presence of different kinds of fauna, for example, mice and rats.

5.2.4.8 *Conduits, ducts and trunking systems*

For locations where livestock is kept, external influences shall be classified AF4, and conduits shall have protection against corrosion of at least Class 2 (medium) for indoor use and Class 4 (high protection) outdoor according to IS 16205 (Part 21).

For locations where the wiring system may be exposed to impact and mechanical shock due to vehicles and mobile agricultural machines etc., the external influences shall be classified AG3:

a) conduits shall have a degree of protection against compression of at least Class 4 (heavy) according to IS 16205 (Part 21);

b) cable trunking and ducting system shall provide a heavy degree of protection against impact according to IS 14927 (Part 2).

5.3 Selection and Erection of Equipment

Equipment shall be so selected that they suit the environmental conditions of use and shall be installed in such a way that their normal functioning is not affected by the external influences enumerated in **4**.

5.3.1 It is recommended to protect final sub-circuits by residual current devices, the rated operating residual current not exceeding 30 mA and as low as practicable but avoiding nuisance tripping.

In agricultural or horticultural premises, electrical equipment shall have a minimum degree of protection of IP 44, when used under normal conditions. Where equipment of IP 44 rating is not available, it shall be placed in an enclosure complying with IP 44.

Socket-outlets shall be installed in a position where they are unlikely to come into contact with combustible material.

Where there are conditions of external influences >AD4, >AE3 and/or >AG1, socket outlets shall be provided with the appropriate protection.

Protection may also be provided by the use of additional enclosures or by installation in building recesses.

These requirements do not apply to residential locations, offices, shops and locations with similar external influences belonging to agricultural and horticultural premises where, for socket-outlets IEC 60884-1 applies.

Where corrosive substances are present for example, in dairies, byres, the electrical equipment shall be adequately protected.

5.3.2 *Selection and Erection of Electrical Equipment*

Earthing arrangements, protective conductors and protective bonding conductors

5.3.3 *Protective Bonding Conductors (Equipotential Bonding Conductors)*

5.3.4 *Protective Bonding Conductors for Supplementary Bonding*

Protective (equipotential) bonding conductors shall be protected against mechanical damage and corrosion, and shall be selected to avoid electrolytic effects.

For example, the following may be used:

a) hot-dip galvanized steel strip with a dimension of at least 30 mm × 3 mm,

b) hot-dip galvanized round steel with at least 8 mm diameter,

c) copper conductor having a minimum cross-sectional area of 4 mm^2, and

d) copper coated steel conductor with at least 6 mm diameter.

Other suitable materials may be used.

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5.3.5 *Selection and Erection of Electrical Equipment – Other Equipment*

5.3.5.1 *Socket-outlets*

Socket-outlets of agricultural and horticultural premises shall comply with:

a) IS/IEC 60309-1,
b) IS/IEC 60309-2 when interchangeability is required, or
c) relevant national standards provided the rated current does not exceed 20 A.

5.3.6 *Safety Services*

5.3.6.1 *Automatic life support for high density livestock rearing*

For high density livestock rearing, systems operating for the life support of livestock shall be taken into account as follows:

a) Where the supply of food, water, air and/or lighting to livestock is not ensured in the event of power supply failure, a secure source of supply shall be provided, such as an alternative or back-up supply (*see* also 5.5.2 of IS 732). For the supply of ventilation and lighting units separate final circuits shall be provided. Such circuits shall only supply electrical equipment necessary for the operation of the ventilation and lighting.
b) Discrimination of the main circuits supplying the ventilation shall be ensured in case of any overcurrent and/or short-circuit to earth.
c) Where electrically powered ventilation is necessary in an installation one of the following shall be provided:
   1) A stand-by electrical source ensuring sufficient supply for ventilation equipment; or

      NOTE — For the functional efficiency, a notice should be placed adjacent to the stand-by electrical source, indicating that it should be tested periodically according to the manufacturer's instruction.

   2) Temperature and supply voltage monitoring. This can be achieved by one or more monitoring devices. The device(s) shall release a visible or audible signal that can be readily observed by the user and shall operate independently from the normal supply.

      NOTES

      1 Consideration should be given to legal requirements for the keeping of livestock.

      2 The reliability of the installation for ventilation will be increased if, for this purpose, separate supply circuits are erected downstream from the main distribution board.

5.3.7 *Luminaires and Lighting Installations*

Luminaires shall comply with the IEC 60598 or IS 10322 series and be selected regarding their degree of protection and surface temperature according to the conditions of the surrounding areas and the places of installation (for example, IP 54, suitable temperature marking  for mounting on combustible material).

In areas where a fire risk and a danger from a combustible coating of dust exist, only luminaires marked in accordance with IEC 60598-2-24, luminaires with limited surface temperature, shall be used.

Luminaires marked  shall only be installed if the luminaire containing the lamps are in compliance with the degree of protection IP 54.

Luminaires shall be mounted at places where a sufficiently large distance from combustible materials is ensured taking into account the storage of goods and other dangerous work processes.

NOTE — Safety distances are given in the manufacturer's instructions for mounting. Furthermore, reference is made 4.3.2 of IS 732.

The switched conditions (on or off) of luminaires installed in hay or straw storage places or similar locations, shall either be recognizable at the location of the switch or indicated there by a visible signal.

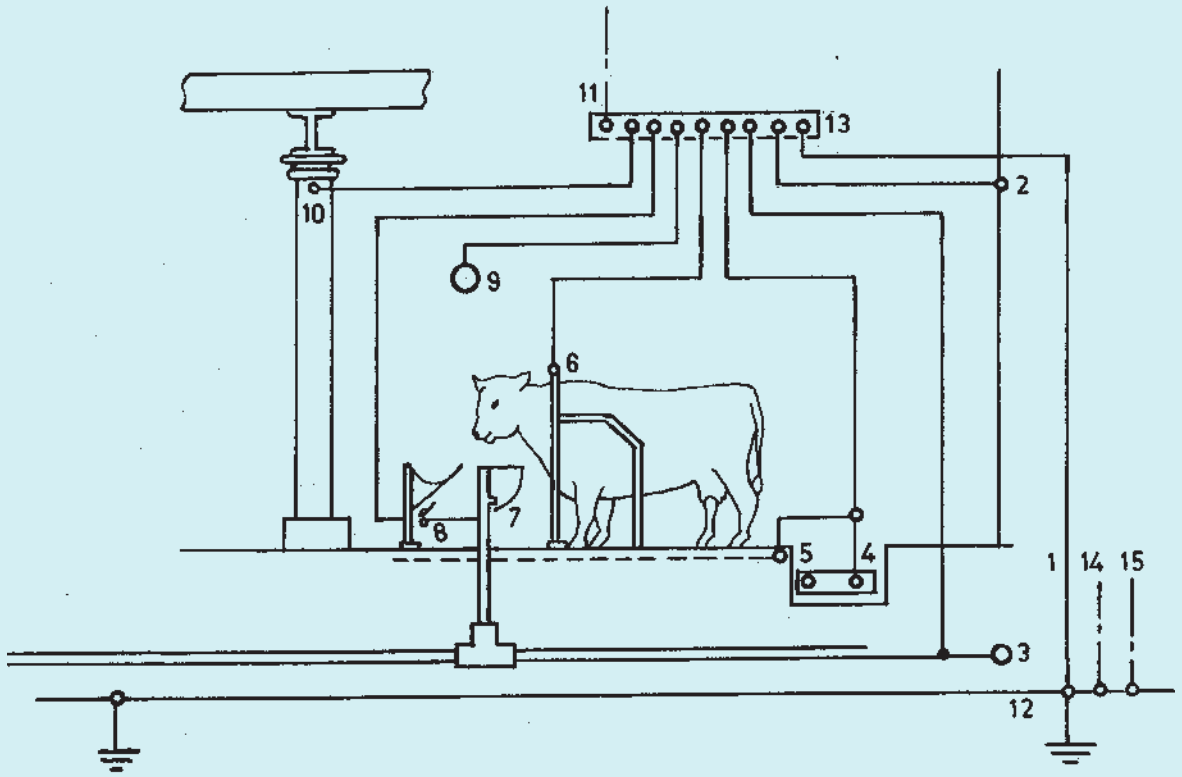
5.4 System Protection

5.4.1 *Protection Against Electric Shock*

For the application of protective measure by safety extra-low voltage in locations in which livestock are present or situated outside, protection against direct contact shall be provided by:

a) barriers or enclosures affording at least the degree or protection IP2X, or
b) insulation capable of withstanding a test voltage of 500 V for 1 min.

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1. Earth conductor
2. Sheet metal and foil partitions
3. Water pipe
4. Manure removal device
5. Potential equalization, for example, structural steel mat
6. Tethering device
7. Automatic watering device
8. Feeding apparatus
9. Milking apparatus
10. Steel structure
11. Protective earth conductor (PE)
12. Earth electrode
13. Busbar for equipotential bonding
14. Earth electrode for lightning protection
15. Earth electrode for electric fences

FIG. 1 EXAMPLE OF EQUIPOTENTIAL BONDING ON AGRICULTURAL PREMISES

For achieving protection by automatic disconnection of supply, the conventional voltage limit in locations in which livestock are present or situated outside is U_L = 25 V. These conditions are also applicable to locations directly connected through extraneous conductive parts to the locations where livestock are present.

Where electrical equipment is installed in livestock building, supplementary equipotential bonding shall connect all exposed conductive parts which can be touched by livestock and the protective conductor of the installation.

NOTE — A metallic grill connected to the protective conductor laid in the floor is recommended (*see* Fig. 1).

5.4.2 *Protective Measure: Automatic Disconnection of Supply*

5.4.2.1 *General*

In circuits, whatever the type of earthing system, the following disconnection device shall be provided:

a) in final circuits supplying socket-outlets with rated current up to 32 A, a RCD with $I\Delta$ n not exceeding 30 mA;

b) in final circuits supplying socket-outlets with rated current more than 32 A, a RCD with $I\Delta$ n not exceeding 100 mA; and

c) in all other circuits RCDs with $I\Delta$ n not exceeding 300 mA.

NOTE —Where improved continuity of service is required, RCDs with a rated residual operating current up to 300 mA should be of the S type or time delayed.

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5.4.2.2 *Protective measure: extra-low-voltage provided by SELV and PELV*

5.4.2.3 *Requirements for SELV and PELV circuits*

5.4.2.4 Where the protective measure SELV or PELV is applied, whatever the nominal voltage, protection against direct contact (basic protection) shall be provided by one of the following measures:

a) barriers or enclosures affording a degree of protection of at least IP XXB or IP 2X, or

b) insulation capable of withstanding a test voltage of 500 V a.c. r.m.s for 1 min.

5.4.3 *Additional Protection: Supplementary Protective Equipotential Bonding*

In locations intended for livestock, supplementary bonding shall connect all exposed-conductive-parts and extraneous-conductive-parts that can be touched by livestock. Where a metal grid is laid in the floor, it shall be included within the supplementary bonding of the location (*see* figures of Annex A).

Extraneous-conductive-parts in, or on, the floor for example, concrete reinforcement in general or reinforcement of cellars for liquid manure, shall be part of the supplementary equipotential bonding.

It is recommended that spaced floors made of prefabricated concrete elements be part of the equipotential bonding (*see* Fig. A-3). The supplementary equipotential bonding and the metal grid, if any, shall be erected so that it is durably protected against mechanical stresses and corrosion

5.4.4 *Protection Against Thermal Effects*

5.4.4.1 *Protection against thermal effects*

The electrical installation shall be so arranged to minimize the risk of damage or ignition of flammable materials due to high temperature or electric arc. In addition, during normal operation of the electrical equipment, there shall be no risk of persons or livestock suffering burns.

5.4.4.2 For fire protection purposes, RCDs shall be installed with a rated residual operating current not exceeding 300 mA (*see* 705.411 of IEC 60364-7-705). RCDs shall disconnect all live conductors. Where improved continuity of service is required, RCDs not protecting socket-outlets shall be of the S type or have a time delay.

NOTE — The protection of the final circuits by RCD required according to 705.413.1 of IEC 60364-7-705 is also effective for protection against fire.

5.4.4.3 In locations where a fire risk exists conductors of circuits supplied from extra low voltage shall be protected either by barriers or enclosures affording a degree of protection according to IP XXD or IP 4X or in addition to their basic insulation by an enclosure of insulating material.

5.4.5 Electrical heating appliances used for the breeding and rearing of livestock shall comply with IEC 60335-2-71 and shall be fixed mounted in an appropriate position in order to avoid:

a) any risk of burns to livestock, and

b) any risk of fire by ignition of combustible material.

Radiant heaters shall be installed at a distance of at least 0.5 m from livestock and from combustible material unless a greater distance is specified by the manufacturer of the apparatus in the instructions for use.

5.4.5.1 For fire protection purposes, RCDs shall be installed with a rated residual operating current not exceeding 300 mA (*see* 705.411 of IEC 60364-7-705). RCDs shall disconnect all live conductors. Where improved continuity of service is required, RCDs not protecting socket-outlets shall be of the S type or have a time delay.

NOTE — The protection of the final circuits by RCD required according to 705.413.1 of IEC 60364-7-705 is also effective for protection against fire.

5.4.5.2 In locations where a fire risk exists conductors of circuits supplied from extra low voltage shall be protected either by barriers or enclosures affording a degree of protection according to IP XXD or IP 4X or in addition to their basic insulation by an enclosure of insulating material.

6 PROTECTION AGAINST OVERCURRENT

Persons and livestock shall be protected against injury and property shall be protected against damage due to excessive temperatures or electromechanical stresses caused by any overcurrent likely to arise in conductors.

Protection can be achieved by limiting the overcurrent to a safe value or duration.

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6.1 Protection against Overvoltage of Atmospheric Origin or Due to Switching

NOTE — Where electronic equipment is used, it is recommended to provide protective measures against lightning according to IS/IEC 62305-3 and IS/IEC 62305-4 and against overvoltage according to 4.5.3 of IS 732 and 5.3.5 of IS 732.

6.2 Protection Against Fault Currents

Conductors, other than live conductors, and any other parts intended to carry a fault current shall be capable of carrying that current without attaining an excessive temperature. Electrical equipment, including conductors shall be provided with mechanical protection against electromechanical stresses of fault currents as necessary to prevent injury or damage to persons, livestock or property.

Live conductors shall be protected against overcurrent arising from faults by the methods in 4.1.2.4 of IS 732.

NOTE — Particular attention should be given to PE conductor and earthing conductor currents.

6.3 Protection against Voltage Disturbances and Measures Against Electromagnetic Influences

6.3.1 Persons and livestock shall be protected against injury and property shall be protected against any harmful effects as a consequence of a fault between live parts of circuits supplied at different voltages.

6.3.2 Persons and livestock shall be protected against injury and property shall be protected against damage as a consequence of overvoltage, such as those originating from atmospheric events or from switching.

NOTE — For protection against direct lightning strikes, *see* IS/IEC 62305 series.

6.3.3 Persons and livestock shall be protected against injury and property shall be protected against damage as a consequence of under voltage and any subsequent voltage recovery.

6.3.4 The installation shall have an adequate level of immunity against electromagnetic disturbances so as to function correctly in the specified environment. The installation design shall take into consideration the anticipated electromagnetic emissions, generated by the installation or the installed equipment, which shall be suitable for the current-using equipment used with, or connected to, the installation.

7 PROTECTION AGAINST POWER SUPPLY INTERRUPTION

Where danger or damage is expected to arise due to an interruption of supply, suitable provisions shall be made in the installation or installed equipment.

8 ISOLATION AND SWITCHING

For fire safety purposes, a residual current protective device shall be installed having a rated residual operating current of 0.5A. Devices for emergency electrical switching including emergency stopping shall not be installed within reach of livestock or in any position where access to them may be impeded by livestock, account being taken of the condition likely to arise in the event of panic by livestock.

9 SERVICES IN AGRICULTURAL PREMISES

Farm houses and livestock houses do not in general require sophisticated electrical services, but in the case of the latter, lack of proper ventilation or lighting leads to insanitation and discomfort to the livestock thereby leading to retarded growth, high mortality or poor fertility. The houses are required to be maintained reasonably cool in summer and warm in winter, with a regular supply of fresh air and light. The guidelines given in **9.1** to **9.3** shall be adhered to.

9.1 Poultry Housing

A minimum of 14 h day length shall be provided to the birds and artificial lighting shall be provided for the same. For the purposes, 1 W (GLS) or 0.75 W (fluorescent) per bird or 1 W per 28-38 cm are considered adequate. The light sources shall be hung at a height not less than 1.8 m above floor. For poultry sheds of 6 m width and below, one row of bulbs in the centre shall be adequate. For sheds of larger width two rows of lamps properly interspaced may be desirable.

9.2 Abattoir

In meat houses and abattoirs, in halls where meat or carcasses are hung, a temperature of not greater than 10°C would be required and air-conditioning may be required. In unrefrigerated work rooms, ample artificial light and ventilation shall be provided by electrical means. The overall intensity in every abattoir shall not be less

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than 200 lux throughout the slaughter hall and workroom and at places where meat inspection is carried out, the illumination shall be at least 500 lux.

9.3 Farm Cattle Housing

In large dairy farms, roof-lights shall be provided to give 50-200 lux of artificial lighting. The lamps shall be hung at a height not less than 2 m above floor level.

10 TESTING OF INSTALLATION

Before commissioning the installation shall be tested and inspected as given in Part 1/Sec 17 of the Code.

11 MISCELLANEOUS PROVISIONS

For large scale livestock keeping, such as in a dairy farm, it shall be essential to provide:

a) a warning device for indicating failure of air circulation system; and

b) for continuity of supply, a fast acting emergency supply system is recommended.

11.1 Electric Fences

Where electric fences are in the vicinity of overhead lines, appropriate distances shall be observed to take account of induction currents, falling lines, etc.

Any earth electrode connected to the earth terminal of an electric fence controller shall be separate from the earthing system of any other circuit and shall be situated outside the resistance area of any electrode used for protective earthing.

11.2 Circuits of wirings which are only occasionally used, for example, during threshing time, shall be fitted with a separate switch marked accordingly.

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ANNEX A

(*Informative*)

EXAMPLES OF EQUIPOTENTIAL BONDING IN AGRICULTURAL PREMISES

Figures A-1 to A-4 show examples of equipotential bonding in agricultural premises

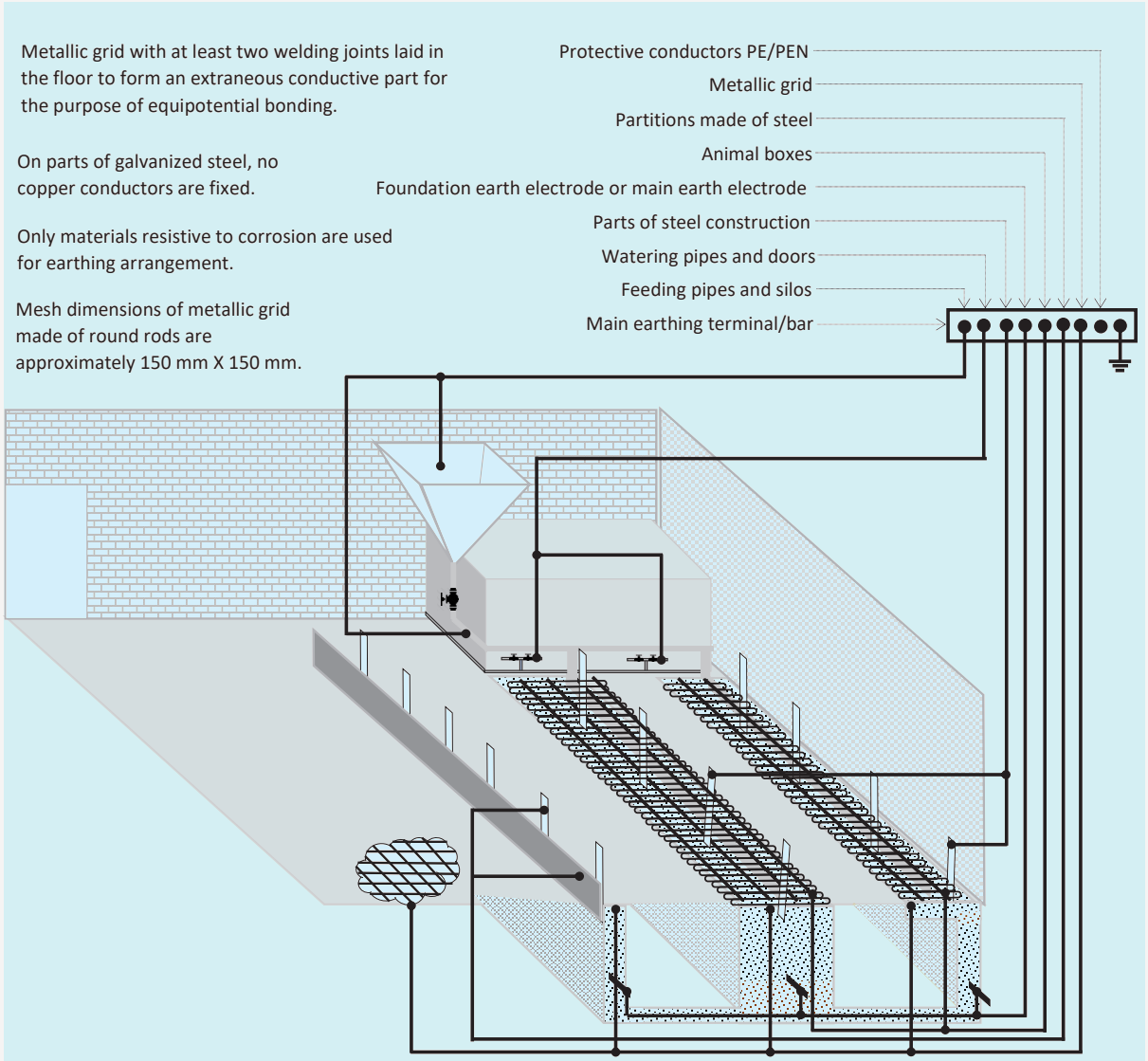


FIG. A-1 EXAMPLE OF EQUIPOTENTIAL BONDING WITHIN COWSHED

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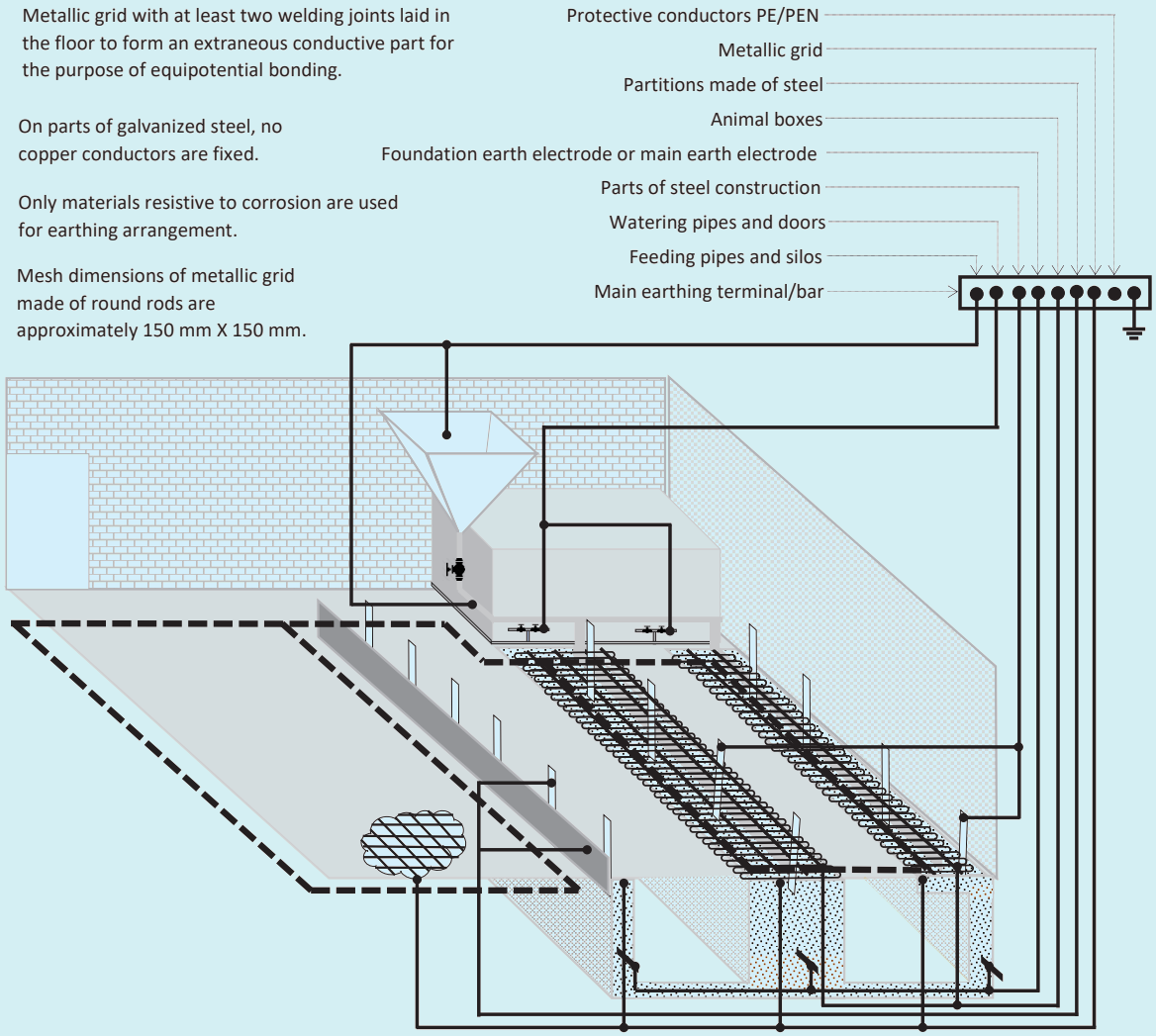


FIG. A-2 EXAMPLE OF EQUIPOTENTIAL BONDING FORMED AS RING WITHIN COWSHED

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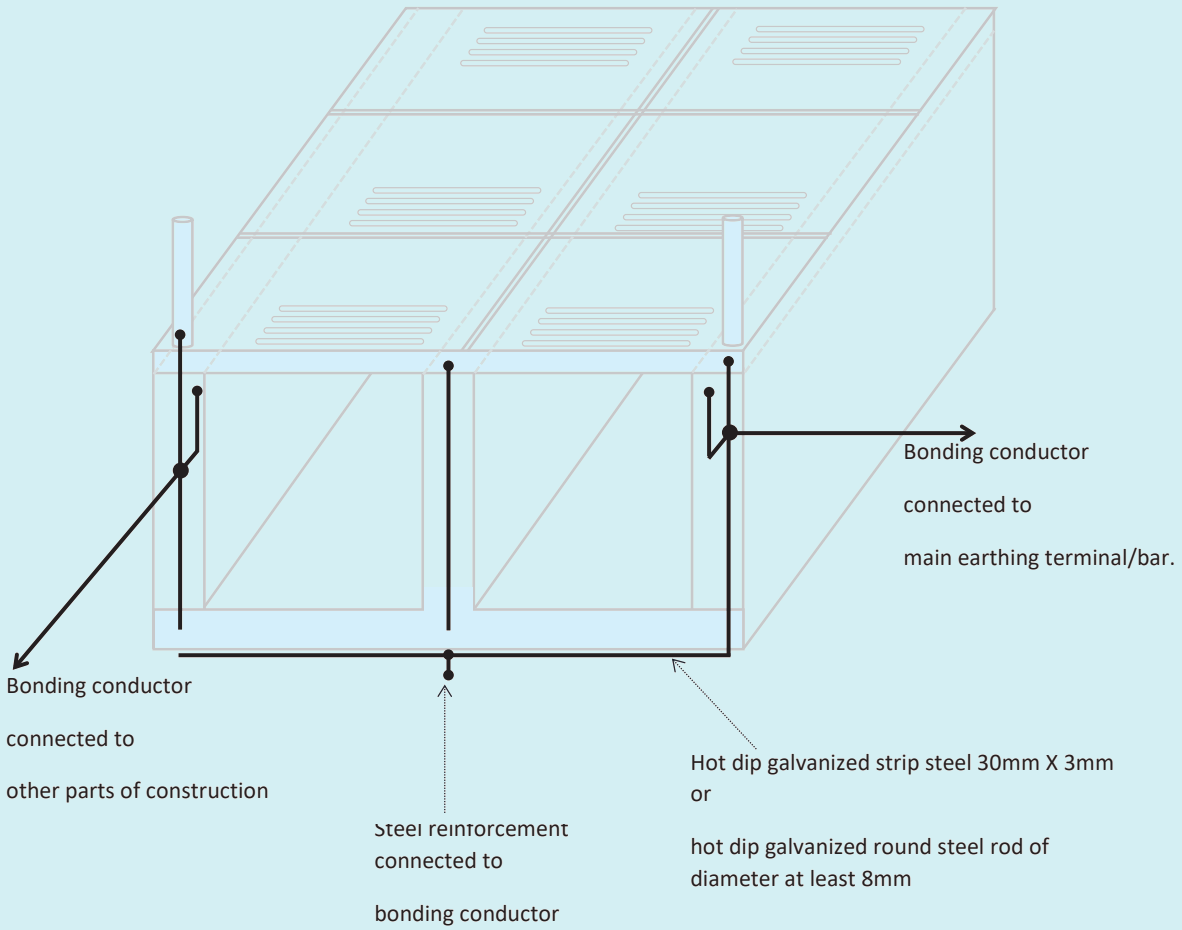


FIG. A-3 EXAMPLE OF EQUIPOTENTIAL BONDING TO CONCRETE CONSTRUCTION WITH SPACED FLOOR FOR COLLECTION OF MANURE

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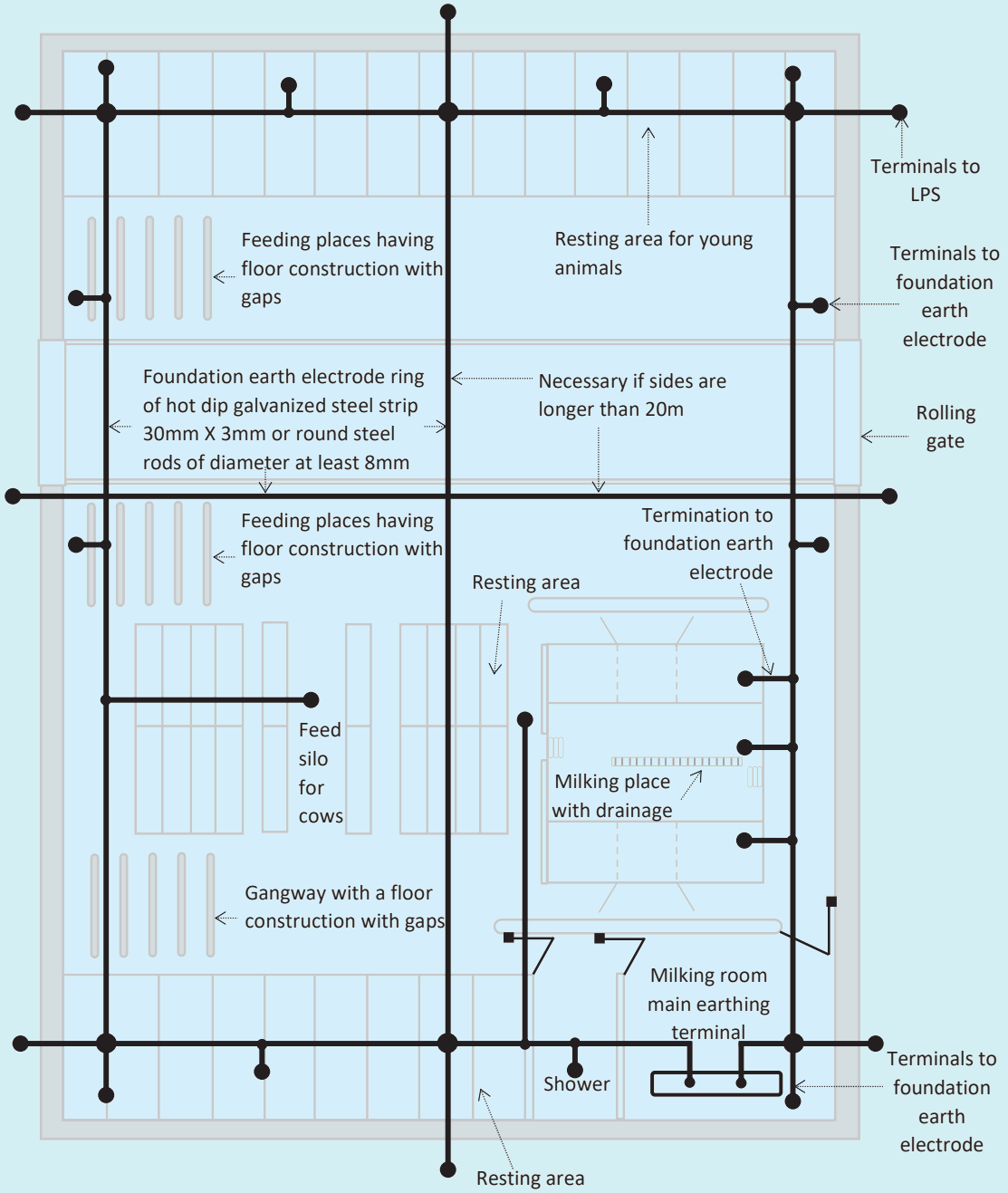


FIG. A-4 EXAMPLE OF ARRANGEMENT OF FOUNDATION EARTH ELECTRODE WITHIN A COWSHED

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ANNEX B

(*Normative*)

OBSTACLES AND PLACING OUT OF REACH

B-1 OBSTACLES

Protection by obstacle is not permitted.

B-2 PLACING OUT OF REACH

Protection by placing out of reach is not permitted.

ANNEX C

(*Normative*)

PROTECTIVE MEASURES FOR APPLICATION ONLY WHEN THE INSTALLATION IS CONTROLLED OR UNDER THE SUPERVISION OF SKILLED OR INSTRUCTED PERSONS

C-1 NON-CONDUCTING LOCATION

Protection by non-conducting location is not permitted.

C-2 PROTECTION BY EARTH-FREE LOCAL EQUIPOTENTIAL BONDING

Protection by earth free equipotential bonding is not permitted.

ANNEX D

(*Normative References*)

IS No.	*Title*
732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
IS/IEC 60309-1 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 1 General requirements
IS/IEC 60309-2 : 2002	Plugs, socket-outlets and couplers for industrial purposes: Part 2 Dimensional interchangeability requirements for pin and contact-tube accessories
IEC 60335-2-71	Household and similar electrical appliances — Safety — Part 2-71: Particular requirements for electrical heating appliances for breeding and rearing animals
IEC 60364-5-53	Low-voltage electrical installations of buildings — Part 5-53: Selection and erection of electrical equipment — Isolation, switching and control
IEC 60364-5-55	Low voltage electrical installations — Part 5-55: Selection and erection of electrical equipment — Other equipment
IS 10322/IEC 60598 (all parts)	Luminaires
IEC 60598-2-24	Luminaires — Part 2-24: Particular requirements — Luminaires with limited surface temperatures
IEC 60884-1	Plugs and socket-outlets for household and similar purposes — Part 1: General requirements

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NATIONAL ELECTRICAL CODE OF INDIA

PART 7 ELECTRICAL INSTALLATIONS IN HAZARDOUS AREAS

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PART 7 ELECTRICAL INSTALLATIONS IN HAZARDOUS AREAS

FOREWORD

Explosive gas atmosphere is the atmosphere where mixture with air, under atmospheric conditions, of flammable substances in the form of gas or vapour, which, after ignition, permits self-sustaining flame propagation. Area in which an explosive gas atmosphere is present, or may be expected to be present, in quantities, such as to require special precautions for the construction, installation and use of equipment is referred as a hazardous area and has to be treated in a special manner from the point of the design of electrical installation.

Many liquids, gases and vapours which in industry are generated, processed, handled and stored are combustible. When ignited, these may burn readily and with considerable explosive force when mixed with air in the appropriate proportions. With regard to electrical installations, essential ignition sources include arcs, sparks or hot surfaces, produced either in normal operation or under specified fault conditions.

This Part 7 of the Code is intended to provide guidelines for electrical installations and equipment in locations where a hazardous atmosphere is likely to be present, with a view to maximizing electrical safety. The scope of this Part therefore includes installations in hazardous areas such a petroleum refineries and petrochemical and chemical industries. The requirements laid down herein are in addition to those specified in Part 4 of this Code.

It is recognized that when electrical equipment is to be installed in or near a hazardous area, it is frequently possible, by taking care in the layout of the installation, to locate much of the equipment in less hazardous or non-hazardous areas and thus reduce the amount of special equipment required.

NOTE — Hazardous areas can be limited in extent by construction measures, that is, walls or dams. Ventilation or application of protective gas will reduce the probability of the presence of explosive gas atmosphere so that areas of greater hazard can be transformed to areas of lesser hazard or to non-hazardous areas.

This Part includes generalized statements and recommendations on matters on which there are diverse opinions. It is, therefore, important that sound engineering judgment should be exercised while applying these guidelines.

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1 SCOPE

1.1 This Part of the Code (Part 7) covers recommendations for electrical installations in chemical industries, petroleum refineries and other similar areas where hazards of explosion due to gases and vapours exist, and in which flammable gases and volatile liquids are processed, stored, loaded, unloaded or otherwise handled.

1.2 In addition to the recommendations given in this Part 7, the electrical installations in hazardous areas shall comply, with the requirements for industrial installation in non-hazardous areas laid down in Part 4 of this Code.

1.3 This Part does not apply to installations in hazardous areas having ignitable dusts and fibres. As distinct from the hazardous areas on the surface, environmental conditions in mines demand special consideration. This Part of the Code does not include provisions for installations in underground mines.

1.4 In any plant installation, irrespective of size, there may be numerous sources of ignition apart from those associated with electrical apparatus. Precautions may be necessary to ensure safety but guidance on this aspect is outside the scope of this Part.

NOTE — Some examples of industrial locations which require application of the guidelines in this Part are given in Annex A.

2 REFERENCES

The standards listed in Annex E contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 TERMINOLOGY

For the purpose of this Part, the following definitions shall apply.

3.1 Flammable Material — A flammable material is a gas, vapour, liquid and/or mist which can react continuously with atmospheric oxygen and which may therefore, sustain fire or explosion when such reaction is initiated by a suitable spark, flame or hot surface.

3.2 Flammable Gas-Air Mixture — A mixture of flammable gas, vapour or mist with air, under atmospheric conditions, in which after ignition, combustion spreads throughout the unconsumed mixture.

3.3 Hazard — The presence, or the risk of presence, of a flammable gas-air mixture.

3.4 Explosive Gas Atmosphere — Mixture with air, under atmospheric conditions, of flammable substances in the form of gas or vapour, which, after ignition, permits self-sustaining flame propagation.

3.5 Hazardous Area — Area in which an explosive gas atmosphere is present, or may be expected to be present, in quantities, such as to require special precautions for the construction, installation and use of equipment.

3.6 Explosive (Flammable) Limits — The extreme values for the concentration of a flammable gas or vapour in air under atmospheric conditions, under which flammable gas-air mixture can be ignited by an electrical arc or spark. These limits are called the ‘lower explosive limit’ (LEL) and the ‘upper explosive limit’ (UEL).

3.7 Flammability Range — The range of gas or vapour mixtures with air between the flammable limits over which the gas mixtures are continuously explosive.

3.8 Flammable Gas or Vapour — Gas or vapour which, when mixed with air in certain proportions, will form an explosive gas atmosphere.

3.9 Flammable Liquid — A liquid capable of producing a flammable vapour, gas or mist under any foreseeable operating conditions.

3.10 Flammable Mist — Droplets of flammable liquid, dispersed in air, so as to form an explosive gas atmosphere.

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3.11 Liquefied Flammable Gas — Flammable gas which, under normal ambient pressures and temperatures, is in gaseous state but which is handled in a liquid state under the applied conditions of pressure and/or temperature.

3.12 Flash Point — The temperature at which the liquid gives so much vapour that this vapour, when mixed with air, forms an ignitable mixture and gives a momentary flash on application of a small pilot flame under specified conditions of test.

3.13 Boiling Point — The temperature of a liquid boiling at an ambient pressure of 101.3 kPa.

NOTE — For liquid mixtures the initial boiling point shall be considered. 'Initial boiling point' is used for liquid mixtures to indicate the lowest value of the boiling point for the range of liquids present.

3.14 Ignition Temperature — The lowest temperature at which ignition occurs in a mixture of explosive gas and air when the method specified in ISO/IEC 80079-20-1 is followed.

3.15 Source of Release — A source of release is a point or location from which a gas, vapour, mist or liquid may be released into the atmosphere so that an explosive gas atmosphere could be formed.

3.16 Restricted Release — A release (normal or abnormal) of flammable gas or vapour which can be diluted below the lower flammable limit.

3.17 Unrestricted Release — A release (normal or abnormal) of flammable gas or vapour which cannot be diluted below the lower flammable limit.

3.18 Adequate Ventilation — Adequate ventilation is that which is sufficient to prevent accumulations of significant quantities of gas-air mixtures in concentration over one-fourth of the lower flammable limit.

Adequately ventilated area could be naturally ventilated or artificially ventilated.

3.19 Relative Density of Gas or Vapour — The density of a gas or a vapour relative to the density of air at the same pressure and the same temperature.

3.20 Non-hazardous (Safe) Area — Area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of equipment.

3.21 Electrical Apparatus for Hazardous Areas — Electrical apparatus which will not ignite the surrounding flammable atmosphere in which it is used.

3.22 Ignition Capable Apparatus — Apparatus which in normal operation produces sparks, hot surfaces, or a flame which can ignite a specific flammable mixture.

3.23 Safety Measures — Measures taken to ensure that electrical apparatus cannot cause an explosion.

3.24 Type of Protection — Specific measures applied to electrical equipment to avoid ignition of a surrounding explosive atmosphere.

3.25 Maximum Surface Temperature — Highest temperature which is attained in service under the most adverse operating conditions (but within recognized tolerances) by any part or surface of the electrical equipment, which would be able to produce an ignition of the surrounding explosive atmosphere.

NOTES

1 The most adverse conditions include recognized overloads and fault conditions recognized in the specific standard for the type of protection concerned.

2 The relevant surface temperature may be internal and/or external depending upon the type of protection concerned.

3.26 Flame Arrester — A device for releasing gas from an enclosure in such a way that in case of an internal explosion there is no appreciable increase in internal pressure and the released gas will not ignite the surrounding flammable atmosphere.

3.27 Inert Gas — A gas which cannot be ignited when mixed with a flammable gas or vapour in any concentration.

4 STATUTORY REGULATIONS

4.1 In following the recommendations of this Part, the various statutes and regulations in force in the country, applicable to the installation and use of electrical apparatus in hazardous areas shall be kept in view.

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4.2 Attention is invited to the fact that the manufacture and use of equipment in hazardous areas is controlled by the statutory authorities listed below for the area of their jurisdiction:

a) The Directorate General of Mines Safety; and
b) The Chief Controller of Explosives, Petroleum and Explosives Safety Organisation.

4.3 Testing

Equipment to be installed in hazardous area have to be certified by a recognized testing authority.

4.4 Marking of equipment shall conform to IS/IEC 60079-0.

5 FUNDAMENTAL CONCEPTS

5.1 Flammable gases and vapours may cause a fire or explosion when the following three basic conditions are satisfied:

a) Presence of sufficient quantity of a flammable gas or vapour,
b) Mixing of flammable gas or vapour with air or oxygen in the proportions required to produce an explosive or ignitable mixture, and
c) Occurrence of ignition.

In applying this principle to any potential hazard, the quantity of the substance that might be liberated, its physical characteristics and the natural tendency of vapours to disperse in the atmosphere shall be recognized. Flammable substances, the potential release of which shall be considered in area classification of electrical installations include the following:

a) Non-liquefiable gases,
b) Liquefied petroleum gas, and
c) Vapour or flammable gas.

5.2 It is recommended that plants and installations in which flammable materials are handled or stored be so designed that the degree and extent of hazardous areas are kept to a minimum. Similarly consideration should be given to design and operation of process equipment to ensure that even when it is operating abnormally, the amount of flammable material released to the atmosphere is minimized in order to reduce the extent of the area made hazardous.

Once a plant has been classified, it is important that no modification to equipment or operating procedures is made without discussion with those responsible for the area classification. Unauthorized action may invalidate the area classification.

It is necessary to ensure that process equipment which has been subjected to maintenance shall be carefully checked during and after re-assembly to ensure that safety aspect or integrity of the original design has been maintained before it is returned to service.

5.3 Where it is necessary to use electrical apparatus in an environment in which there may be an explosive gas atmosphere and it is not possible to:

a) eliminate likelihood of an explosive gas atmosphere occurring around the source of ignition, or
b) eliminate the source of ignition.

Then measures should aim at reducing the likelihood of occurrence of either or both of the above factors so that the likelihood of coincidence is so small as to be negligible.

5.4 In most practical situations where flammable materials are used it is difficult to ensure that an explosive gas atmosphere will never occur. It may also be difficult to ensure that the electrical apparatus will never give rise to a source of ignition. Reliance is therefore placed on using electrical apparatus which has an extremely low likelihood of creating a source of ignition in situations where a flammable atmosphere has a high likelihood of occurring. Conversely where the likelihood of an explosive gas atmosphere is reduced, electrical apparatus which has an increased likelihood of becoming a source of ignition may be used.

6 CLASSIFICATION OF HAZARDOUS AREAS

The objective of the hazardous area classification is to ensure an adequately safe level of operation of electrical apparatus in flammable atmospheres using the fundamental concepts outlined in **5**.

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The basis for hazardous area classification recognizes the differing degrees of probability with which flammable atmospheres (explosive concentrations of combustible gas or vapour) may arise in installations in terms of both the frequency of occurrence and the probable duration of existence on each occasion.

6.1 Area Classification

Hazardous areas are classified in zones based upon the frequency of the appearance and the duration of an explosive gas atmosphere as follows:

6.1.1 *Zone 0*

An area place in which an explosive atmosphere is present continuously or for long periods or frequently.

6.1.2 *Zone 1*

An area in which an explosive atmosphere is likely to occur in normal operation occasionally.

6.1.3 *Zone 2*

An area in which an explosive atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Normal Operation — The situation when the plant equipment is operating within its design parameters.

NOTES

1 Minor release of flammable material may be part of normal operation. For example, release from seals which rely on wetting by the fluid being pumped are considered to be minor release.

2 Failures (such as the breakdown of pump seals, flange gaskets or spillage caused by accidents) which involve urgent repair or shutdown are not considered to be part of normal operation nor are they considered to be catastrophic.

3 Normal operation includes start-up and shutdown conditions.

6.1.4 *Classification of Hazardous Area*

To determine the type of electrical installation appropriate to a particular situation, the hazardous area have been divided into three zones, namely, Zone 0, Zone 1 and Zone 2, according to the degree of probability of the presence of hazardous atmosphere.

Typical examples of such classifications are given below:

6.1.4.1 *Zone 0 areas*

Examples are vapour space above closed process vessels, storage tanks or closed containers, areas containing open tanks of volatile, flammable liquid.

6.1.4.2 *Zone 1 areas*

Zone 1 locations may be distinguished when any of the following conditions exits:

a) Flammable gas or vapour concentration is likely to exist in the air under normal operating conditions;
b) Flammable atmospheric concentrations is likely to occur frequently because of maintance, repairs or leakage;
c) Failure of process, storage or other equipment is likely to cause an electrical system failure simultaneously with the release of flammable gas or liquid;
d) Flammable liquid or vapour piping system (containing valves, meters or screwed or flanged fittings) is in an inadequately ventilated area; and
e) The area below with surrounding elevation or grade is such that flammable liquids or vapours may accumulate therein.

This classification typically includes:

a) Imperfectly fitting peripheral seals on floating roof tanks;
b) Inadequately ventilated pump rooms for flammable gas or for volatile, flammable liquids;
c) Interiors of refrigerators and freezers in which volatile flammable materials are stored in lightly stoppered or easily raptured containers;
d) API separators;
e) Oily waste water sewer/basins;
f) LPG cylinder filling and cylinder evacuation area: and
g) Areas in the immediate vicinity of vents and filling hatches.

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6.1.4.3 *Zone 2 areas*

Zone 2 locations may be distinguished when any one of the following conditions exist:

a) The system handling flammable liquid or vapour is in an adequately ventilated area and is so designed and operated that the explosive or ignitable liquids, vapours or gases will normally be confined within closed containers or closed systems from which they can escape only during abnormal conditions, such as accidental failure of a gasket or packing;

b) The flammable vapours can be conducted to the location as through trenches, pipes or ducts;

c) Locations adjacent to zone 1 area; and

d) In case of use of positive mechanical ventilation, as the failure or abnormal operation of ventilating equipment can permit atmospheric vapour mixtures to build up to flammable concentrations.

6.1.4.4 *Areas not classified*

In general the following locations are considered safe from the point of view of electrical installations:

a) Areas where the piping system is without valves, fittings, flanges or similar appurtenances;

b) Areas where flammable liquids or vapours are transported only in suitable containers or vessels;

c) Areas where permanent ignition sources are present like area where combustion gases are present, for example flare tips, flare pits, other open flames and hot surfaces;

d) Enclosed premises in which a plenum or purging stream of safe atmosphere is continuously maintained, so that no opening there in may be a point of ingress of gases or vapours coming from an external source of hazard;

e) Gas turbine installation meeting requirements of IS 16724;

f) Rooms/sheds for housing internal combustion engine, having adequate ventilation; and

g) Oil/gas fired boilers installations. Consideration should be given, however, to potential leak sources in pumps, valves, etc. or in waste product and fuel lines feeding flame or heat producing equipment to avoid instillation electrical devices which could then become primary ignition sources for such leaks.

NOTES

1 A protected fired vessels is not considered a source of ignition and the surrounding area is classified the same as for a hydrocarbon pressure vessel.

2 The area around the fired components and exhaust outlets of unprotected fired vessels need not be classified from the standpoint of installation of electrical equipment.

3 The area around a flare tip or flare pit need not be classified from the stand point of installation of electrical equipment. However, the area classification for the associated equipment (for example, knock out drum blow down pump etc.) located a grade level shall be followed as applicable.

4 Lack of classification around unprotected fired vessels and flare tips does not imply the safe placement of fired vessels and flare tips in the proximity to others production equipment because these are themselves sources of ignition.

5 Electrical equipment may be exposed to flammable gas during a purge cycle of a fired heater or furnace.

6.2 Extent of Hazardous Area

6.2.1 A complete knowledge of the physical properties of the flammable materials involved is essential for classifying a hazardous area. Properties of primary interest from an ignition standpoint are:

a) relative density,

b) flammable limits,

c) flash point,

d) volatility,

e) ignition temperature, and

f) ignition energy.

Some of these characteristics have a direct influence on the degree and extent of hazardous areas while the others affect the design of electrical equipment.

6.2.1.1 *Relative density*

Where a substantial volume of gas or vapour is released into the atmosphere from a localized source, a relative density less than one, that is, lighter-than-air, for the combustible indicates the gas or vapour will rise in a comparatively still atmosphere. A vapour density greater than one, that is, heavier-than-air, indicates the gas or

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vapour will tend to sink, and may thereby spread some distance horizontally and at a low level. The latter effects will increase with compounds of greater relative vapour density.

NOTE — In process industries, the boundary between compounds which may be considered lighter-than-air is set at a relative vapour density of 0.75. This limit is chosen so as to provide a factor of safety for these compounds whose densities are close to that of air and where movement may not, therefore, be predicted without a detailed assessment.

6.2.1.2 *Flammable limits*

The lower the 'lower flammable limit' the larger may be the extent of the hazardous area.

6.2.1.3 *Flash point*

A flammable atmosphere cannot exist if the flash point is significantly above the relevant maximum temperature of the flammable liquid. The lower the flash point, the larger may be the extent of the hazardous area.

6.2.1.4 *Volatility*

Boiling point can be used for comparing the volatility of flammable liquids. The more volatile a liquid and the lower its flash point, the more closely it approximates a flammable gas.

6.2.1.5 *Ignition temperature and ignition energy*

Ignition temperature and ignition energy of a flammable gas or vapour are taken into account in the design of electrical apparatus for hazardous areas so that these do not present an ignition risk.

6.2.1.6 *Equipment protection level (EPL)*

The level of protection assigned to equipment based on its risk of becoming a source of ignition and distinguishing the differences between explosive gas atmospheres, explosive dust atmospheres, and the explosive atmospheres which may exist in coal mines.

NOTE — The EPL may optionally be employed as part of a complete risk assessment of an installation.

a) EPL 'Ga'

Equipment for explosive gas atmospheres, having a very high level of protection, which is not a source of ignition in normal operation, expected malfunction or when subject to rare malfunction. Such equipment will have a form of protection which will remain effective even in the presence of two potential faults (for example, intrinsic safety, level of protection ia), or will have two independent means of protection (for example, Ex e and Ex d acting independently of each other).

b) EPL 'Gb'

Equipment for explosive gas atmospheres, having a high level of protection, which is not a source of ignition in normal operation or when subject to faults that may be expected, though not necessarily on a regular basis.

c) EPL 'Gc'

Equipment for explosive gas atmospheres, having a enhanced level of protection, which is not a source of ignition in normal operation and which may have some additional protection to ensure that it remains inactive as an ignition source in the case of regular expected occurrences (for example, failure of a lamp).

6.2.2 *Factors Affecting Extent of Hazard*

In addition to the properties of flammable materials involved, the following factors need to be considered for determining the degree and extent of hazardous areas while applying the guidelines given in IS 5572.

6.2.2.1 *Risk points*

Normal operation is the situation in which all plant equipment is operating within its design parameters. Minor releases of flammable material may be part of normal operation but leakages which entail repair or shut down are not part of normal operation.

Some examples of persistent risk points are as follows:

a) Interior of pressure vessels and pipes containing gas-air mixtures;
b) Free space above liquid level in tanks;
c) Free space immediately above open dipping baths, etc; and
d) The immediate vicinity of vapour exhausts and liquid outlets where these are designed to discharge as part of normal plant function.

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Examples of occasional risk points are the immediate vicinity of mechanical glands, seals relying on wetting by the fluid being pumped and other localized spillage points and of vapour exhausts and liquid outlets designed to discharge only on plant malfunction.

6.2.2.2 *Temperature of process liquid*

The extent of a hazardous area may increase with increasing temperature of process liquid provided the temperature is above the flash point. It should be noted that the liquid or vapour temperature after the release maybe increased or decreased by the ambient temperature or other factors (for example, a hot surface).

NOTE — Some liquids (such as certain halogenated hydrocarbons) do not possess a flash point although they are capable of producing a flammable atmosphere; in these cases, the equilibrium liquid temperature corresponding to saturated concentration at lower flammable limit should be compared with the relevant maximum liquid temperature.

6.2.2.3 *Concentration of vapour*

For flammable liquids, the concentration of the released vapour is related to the vapour pressure at the relevant maximum liquid temperature. The lower the initial boiling point, the greater the vapour pressure for a given liquid temperature and hence the greater concentration of vapour at the release source resulting in greater extent of hazardous area.

6.2.2.4 *Rate of release*

The extent of hazardous area may increase with increasing rate of release of flammable material.

6.2.2.5 *Release velocity*

Due to an improved dilution for release of flammable gases, vapours and/or mists in the air, the extent of hazardous area may decrease if, with constant release rate, the release velocity increases above that which causes turbulent flow.

NOTE — Elevated or depressed sources of release will alter the areas of potential hazard.

6.2.2.6 *Air current*

Air currents may substantially alter the outline of the limits of potential hazard. A very mild breeze may serve to extend the area in those directions to which vapours might normally be carried. However, a stronger breeze may so accelerate the dispersion of vapours that the extent of potentially hazardous area would be greatly reduced.

6.2.2.7 *Ventilation*

With an increased rate of ventilation, the extent of hazardous area may be reduced. The extent may also be reduced by an improved arrangement of the ventilation system.

6.2.2.8 *Obstacles*

Obstacles (for example, dykes, walls) may impede the ventilation and thus may enlarge the extent. On the other hand, they may limit the movement of a cloud of an explosive gas atmosphere and thus may reduce the extent.

6.2.2.9 For vapours released at or near ground level, the areas where potentially hazardous concentrations are most likely to be found are below ground, those at ground are next most likely, and as the height above ground increase, the potential hazard decreases.

NOTE — For lighter-than-air gases, the opposite is true, there being little or no potential hazard at and below ground and greater potential hazard above ground.

6.2.3 *Internal Hazards*

In cases where electrical apparatus, like those used for measurement and control of process variable, are connected directly to gas or a liquid process equipment, this may introduce additional source of internal and/or external release and consequently influence the external area classification.

6.2.3.1 The hazards created inside the electrical apparatus by an internal release of flammable gas or vapour may be compared to the external area classification as follows:

a) Where pressurization with inert gas is applied, the internal releases cannot create a flammable gas atmosphere, because no oxygen is present.

b) Where dilution with air is applied in case of a restricted normal release the internal hazards are comparable to those in a safe area. This applies also when the abnormal release (when occurring) would be restricted. When, however, the abnormal release would be unrestricted, the internal hazards are comparable to the external hazards in Zone 2.

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c) In all other types of protection, the internal hazards are comparable to the external hazards in Zone 2, provided that there is no normal release and that an abnormal release would be very infrequent and of a relatively short duration. When there is a normal release, the internal hazards are comparable to the hazards in Zone 0 and the abnormal release is not relevant.

6.2.3.2 When apparatus in which the internal hazards are comparable to Zone 2 is installed in a safe area or in Zone 2, the internal hazards determine the actual hazard condition, but when the same apparatus is installed in Zone 1 or Zone 0 the external hazards determine the actual hazard condition. When an apparatus in which the internal hazards are comparable to Zone 1 is installed in a Zone 0 hazardous area, the area classification would determine the actual hazard.

6.2.4 *Extent of Zones of Hazard*

6.2.4.1 The treatment of hazardous area, from the point of view of determining the extent of hazardous zones (and their classification) around the source of hazard differ in the following broad situations:

a) Open-air situations (freely ventilated process area):
   1) Source of hazard located near ground level, and
   2) Source of hazard above ground level.
b) Enclosed premises and surrounding area (process area with restricted ventilation).
c) Storage tanks:
   1) Floating roof, and
   2) Fixed roof tank with vent.

6.2.4.2 Detailed guidelines on the above situations can be had from IS 5572 (Classification of hazardous area (other than mines) having flammable gases and vapours for electric installation).

7 SPECIFIC GUIDELINES FOR ELECTRICAL INSTALLATIONS IN HAZARDOUS AREAS

7.1 General

7.1.1 *Mechanical Strength*

All apparatus shall be installed with due regard to the possibility of external mechanical damage. Where adequate protection cannot be ensured, for example, by location, reference should be made to the impact test requirements according to IS/IEC 60079-0 for the apparatus before deciding on any additional measures such as the provision of guards for transparent parts.

7.1.2 *Earthing and Bonding*

7.1.2.1 Earthing shall be in accordance with Part 1/Sec 18 of this Code. The connection between metal part to be earthed and the earthing conductor shall be made secure mechanically and electrically by using adequate metallic fitting. The earthing conductors shall be sufficiently strong and thick, and the portions of conductor which are likely to be corroded or damaged shall be well protected. Earthing conductors which shall not reach a hazardously high temperature due to the anticipated maximum earth fault current flowing shall be used.

7.1.2.2 Protection against lightning shall be provided in accordance with Part 1/Sec 19 of this Code. Specific guidelines for installations in hazardous locations are given in Annex B. Interconnection system with other buried metal services and/or earth terminations for equipment earthing for the purpose of equalizing the potential distribution in the earth should preferably be made below earth.

7.1.2.3 Portable and transportable apparatus shall be earthed with one of the cores of flexible cable for power supply. The earth continuity conductor and the metallic screen wherever provided for the flexible cable should be bonded to the appropriate metal-work of the apparatus and to the earthing pin of the plug.

7.1.2.4 Efficient bonding should be installed where protection against stray currents or electrostatic charges is necessary.

7.1.2.5 *Earthing and bonding of pipelines and piperacks*

Unless adequately connected to earth elsewhere, all utility and process pipelines should be bonded to a common conductor by means of earth bars or pipe clamps and connected to the earthing system at a point where the

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pipelines enter or leave the hazardous area, except where conflicting with the requirements of catholic protection. In addition, it is recommended that steel pipe racks in the process units and off-site areas should be earthed at every 25 m.

7.1.3 *Automatic Electrical Protection*

7.1.3.1 It is essential that the severity and duration of faults internal or external to the electrical apparatus be limited, by external means, to values that can be sustained by the apparatus without disruptive effect.

7.1.3.2 All circuits and apparatus in hazardous areas shall be provided with means to ensure disconnection quickly in the event of excessive overloads, overcurrent, internal short-circuit or earth-fault conditions. In case of distribution systems with isolated neutral, an automatic earth-fault alarming device may be considered adequate, in addition to overload/ overcurrent and short-circuit protection.

7.1.3.3 Protection and control apparatus shall be normally located in a non-hazardous area. Where its installation in a potentially hazardous area cannot be avoided, such apparatus should be provided with the appropriate type of protection.

7.1.3.4 Apart from self-powered apparatus and hand lamps, earth-leakage protection or earth monitoring, or both should be included in the protection of the portable and transportable apparatus. Protection, of the circulating-current type which automatically cuts off the supply in the event of the earth continuity conductor becoming disconnected, may, with advantage, be adopted as the earth-monitoring device.

7.1.4 *Isolation*

7.1.4.1 All electrical circuits should be provided with an effective means of complete circuit isolation, including the neutral. Such means of isolation should be provided for each item of electrical apparatus and/or each sub-circuit.

7.1.4.2 The means of isolation, when located in a hazardous area, shall be a switch which breaks all poles, including the neutral, and which is provided with an appropriate type of protection against explosive hazards. This applies equally to single phase sub-circuits. When the means of isolation is located in a non-hazardous area, the switch shall break all poles, the neutral being isolated by a removable link. The means of isolation shall be capable of being locked in the 'OFF' position.

7.1.4.3 When the means of isolation is not immediately adjacent to the associated apparatus, effective provision should be made to prevent the restoration of supply to the apparatus while the risk of exposure of live conductors to a flammable gas air mixture continues.

7.1.5 *Operation and Maintenance*

7.1.5.1 None of the protection techniques for electrical equipment for explosive gas atmospheres are effective unless the apparatus is operated within the limits indicated by its nameplate marking and is properly maintained according to the recommendations of appropriate Indian Standards.

7.1.5.2 Care shall be taken when inspecting equipment in hazardous areas; circuits shall be made dead before removing covers. Flexible cables are a potential source of hazard; they should be frequently inspected, together with the portable apparatus. Equipment should be examined for mechanical faults, cracked glasses, deterioration of cement, slackened conduit joints and corrosion. Electrical tests should be carried out at fixed intervals.

7.2 Wiring Installation

Cabling/wiring and end termination for hazardous area equipments shall be in line with the requirements given in IS 16724.

7.3 Selection of Equipment

7.3.1 *General*

7.3.1.1 The selection of electrical apparatus for explosive gas atmospheres is based on the general principle that the likelihood of the simultaneous presence of a hazardous atmosphere and a source of ignition is reduced to an acceptably low level.

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7.3.1.2 When the electrical apparatus does not have an internal release of flammable material, the classification of the hazardous area surrounding the electrical equipment decides the selection of an adequate type of protection.

7.3.1.3 When the electrical apparatus has an internal release of flammable material, the actual hazard is a combination of the external and internal hazards and both must be taken into account when selecting an adequate type of protection.

7.3.1.4 The selected apparatus will normally have a recognized type of protection and should also be selected for the appropriate temperature class and the appropriate apparatus group applicable. Where gases of different degrees of hazard exist in the same area, the type of protection appropriate for the highest degree of hazards shall be applicable.

7.3.1.5 The selected electrical apparatus shall be adequately protected against corrosive and solvent agencies, and against water ingress and thermal and mechanical stresses as determined by the environmental conditions. These construction requirements should ensure that the protection against explosion is not reduced when the apparatus is used in the specified conditions of service.

7.3.1.6 Particular consideration shall be given to the location of apparatus which incorporates aluminium or light alloys in the construction of its enclosure.

7.3.1.7 As electrical apparatus for flammable gas atmospheres requires special safety maintenance after they are installed, the selection of electrical apparatus shall be made with full considerations to the facility and frequency of inspection and maintenance, preparation for spares and repairing materials and the extent of allowable interruption of power supply during maintenance work.

7.3.1.8 It is advisable that the selection of electrical apparatus be made after full considerations have been given not only to the initial cost of installation but also to the expected life and expenses for operation and maintenance of the apparatus.

7.3.1.9 Unless otherwise specified for particular equipment, the guidance provided in Table 1 shall be followed in the selection of equipment for hazardous areas. However, any equipment which in the opinion of the authorized inspector affords a degree of safety not less than that afforded by the equipment specified may be accepted as an alternative.

7.3.1.10 The necessity for equipment with flameproof enclosures or other enclosures may sometimes be eliminated by the adoption of special design, such as pressurized equipment.

7.3.2 *Selection Procedure*

7.3.2.1 In order that electrical apparatus may be selected for use in hazardous area, the following information is necessary:

a) The classification of the area, that is, the zone; and
b) The ignition temperature of the gas or vapour involved, or the lowest values of ignition temperature if more than one combustible material is present.

   This will permit determination of the temperature classification required for the apparatus, or the upper-limit temperature for any unprotected surface according to IS/IEC 60079-0. The characteristics of the gas or vapour involved in relation to:

   1) Ignition current or minimum ignition energy in the case of installations of intrinsically safe apparatus, or
   2) Safe gap data in the case of installations for flameproof enclosures.

7.3.2.1.1 Apparatus certified to the constructional and design requirements for a particular group may also be used with compounds of lesser risk and which would be allocated therefore to a lesser group, subject again to consideration of temperature classification and chemical compatibility.

Similarly, electrical apparatus which is designed so that it may be used with certain flammable materials in a particular zone may be used with flammable materials in zone of lesser risk without restriction provided it is determined that the flammable materials likely to be present are compatible with the following characteristics of the apparatus:

a) Apparatus grouping (where this is applicable);
b) Temperature classification; and
c) Chemical compatibility.

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7.3.2.2 *Selection of type of protection*

The selection of type of protection of the equipment for different zone of hazardous areas shall be made in accordance with IS 16724 (*see* Table 2). Besides the danger of explosion caused by an electric spark or arc, there is also a danger of ignition at a hot surface exposed to a flammable atmosphere. The maximum surface temperature of any unprotected surface of electrical equipment should not exceed the ignition temperature of the gas or vapour.

Flammable gases and vapours fall into fairly well defined groups when classified with reference to their ignition temperature. To simplify the manufacture of apparatus, the permitted maximum surface temperatures have been classified in Table 4 of IS 16724/IEC 60079-14 as follows:

Temperature Class Required by the Area Classification	*Ignition Temperature of Gas or Vapour* (°C)	*Allowable Temperature Classes of Equipment*
T1	>450	T1-T6
T2	>300	T2-T6
T3	>200	T3-T6
T4	>135	T4-T6
T5	>100	T5-T6
T6	>85	T6

If the marking of the electrical equipment does not include an ambient temperature range, the equipment shall be used only within the temperature range –20 °C to +40 °C. If the marking of the electrical equipment includes an ambient temperature range, the equipment shall only be used within this range.

If there is an influence from an ambient temperature outside the temperature range, the process temperature or exposure to sun light, the effect on the equipment shall be verified as suitable for the application and documented.

Ambient temperatures do not consider solar radiation. Where applicable, additional factors should be applied.

Junction boxes and switches in intrinsically safe circuits, however, can be assumed to have a temperature classification of T6 because, by their nature, they do not contain heat dissipating components. Simple apparatus used within an intrinsically safe circuit shall be temperature classified in accordance with IS 16724.

Table 1 Equipment Protection Levels (EPLs) where Only Zones are Assigned

(*Clause* 7.3.1.8)

Zone	Equipment Protection Levels (EPLs)
0	Ga”
1	Ga’ or ‘Gb’
2	Ga’ or ‘Gb’ or ‘Gc”
20	Da”
21	Da’ or ‘Db’
22	Da’, ‘Db’ or ‘Dc’

Table 2 Relationship between Type of Protection and EPLs

(*Clause* **7**.3.2.2)

EPL	Type of protection	Code	According to
“Ga”	Intrinsically safe	“ia”	IS/IEC 60079-11
	Encapsulation	“ma”	IS/IEC 60079-18
	Two independent types of protection each meeting EPL “Gb”		IS/IEC 60079-26
	Protection of equipment and transmission systems using optical radiation	“op is”	IS/IEC 60079-28
	Special protection	“sa”	IEC 60079-33

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Table 2 (*Concluded*)

EPL	Type of protection	Code	According to
"Gb"	Flameproof enclosures	"d"	IS/IEC 60079-1
	Increased safety	"e"	IS/IEC 60079-7
	Intrinsically safe	"ib"	IS/IEC 60079-11
	Encapsulation	"m" "mb"	IS/IEC 60079-18
	Oil immersion	"o"	IS/IEC 60079-6
	Pressurized enclosures	"p", "px", "py", "pxb" or "pyb"	IS/IEC 60079-2
	Powder filling	"q"	IS/IEC 60079-5
	Fieldbus intrinsically safe concept (FISCO)		IS/IEC 60079-27
	Protection of equipment and transmission systems using optical radiation	"op is" "op sh" "op pr"	IS/IEC 60079-28
	Special protection	"sb"	IS/IEC 60079-33
"Gc"	Intrinsically safe	"ic"	IS/IEC 60079-11
	Encapsulation	"mc"	IS/IEC 60079-18
	Non-sparking	"n" or "nA"	IS/IEC 60079-15
	Restricted breathing	"nR"	IS/IEC 60079-15
	Energy limitation	"nL"	IS/IEC 60079-15
	Sparking equipment	"nC"	IS/IEC 60079-15
	Pressurized enclosures	"pz" or "pzc"	IS/IEC 60079-2
	Protection of equipment and transmission systems using optical radiation	"op is" "op sh" "op pr"	IS/IEC 60079-28
	Special protection	"sc"	IEC 60079-33
"Da"	Encapsulation	"ma"	IS/IEC 60079-18
	Protection by enclosure	"ta"	IS/IEC 60079-31
	Intrinsically safe	"ia" or "iaD"	IS/IEC 60079-11 or IEC 61241-11
	Special protection	"sa"	IEC 60079-33
"Db"	Encapsulation	"mb"	IS/IEC 60079-18
	Protection by enclosure	"tb" or "tD"	IS/IEC 60079-31 IEC 61241-1
	Pressurized enclosures	"pD"	IEC 61241-4
	Intrinsically safe	"ib" or "ibD"	IS/IEC 60079-11 or IEC 61241-11
	Special protection	"sb"	IEC 60079-33
"Dc"	Encapsulation	"mc"	IS/IEC 60079-18
	Protection by enclosure	"tc" or "tD"	IS/IEC 60079-31 IEC 61241-1
	Pressurized enclosures	"pD"	IEC 61241-4
	Intrinsically safe	"ic"	IS/IEC 60079-11
	Special protection	"sc"	IEC 60079-33
New protection marking codes with identification of EPLs may be introduced in the future.			

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Cable glands in normal service do not create a heat source and therefore do not have a temperature class or ambient operating temperature range marked on them. In general cable glands will be marked with service temperature. If no marking exists it is assumed that the service temperature is –20°C to + 80°C.

NOTE — Consideration of the capability of the equipment and cables to operate in the required temperature range should include normal operating limits as well as temperature rise.

7.3.3 *Individual Features of Electrical Equipment for Hazardous Areas*

The essential features of individual equipment for installation in hazardous areas are indicated in Table **3**.

Table 3 Features of Electrical Equipment for Hazardous Areas

(*Clause* 7.3.3)

Sl No.	Equipment	Zone 0	Zone 1	Zone 2
i)	Motors	No motor shall be used in this area	a) Motor with type of protection 'd' b) Motors with type of protection 'p'	a) Motor suitable for zone 1 area. b) Motors with type of protection 'n' and 'e'. However, all normally sparking parts such as slip-rings and brushes shall be provided with type of protection 'd' or 'p'. Motors provided with a combination of the above forms of protection. For example, slip-ring motors in which the main enclosures and windings are of type 'e' but the normally sparking parts of type 'd' protection
ii)	Transformers and capacitors	No transformer or capacitor shall be used in this area	a) All power and distribution transformers and capacitors with type 'd' protection. b) Type 'i' protection for control and instrumentation, with transformers and capacitors forming part of flameproof or intrinsically safe equipment.	Transformers and capacitors suitable for zone 1 area. Transformers and capacitors that are dry type or containing liquids need not have any special enclosure provided that the following requirements are satisfied : a) Cable boxes shall be suitable for specified level of current and fault clearing time. b) Only off-circuit manually operated tap changers shall be allowed with provision for locking the operating handle in position. c) Auxiliary devices shall be intrinsically safe or if they have sparking contacts, these shall be : i) Type 'd' ii) Under adequate head of oil iii) of mercury in glass type with adequate mechanical protection iv) of enclosed break type or, alternatively, auxiliary devices may be deleted or installed in a safe zone. d) Any other sparking accessories or switches shall comply with the requirements for zone 1 area. Where oil filled transformers are used, necessary precautions against spread of fire (*see* IS 1646) shall be complied with.
iii)	Lighting fittings (*see* Notes 1 and 2)	No lighting fitting shall be used	All switches, circuit breakers, fuses and other equipment shall be housed in an enclosure with type'd' protection.	a) Lighting fittings for zone 1. b) Lighting fittings with type of protection 'e' or 'n'. c) For critical/emergency lighting applications, lighting fittings for zone 1 shall be used.

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Table 3 (*Concluded*)

Sl No.	Equipment	Zone 0	Zone 1	Zone 2
iv)	Switchgear and control gear	No switchgear and control gear shall be used. When not practicable use type 'i' protection	All switches circuit breakers, fuses and other equipment, the enclosure together with the enclosed apparatus shall be type'd' protection.	All equipment where arcing may occur under normal conditions of operating shall be of type 'd', unless the current interrupting contacts are oil-immersed, or the switches are enclosed break type with flameproof breaking chamber or having mercury in glass switches or enclosed break micro switches.
v)	Generators	No generator shall be used	Generators with Type 'd' and 'p' protection	Equipment suitable for zone 1 areas Generators with type 'n' protection or 'e' and having brushless excitation system and sparking parts, if provided shall comply with zone 1 requirements.
vi)	Diesel engines	Unacceptable	The use of permanently installed diesel engines to be avoided. Where necessary, they shall satisfy the requirements as given in Appendix C.	i) The use of permanently installed diesel engines to be avoided. ii) Equipment suitable in zone 1 areas.
vii)	Storage batteries	Shall not be used	Storage batteries shall not be installed in zone 1 areas, except those in portable torches where the enclosures housing the bulb, switch and battery shall be flameproof type.	Storage batteries shall be of type 'e' protection

NOTES

1 Low-pressure sodium lamps shall not be used in a hazardous area owing to the risk of ignition from the free sodium from a broken lamp.

2 If luminaires with fluorescent lamps are used in a hazardous area, then the area should be confirmed to be free from group IIC gas/vapour before lamps are transported through the area or changed, unless suitable precautions are taken to prevent tubes being broken.

7.4 Miscellaneous Requirements

7.4.1 *Exceptional Circumstances*

7.4.1.1 In exceptional circumstances (for example, research, development or repair-work, and in emergency situations) apparatus may be used which is not specially designed for use in Zone 1 or Zone 2 hazardous areas, provided that adequate measures have been taken to ensure an adequate level of safety.

7.4.1.2 Apparatus which is intended to be used for short periods only may be of normal industrial design but only when operating in Zone 2, it is either regularly supervised by trained personnel or gas-free conditions are regularly monitored.

7.4.2 *Static Electricity (see IS 7689)*

7.4.3 *Pressurized Rooms*

7.4.3.1 Where unavoidable, electrical switchgear and equipment may be located in a pressurized room within a hazardous area meeting the following requirements:

a) The pressurized room shall be situated in such area within a hazardous location, which is least hazardous and from which the operators working in the room can easily evacuate in the event of an accident.
b) Main structural parts, such as wells, pillars, ceiling, floor, doors and the like shall be on non-combustible materials and shall be sufficiently resistant to explosion blasts or other mechanical effects.
c) Structural materials and construction of the room shall be, such as not to allow gases or vapours to penetrate easily through them.
d) More than one doorway shall be provided, and at least one of them shall face the direction of no source of hazard as for as practicable.

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e) The design of the doorway facing the hazardous area shall be such that the doors can only be opened outwards from the interior and they shall be double doors.

f) In case it is necessary to provide a window facing the hazardous area, the window shall have enough strength to resist an explosion blast, blowout of gases or other possible mechanical effects.

g) The source of air shall be free of hazardous concentrations of flammable gases and vapours contaminants and any other foreign matter. It shall be determined from the nature of the process and the physical layout.

h) The volume and pressure of supply air shall be such that the air pressure in the vicinity of doorways is maintained higher than the atmospheric pressure outside the room.

j) An alarm or other device shall be provided so that any disorder in the pressurization system may be assuredly noticed.

k) Openings to lead wirings or pipings from the hazardous locations into the room shall be so constructed as not to admit explosive gases into the room, by filling tightly the space around conduits or pipes with cement or similar incombustible materials.

NOTE — Elevated ambient temperatures can be expected in pressurized rooms. Accordingly, it is advisable that due account be taken while selecting electrical equipment for installation in pressurized rooms.

7.4.3.2 Prior to commissioning apparatus protected by pressurization or continuous dilution, it shall be verified by competent personnel that the installation of the equipment fulfils the requirements of IS/IEC 60079-2, either by inspection of the reference documents, or by tests if necessary.

The following shall be considered:

a) The protective gas supply is suitable, that is, impurities in the protective gas will not reduce the level of safety, such as by attacking the enclosure or ducting material or introducing flammable material into the enclosure.

b) The apparatus design and safety provisions are such that purging can be completed satisfactorily.

c) The minimum pressure required is maintained with the minimum protective gas supply stated by the manufacturer.

d) The maximum temperature limits stated are not exceeded.

NOTE — Satisfactory completion of purging would include passing a volume of protective gas of at least five times the free internal volume of the protected enclosure and associated ducting, prior to energizing the electrical apparatus.

7.4.3.2.1 With regard to installation practices, the following shall be considered:

a) For wiring systems:

1) When cable wiring systems are used, the cable entries shall prevent excess leakage of the protective gas and ensure that sparks or incandescent particles do not escape from the enclosure.

2) When conduit wiring systems are used, it is recommended that all conduit entrances to an enclosure be sealed to prevent excess leakage of protective gas unless the conduit system is being used as a duct for supplying the protective gas.

b) The point at which the protective gas enters the supply duct or ducts should be situated in a non-hazardous area.

c) Ducting should, as far as possible, be located in a non-hazardous area. If ducting passes through a hazardous area, it shall be checked for leaks prior to start-up of the electrical apparatus to ensure that the requirements of **7.4.3.2** (a) are met.

d) Exhaust ducting shall vent to a non-hazardous area or otherwise be designed to prevent the emission of sparks or hot particles such as by the use of spark arrestors or baffles. Care should be taken to ensure that the exhaust does not result in a secondary hazardous source in an otherwise non-hazardous area.

7.4.4 *Intrinsically Safe Installations*

A fundamentally different installation philosophy has to be recognized in the installation of intrinsically safe circuits. In comparison with all other types of installations, where care is taken to confine electrical energy to the installed system as designed so that a hazardous environment cannot be ignited, the integrity of an intrinsically safe circuit has to be electrically protected from the environment in order that the safe energy limitation in the circuit is not exceeded, even when breaking, shorting or earthing of the circuit occurs.

As a consequence of this principle the aim of the installation rules for intrinsically safe circuits is to maintain separation from other circuits.

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7.4.4.1 Intrinsically safe circuits may be installed either:

a) isolated from earth,

b) connected at one point to the potential equalization conductor if this exists in the whole area of the installation of the intrinsically safe circuits, or

c) connected to earth at one point only, if earthing is required for functional or protective purposes.

The installation method shall be chosen with regard to the functional requirements of the circuits according to the manufacturers' instructions.

If the circuit is isolated from earth, particular attention should be given to any possible danger due to static charges.

More than one earth connection is permitted on a network provided that the network is galvanically separated into circuits each of which has only one earth point.

7.4.4.2 Where a safety barrier is used, the maximum fault voltage in apparatus connected to the barrier input terminals shall not exceed the fault voltage rating of the barrier, for example, 250 V. Where a safety barrier requires a connection to earth, the connecting load to the earthing terminal of the safety barrier should be as short as possible. The cross-section of the connecting load shall take account of the short circuit current to be expected, and shall have a minimum value of 1.5 m^2 copper.

Consideration should be given to the need for earthing of the supply system connected to the barrier input terminals.

7.4.4.3 In installations with intrinsically safe circuits, for example, in measuring and control cabinets, the terminals shall be reliably separated from the no intrinsically safe circuits (for example, by a separating panel, or a gap of at least 50 mm). The terminals of the intrinsically safe circuits shall be marked as such. All terminals shall satisfy the requirements of relevant Indian Standards.

Where terminals are arranged to provide separation of circuits by spacing alone, care shall be taken in the layout of terminals and the wiring method used, to prevent contact between circuits should a wire become disconnected.

7.4.4.4 Enclosures and wiring of intrinsically safe circuits should meet the requirements which would be applied to similar types of equipment which are intended to be installed in non-hazardous areas otherwise having the same environmental conditions. If an enclosure contains both intrinsically safe circuits and non-intrinsically safe circuits, the intrinsically safe circuits shall be clearly identified.

In installation containing both intrinsically safe apparatus and apparatus having another type of protection, the intrinsically safe circuits shall be clearly marked.

7.4.4.5 Marking may be achieved by labelling or color coding of enclosure, terminals and cables. Where a colour is used for this purpose it shall be light blue.

7.4.4.6 Where intrinsically safe circuits may be exposed to disturbing magnetic or electric fields, suitable attention shall be given to transposition or shielding to ensure that these fields do not adversely affect the intrinsic safety of the circuit.

7.4.4.7 Unless specifically permitted, conductors of intrinsically safe circuits and conductors of no intrinsically safe circuits shall not be run together in cables, cords, conduits, or bundles. In cable ducts and trays, intrinsically safe cables shall be separated from non-intrinsically safe cables by a mechanical barrier. Such a barrier is not required if all cables are provided with additional protective sheathing or sleeves which provide equivalent separation, or if the cables are securely fastened to ensure that physical separation is maintained.

7.4.4.8 A flexible cable may contain more than one intrinsically safe circuit if the cable installation is such as to minimize the risk of damage which could cause interconnection between different circuits.

7.4.4.9 The installation of intrinsically safe circuits shall be such that the extreme permitted values, such as capacitance, inductance and inductance to resistance ratio, are not exceeded. The permissible values shall be taken from the certificate, the nameplate of the apparatus, or from the installation instructions.

7.4.4.10 Where intrinsically safe circuits are interconnected to form a system, due account shall be taken by calculation or by measurement of the resultant combination of electrical parameters, such as inductance, and capacitance, which may affect the intrinsic safety of the system as a whole.

NOTE — In addition to electrical sparking due account should be taken of thermal effects particularly where non-certified apparatus is used.

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7.4.4.11 The following equipment is considered to be intrinsically safe without certification:

Devices whose electrical parameters, according to the manufacturer's specification, do not exceed any of the values 1.2 V, 0.1 A, 20 J or 25 mW need not be certified or marked. They will be subject, however, to the requirements of relevant Indian Standard, if they are connected to a device which contains a source of energy which could cause the circuit to exceed these parameters.

8 TESTING OF INSTALLATION

All equipment intended for use in hazardous areas shall be approved by a recognized, testing and certifying authority (*see* **4.2**).

8.1 Installation tests should include insulation resistance and earth continuity resistance and the checking of fused ratings and other protection devices, settings and operation.

8.2 For periodical electrical testing, the following precautions shall be followed:

a) Insulation tests should, in general, be carried out with certified intrinsically safe insulation tester for use in hazardous areas;

b) Earth continuity tests, in general, be carried out with certified intrinsically safe earth tester embodying a hand-driven generator suitable for use in hazardous areas; and

c) The rating of fuses and the settings of protective devices, where practicable, and the operation of other protective devices should be checked.

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ANNEX A

(*Clause* 1.4)

EXAMPLE OF INDUSTRIES AND THEIR WORKING PLACES WHICH REQUIRE CONSIDERATIONS IN REGARD TO HAZARDOUS LOCATIONS

A-1 Though it is difficult to determine hazardous locations merely according to kind of industries or kind of working places, typical industries and working places, which require considerations in regard to hazardous locations are listed below:

A-1.1 Ammonium Sulphate Manufacturing Industry — Places where gaseous raw materials are produced, electrolysis of water is conducted or synthesis of ammonia is carried out.

A-1.2 Soda Manufacturing Industry — Working places of electrolysis, synthetic hydrochloric acid manufacturing and liquid chlorine handling.

A-1.3 Electric Furnace Industry — Working places where calcium carbide is pulverized and storage of it.

A-1.4 Compressed or Liquefied Flammable Gas Industry — Working places where flammable gases are produced, compressed or filled. Storage of containers filled with flammable gases.

A-1.5 Coal Tar Products Industry — Working places where coal tar is fractionally distilled or light oil extracted from coal is refined or fractionally distilled. Places where benzene or the other volatile flammable liquids are filled or stored.

A-1.6 Dyestuffs and Their Intermediates Manufacturing Industry — Working places where flammable gases or volatile flammable liquids are handled in large quantity.

A-1.7 Fermentation Industry — Working places where volatile flammable liquids are distilled or filled. Storage of volatile flammable liquids.

A-1.8 Acetylene, **Ethylene or Methanol Derivative Manufacturing Industries —** Working places where gaseous raw materials or volatile flammable liquids are produced, refined reacted, distilled, filled, or stored.

A-1.9 Synthetic Resin and Plastic Manufacturing Industry — Working places where flammable gases or volatile flammable liquids are handled in large quantity.

A-1.10 Synthetic Fibres Manufacturing Industry — Working places where flammable gases or volatile flammable liquids are added, reacted, produced, recovered or stored.

A-1.11 Vegetable Oil Industry, **Solvent Extraction Plants —** Working places where extraction or recovery is conducted using volatile flammable liquids. Storage of volatile flammable liquids. Hydro generation plants.

A-1.12 Fatty Acids, **Hardened Oil and Glycerin Manufacturing Industry —** Working places where hydrogen is produced or added. Other working places where flammable gases or volatile flammable liquids are used in large quantity.

A-1.13 Wood Dry Distillation Industry — Working places where dry distillation or rectification is conducted. Places where volatile flammable liquids are filled or stored.

A-1.14 Drugs and Medicine Manufacturing Industry — Working places where flammable gases or volatile flammable liquids are handled in large quantity. Storage of the gases and liquids.

A-1.15 Paints Manufacturing Industry — Working places where volatile flammable paints or thinners are produced. Places where volatile flammable raw materials or finished products are stored.

A-1.16 Insecticides and Germicides Manufacturing Industry — Working places where flammable gases or volatile flammable liquids are handled in large quantity.

A-1.17 Perfumes and Cosmetics Manufacturing Industry — Working places where volatile flammable liquids are added, prepared, distilled or extracted. Storage of these liquids.

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A-1.18 Photographic Sensitive Materials Manufacturing Industry — Working places where volatile flammable liquids are added, prepared, applied, recovered or distilled. Storage of these liquids.

A-1.19 Oil Refining and Petrochemical Industry — Working places where various refining processes or chemical reactions are conducted. Places where volatile flammable liquids are transported, filled or stored.

A-1.20 Gum Products Industry — Working places where gum arabic is produced or applied. Storage of volatile flammable liquids.

A-1.21 Brewing Industry — Places where alcohol is distilled, added or stored.

A-1.22 Processed Paper or Coated Cloth Manufacturing Industry — Working places where volatile flammable liquids are added, applied or recovered.

A-1.23 Dry-cleaning Industry — Working places where washing using flammable liquids and recovery of the said liquids are conducted. Storage of the said liquids.

A-1.24 Finishing Processes — Working places where preparation of volatile flammable paints, locations where paints, lacquers or other flammable finishers are regularly or frequently applied by spraying, dipping, brushing or by other means, where flammable thinners are used, and where readily ignitable deposits or residues from such paints, lacquers finishers may occur.

A-1.25 Printing Industry — Working places where printing is done using inks with addition of volatile flammable liquids.

A-1.26 Aircraft Hangars — Location used for storage or servicing of aircraft in which gasoline, jet fuels or other volatile flammable liquid or flammable gases are used.

A-1.27 Petrol Bunks and Service Stations — Location where petrol or other volatile flammable liquids, or liquefied flammable gases are transferred to the fuel tanks of vehicles.

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ANNEX B

(*Clause* 7.1.2.2)

LIGHTNING PROTECTION OF STRUCTURES WITH EXPLOSIVE OR HIGHLY FLAMMABLE CONTENTS

B-0 The presence of explosives or highly flammable materials in a structure may increase the risk to persons or to the structure in the event of a lightning stroke, as lightning acts as a source of ignition in the hazardous area. Necessary protection measures shall be implemented based on the risk assessment as per IS/IEC 62035-2. Lightning strike in the hazardous area will induces voltages and unwanted current in cable and supply lines, which may result in spark over in intrinsically safe equipment. Protection of equipment (electrical/electronic) within structures should be considered.

Protection of a different degree may be secured in the case of both inherently self-protecting and other structures by installation of various types of protection equipment, such as vertical and horizontal air terminations and other means. The recommendations given in **B-1** to **B-5.4** should be followed for structures in which explosive or highly flammable solids, liquids, gases, vapors or dusts are manufactured, stored or used or in which highly flammable or explosive gases, vapors or dusts may accumulate.

B-1 PRECAUTIONS

Following precautions should be taken for the protection of structures and their contents from lightning:

a) Storage of flammable liquids and gases in all metal structures, essentially gas-tight,

b) Closure or protection of vapour or gas openings against entrance of flames,

c) Maintenance of containers in good condition, so far as potential hazards are concerned,

d) Avoidance, so far as possible, of the accumulation of flammable air-vapour mixtures about such structures,

e) Avoidance of spark gaps between metallic conductors at points where there may be an escape or accumulation of flammable vapours or gases,

f) Location of structures not inherently selfprotecting in positions of lesser exposure with regard to lightning, and

g) For structures not inherently self-protecting, the establishment of zones of protection through use of earthed rods, masts, or the equivalent.

B-2 GENERAL PRINCIPLES OF PROTECTION

For the protection of structures with explosives or highly flammable contents, refer to Part 1/Sec 19 and IS/IEC 62305 (Part 1 to 4).

B-3 TYPES OF LIGHTNING PROTECTION SYSTEM

B-3.1 These should generally be of the integral mounted system with the horizontal air terminals running along the perimeter of the roof in all cases except for buildings containing highly sensitive explosives and very small buildings. The following types of protection are recommended:

Type of Building	*Recommended Type of Protection*
(1)	(2)
Building with explosives dust or flammable vapour risk	Integrally mounted system with vertical air terminals 1.5 m high and horizontal air terminals spaced 3 to 7.5 m from each other depending on the type of storage and processes involved
Explosives storage building and explosives workshops	Integrally mounted system with vertical air terminals 0.3 m high and horizontal air terminals spaced 7.5 m.
Small explosives storage buildings	Vertical pole type.
Buildings storing more dangerous types of explosives, for example, nitroglycerine (NG) and for initiatory explosives manufacturing	Suspended horizontal air terminations at least 2 m higher than the structure and with a spacing of 3 m.

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B-3.2 Each separate structure protected in accordance with B-2.3 should be equipped with twice the number of down conductors recommended in Part 1/Section 19 of this Code.

B-3.3 The earth terminations of each protective system should be interconnected by a ring conductor. This ring conductor should preferably be buried to a depth of at least 0.5 m unless other considerations, such as the need for bonding other objects to it, testing, or risk of corrosion make it desirable to leave it exposed in which case it should be protected against mechanical damage. The resistance value of the earth termination network should be maintained permanently at 10 ohm or less. If this value proves to be unobtainable, the methods recommended in IS/IEC 62305 should be adopted, or the ring conductor should be connected to the ring conductors of one or more neighboring structures until the above value is obtained.

B-4 BONDING

B-4.1 All major members of the metallic structure, including continuous metal reinforcement and services, should be bonded together and connected to the lightning protective system. Such connections should be made at least in two places and should, so far as is possible, be equally spaced round the perimeter of the structure at intervals not exceeding 15 m.

B-4.2 Major metalwork inside the structure should be bonded to the lightning protective system.

B-4.3 Electrical conductors entering a structure of this category should be metal-cased. This metal casing should be electrically continuous within the structure. It should be earthed at the point of entry outside the structure on the supply side of the service and bonded directly to the lightning protective system.

B-4.4 Where the electrical conductors are connected to an overhead electric supply line, a length of buried cable with metal sheath or armouring should be inserted between the overhead line and the point of entry to the structure and a surge protective device, for example, of the type containing voltage-dependent resistors, should be provided at the termination of the overhead line. The earth terminal of this protective device should be bonded direct to the cable sheath or armouring. The voltage protection level of the protective device should be selected based on the impulse voltage withstand of the equipment according to 4.5.3 of IS 732 and Table 6. On account of the low impulse strength of mineral insulated metal-sheathed cable, such cables are not recommended for the above purpose.

B-4.5 Metallic pipes, electrical cable sheaths, steel ropes, rails or guides not in continuous electrical contact with the earth, which enter a structure of this kind, should be bonded to the lightning protective system at the entry point. Further equipotential bondings are necessary for these metal lines at every 25 meter.

B-5 MISCELLANEOUS REQUIREMENTS

B-5.1 For a buried structure or underground excavation to which access is obtained by an adit or shaft, the recommendation in **B-4.5** as regards extra earthing should be followed for the adit or shaft at intervals not exceeding 75 m.

B-5.2 The metal uprights, components and wires of all fences, and of retaining walls in close proximity to the structure, should be connected in such a way as to provide continuous metallic connection between themselves and the lightning protective system. Discontinuous metal wire fencing on non-conducting supports or wire coated with insulating material should not be employed.

B-5.3 The vents of any tanks containing flammable gas or liquid and exhaust stacks from process plants emitting flammable vapours or dusts should either be constructed of non-conducting material or be filled with flame traps.

B-5.4 Structures of this category should not be equipped with a tall component, such as spire or flagstaff or radio aerials on the structure or within 15 m of the structure. This clearance applies also to the planting of new trees, but structures near existing trees should be treated in accordance with IS/IEC 62305.

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ANNEX C

[*Table* 3, *Item* vi)]

RECOMMENDATIONS FOR THE PROTECTION OF DIESEL ENGINE FOR PERMANENT INSTALLATION IN HAZARDOUS AREAS

C-0 To ensure a maximum degree of safety in the event of a permanently installed diesel engine being necessary in Zone 1 or Zone 2 it is recommended that it should have the following protection.

C-1 The starter shall be either of flameproof electrical type (usually operated from the mains supply) or of the following non-electric types:

a) Pneumatic,
b) Hydraulic,
c) Spring recoil,
d) Inertia, or
e) Hand start.

Any other electrical equipment associated with the engine shall be flameproof, electrical equipment shall be effectively earthed and bonded.

C-2 Cooling fan blades shall be made from non-metallic materials, which do not accumulate electrostatic charge.

All belts shall be of antistatic fire resistant type.

C-3 In order to contain discharge of sparks or flames from the exhaust system, a gas conditioner box and a flame trap shall be installed. Alternatively, the exhaust should be designed to discharge to a location within a safe area.

C-4 To prevent flash back through induction system, wherever possible, air intakes for engines shall be located in a safe area. Alternatively, a flame trap should be installed.

C-5 The surface temperature of the engine and exhaust system shall not exceed 250°C, when tested under full load conditions. In some situations cooling of the exhaust manifold and piping may be necessary, using water-jacketing or finned coolers and/or high temperature cut outs or alarms should be provided.

However, when either the free movement of air is restricted by thermal or acoustic shielding or the ignition temperature of the surrounding flammable atmosphere is below 200°C, exposed surface temperature of engine shall not exceed the minimum ignition temperature of the gases involved.

C-6 To prevent over speeding of the engine due to induction of flammable gases or vapours, means shall be provided to stop the engine. It can be either:

a) a valve to close the air intake, or
b) a system to inject carbon dioxide into the air intake.

C-7 Alarms or automatic shutdown devices shall be provided, activated by excessive water temperature and low lube oil pressure

C-8 A system using an alarm or trip device to protect the engine from excessive vibration should be considered.

C-9 An engine having a crankcase volume of over 0.5 m^3 shall be provided with relief devices. Relief valves or breathers on engines shall be fitted with flame traps or discharge into the induction system downstream of the flame trap, if fitted, and upstream of the shut-off valve, if fitted, as specified in **D-7**. Dipsticks and/or filler caps should be screwed or effectively secured by other means.

C-10 Intake and exhaust system design shall meet the following minimum requirements:

a) The length of the flame path through or across any joint shall be not less than 13 mm;
b) Suitable metal-clad or other acceptable jointing material shall be interposed between all joint faces to ensure that leakage does not occur;
c) Where valve spindles pass through the walls of any component of the induction system. The diametrical clearance shall not exceed 0.13 mm for an axial length of not less than 25 mm unless end caps are fitted; and

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d) No screw, stud or bolt hole shall pass through the wall of any component of the system.

C-11 Decompression system should not normally be provided. However, if they are essential, then the decompression parts should be provided with flame traps and ducted away to safe area.

C-12 The fuel injection pump land governor, where fitted, should be so designed that reverse running of the engine is not possible.

ANNEX D

[*Table 3, Item* vii)]

RECOMMENDATIONS FOR STORAGE BATTERIES FOR USE IN ZONE 2 AREAS

D-0 Storage batteries for use in Zone 2 areas shall be of increased safety type. These shall meet the following requirements.

D-1 Celluloid and similar combustibles shall not be used as constructional materials.

D-2 Battery containers as well as fittings and insulating parts outside the enclosed cells shall not consist of porous materials, for example, wood or other flammable materials and shall be resistant to flame and the action of electrolytes.

D-3 Openings of cells necessary for the escape of the gases given off shall be so constructed as to prevent splashing of the electrolyte.

D-4 The exterior of the cells shall be so constructed as to resist impact, and the cell cases shall be firmly fixed.

D-5 The cells shall be so built into the containers that working loose of connection of the cells with one another is impossible and normally a discharge voltage exceeding 24 V shall not appear between adjacent rows of cells.

The creepage distance between two poles of adjacent cells shall not be less than 35 mm. Where the discharge voltage exceeds 24 V, the creepage distance shall be correspondingly increased by 1 mm/2 V.

Where voltage of batteries is not less than 50 V either the battery case shall be sub-divided by partitions or the batteries shall be grouped into containers so that in no grouping does a voltage exceeding 50 V occur. In these cases, the partitions or the containers shall have heights at least half that of the battery case.

D-6 The battery case shall be so constructed as to ensure sufficient ventilation in order to prevent accumulation of gases given off from the battery, and the free space within the case shall be as small as possible.

D-7 The metallic cover of the battery case shall be lined with materials resistant to electrolyte.

D-8 The cover of the battery case shall have special fastenings.

D-9 Exposed live parts of battery contained in a case shall be protected with rubber or equivalent insulating materials. However, the opening for checking voltage may be provided.

NOTE — Charging of storage batteries shall be conducted in non-hazardous location, while the cover of the battery enclosure is kept open.

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ANNEX E

(*Clause* 2)

REFERENCES

IS No.	*Title*
1646 : 2015	Fire safety of buildings (general): Electrical Installations — Code of Practice (*third revision*)
5572 : 2009	Classification of hazardous areas (other than mines) having flammable gases and vapors for electrical installation (*third revision*)
IS/IEC 60079-0 : 2017	Explosive Atmospheres: Part 0 Equipment — General Requirements (*third revision*)
IS/IEC 60079-1 : 2014	Explosive Atmospheres: Part 1 Equipment Protection by Flameproof Enclosures "d" (*first revision*)
IS/IEC 60079-2 : 2014	Explosive atmospheres: Part 2 Equipment protection by pressurized enclosure "p" (*first revision*)
IS/IEC 60079-5 : 2015	Explosive atmospheres: Part 5 Equipment protection by powder filling "q" (*first revision*)
IS/IEC 60079-6 : 2015	Explosive atmospheres: Part 6 Equipment protection by liquid immersion "o" (*first revision*)
IS/IEC 60079-7 : 2015	Explosive atmospheres: Part 7 Equipment protection by increased safety "e" (*first revision*)
IS/IEC 60079-11 : 2011	Explosive atmospheres: Part 11 Equipment protection by intrinsic safety "i" (*first revision*)
IS/IEC 60079-13 : 2010	Explosive atmospheres: Part 13 Equipment protection by pressurized room "p"
16724 : 2018/ IEC 60079-14 : 2013	Explosive atmospheres: Part 14 Electrical installations design selection and erection
IS/IEC 60079-15 : 2010	Explosive atmospheres: Part 15 Equipment protection by type of protection "n" (*first revision*)
IS/IEC 60079-16 : 1990	Electrical apparatus for explosive gas atmospheres: Part 16 Artificial ventilation for the protection of analyzer (s) houses
IS/IEC 60079-18 : 2014	Explosive atmospheres: Part 18 Equipment protection by encapsulation "m" (*second revision*)
IS/IEC 60079-26 : 2014	Explosive atmospheres: Part 26 Equipment with equipment protection level (EPL) Ga (*first revision*)
IS/IEC 60079-28 : 2015	Explosive Atmospheres: Part 28 Protection of equipment and Transmission systems using optical radiation (*first revision*)
IS/IEC 60079-31 : 2013	Explosive atmospheres: Part 31 Equipment dust ignition protection by enclosure "t" (*first revision*)
IS/IEC 62305 (Parts 1 to 4) : 2010	Protection against lightning
IEC 60079-33 : 2012	Explosive atmospheres — Part 33: Equipment protection by special protection 's'
ISO/IEC 80079-20-1 : 2017	Explosive atmospheres — Part 20-1: Material characteristics for gas and vapour classification — Test methods and data

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NATIONAL ELECTRICAL CODE OF INDIA

PART 8 SOLAR PHOTOVOLTAIC (PV) POWER SUPPLY SYSTEMS

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PART 8 SOLAR PHOTOVOLTAIC (PV) POWER SUPPLY SYSTEMS

FOREWORD

Solar energy is a natural resource which is, for practical purposes, free, renewable and inexhaustible and can supplement/augment the depleting fossil fuel resources. Greenhouse gases and pollutant emissions which result from fossil fuel power generation can be offset by solar photovoltaic power generation. It can be used in grid interactive mode. The solar energy converter does not have moving parts and has a comparatively long lifetime. It is expected that such advantages would lead to further growth of solar photovoltaic power supply systems.

In order to achieve Government of India target of 100 GW Solar PV installations (including 40 GW rooftop solar PV installations) by 2022, quality standards and best practice recommendations are essential. It is also imperative to put in place an efficient and rigorous monitoring mechanism for adherence to quality standards and best practice recommendations.

This Part 8 of the National Electrical Code of India is primarily intended to cover the requirements relating to design of electrical installations of power supply system based on the solar photovoltaic energy. Solar PV electrical installation Code is designed to include safety and quality standards applicable to Solar PV components and systems as well as best practice recommendations.

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1 SCOPE

This Part of the National Electrical Code of India (Part 8) covers essential requirements for electrical installations for power supply systems based on the solar photovoltaic (PV) energy including PV modules, PV array circuits, inverters, controllers and balance of system components used for such systems. These systems may be interactive with electric power utility or other electrical power production sources, such as diesel generator (DG) or may be stand-alone, with or without electrical energy storage, such as batteries. These systems may have a.c. or d.c. output for utilization.

The objective of this document is to address the design, installation, safety and quality requirements arising from the characteristics specific of PV installations.

The scope of this Part of the Code includes following:

a) General safety procedures and practices in Solar PV Installations, both rooftop and utility scale.

b) General characteristics of solar PV components and installations, both rooftop and utility scale.

c) Requirements and recommendations in wiring and earthing of rooftop PV installations on buildings or industrial structures.

d) Requirements and recommendations in electrical safety protection of solar PV systems, both rooftop and utility scale.

The Part of the Code is not intended to apply to systems of distribution of energy to public and power generation and transmission for such systems.

2 REFERENCES

The Indian Standards listed in Annex A contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 CLASSIFICATION

Solar PV power generating systems are classified as follows.

3.1 Standalone PV System — Standalone PV System is an independent power producing system that is not connected to electric power utility. PV array d.c. input is converted to a.c. by standalone inverter. Charge controller for battery backup may be separate or built-in with inverter. Electrical loads may be d.c. and/or a.c.

3.2 Utility Connected PV System — Utility/grid connected PV system is a power producing system that is connected with electric power utility. PV array d.c. input is converted to a.c. by grid-tied inverter. MPP tracker is built-in with inverter. Battery backup may or may not be provided. Utility connected PV system supplies captive load and feeds excess power to utility by default, may be configured to supply captive load only using reverse power control. The reverse power control is also required when system output is connected to DG set in the event LT distribution grid is not available.

Refer Fig. 1 for grid connected distributed rooftop PV power plant blocks.

Refer Fig. 2 for grid connected central PV power plant blocks.

3.3 Hybrid PV System — Hybrid PV System is an independent power producing system (from solar PV and/or wind and/or other RE power sources) that is connected with electric power utility and/or DG. Hybrid PCE converts PV array d.c. input to a.c. and has built-in charge controller for battery pack. PV array, battery pack, utility grid and DG are input sources to hybrid PCE and a.c. electrical loads are supplied by hybrid PCE output.

3.4 Building Integrated Photo Voltaic (BIPV) System — BIPV System is a power producing system integrated with building that may or may not be connected with electric power utility. BIPV system may be Standalone, Utility Connected or Hybrid PV system.

Any of these systems may be with or without electrical energy storage such as batteries.

NOTE — The term ‘utility’ is also referred to as the ‘grid’.

4 GENERAL CHARACTERISTICS AND COMPLIANCE OF SYSTEM COMPONENTS

All d.c. components shall have voltage rating equal to or greater than the PV array maximum voltage determined in **5.8.1** and shall be rated for current according to **11.4**.

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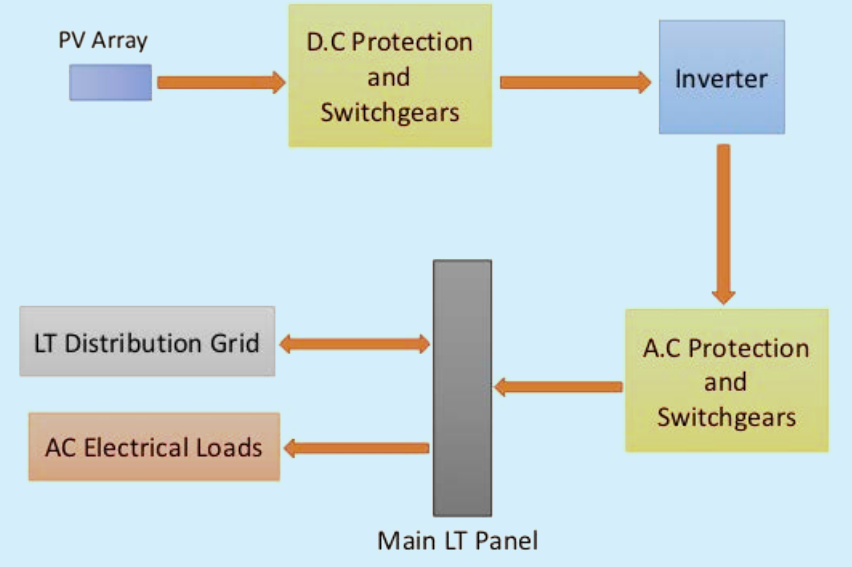


FIG. 1 DISTRIBUTED ROOFTOP PV POWER PLANT

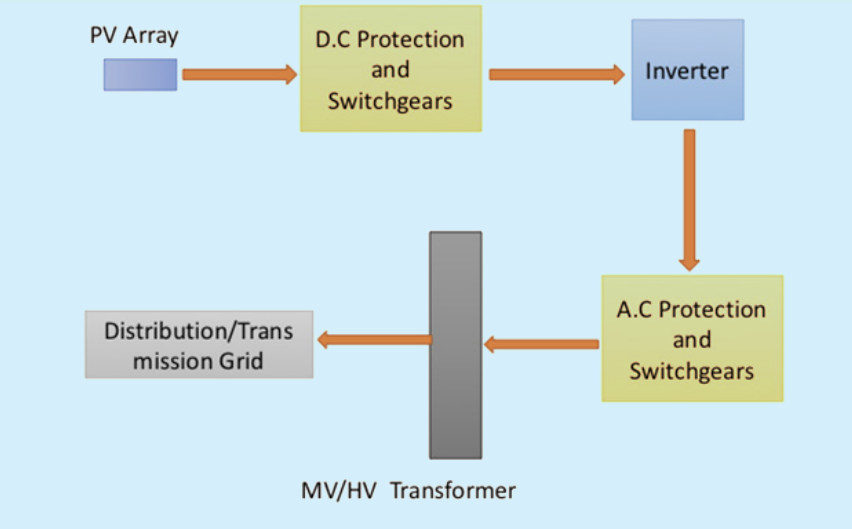


FIG. 2 CENTRAL PV POWER PLANT

4.1 PV Module

Crystalline silicon PV modules design qualification and type approval shall comply with IS 14286 (Part 1/Sec 1). IS 14286 outlines procedures for sampling, marking and testing of mono-and multi-crystalline silicon PV modules and test schedules of visual inspection, maximum power determination, insulation test, measurement of temperature coefficients, environmental tests etc.

Thin film PV modules design qualification and type approval shall comply with IS 14286 (Part 1/Sec 1), IS 14286 (Part 1/Sec 2), IS 14286 (Part 1/Sec 3) and IS 14286 (Part 1/Sec 4) outlines procedures for sampling, marking and testing of thin-film PV modules, such as amorphous silicon, cadmium telluride (CdTe), copper indium gallium selenide (CIGS), micro-morph and other thin film technologies.

Concentrator photovoltaic (CPV) modules and assemblies design qualification and type approval shall comply with IS 16228.

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All PV modules safety qualification shall comply with IS/IEC 61730-1 requirements for construction and IS/IEC 61730-2 requirements for testing in order to provide safe electrical and mechanical operation during their expected lifetime.

Crystalline silicon PV modules shall comply with IS 17210 (Part 1)/IEC 62804-1 PID testing requirements for system voltage > 600 Vd.c.

PV modules shall comply with IS/IEC 61701 salt mist corrosion testing requirements as applicable based on site environmental conditions (recommended in coastal areas).

PV modules irradiance and temperature performance measurement and power rating shall comply with IS 16170/IEC 61853-1.

PV modules shall comply with IS 16664/IEC 62716 Ammonia (NH_3) corrosion testing requirements as applicable based on site environmental conditions (dairies, toilets, mines etc.).

PV module package units shall comply with IEC 62759-1 requirements of transportation and shipping.

PV modules shall be tested for dust and sand exposure based on IS 9000 (Part 12)/IEC 60068-2-668 for high dust/sand geographical sites.

PV modules shall contain following clear indelible marking laminated inside the glass as per IS/IEC 61730-1.

a) Name, monogram or symbol of manufacturer;
b) Model number;
c) Unique serial number;
d) Nominal wattage ± 2 percent;
e) Year and country of origin; and
f) Brand name if applicable.

PV module may be RFID embedded inside module laminate and is recommended. RFID consists of following information.

a) Name of the manufacturer of PV module;
b) Name of the manufacturer of solar cells;
c) Month and year of the manufacture (separately for solar cells and module);
d) Country of origin (separately for solar cells and module);
e) I-V curve for the module;
f) Name of the test lab issuing IEC certificate;
g) Date and year of obtaining IEC PV module qualification certificates;
h) Peak wattage (Wp), Imp, Vmp and FF for the module;
j) Unique Serial No and Model No of the module; and
k) Other relevant information on traceability of solar cells and module as per ISO 9000 series.

4.1.1 *PV Module Class*

Class A (safety class II) modules shall be used for general applications where PV system voltage exceeds DVC-A limit of 50Vd.c. Class C (safety class III) modules shall be used for low voltage applications where PV system voltage is within DVC-A limit of 50V d.c. Class B modules shall not be used (Refer IS/IEC 61730-1).

Where the protective measure used on the d.c. side is double or reinforced insulation, PV modules shall be selected according to class II or equivalent insulation. Where the protective measure used on the d.c. side is extra low voltage by means of SELV or PELV, PV modules shall be selected according to class III or class II or equivalent insulation.

4.1.2 *Junction Box*

Junction Box combines all PV cell strings, and is attached at back surface of PV module and is hermetically sealed. It provides PV modules positive and negative conductor outputs 1.2 m long, 4 sq. mm copper cables as per IS 17293 recommended termination on male and female connectors respectively.

PV module junction box shall comply with IS/IEC 60529. Junction box material shall be thermo-plastic. Junction box shall have min. rating of IP65.

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4.1.3 *Bypass Diode*

Bypass diodes are used to prevent PV modules from being reverse biased and consequent hot spot heating. These are normally installed in the junction box or embedded in PV module encapsulation.

Bypass diodes installed external to PV module or Junction Box shall comply with following requirements:

a) Voltage rating min. 2 × VOC MOD of the protected module;
b) Current rating of min. 1.4 × ISC MOD of the protected module;
c) Installed according to module manufacturer's recommendations;
d) Installed such that no live parts are exposed; and
e) Protected from degradation due to environmental factors.

4.1.4 *Blocking Diode*

Blocking diodes are used to prevent reverse current in sections of a PV sub-array or array.

It is recommended not to use blocking diodes as a replacement of overcurrent protection in PV systems without batteries.

In systems with batteries, blocking diodes are recommended as one of the possible solutions to avoid reverse current leakage from the batteries into the array at night. The best practice recommendation is to incorporate blocking diode integral with charge controller.

Blocking diode shall comply with following requirements.

a) Voltage rating of minimum 2 × PV array maximum voltage determined in **5.8.1**;
b) Current rating of minimum 1.4 times the short circuit current at STC of the protection circuit (string, sub-array or array);
c) Installed such that no live parts are exposed; and
d) Protected from degradation due to environmental factors.

4.2 a.c. PV Modules

a.c. module is a complete, environmentally protected unit consisting of solar cells, optics, inverter, and other components, exclusive of tracker, designed to generate a.c. power when exposed to sunlight. Grid-tied micro-inverter is typically integrated onto the back side of the module.

The PV source circuit, conductors and inverters shall be considered as internal components of a.c. PV module. The requirements of PV source circuit shall not apply to a.c. PV module. The output of ACPV module (nominal rating of 240 V a.c.) shall be considered as an inverter output circuit. Phase and neutral terminations are provided for a.c. PV modules and earthing termination is a recommended best practice.

4.3 PV Strings and Arrays

A set of PV modules connected in series makes a PV string. PV string voltage is N × PV module voltage, N is the no. of PV modules connected in series. PV string current is equal to the PV module current.

A set of PV strings connected in parallel makes a PV array. PV array current is M × PV string current, M is the no. of PV strings connected in parallel. PV array voltage is equal to the PV string voltage.

4.4 PV String and Array Combiner Boxes

PV array and PV string combiner boxes shall comply with IS/IEC 60529 for degree of protection and complete assembly shall comply to IS/IEC 61439-2, shall be of thermo-plastic/Polycarbonate/FRP material, minimum IP 65 compliant, and UV resistant when exposed to outdoor environment.

PV array and PV string combiner boxes shall be minimum IP 54 compliant when exposed to indoor environment.

PV array and PV string combiner boxes which contain overcurrent protection and/or switching devices shall be easily accessible for inspection, maintenance or repairs.

4.4.1 *Combiner Box Class*

Where the protective measure used on the d.c. side is double or reinforced insulation, combiner boxes shall be selected according to class II or equivalent insulation. Where the protective measure used on the d.c. side is extra low voltage by means of SELV or PELV, combiner boxes shall be selected according to class III or class II or equivalent insulation.

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4.5 PCE/Inverters

PCE/Inverters are d.c. to a.c. converters and used in all PV systems with a.c. power output.

The minimum requirements for the design and manufacture of PCE/Inverters for safety like protection against electric shock, energy, fire, mechanical and other hazards shall comply with IS 16221 (Part 2).

Procedure for measuring efficiency of PV system PCE shall comply with IS/IEC 61683.

Procedure for measuring overall efficiency (including static and dynamic MPPT efficiency) of grid connected PV inverter shall comply with IEC 62891.

Test procedure of islanding prevention measures for utility connected PV inverters shall comply with IS 16169.

Environmental testing of PCE/inverters shall comply with relevant parts of IS 9000 series as given in IS 16221 (Part 2).

EMC/EMI testing of PV inverters shall comply with relevant parts of IS 14700 series as given in IS 16221 (Part 2).

4.6 Transformers

Isolation transformers may be used with string inverters for PV array functional earthing requirements. Power transformers are used with central inverters for combining multiple inverter outputs and/or stepping up voltage output.

All isolation/power transformers used with inverters shall comply with IS 2026 (Part 1), IS 2026 (Part 2), IS 2026 (Part 3), IS 2026 (Part 4), IS 2026 (Part 5) and IS 2026 (Part 10) (general, temp. rise, insulation tests, short circuit, sound levels resp.).

4.7 Storage Batteries

General requirements and methods of testing for secondary cells and batteries for solar PV applications shall comply with IS 16270.

4.8 Charge Controllers

PWM and MPPT are two types of charge controllers used to charge battery packs with PV array output.

Charge controllers design qualification for natural environments shall comply with IS 16229. For charge controller in-built with the inverter, no separate IS 16229 test is required.

Charge Controllers shall comply with IS 16797/IEC 62509 for Performance and functioning.

All BOS components: Batteries, inverters, charge controllers, system diode packages, heat sinks, surge protectors, system junction boxes, maximum power point tracking devices and switch gear etc. design qualification for natural environments shall comply with IS 16229.

Environmental testing of charge controllers and MPPT units shall comply with IS 9000 (Part 2), IS 9000 (Part 3), IS 9000 (Part 5), IS 9000 (Part 6), IS 9000 (Part 7) and IS 9001 (Part 13).

4.9 Cables

4.9.1 *d.c. Cables*

All solar PV d.c. cabling shall comply with IS 17293. This standard applies to low smoke halogen-free, flame retardant, UV resistant, flexible, tinned-copper conductor, single-core, double insulated power cables with electron beam cross-linked (EBXL) insulation and sheath, for use at the d.c. side of photovoltaic systems, with a nominal d.c. voltage up to 1.5 kV between conductors and between conductor and earth and temperature rating of –40 °C to +90 °C.

It is recommended to use cable as per IS 17293, UV stabilized single core flexible copper conductor cables for solar PV d.c. cabling. Multi-core cables shall not be used. Use of aluminum conductor d.c. cables requires larger diameter, calls for due precautions in cable termination, and poses higher potential risk of loose termination, d.c. arcing and fires as compared to use of copper conductor d.c. cables.

4.9.2 *a.c. Cables*

All indoor a.c. Cabling shall comply with atleast FRLSH grade as per IS 694/IS 1554 (Part 1 and 2) standards as appropriate. Use of copper conductors is recommended up to 25 mm^2 size.

All outdoor a.c. cabling shall comply with IS 7098 (Part 1), IS 7098 (Part 2) and IS 7098 (Part 3). Use of copper conductors is recommended up to 25 mm^2 size.

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Underground a.c. cables shall be armoured preferably with copper conductor. Aluminum conductor a.c. cables of suitably larger diameter may be used with extra care and precaution following recommended cable termination practices.

4.10 Plugs, Sockets and Connectors

Plugs and sockets normally used for the connection of household equipment to low voltage a.c. power supply shall not be used in PV arrays.

Plugs and socket connectors mated together in a PV system shall be of the same type from the same manufacturer (NOT equivalent type from another manufacturer). In other words, a plug from one manufacturer and a socket from another manufacturer or vice versa shall not be used to make a connection.

It is recommended to use appropriate MC4 plug and socket connectors for PV module terminations, string interconnections and string terminations onto SCBs and/or string inverters. Connectors safety requirements and tests shall be compliant with IS 16781 and corresponding connection shall be done in compliance with IS 16221 (Part 2). It is recommended to use MC4 equivalent connectors which connects both plug and socket of the same type from the same manufacturer. Extra precaution is required in matching type and manufacturer of terminations for PV modules, PV strings, SCBs and inverters.

Plugs, sockets and connectors shall comply with following requirements:

a) Comply with IS 16221 (Part 2);
b) Voltage rating equal to or greater than the PV array maximum voltage determined **5.8.1**;
c) Shrouded/protected from contact with live parts in connected and disconnected state
d) Rated current according to **11.4**;
e) Capable of accepting the cable used for the circuit to which they are fitted (typ. 2.5, 4 and 6 mm^2 Cu);
f) Shall be of the latching/locking type where two independent actions and deliberate force are required to disconnect (use of tool is recommended for disengagement);
g) Rating suitable for installation location;
h) If multi-polar, be polarized and non-interchangeable with receptacles in other electrical systems installed at the location;
j) Comply with Class II for systems operating above DVC-A voltages (50 Vd.c.);
k) UV-resistant and min. IP65 rated form outdoor use;
m) Shall be installed with min. strain on the connectors (for example, supporting the cable on either side of the connector);
n) The protective earth connection shall be the first to make and the last to break contact with the mating connector;
p) Busbar terminations internal to inverters shall comply with IS 16221 (Part 2) for safety requirements.

4.11 Earthing Components

4.11.1 *Earthing Cables and Strips*

All d.c. and a.c. earthing conductors and earth electrodes installations shall comply with IS 3043 and IS 732.

All LA air termination, down conductors, earthing conductors and earth electrodes shall comply with IEC 62561 (Part 1 and 2).

Earth enhancing compounds shall comply with IEC 62561-7.

NOTE — In soil with resistivity higher than 3 000 Ωm, the use of type B earth electrodes or earthing enhancing compounds is recommended in IS/IEC 62305.

Following best practices are recommended.

a) The d.c. earthing conductor should be rated for 1.56 times the maximum short circuit current of the PV string/sub-array/array (25 percent design safety factor and 25 percent irradiance factor);
b) Min. 6 mm^2 copper conductor, outdoor rated (IS 7098) cable for PV module frame interconnections;
c) Min. 6 mm^2 copper conductor, outdoor rated (IS 7098) cable for module frame to MMS connection;
d) Min. 50 mm^2 copper conductor or 50 mm^2 copper coated steel conductor, or 25 × 3 mm GI strip for MMS to MET connection;

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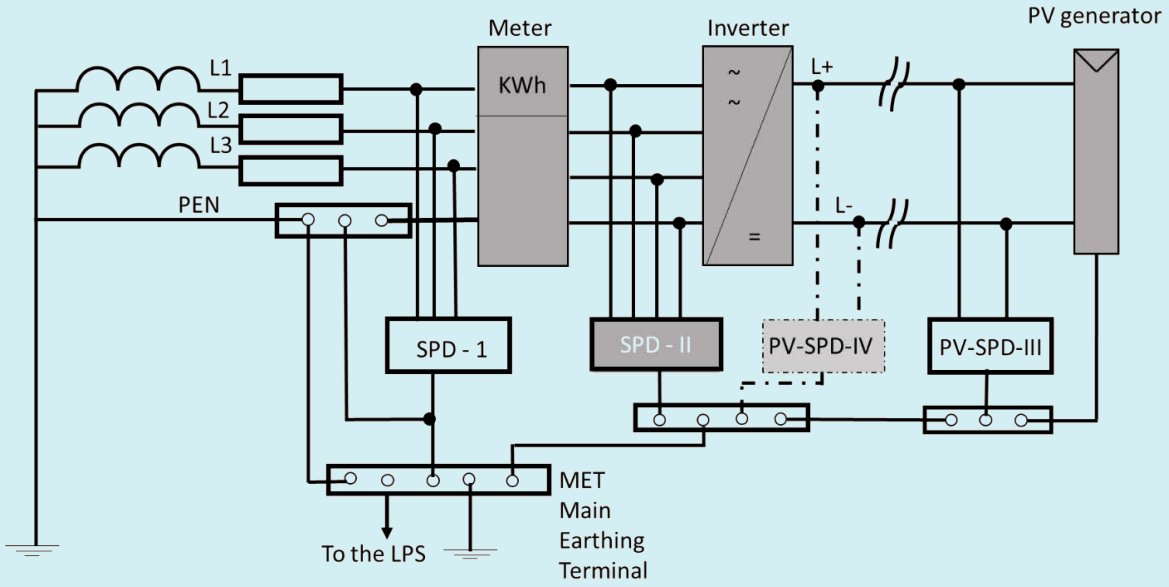


FIG. 3 TYPICAL EARTHING, EQUIPOTENTIAL BONDING AND SPD'S IN A GRID CONNECTED PV SYSTEM

e) Min. 50 mm² copper conductor or 50 mm² copper coated steel conductor, or 25 × 3 mm GI strip for SCB/AJB/Inverter chassis to MET connection; and

f) Min. 50 mm² copper conductor or 50 mm² copper coated steel conductor, or 25 × 3 mm GI strip for Lightning Protection earth electrode.

4.12 Electrical Protection Components

4.12.1 *Overcurrent Protection*

4.12.1.1 *d.c. fuses*

Fuses used in PV arrays shall comply with the following requirements:

a) Rated for d.c. use. (PV fuse);

b) Overcurrent and short circuit current protective type suitable for PV complying with IS/IEC 60269 Low-voltage fuses (Part 1 and 6);

c) Voltage rating equal to or greater than the PV array maximum voltage determined in **5.8.1**;

d) Rated to interrupt fault currents from the PV array and any other connected power sources, such as batteries, if present; and

e) Rated for current according to **11.4**.

When fuses are provided for overcurrent protection, the use of fused switch-disconnectors is recommended. Use of Load break switches is recommended for multiple fused inputs.

4.12.1.2 *d.c. Fuse holders*

Fuse holders shall comply with following requirement:

a) Voltage rating equal or greater than the PV array maximum voltage determined in **5.8.1**;

b) Current rating equal to or greater than the corresponding fuse current rating; and

c) Provide degree of protection suitable for the location and not less than IP 2X.

It is recommended for d.c. fuse to have DIN rail mountable fuse holder housed in IP65 rated thermoplastic enclosure with transparent cover.

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4.12.1.3 *Circuit breakers*

Circuit breakers used for overcurrent protection in d.c./a.c. side of PV system shall comply with IS/IEC 60947 (Part 1 and Part 2).

Circuit breakers if used for overcurrent protection in PV arrays, shall meet following requirements.

a) Rated for d.c. operation;
b) Certified to IS/IEC 60947 (Part 1 and Part 2);
c) Not be polarity sensitive;
d) Rated to interrupt full load and prospective fault currents from the PV array and any other connected d.c. power sources, such as batteries; and
e) Rated for current according to **11.4**.

4.12.2 *Overvoltage Protection Components*

4.12.2.1 *d.c. SPD*

d.c. SPD shall comply with requirements and test methods specified in IEC 61643-31.

4.12.2.2 *a.c. SPD*

LV a.c. SPD shall comply with requirements and test methods specified in IS16463-11 and IS/IEC 61643 (Part 11 and 12).

4.12.2.3 *Data/signal line SPD*

Data/signal line SPD shall comply with requirements and test methods specified in IEC 61643-21 and IEC 61643 22.

4.12.3 *Earth Fault Protection Components*

4.12.3.1 *Earth Fault detection and residual current monitoring system*

Earth fault detection by residual current monitoring shall comply with IS/IEC 62548 and/or IEC 62109 (Part 1 and Part 2).

4.12.3.2 *RCD*

RCD protects personnel from electrical shock in the event of earth leakage current from a.c. output of PCE/Inverter/transformer.

RCD shall be of type B having requirements and tests in accordance with IEC 62423.

RCD is not required when the PV array is functionally earthed and the Isolated Inverter complies with the leakage current limits as per Table 30 of IEC-62109-2.

4.12.4 *Lightning Protection Components*

Lightning protection shall comply to IS/IEC 62305. Connection components shall comply with IEC 62561-1.

4.12.5 *Disconnectors*

All disconnectors shall be rated to interrupt full load and prospective fault currents from the PV array and any other connected power sources, such as batteries, generators and the grid if present.

4.12.5.1 *d.c. Disconnectors*

A d.c. switch-disconnector shall be used between the photovoltaic array and the inverter.

All d.c. disconnectors shall comply with the following requirements:

a) Not have exposed live metal parts, either connected or not connected in circuit.
b) Not be polarity sensitive. Fault currents in a PV array may flow in the opposite direction of normal operating currents.
c) Have current rating equal to or greater than the associated overcurrent protection device, or in the absence of such device, be rated for current according to **11.4**.
d) Have d.c. voltage rating of min. 1 000 V d.c. It is recommended to use plug and socket connections for interruption under no load. The interruption of plug and socket connection under load poses potential risk of overheating and d.c. arcing causing damage to the connection.

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4.12.5.2 *a.c. Disconnectors*

LV switch-disconnectors shall be certified to IS/IEC 60947 (Part 1 and 3) and have mechanisms that have independent manual or automatic operation.

Type testing specifications of LV switchgear and control gear assemblies shall comply with IS/IEC 61439-2.

Particular specifications of LV switchgear and control gear assemblies for busbar trunk systems (busways) shall comply with IS/IEC 61439-2.

HV switchgear and control gear specifications shall comply with IS/IEC 62271.

4.13 Energy Meters

4.13.1 *Gross Energy Meter/Feed-in Meter*

A load energy meter records import of conventional energy from grid. Solar energy is exported to the grid and is separately recorded through a different gross energy meter/feed-in meter.

4.13.2 *Net Energy Meter*

A single net energy meter records import of conventional energy from grid and export of solar energy into grid. Net energy import/export is also recorded by net energy meter.

Static direct connected smart net energy meter (class 1 and 2 specifications) shall comply with IS 16444.

4.13.3 *TOD (Time of Day) Energy Meter*

TOD energy meter is a net energy meter having facility to separately record energy import/export in pre-defined time slots.

5 GENERAL CHARACTERISTICS OF INSTALLATIONS

5.1 General Requirements

An overview of PV power-generating systems including functional description of major components and interfaces and also possible configurations is given in IS 14153.

Solar PV systems shall be permitted to supply power to a building or similar structure in addition to any other electrical power supply system.

The installation of Solar PV system equipment and all associated wiring and interconnections shall be performed only by suitably qualified persons.

Installation of multiple PV systems shall be permitted in a single building, each system shall provide dedicated disconnecting means.

5.2 Standalone PV Systems

Standalone PV systems operate with battery backup independent of utility/grid.

Specifications and methods of test in selection of stand-alone lighting kits for rural electrification shall comply with IEC/TS 62257-9-5.

Standalone PV systems design qualification (for example, functionality, autonomyand ability to recover after periods of low state of charge of the battery) and type approval shall comply with IS 16230/IEC 62124.

5.2.1 *Standalone Inverter Output*

The a.c. output power of standalone inverter shall be connected to building electrical load *via* suitable disconnector. The inverter a.c. output power shall not exceed calculated load connected to the disconnector.

5.3 Utility Connected Systems

Utility/grid connected or grid-tied systems are directly connected to the utility grid *via* grid-tied inverters. Utility connected systems are capable of exporting surplus power into the grid and are designed to automatically shut down in the event grid is not available or anomalies in the grid parameters, such as voltage, frequency, etc. are detected. Grid-tied systems shall be permitted to have battery backup to supply power to critical loads in grid-isolated mode.

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Table 1 Recommended Interconnection Voltages for Utility Connected Systems Based on Capacity

(*Clause* 5.3)

PV System a.c. Capacity	Interconnection Voltage
< = 10 kW	240V, 1-ph or 415V, 3ph
>10 kW and < = 100kW	415 V, 3-ph
>100 kW and < = 1MW	11 kV, 3-ph
>1 MW and < = 10MW	33 kV, 3-ph
>10 MW and < = 100MW	66 kV, 3-ph
>100 MW	132 kV, 3-ph and above

Recommended max. capacity of Grid-tied PV system connected to distribution transformer output is 40 percent of distribution transformer rated capacity. Specific grid/load flow studies are required in the event grid-tied PV system capacity exceeds 40 percent of distribution transformer rated capacity.

5.4 Hybrid PV Systems

Hybrid PV systems are connected to grid and also have a battery backup. In the event grid is not available or anomalies in the grid parameters are detected, Hybrid PV systems are designed to supply power to critical load in an isolated mode. Hybrid PV systems may be connected with DG in grid-isolated mode. When connected with DG, reverse power controller is employed for protection of DG circuits.

5.5 PV Systems over 1 000 V d.c.

Utility scale Solar PV systems rated at 1 500 V d.c. are used to reduce d.c. current levels, d.c. cable sizes and BOS components requirements (No. of Strings, SCBs, Inverters). All components used in PV systems over 1 000 V d.c. shall comply with relevant IS/IEC specifications.

5.6 PV Circuits

PV array source circuits are used to supply power to application circuits.

Three kinds of PV application circuits are considered:

a) *d.c. PV Circuits*: PV array connected to d.c. electrical loads either directly or *via* DC-DC converter;

b) *Bipolar or Floating PV Circuits*: PV array connected to a.c. electrical loads *via* PCE that does not include simple separation and PV array is electrically not connected to earth; and

c) *Earthed PV Circuits*: PV array connected to a.c. electrical loads *via* PCE that includes at least simple separation and PV array is electrically connected to earth.

The electrical configurations of single string, multiple parallel string and multi-sub-array PV circuits connected to PCE with single MPPT input or multiple MPPT inputs are as per 5.1.3 of IS/IEC 62548.

5.6.1 *d.c. PV Circuits*

One of the conductors of the PV array may or may not be connected to earth. Electrical load equipment on the d.c. side shall be suitable for direct voltage and direct current.

5.6.2 *Bipolar or Floating PV Circuits*

Earthing of one of the conductors of the PV array is not allowed when it is connected to non-isolated (transformer-less) PCE/Inverter for functional reasons.

5.6.3 *Earthed PV Circuits*

Earthing of one of the conductors of the PV array for functional reasons is allowed when there is at least simple separation from mains earth provided either internally in the PCE or externally *via* a separate transformer.

5.6.4 *Series and Parallel Configuration of PV Circuits*

According to 5.1.5 of IS/IEC 62548, all PV modules within a PV string connected in series shall be of the same technology and all PV strings within a PV array connected in parallel shall have the same number of series connected PV modules.

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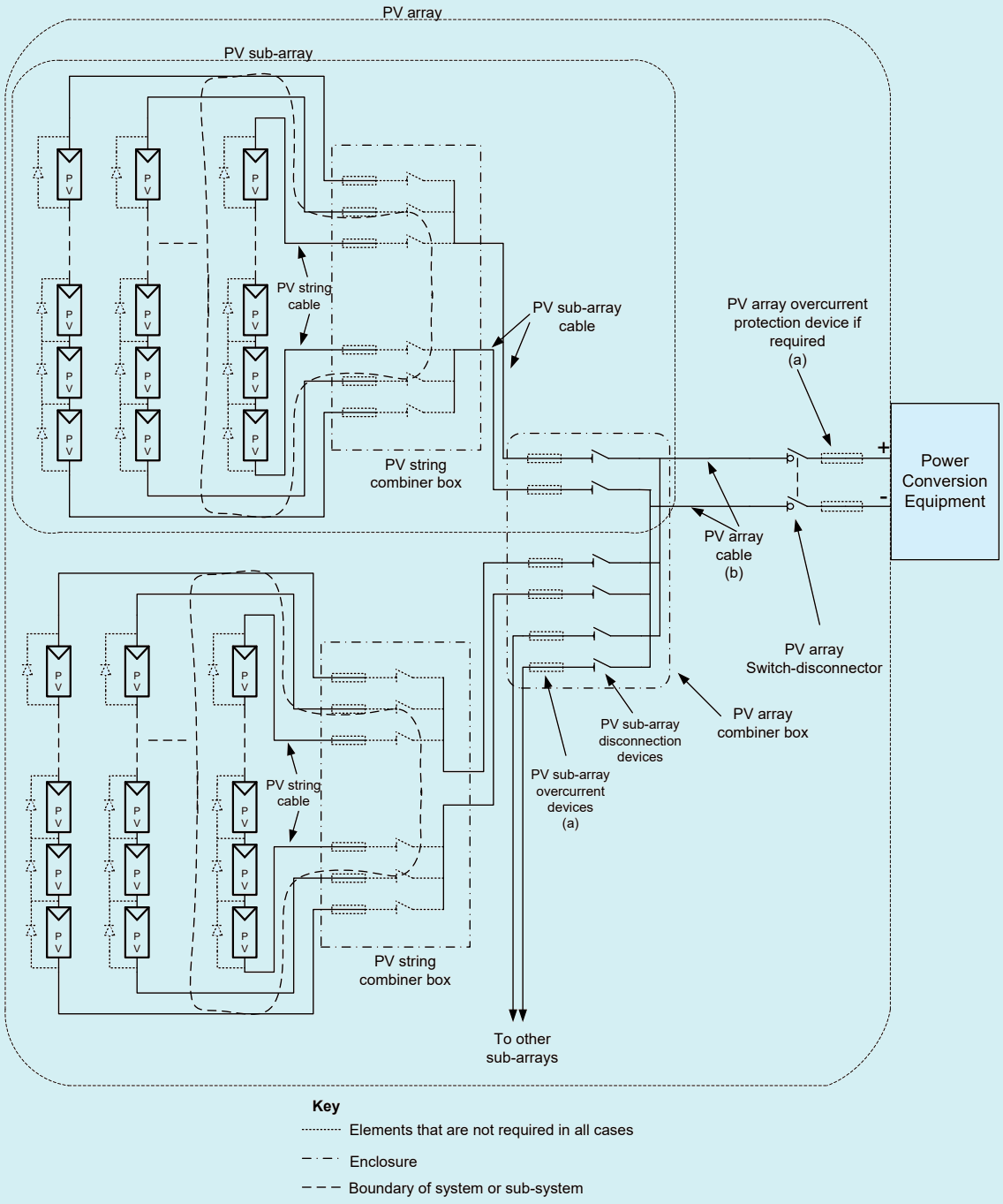


FIG. 4 PV ARRAY DIAGRAM — MULTIPLE PARALLEL STRING EXAMPLE WITH ARRAY DIVIDED INTO SUB-ARRAYS

In addition, all PV modules connected in series and parallel within the PV array shall have similar rated electrical characteristics including short circuit current, open circuit voltage, maximum power current, maximum power voltage and rated power (all at STC).

It is recommended to use PV modules of identical make, model and type when connected in series and parallel within a PV array.

When single or multiple strings in parallel are connected to the MPPT input of string inverter, string lengths (number of series connected modules in strings) shall be identical. For string inverter with multiple MPPT inputs, string lengths connected to one input may not be identical to string lengths connected to another input.

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5.7 PV Circuit Current

PV circuit current is limited by short circuit current rating of PV modules.

5.7.1 *Maximum PV Source Circuit Current*

The max. PV source circuit current shall not be less than sum of parallel connected PV strings or array STC rated short circuit current.

The max. PV source circuit current shall be calculated by following two methods and shall be considered maximum of the two:

a) The sum of parallel connected PV strings or array rated short circuit current multiplied by 125 percent (to allow for radiation and ambient temp. peaks); and

b) The calculated maximum current value based on the highest 4-hour current average in a year resulting from the local irradiance on the PV array for given plane of array (POA). The current value calculated by this method shall be minimum 80 percent of the value calculated by method 1.

5.7.2 *Maximum PV Output Circuit Current*

The maximum PV output circuit current shall be the sum of parallel source circuit maximum currents as calculated in **5.7.1**.

5.7.3 *Inverter Input Circuit Current*

The maximum inverter input circuit current shall be the inverter continuous input current rating at rated power and at min. input voltage.

5.7.4 *Inverter Output Circuit Current*

The maximum inverter output circuit current shall be the inverter continuous output current rating.

5.7.5 *PV Conductor Sizing and Current Carrying Capacity (CCC)*

PV arrays not connected to batteries are current limited systems but because of parallel connection of strings, and sub-arrays, abnormally high currents may flow in array wiring under fault conditions. Overcurrent protection is specified where required and cables shall be capable of handling the worst case current from any remote part of the array through the nearest overcurrent protection device plus the worst case current available from any adjacent parallel strings.

PV array currents are not continuous based on the bell shaped and non-continuous solar radiation pattern during the day. As a result, additional safety factor of 125 percent is not recommended in determination of PV conductor current rating. Note that 125 percent of safety factor is already applied to allow for radiation and ambient temp. peaks (*see* **5.7.1**).

Current rating for PV string cables, PV sub-array cables and PV array cables shall be determined with regard to following four criteria:

a) Minimum current rating of PV circuits as per 7.3.6 and Table 6 of IS/IEC 62548;

b) Overcurrent protection ratings where in use;

c) Prospective fault current where overcurrent protection is not in use; and

d) Recommended voltage drop considerations.

The largest current rating obtained from these four criteria shall be applied.

Note that individual PV module interconnection cable current rating shall match that of PV string cable current rating.

The minimum cable sizes for PV array wiring shall be based upon the current rating calculated as above, and the CCC of cables as specified in IS 3961. Cable derating factors (for edited, ambient temperature, UV, grouping, depth of laying etc.) taking into consideration cable location and installation method shall be applied.

In some PV module technologies, I_{SC_MOD} is higher than the nominal rated value during the first weeks or months of operation, and in other technologies I_{SC_MOD} increases over time. This shall be taken into account when establishing PV conductor current ratings.

5.8 PV Circuit Voltage

PV module voltage falls within DVC-A (<=60Vd.c.) category, while PV string/array voltage falls within DVC-B (>60Vd.c., <=120Vd.c.) or DVC-C (>=120Vd.c.) categories.

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5.8.1 *Maximum PV Circuit Voltage*

The PV array maximum voltage is considered to be equal to V_{OC_ARRAY} corrected for the lowest expected operating temperature and highest expected operating radiation.

Based on electrical safety considerations, a maximum voltage of 1 000 V d.c. is recommended for circuits located on building rooftops. A maximum voltage of 1 500 V d.c. is recommended for circuits located on ground.

PV modules may be connected in series up to the maximum allowed operating voltage of the PV modules or the PV inverter, whichever is lower. Both standard PV module and inverter are rated for 1 000V d.c.The maximum PV circuit voltage shall be used to determine voltage rating of conductors, cables, disconnects, overcurrent protection devices and other equipment.

5.8.2 *PV Module Voltage Correction Factors*

5.8.2.1 *Temperature correction factor*

The temperature correction factors for V_{oc} of silicon PV modules shall be as per IS/IEC 62548. The temperature correction factors for V_{oc} of PV modules other than silicon shall be based on the temperature coefficient of V_{oc} as specified by the manufacturer.

5.8.2.2 *Radiation correction factor*

PV module Voc varies directly with radiation, the correction factor depends on cell technology.

Photovoltaic (PV) module performance testing and power rating with irradiance and temperature shall be as per IEC 61853-1.

5.9 Connections to other Sources

Solar PV system may be connected to electrical load and/or utility. d.c. or a.c. electrical output of solar PV system may be connected to electrical load. Solar inverter or a.c. PV module may be connected to utility in a grid interactive system.

5.9.1 *Connection to Electrical Load*

In the event multiple sources of power are connected to electrical load disconnector, all power sources shall be disconnected in the off position.

5.9.2 *Connection to Utility/Grid*

Solar PV system shall automatically de-energize its output connected to utility upon loss of grid voltage and shall remain in that state until the grid voltage has been restored.

A grid-interactive solar PV system shall be permitted to supply power to critical loads with battery backup, provided critical loads have been isolated from the utility grid.

Distributed generating resource shall not inject d.c. power greater than 0.5 percent of the full rated output at the interconnection point. THD shall be below 8 percent and individual harmonic shall be below 5 percent for PCC voltage below 1 kV a.c. Phase imbalance voltage arising from single phase inverters feeding into the distribution grid shall not exceed 3 percent.

PV systems characteristics of utility interface shall comply with IS/IEC 61727.

Grid-tied PV system shall not cause voltage flicker in excess of limits stated in the relevant sections of IS 14700/IEC 61000-3-3 for PCE/Inverter output a.c. current per phase less than 16 A, and IS 14700/IEC 61000-3-5 for > = 16A.

The range of grid-tied PCE/inverter power factor adjustment shall be min. 0.8 lead and 0.8 lag. Grid-tied PCE/inverter feed a.c. power at unity power factor by default, reduces power factor of utility/grid supply that requires additional power factor correction.

When the PV installation is generating power, the voltage at the PCE terminals is higher than the voltage at the grid connection point. It is recommended to keep this voltage difference to a minimum in order to prevent the PCE from nuisance tripping on overvoltage.

5.9.3 *Grid-tied system Shutdown Procedure*

Grid-tied system shutdown procedure shall be displayed on chart in inverter/a.c. control room.

PV array shall be open circuit when disconnected from inverter/PCE. Disconnect grid supply prior to disconnecting PV array when system is shut down for maintenance.

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PV array shall be open circuit when connected to inverter/PCE. Connect PV array prior to connecting grid supply when system is energized.

5.9.4 *Connections to DG*

When connected to DG source, grid-tied and hybrid PV systems shall provide protection against reverse current. Electronic power controllers are employed to provide reverse current protection and meet minimum. recommended base load requirements of DG. PV generated power is also controlled to meet total load requirement in a grid-tied captive power plant.

6 WIRING

All cabling and electrical wiring of the installation shall be done in accordance with IS 732.

All connections shall be verified for tightness and polarity during installation to reduce the risk of faults and possible arcs during commissioning, operation and future maintenance.

It is recommended to clamp all cables and conduits to rooftop, walls and ceilings with UV rated thermoplastic clamps/cable ties at intervals not exceeding 50 cm. It is recommended to raise clamps above terrace floor level by min. 5 cm to prevent water logging.

6.1 d.c. Wiring

All d.c. cables shall have current rating equal to or greater than the PV circuit maximum current determined in **5.7.2** and voltage rating equal to or greater than the PV circuit maximum voltage determined in **5.8.1**.

d.c. cable sizing shall be based on both CCC and power loss considerations (*see* **7.1.1**). Minimum d.c. cable size shall be 4 mm^2, copper conductor complying to IS 17293.

6.1.1 *d.c. Power Loss in Cables*

In the design process, the sizing of cables within the array and in cable connections from the array to the application circuit affect the voltage drop in those cables under load. This can be particularly significant in systems with low output voltage and high output current. It is recommended that under maximum load conditions, the voltage drop from the most remote module in the array to the terminals of the PCE/Inverter does not exceed 2 percent of the PV array voltage at its maximum power point.

6.1.2 *d.c. Cable Layout*

a) It is recommended to protect PV module/string cables by UV stabilized PVC conduits of adequate diameter and minimum wall thickness of 1.5 mm. The cables shall be suitably clamped to relieve tension in order to prevent the conductor from coming loose/free from the connection;

b) All d.c. cables shall be installed so that positive and negative cables of the same string, sub-array and the array are bundled together, avoiding the creation of loops in the system, in order to minimize over voltages induced by lightning as per 7.4.3.3 of IS/IEC 62548. The requirement for bundling includes any associated earthing/bonding conductors;

c) Where conductors enter a combiner box without conduit, a tension relief system shall be used (for example by using a gland connector) to avoid cable disconnections inside the box. All cable entries when installed shall maintain the IP rating of the enclosure;

d) Segregation between positive and negative conductors within combiner boxes is recommended to minimize the risks of d.c. arcs occurring between these conductors;

e) Segregation is recommended between d.c. and a.c. circuit cables to the same requirements as for segregation of different voltage levels as per IS 732;

f) Where wiring devices (for example, conduits, cable ties) with integral enclosures are used, sufficient length of cables shall be provided to facilitate replacement;

g) PV source circuits and output circuits shall not be installed in the same enclosures (for example, conduit, cable tray, junction box) as that of inverter output circuits or other non-PV circuits;

h) SCBs and other enclosures located behind PV modules/panels shall be installed such that the internal wiring is accessible directly or by removal of PV modules/panels secured with removable fasteners and connected by flexible wiring system; and

j) Considering personnel safety in the event of fire, the Grid-tied Inverter shall be located in close proximity to Solar PV Array on the terrace/top floor. If installed on the lower floors, inverter shall be installed close to

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periphery of the building and the d.c. cables connected to inverter shall be routed through the outside wall of the building and shall be clearly identified.

6.1.3 *d.c. Cables for Tracking PV Arrays*

d.c. Cables used for Tracking PV Arrays shall be flexible, copper conductor cables, rated for outdoor use.

6.1.4 *BIPV d.c. Cables*

d.c. circuit cables inside buildings shall be either armored or installed in a metal conduit from the point of penetration of the building wall to the first accessible circuit disconnector.

6.2 a.c. Wiring

a.c. cable sizing shall be based on both CCC and power loss considerations (*see* **7.2.1**).

It is recommended to use copper conductor a.c. cables.

In three phase systems, size of neutral conductor shall be same as the size of phase conductors.

6.2.1 *a.c. Power Loss in Cables*

It is recommended to limit a.c. voltage drop in cable segments between inverter output and IIP/GIP below 1 percent. a.c. voltage drop in cable segments between IIP/GIP output and PCC (a.c. power distribution board) is recommended to be below 1 percent. The sum total a.c. voltage drop in cable segments between inverter output and PCC is recommended to be below 2 percent of mains a.c. voltage.

6.2.2 *a.c. Cable Layout*

a) Segregation shall be provided between d.c. and a.c. circuit cables to the same requirements as for segregation of different voltage levels as per IS 732/relevant section of this code.
b) a.c. cables shall be suitably clamped to relieve tension in order to prevent the conductor from coming loose/free from the connection.
c) Where cables enter inverter/IIP/GIP without conduit, a tension relief system shall be used (for example by using a gland connector) to avoid cable disconnections inside the box. All cable entries when installed shall maintain the IP rating of the enclosure.
d) Where wiring devices (for example, conduits, cable ties) with integral enclosures are used, sufficient length of cables shall be provided to facilitate replacement.
e) Inverter output circuits shall not be contained in the same enclosure (for example, conduit, cable tray) as that of PV source/output circuits.

6.3 Earth Wiring

Wiring with separate protective conductor shall be used. With respect to material and type, insulation, identification, installation and connections, the earthing conductors shall comply with the provisions for earthing conductors set out in IS 3043 and IS 732.

6.4 Cabling Selection and Installation in Relation to External Influences

a) PV string, sub-array and array cables shall be selected and installed so as to minimize the risk of earth faults and short-circuits due to external influences.
b) Cables shall be supported so they do not suffer fatigue due to wind/snow affects.
c) Cables shall be protected from sharp edges.
d) All non-metallic conduit, ducting and cable ties exposed to sunlight shall be of UV resistant type.
e) It is recommended to make provision to allow any water or condensation that may accumulate in the conduit or tray to escape through properly designed and installed vents.

7 EARTHING

TN-S system with separate protective conductor shall be used as below in the a.c. side. For d.c. side various configurations are explained in **7.1**. However in all systems, separate protective conductor is necessary.

PV array configuration shall be permitted with and without functional (Active) d.c. earthing.

NOTES

1 TN-C system shall not be used.

2 TT system if used on a.c. side shall be protected with an RCD of 30 m ssA at origin of installation.

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7.1 d.c. Side Earthing

PV d.c. configurations:

d.c. Side	Refer Fig. No.	Application Circuit	Consequence on the Status of the PV Array
Un earthed	Fig. 5	a.c. side connected *via* a PCE with a transformer inside of the PCE	floating
	Fig. 6	a.c. side connected *via* a PCE without a transformer	Fixed by the status of the neutral or a line conductor of the supply circuit
Earthed	Fig. 7	a.c. side connected *via* a PCE with a transformer inside of the PCE	Fixed to earth
	Fig. 8	a.c. side connected *via* a PCE without a transformer inside of the PCE but a transformer outside of the PCE	Fixed to earth

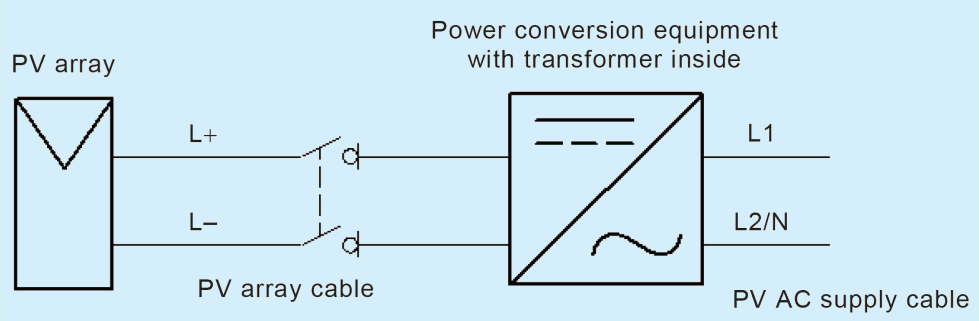


FIG. 5 UNEARTHED PV ARRAY CONNECTED TO THE AC SIDE VIA A PCE WITH TRANSFORMER

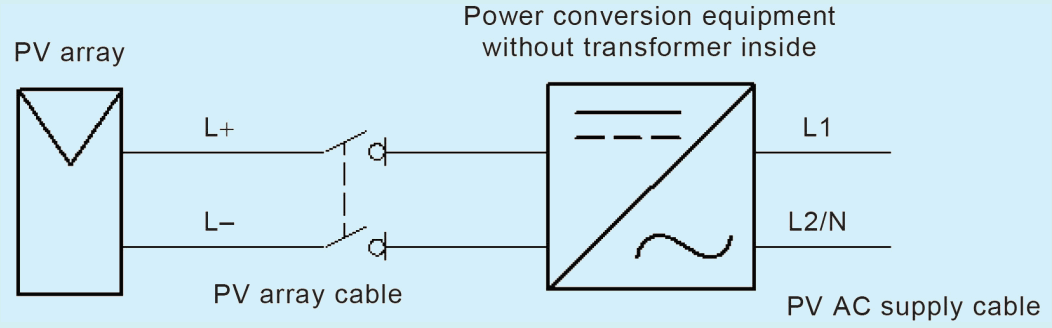


FIG. 6 UNEARTHED PV ARRAY CONNECTED TO THE AC SIDE VIA A PCE WITHOUT A TRANSFORMER

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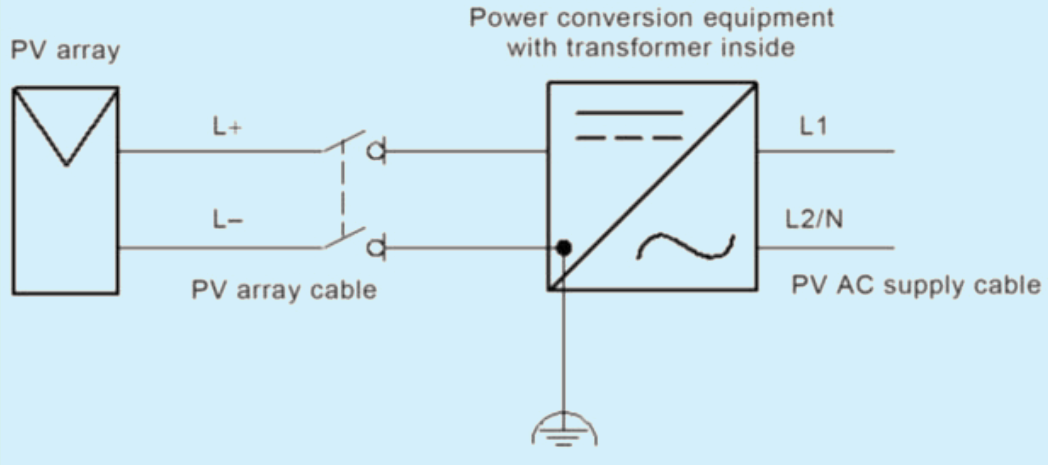


FIG. 7 EARTHED PV ARRAY CONNECTED TO THE AC SIDE VIA A PCE WITH TRANSFORMER

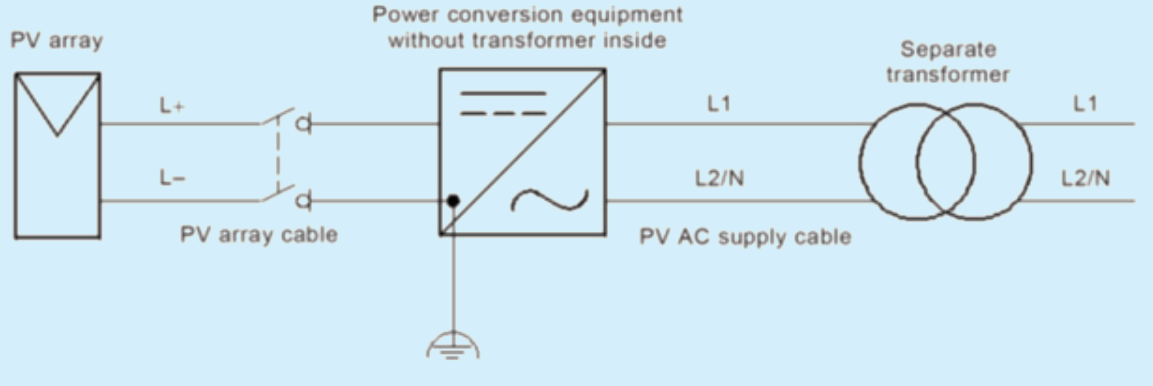


FIG. 8 EARTHED PV ARRAY CONNECTED TO THE AC SIDE VIA A PCE WITHOUT A TRANSFORMER, THE TRANSFORMER BEING SEPARATE



Fig. 9 (A)

To identify an earth terminal in cases where neither clean or protective earth is explicitly stated.



Fig. 9 (B)

To identify a noiseless (clean) earth terminal, e.g. of a specially designed earthing system to avoid causing malfunction of the equipment.



Fig. 9 (C)

To identify any terminal which is intended for connection to an external conductor for protection against electrical shock in case of a fault, or the terminal of a protective earth electrode.



Fig. 9 (D)

To identify a frame or chassis terminal

FIG. 9 (A,B,C,D): EARTHING SYMBOLS BASED ON APPLICATION

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7.1.1 *Functional (Active) d.c. Earthing*

Earthing of one of the live conductors of the d.c. side is permitted if there is at least simple separation between the a.c. side and the d.c. side.

Some PV module types require functional earthing of one of the current carrying poles of the PV array for proper operation. Thin film modules typically need to be negatively earthed, to prevent 'bar-graph' corrosion inside the module. Back-contact modules need to be positively earthed to achieve their rated efficiency.

Functional PV module earth is useful to bleed charge away from the PV cells and mitigate PID of cells. Negative pole of crystalline silicon PV module/string/array is typically connected to earth for PID mitigation. It is recommended to connect pole to earth with a series resistor of highest value permissible by manufacturer.

The functional earth connection shall be made at a single point and connected to the d.c. earthing terminal. The functional earth connection point of systems without batteries shall be between PV array and PCE, preferably closer to PCE or inside PCE. In systems with batteries, this connection point shall be between the charge controller and the battery protection device.

The minimum current carrying capacity of the functional earth conductor shall be greater than the functional earth fault interrupter (GFDI) nominal current rating for system with direct earth connection without a resistor, and shall be greater than (PV array maximum voltage)/R, where R is the resistance value used in series with the functional earth connection for the system.

7.1.2 *Equipotential Bonding/Protective d.c. Side Earthing*

Supplementary equipotential bonding between the exposed conductive non-current carrying parts of PV array (for exaple, PV module frame, MMS) and application circuit (for example, SCB/AJB chassis, Charge controller, Battery pack frame) is essential in protecting personnel from electric shock and electrical equipment against lightning over voltages.

PV array equipotential bonding conductors shall be run as close to the positive and negative PV array and or sub-array conductors as possible to reduce induced voltages due to lightning.

Equipotential bonding on all PV module frames and MMS is recommended for PV array connected to non-isolated inverter to prevent voltage induced on module frames due to high frequency induction caused by high frequency switching in non-isolated inverter. Continuous protective earthing of PV module frames is recommended using star washers (to ensure good electrical contact with aluminum frame) and 6 sq mm copper conductor cables rated for outdoor use (IS 7098).

Main equipotential bonding/protective earthing of exposed conductive non-current carrying parts of PV array shall be performed in accordance with 7.4.2 and Fig. 10 of IS/IEC 62548. Recommended minimum size of PV array protective earth copper conductor is 16 mm^2 in the event lightning protection is required and it is 6 mm^2 in the event lightning protection is not required.

Protective d.c. side earthing allows fault current path and facilitates detection of d.c. leakage current.

7.2 a.c. Side Earthing

7.2.1 *Neutral Earthing*

Compatibility of PCE/inverter with grid configuration shall be checked. Neutral earthing shall be provided at distribution transformer secondary. Neutral earthing shall not be provided at PCE/inverter, IIP or GIP.

7.2.2 *Protective a.c. Side Earthing*

Protective earthing (PE) shall be provided for PCE/inverter circuits and chassis. Second PE conductor is recommended for redundancy (One PE conductor connected to PCE/inverter circuit PE termination, second conductor connected to chassis and chassis internally connected to PCE/inverter circuit PE termination). The minimum size of earthing conductor shall be equal to the size of power conductor cable.

Protective a.c. side earthing allows fault current path and facilitates detection of a.c. leakage current to earth.

8 ELECTRICAL SAFETY PROTECTION

PV equipment on the d.c. side shall be considered to be energized, even when the system is disconnected from the a.c. side. The selection and installation of equipment shall facilitate safe maintenance and shall not adversely affect provisions made by the manufacturer of the PV equipment to enable maintenance or service work to be carried out safely.

NOTE — 6 of IS/IEC 62548 can also be referred for safety requirement.

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8.1 Protection Against Electric Shock

For protection against electric shock, refer PV module safety classification in **4.1**.

The protective measures using obstacles and placing out of reach, non-conducting location, earth-free local equipotential bonding, electrical separation for the supply of more than one item of current-using equipment shall not be used

On the d.c. side, one of the following protective measures shall be used:

a) Double or reinforced insulation: The d.c. side equipment (for example, PV modules, SCB, AJB) shall be Class II or equivalent insulation. according to IEC 61140.

b) SELV or PELV: For the use of SELV and PELV protective measures on the d.c. side, VOC_ARRAY shall not exceed 60 V d.c.

PV module and MMS exposed metal earthing and bonding shall be according to 7.4.2 of IS/IEC 62548.

PV modules are energized while exposed to light. Installation, replacement, or servicing of PV array components while modules are energized may expose personnel to electric shock. Open circuiting or opaque covering is recommended to be used to electrically disable PV module/sub-array/array for installation or service. It is recommended to carry out installation or service of PV array during dawn/dusk hours when PV modules are not energized to full power.

Refer electrical and general safety protections outlined in Part 1/Section 9 and Part 1/Section 22 of this NEC respectively.

8.2 Protection by Disconnection of d.c. Supply

Disconnecting means shall be provided in PV arrays according to 7.4.1.3 and Table 6 of IS/IEC 62548 to isolate the PV array from the PCE and to allow for maintenance and inspection tasks to be carried out safely.

Sheathed (touch safe) plug and socket connector, withdrawable fuse, or isolator switch are examples of suitable disconnection devices. Suitably rated circuit-breakers used for overcurrent protection may also provide load breaking disconnecting facilities. Other disconnection and isolation devices having the characteristics as per 7.3.4 of IS/IEC 62548 shall be used as load breaking disconnection means. Fuse systems used for overcurrent protection are acceptable non-load breaking disconnecting means if they have removable fusing elements with finger safe fuse holders, preferably with a disconnection mechanism (fused disconnector).

Disconnection devices shall be installed in all live conductors where a live conductor is one that is not directly connected to Earth. Where load breaking (switch-disconnector) is a requirement, this capability shall be on all poles of the device and all poles shall be ganged. In the case of PV arrays with a direct earth connection for functional reasons, requirements for earth fault interrupters (GFDI) shall be as per 6.3 and 6.4 IS/IEC 62548.

Disconnectors/Isolators shall be installed in circuits connected to equipment at a location within the equipment (for example, string circuits connected to SCB), or within close proximity of the equipment.

8.2.1 *Voltage Rating of Disconnectors*

Voltage rating of disconnectors depends on consequence of first earth fault governed by array configuration and inverter type used as given in Table 2.

Table 2 Minimum Voltage Rating of Disconnector Based on Different Configurations

(*Clause* 8.2.1)

Array Configuration (Functional-Active Earthing)	Inverter Type	Consequence of First Earth Fault	Min. Voltage Rating of Each Pole of Disconnector/Isolator
Not earthed	Isolated	No current flow through earth fault-both poles effective	0.5 × PV Array max. voltage
Earthed	Isolated	Current flow through earth fault-one pole bypassed	PV Array max. voltage
Not earthed	Non-isolated	Current flow through earth fault-one pole bypassed	PV Array max. voltage
Earthed	Non-isolated	NOT Permitted	

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Non-isolated (transformer-less) inverter output neutral is connected to earth and earthing of arrays is not permitted when used with non-isolated inverters due to potential risk of the inverter introducing d.c. current into the a.c. electricity grid.

8.2.2 *PV String Disconnector*

A disconnection device having rating equal to or greater than CCC of string cable is recommended. Module or string cable MC4 plug and socket connector and/or String fuse is acceptable only as non-load breaking disconnecting means and String d.c. input to PCE shall be open circuit prior to disconnection.

8.2.3 *PV Sub-array Disconnector*

A disconnection device shall be used for PV Sub-array rated for any voltage. Its rating shall be same as the associated overcurrent protection device. In absence of overcurrent protection device, the rating of the disconnection device shall be equal to or greater than the min. required CCC of the circuit. Readily available load breaking switch disconnector is recommended for PV Array rated for DVC-B and C (PV Sub-array Voltage > = 60Vd.c.)

8.2.4 *PV Array Disconnector*

A load breaking switch disconnection device shall be used for PV array (on d.c. side of the PCE/inverter) rated for any voltage. Its rating shall be same as the associated overcurrent protection device. In absence of overcurrent protection device, the rating of the switch disconnector shall be equal to or greater than the min. required CCC of the circuit.

8.2.5 *Switch Disconnector for PCE*

The switch disconnector shall be located externally or connected to PCE to facilitate PV string/array disconnection. Additional switch disconnector may be located inside PCE in order to facilitate repair or replacement of PCE as per 7.4.1.2 of IS/IEC 62548. The rating of the disconnection device shall be equal to or greater than the min. required CCC of the circuit.

8.3 Protection by Disconnection of a.c. Supply

On the a.c. side, the PCE/inverter supply cable shall be connected to the supply side of the protective device for automatic disconnection of PCE/Inverter a.c. circuits.

A main switch lockable in off position is required to be installed in the switchboard, which is located at a height above the ground level determined by IEC 61439. This allows the PV system to be disconnected from the mains power supply. This mains switch may not be rated for load break nor may have feature of overcurrent protection.

Where an electrical installation includes a PV power supply system without at least simple separation between the a.c. side and the d.c. side, a Residual Current Device (RCD) installed to provide earth fault protection by automatic disconnection of a.c. supply shall be Type B according to Indian Standards.

8.4 Protection against Overcurrent on d.c. Side

Overcurrent protection devices shall not be required for circuits with adequate CCC for the highest available current (for example, PV module, PV string). The circuits connected to sources having higher current availability (for example, Parallel strings of modules) shall be protected at the higher current source connection.

Following are the considerations in overload protection based on PV Array characteristics:

a) Overcurrent within a PV array can result from earth faults in array wiring or from fault currents due to short circuits in modules, in junction boxes, combiner boxes or in module wiring.

b) The overcurrent can be caused by the sum of currents from multiple parallel adjacent strings and/or external sources (for example, batteries).

c) Earth fault detection and PV array output disable could be required as part of the system protection functions, depending on the array size and location, to eliminate the risk of fire.

d) Electric arcs can be formed due to inadvertent wire disconnections in a PV array with fault currents that would not operate an overcurrent device.

e) The location of overcurrent protection devices and/or load breaking disconnecting means shall be at the end of the cable that is electrically most remote from the PV modules. The reason for this location is that fault currents in parts of an array originate from parts of the other sub-arrays and fault currents in parts of a sub-array originate from parts of the other strings.

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f) In systems that include a functional earth, overcurrent protective devices required for string and sub-array cables shall be placed in all unearthed conductors (that is, all circuits not directly connected to the functional earth).

g) In systems not connected to a functional earth the overcurrent protective devices required for string and sub-array cables shall be placed in one of the active conductors.

h) This provision of a single overcurrent device is allowed for floating PV systems because of the requirement for detection and alarm on a single earth fault and because of the double insulation required on conductors in all array circuits.

j) A single overcurrent protection device shall be permitted to protect both PV source and output circuits, all overcurrent protection devices shall be placed in the same polarity for all circuits within the PV system.

k) An overcurrent protection device shall be accessible within the PV system for ease of replacement.

m) Where PCE/Inverter is capable of providing back feed current into the array under fault conditions, its value shall be taken into account in all calculations of PV circuit current ratings.

Overcurrent protection devices required for the protection of PV strings, sub-array and arrays shall be selected to operate within 2 h when an overcurrent of 135 percent of the nominal device current rating is applied as per 6.5 of IS/IEC 62548.

8.4.1 *PV Module Overcurrent Protection*

Overcurrent protection device is not required for single module or a single string of modules connected to PCE. The CCC of module or string cable shall be greater than $1.25 \times I_{SC_MOD}$.

8.4.2 *PV String Overcurrent Protection*

If $(n-1) \times I_{SC_MOD} > I_{MOD_MAX_OCPR}$, where n is the number of strings connected in parallel, string over current protection is required. The trip current rating of the d.c. fuse shall be between 1.5 times and 2.4 times I_{SC_MOD} as per **6.5.3** of IS/IEC 62548.

8.4.3 *PV Sub-array Overcurrent Protection*

If the number of sub-arrays is 2, over current protection is required only if $1.25 \times I_{SC_ARRAY}$ is greater than sub-array cable and/or sub-array isolator CCC.

If the number of sub-arrays is more than 2, over current protection is required for each sub-array. The trip current rating of the d.c. fuse shall be between 1.25 times and 2.4 times $I_{SC_S\text{-}ARRAY}$ as per 6.5.5.2 of IS/IEC 62548.

8.4.4 *PV Array Overcurrent Protection*

PV array overcurrent protection is only required for systems connected to batteries or where other sources of current may feed into the PV array under fault conditions. The trip current rating of the d.c. fuse shall be between 1.25 times and 2.4 times I_{SC_ARRAY} as per 6.5.5.3 of IS/IEC 62548.

For PV string, sub-array and array overcurrent protection, use of d.c. Fuses in both positive and negative conductors is the recommended best practice. Alternatively, single fuse (in either positive or negative conductor) in combination with adequate earth fault protection may be used.

8.4.5 *PV Array Cable Protection*

The continuous CCC of the PV array cable shall be greater than or equal to the maximum short-circuit current of the PV array.

8.5 Protection against Battery Overcurrent in Standalone Systems

The location of fault current protection related to battery in standalone systems shall be as close as practical to the battery. This protection shall be used to provide overcurrent protection for PV array cables and/or charge controller output cables provided CCC of these cables are greater than 1.25 times trip current rating of battery overcurrent protection device. No further PV array overcurrent protection between the PV array and the charge controller is required.

Battery overcurrent protection shall be placed in both positive and negative conductors provided they are not connected to earth.

All string, sub-array and array overcurrent protection used shall be capable of interrupting the maximum prospective fault current from the battery.

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8.6 Protection against Overcurrent/Short-circuit Current on a.c. Side

The circuits connected to current limited supplies (for example, DC-DC converters, grid-tied inverter output circuits) and also connected to sources having higher current availability (for example, utility power, DG) shall be protected at the higher current source connection.

8.6.1 *Protection of PV a.c. Supply Cable*

The rated current for the overload protective device of the a.c. supply cable shall take into account the maximum a.c. current given by the PCE manufacturer or 1.1 times its rated a.c. current.

The PV a.c. supply cable shall be protected against short circuit by an overcurrent protective device installed at the PCC.

8.6.2 *Transformer Overcurrent Protection*

A power transformer current rating on the side connected to grid-tied inverter output shall be greater than the rated continuous output current of the inverter, this side shall be permitted without overcurrent protection. Suitable overcurrent protection shall be provided for the power transformer side connected to utility grid.

8.7 Overvoltage/Surge voltage Protection

Overvoltage/surge voltage may be caused by the distribution network as a result of switching surges and/or lightning strikes (nearby or on buildings and PV installations, or on Lightning protection system).

The design and methodology for overvoltage protection of electrical and electronic equipment in a lightning environment shall be as per IS/IEC 62305-4. Protection against lightning (10/350 µsec) and switching surges (8/20 µsec) both are required for d.c. side, a.c. side and signal lines in a solar PV installation. *See* **8.7**, Table 3 and Fig. 3.

The SPDs are selected from Table 3 depending on the test class and minimum cross-section of the equipotential bonding as per Fig. 3.

Table 3 SPD Selection Based on Application (Location I, II, III and IV, Refer Fig. 3)

(*Clause* 8.7)

	Situation	Equipotential Bonding	SPD location at "I"	SPD location "II"	SPD location at "III" and "IV"
(1)	(2)	(3)	(4)	(5)	(6)
A	Installation of spd in a structure with out of external LPS (Fig. 3)	6 mm^2	Class tested II SPD (type 2)	Class tested II SPDs (type 2)	Class tested II SPDs (type 2)
B	Installation of SPD_s in an external lighting protection system (LPS) where separation distance "s" is maintained (Fig. 3)	6 mm^2	Class tested II SPDs (type 2)	Class tested II SPDs (type 2)	Class tested II SPDs (type 2)
C	Installation of SPD_s in an external lighting protection system (LPS) where separation distance "s" is not maintained (Fig. 3)	16 mm^2	Class tested II SPDs (type 2)	Class tested II SPDs (type 2)	Class tested I SPDs (type 2)

NOTE — Class I and II SPDs Specified in IEC 61643-11 & Class III and IV SPDAs Specified In IEC 61643-31 SPD at location IV if necessary.

8.7.1 *d.c. side Overvoltage Protection*

PV Array d.c. cables over 50 m length shall be protected from induced voltages due to mains a.c. line faults and/or lightning strikes. The cables shall be armored or installed in metallic conduits and/or underground or protected by SPD. SPD protection is commonly used.

d.c. SPDs shall be fitted between active conductors and between active conductors and earth at the PCE/Inverter end of the d.c. cabling and additionally at the array (SCB/AJB) if the length of d.c. cables from SCB/AJB to PCE/Inverter is > 10 m. To protect specific equipment, SPDs shall be fitted as close as practical to the device.

d.c. SPDs shall be used to protect both positive and negative conductors of PV string/sub-array/array as per IEC 61643-31. d.c. SPDs shall be rated at continuous operating voltage of min. 125 percent of the open-circuit voltage of the PV string/sub-array/array (typ. 1 000 Vd.c.).

The total length of the parallel connection wires of the d.c. SPDs shall be lower than 50 cm.

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8.7.2 *a.c. Side Overvoltage Protection*

a.c. SPDs shall be installed at the incoming mains ACDB. If distance between PCE/Inverter output and PCC at mains ACDB is greater than 10m, additional SPD is required at PCE/Inverter output. Both common and differential mode SPD protection is recommended.

a.c. SPDs shall be tested according Class I test specified in IS 16463 (Part 11) if the installation is equipped with LPS. a.c. SPDs shall be tested according Class II test specified in IS 16463 (Part 11) if the installation is not equipped with LPS.

The total length of the parallel connection wires of the a.c. SPD shall be lower than 50 cm.

8.7.3 *Overvoltage Protection of Data/Signal Lines*

Monitoring and communication data/signal lines shall be protected against overvoltage with data/signal line SPDs as per IEC 61643-21 and IEC 61643-22.

To minimize voltages induced by lightning, the area of all d.c. and a.c. wiring loops shall be as small as possible.

8.8 Earth Fault Protection

8.8.1 *d.c. Earth Fault Protection*

Requirements for detection of earth faults, actions required and alarms depend on the type of system earthing and whether the PCE provides isolation of the PV array from the output circuit (e.g. utility grid). PV Array Insulation to earth and Residual Current monitoring and fault actions and/or alarm requirements based on PCE isolation and PV array functional earthing shall be as per Table 1 and 6.4.1 of IS/IEC 62548.

Minimum insulation resistance thresholds for detection of failure of PV Array Insulation to earth based on system size in kW shall be as per Table 2 and 6.4.2.2 of IS/IEC 62548. For example, insulation resistance limit of 1 kΩ is specified for system size >= 500kW.

If the inverter a.c. output connects to a circuit that is isolated from earth, and the PV array is not functionally earthed, residual current monitoring is not required.

The residual current monitoring means shall measure the total of d.c. and RMS a.c. components of the residual current.

Where continuous residual current is above the limits, disconnection by a switching device shall operate within 0.3 s and indicate a fault if the continuous residual current exceeds:

a) Maximum 300 mA for PCEs with continuous output power rating ≤ 30 kVA' and
b) 10 mA per kVA of rated continuous output power or 5A, whichever is less, for PCEs with continuous output power rating >30 kVA.

Additionally, it is required to monitor excessive sudden changes in residual current. The response time limits for sudden changes in residual currents shall be as per Table 4 of IS/IEC 62548-6.

When activated, the alarm system shall continue its operation until the system is shut down and/or the earth fault is corrected.

PV arrays that have one conductor directly connected to a functional earth (that is, not *via* a resistance) shall be provided with a functional earth a residual current monitoring system. Residual current monitoring system shall automatically disconnect d.c. current carrying conductors of the faulted circuit from PCE/Inverter and also isolate from functional earth connection. The functional earth fault interrupter shall not interrupt the connection of exposed metal parts to earth. The nominal overcurrent rating of functional earth fault interrupter based on PV Array power rating in kWp shall be as per Table 3 and 6.4.2.4 of IS/IEC 62548. For example, functional earth fault interrupter overcurrent rating of <= 5A is specified for PV Array power rating of > 250 kWp.

8.8.2 *a.c. Earth Fault Protection*

All inverters shall incorporate local a.c. earth fault indication and also a means of signaling a.c. earth fault externally as per IS 16221 (Part 2).

IIP/GIP and a.c. distribution panels shall incorporate RCD protection in compliance with IEC 60755.

RCD used for protection of PV a.c. supply circuit shall be of type B or equivalent internal circuits in compliance with IEC 62423.

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8.9 Protection Against Electromagnetic Interference (EMI)

PCE/Inverters shall be tested for EMI/EMC as specified by IS 14700 (Part 1, Part 3, Part 4, and Part 6).

Refer 5.9.2 for permissible limits of a.c. voltage flicker induced by PCE/Inverters.

8.10 Lightning Protection System (LPS)

The provisions of IS/IEC 62305 (Part 1, Part 2, Part 3 and Part 4) shall apply. General principles of LPS shall comply with IS/IEC 62305-1.

If the physical characteristics of the building change significantly due to the installation of the PV array, it is recommended that the need for a lightning protection system be assessed in accordance with IS/IEC 62305-2 and, if required, it shall be installed in compliance with IS/IEC 62305-3. If LPS is already installed on the building, the PV system shall be integrated into the LPS as appropriate in accordance with IS/IEC 62305-3. The lightning protection of electrical and electronic equipment installed in PV system shall comply with IS/IEC 62305-4. Air termination not confirming as per protection angle/mesh/rolling sphere methods in IS/IEC 62305-3 shall be disregarded.

Large PV systems shall have a dedicated lightning protection system designed according to IS/IEC 62305. The existing lightning protection of a building shall be used, provided it adequately protects the PV installation and is assured of functioning throughout the life of the PV system.

LPS shall be tested according to IEC 62561-1 for minimum LPL III.In all instances where LPS is required or no LPS is required for PV array installed on a building rooftop or in case of a free-standing array, overvoltage protection shall be required to protect the array and the inverter and all parts of the installation.

8.11 Arc Fault Protection

There are three main categories of arcs in PV installations:

a) Series arc resulting from faulty connection or series break in d.c. wiring;

b) Parallel arc resulting from short circuit between adjacent d.c. wiring at different potentials; and

c) Arc to earth resulting from failure of insulation.

In order to prevent arcing, every device without on-load breaking capacity (for example, MC4 connectors, d.c. fuse holders, SPD holders etc.) that could be used to open a d.c. circuit shall be secured against inadvertent or unauthorized operation.

Arc fault protection is recommended to protect d.c. side of PV system from failure in connectivity of any component in d.c. PV circuit, circuit conductor or interconnection. d.c. arcing generated in absence of arc fault protection poses potential risk of a fire incidence.

Arc fault protection is recommended in PV systems in buildings operating at system voltage between any two conductors on d.c. side > 100 V d.c. The purpose of arc fault protection equipment is to accurately detect and discriminate arcs in PV arrays and interrupt the arcs.

8.12 Rapid Shutdown Protection

d.c. PV circuits are live with d.c. voltages up to 1 000 Vd.c. (open circuit voltage) even when disconnected from PCE/inverter and are significant electric shock hazards in an emergency situation.

Rapid shutdown protection that disconnects PV array outputs recommended for PV arrays installed on rooftops to reduce electric shock hazards for fire fighters and other emergency workers.

9 ISOLATION, SWITCHING AND CONTROL

Electrical safety protection shall be provided by disconnection of d.c. supply and by disconnection of a.c. supply.

To allow maintenance of the PV inverter, means of isolating the PV inverter from d.c. and a.c. sides shall be provided.

9.1 Devices for Isolation and Switching

a) The devices for isolation and switching shall be installed between Grid interactive PV installation and the utility supply. The utility supply shall be considered the source and the PV installation shall be considered the load.

b) A switch disconnector shall be provided on the d.c. side of the PV inverter.

c) All junction boxes (SCB, AJB) shall carry a warning label indicating that active parts inside the boxes are electrically live after isolation from the PV inverter.

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d) The devices for isolation and switching shall be installed between standalone/hybrid PV inverter and storage devices.

e) The devices for isolation and switching shall be installed between standalone PV installation and the electrical load.

f) The devices for isolation and switching shall be installed between hybrid PV installation and the utility supply, and between hybrid PV installation and the electrical load.

9.2 Anti-islanding Protection

Anti-islanding protection is designed for safety of workers on grid network in the event of grid failure. All grid-connected and hybrid PV inverters tied to grid shall be designed to shut- down their outputs when the grid supply is off or when its parameters like voltage and/or frequency change beyond the predefined limits.

All PV systems connected to distribution grid below 33kV shall comply with Central Electricity Authority (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations. The deenergize (trip) and energize (reconnect) times in response to grid frequency or voltage variation for disconnection and reconnection of the distributed generators resp. shall comply with Central Electricity Authority (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations.

All PV systems connected to distribution grid above 33 kV shall comply with relevant regulation/Standard for connectivity to grid.

All grid-tied PCE/Inverters shall comply with IS 16169.

9.3 Monitoring, Control and Communication Equipment

All monitoring, control and communication equipment shall be powered by suitable UPS for uninterrupted operation.

All monitoring, control and communication equipment chassis shall be connected to protective earth. All analog sensors (for example, temperature, radiation etc.) shall be connected to monitoring equipment with shielded flexible cables, shield connected to earth. All data lines shall be connected using suitable shielded flexible cables, shield connected to earth. All data/signal line inputs shall be protected against overvoltage using suitable SPD.

10 GENERAL SAFETY REQUIREMENTS

All PV systems shall comply with Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2010.

10.1 Personnel Safety

Following best practices are recommended:

a) Safe and secure access plan for rooftop or ground mounted PV arrays;

b) Emergency exit plan for rooftop and ground mounted solar PV power plants;

c) Protection against human tripping hazards due to cables, structures etc.;

d) Use of PPE including safety shoes, helmet, face shield and gloves during installation;

e) Use of safety belts, wire harness, protective fence etc. during rooftop installation;

f) Provision of first aid kits and fire extinguishers on rooftop and ground installations;

g) Use of insulating gloves/tools/mats for protection against electrical hazards;

h) Provision of electrical shock treatment (CPR); and

j) HVDC, LTAC, and HVAC safety protection charts on rooftop and in a.c. power distribution areas.

10.2 Fire Safety

The provisions of IS 3034 and CEA Electricity Supply Regulations 2010 shall apply.

The arc fault protection (*see* **8.11**) is recommended to prevent fires and rapid shutdown protection (*see* **8.12**) is recommended for safety of fire fighters.

Provision for interrupting a functional earth on the PV array (not the protective earth) is recommended to increase safety for fire and emergency workers. In these instances, the main PV array switch-disconnector may include an extra pole which disconnects the functional earth of the PV array.

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Periodic (min. once in 2 years) Fire safety verification is recommended in buildings where rooftop PV plants are installed. Similar audits are also recommended for ground mounted PV power plants.

Min. spacing of 1m is recommended along the periphery of Rooftop PV plant installation for potential access to fire fighters.

Use of flame retardant clothing is recommended for protection against fire hazards.

Use of Fire survival cable as per IS 17505 (Part 1) is recommended wherever appropriate.

11 PERFORMANCE MONITORING

Refer IS/IEC 61724 series for monitoring of energy-related PV system parameters such as in-plane irradiance, array output, storage input and output and power conditioner input and output; and for the exchange and analysis of monitored data. The overall performance of PV systems is assessed based on procedure outlined in IS/IEC 61724 series.

Refer relevant requirements of IS/IEC 61724 series for parameters to be measured in real time for meteorology, PV array, energy storage, load, grid and back-up sources.

11.1 Data Monitoring

Irradiance data is recorded in the plane of the array (POA) for use in the performance analysis of the PV system. The accuracy of irradiance sensors, including signal conditioning, shall be better than 5 percent of the reading. The radiation sensor window shall be checked periodically for cleanliness. Refer IS/IEC 61724-Series for method and accuracy of monitoring ambient temp, module temp, wind speed and d.c./a.c. voltage, current and power. The sensor calibration shall be checked periodically to maintain required accuracy. The total accuracy of the monitoring system shall be determined by a calibration method such as given in IS/IEC 61724 series.

The sampling interval for parameters which vary directly with irradiance shall be 1 min or less.

All parameters shall be continuously measured during the specified monitoring period.

11.2 Data Recording

The sampled data from each measured parameter shall be processed into time-weighted averages.

The processed data values for each parameter shall be recorded hourly or recording interval shall be sub-multiple of 1 h.

Data format based on separate header record and data records is recommended.

Refer IS/IEC 61724 (Series) for data quality checks.

11.3 Derived Parameters

Various derived parameters related to the system's energy balance and performance may be calculated from the recorded data using sums, averages, maxima, minima, and ratios over reporting periods which are longer than the recording interval (such as, hours, days, weeks, months or years, but expressed in units of hours). Refer IS/IEC 61724 series for POA global irradiation, d.c. and a.c. electrical energy parameters, BOS efficiency and system performance parameters.

11.4 System Performance Indices

PV systems of different configurations and at different locations can be readily compared by evaluating their normalized system performance indices, such as yields, losses and efficiencies. Yields are energy quantities normalized to rated array power. System efficiencies are normalized to array area. Losses are the differences between yields.

Daily array specific yield (kWh a.c./kWp) is the ratio of daily array a.c. yield to installed PV capacity.

The reference yield is the ratio of daily total POA irradiance (kWh/m^2) divided by reference irradiance (1kWh/m^2). The reference yield is effectively Peak Sun Hours (PSH) per day. It is recommended to clean POA radiation sensor on daily basis for accurate monitoring of daily total POA irradiance.

Array capture losses are computed by subtracting array specific yield from reference yield.

The Performance Ratio (PR) or PV system efficiency indicates the overall effect of losses on the array's rated output due to array temperature, array mismatch, incomplete utilization of the irradiation, module soiling, d.c. and a.c. cable losses, MPPT, inverter and transformer efficiencies. PR is computed by dividing PV system specific yield by reference yield. For a grid tied system without energy storage, PR is computed by dividing array specific

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yield by reference yield and PV system losses are computed by subtracting array specific yield from reference yield.

PV module degradation reduces array specific yield and PR. Loss due to PV module degradation shall be computed for PR evaluation on year to year basis. As an example, for fifth year PR evaluation, PV module degradation loss shall be sum of degradation in first year and four times yearly degradation factor.

PV system operational efficiency is determined by overall PV system losses. Array specific yield is affected by plant and grid non-availability in a grid tied solar PV plant. Overall PV system losses include losses due to non-availability of plant and grid. Losses due to non-availability of plant and grid may be subtracted from total PV system losses for evaluation of PV system functional efficiency.

d.c. and a.c. side PR may be computed separately for evaluation of d.c. and a.c. side system components. d.c. PR is the ratio of array d.c. specific yield (kWh d.c./kWp) and reference yield. a.c. PR is the ratio of array a.c. specific yield and array d.c. specific yield.

Evaluation of PR and PV system losses is recommended on monthly and yearly basis.

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ANNEX A

(*Clause* 2)

IS No./Other Publications	*Title*
732 : 2019	Code of practice of electrical wiring installation
61997 : 2018	Requirements for low-voltage special electrical installations or locations — Solar photovoltaic (PV) power supply systems
3034 : 1993	Code of practice for fire safety of industrial buildings
14286 : 2010/ IEC 61215 : 2005	Crystalline silicon terrestrial PV module design qualification and type approval
16077 : 2013/ IEC 61646 : 2008	Thin film (a-Si, CiGS and CdTe) terrestrial PV module design qualification and type approval
16228 : 2019/ IEC 62108 : 2016	Concentrator photovoltaic (CPV) modules and assemblies design qualification and type approval
IS/IEC 61730-1 : 2016	PV modules safety qualification: Part 1 Requirements for construction
IS/IEC 61730 (Part 2) : 2019	PV modules safety qualification: Part 2 Requirements for testing
IS/IEC 61701 : 2011	PV modules salt mist corrosion testing
16170 (Part 1) : 2014/ IEC 61853-1 : 2011	PV module performance testing and energy rating: Part 1 Irradiance and temperature performance measurements and power rating
17210 (Part 1) : 2019/ IEC 62804-1 :2015	PV modules Test methods for the detection of potential-induced degradation (PID): Part 1 Crystalline silicon PV modules
16664 : 2018/ IEC 62716 : 2013	PV module ammonia (NH3) corrosion testing
IEC 62759-1 :2015	PV module package units transportation and shipping
16221 (Part 1) : 2016	Safety of power converters for use in photovoltaic power systems: Part 1 General requirements
16221 (Part 2) : 2015	Safety of power converters for use in photovoltaic power systems: Part 2 Particular requirements for inverters
IS/IEC 61683 : 1999	Photovoltaic system-power conditioners — Procedure for Measuring efficiency
IEC 62891 : 2020	Procedure for measuring overall efficiency (including static and dynamic MPPT efficiency) of grid connected PV inverter
16169 : 2019	Test procedure of islanding prevention measures for utility connected PV inverters
14700/ IEC 61000 (all Parts)	EMC/EMI testing of PV inverters Solar PV Charge Controller/MPPT Unit Standards
IEC 61000 (Part 2)	Electromagnetic compatibility (EMC) — Part 2: Environment
IEC 61000 (Part 3)	Electromagnetic compatibility (EMC) — Part 3: Limits
IEC 61000 (Part 5)	Electromagnetic compatibility (EMC) — Part 5: Installation and mitigation guidelines
16229 : 2015/ IEC 62093 : 2005	Balance-of-system components for photovoltaic systems — Design qualification natural environments
16270 : 2014	Secondary cells and batteries for solar PV application-general requirements and methods of test
17048 : 2018	Halogen free flame retardant cables for working voltages up to and including 1 100 V
694 : 2010	PVC insulated unsheathed and sheathed cables cords with rigid and flexible conductor for rated voltages up to and including 1 100 V

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IS No./Other Publications	*Title*
1554 (Part 1 and 2) : 1988	PVC insulated heavy duty electric cables: Part 1 For working voltages up to and including 1 100 V
1554 (Part 2) : 1988	PVC insulated heavy duty electric cables: Part 2 for working voltages from 3.3 kV up to and Including 11 kV
7098 (Part 1) : 1988	Cross linked polyethylene (XLPE) insulated PVC sheathed cables: Part 1 For working voltage up to and including 1 100 V
7098 (Part 2) : 2011	Cross linked polyethylene insulated thermoplastics sheathed cables: Part 2 For working voltages from 3.3 kV up to and including 33 kV
7098 (Part 3) : 1993	Cross linked polyethylene insulated thermoplastics sheathed cables: Part 3 For working voltages from 66 kV up to and including 220 kV
17293 : 2020	Electric cables for photovoltaic systems for rated voltage 1 500 V d.c.
17505 (Part 1) : 2021	Specification for thermosetting insulated fire survival cables for fixed installation having low emission of smoke and corrosive gases when affected by fire for working voltages upto and including 1 100 V a.c. and 1 500 V d.c.: Part 1 Requirements for armoured cables
3961 (Part 2)	Recommended current ratings for cables: Part 2 PVC insulated and pvc sheathed heavy duty cables (*first revision*)
3961 (Part 5)	Recommended current ratings for cables: Part 5 PVC insulated light duty cables
3961 (Part 6)	Recommended current ratings for cables: Part 6 Crosslinked polyethylene insulated PVC sheathed cables
3961 (Part 7)	Recommended current ratings for cables: Part 7 Crosslinked polyethylene insulated thermoplastic sheathed cables
IS/IEC 62271-1	High-voltage switchgear and controlgear: Part 1 Common specifications
IS/IEC 62271-100	High-voltage switchgear and controlgear: Part 100 Alternating — Current circuit — Breakers
IS/IEC 62271-102	High-voltage switchgear and controlgear: Part 102 Alternating current disconnectors and earthing switches
IS/IEC 62271-105	High-voltage switchgear and controlgear: Part 105 Alternating current switch — Fuse combinations for rated voltages above 1 kV up to and including 52 kV (*first revision*)
IS/IEC 62271-200	High-voltage switchgear and controlgear: Part 200 a.c. Metal-enclosed switchgear and controlgear for rated voltages above 1 kV up to and including 52 kV (*first revision*)
IS/IEC 62271-202	High-voltage switchgear and controlgear: Part 202 High-voltage/low — Voltage prefabricated substation
IS/IEC 60529 : 2001	Degrees of protection provided by enclosures (IP code)
IEC 60255-27 : 2013	Measuring relays and protection equipment — Product safety requirements
16781 : 2018/ IEC 62852 : 2014	Connectors for d.c. application in photovoltaic systems, safety requirements and tests
IS/IEC 60947-1	Low-voltage switchgear and control gear: Part 1 General rules
IS/IEC 60947-2	Low-voltage switchgear and control gear: Part 2 Circuit breakers first revision
IS/IEC 60947-3	Low-voltage switchgear and control gear: Part 3 Switches disconnectors switch-disconnectors and fuse-combination units (*first revision*)
IS/IEC 60898-1 : 2003	Electrical accessories — Circuit-breakers for overcurrent protection for household and similar installations: Part 1 Circuit-breakers for a.c. operation (*first revision*)
IS/IEC 60898-2 : 2003	Electrical accessories — Circuit-breakers for overcurrent protection for household and similar installations: Part 2 Circuit-breakers for a.c. and d.c. operation

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IS No./Other Publications	*Title*
IS/IEC 60269-6 : 2010	Low-voltage fuses: Part 6 Supplementary requirements for low voltage (up to 1 500 V d.c.) fuse-links for the protection of solar photovoltaic energy systems
16463 (Part 11)	Low-voltage surge protective devices: Part 11 Surge protective devices connected to low-voltage power systems — Requirements and test methods
16463 (Part 12)	Low-voltage surge protective devices: Part 12 Surge protective devices connected to low-voltage power distribution systems — Selection and application principles
IEC 61643-21	Low-voltage surge protective devices — Part 21: Surge protective devices connected to telecommunications and signalling networks — Performance requirements and testing methods
IEC 61643-22	Low-voltage surge protective devices — Part 22: Surge protective devices connected to telecommunications and signalling networks — Selection and application principles
IEC 61643-31 : 2018	Low-voltage surge protective devices — Part 31: Requirements and test methods for SPDs for photovoltaic installations
IEC 61643-32 : 2017	Low-voltage surge protective devices — Part 32: Surge protective devices connected to the d.c. side of photovoltaic installations — Selection and application principles
IEC 60755 : 2017	General requirements for residual current operated protective devices (RCD)
2026 (Part 1) : 2011	Power transformers: Part 1 General
2026 (Part 2) : 2010	Power transformers: Part 2 Temperature rise
2026 (Part 3) : 2018/ IEC 60076-3 : 2013	Power transformers: Part 3 Insulation levels, dielectric tests and external clearances in air
2026 (Part 5) : 2011	Power transformers: Part 5 Ability to withstand short-circuit
2026 (Part 10) : 2009/ IEC 60076-10 : 2001	Power transformers: Part 10 Determination of sound levels resp
16444 : 2015	Static direct connected smart watt-hour meter Class 1 and 2 specifications (with import and export/net energy measurements)
14153 : 1994	Guide for general description of PV power generating systems
IS/IEC 62548 : 2016	Photovoltaic PV arrays design requirements
16960 (Part 1) : 2018/ IEC 62446-1 : 2016	Grid connected photovoltaic systems — Minimum requirements for system documentation, commissioning tests and inspection
IS/IEC 61724 : 1998	PV systems performance monitoring; guidelines for measurement, data exchange and analysis (*all parts*)
16230 : 2017/ IEC 62124:2004	Standalone PV systems design qualification
IS/IEC 62305 (All parts)	Protection against lightning
IS/IEC 61439-2	Low voltage switch gear and control gear assemblies: Part 2 Power switch gear and control gear assemblies

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