



Bureau of Indian Standards
Ministry of Consumer Affairs, Food &
Public Distribution, Government of India.



In association with



**International Copper
Association India**
Copper Alliance

SAFETY IN ELECTRICAL INSTALLATIONS HANDBOOK

A way forward to safety by
National Electrical Code of India.



Published by:

Bureau of Indian Standards

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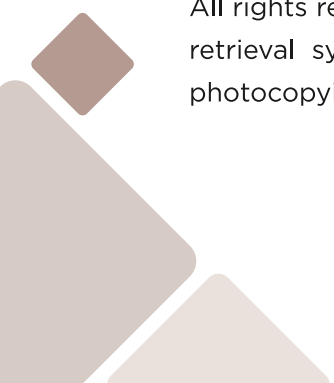
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FOREWORD

India is on the path of development and its infrastructure sector has grown progressively. Due to increase of population and rapid urbanization over last few decades, there has been significant increase in residential, commercial and other buildings in all major cities of the world. This has led to a significant rise in the installation of electrical wiring and electrical services in all types of buildings in urban, semi-urban and rural areas. Good quality electrical installation shall ensure prevention from accident such as electrocution, fire and shall offer trouble free long life for the connected equipment.

To ensure safety of persons and apparatus against electrical faults, it is necessary to follow the requirements for protection as mentioned by various Indian Standards. It is also the requirement of the time that our electrical engineers and technicians shall be familiar to correct practices.

Bureau of Indian Standards through its Electrotechnical Division Council (ETDC) is involved in the preparation of Indian Standards/ Codes in the field of electrical engineering. The Electrical Installations Sectional Committee, ETD 20 under ETDC is responsible for preparation of Indian Standards for safety and related matters in designing, erection and maintenance of electrical installations.

This handbook is based on the National Electrical Code of India and intends to provide technical guidance for wiring installations in buildings. The design, installation and other features given, are to understand the purpose and application in a simplistic way. This will help electrical engineers and technicians to understand the basic need and procedure of testing for safe and reliable electrical LV installations.

All electrical installations in India come under the purview of The Indian Electricity Act, 2003 and the rules and regulations framed, thereunder. Notwithstanding, the provisions given in this document, the provisions of Indian Electricity Act, 2003 and the rules and regulations framed have to be necessarily complied with.

It is not a comprehensive guide, for detailed information, National Electrical Code of India and IS 732:2019 may be referred.

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1. SCOPE

The scope covers guidelines for Wiring Installation in buildings. It is intended for use in design, material selection, installation, verification and testing of fixed wiring installations, up to 1 kV A.C which covers single phase 240V and three phase 415V installations.



2. Regulatory Requirements

The design, installation, verification and maintenance must comply with the Central Electricity Authority (Measures related to Safety and Electric Supply) Regulations, 2010, as amended. It shall be noted that, any contraventions with the provisions of Electricity Act 2003 and the Rules and Regulations, made, thereunder, may attract penal action as per section 146 and responsibilities as per section 149 and 150 of Electricity Act 2003.



2.1 Important Provisions from CEA Regulations:

Central Electricity Authority (Measures relating to safety and electric supply) Regulations 2010 were notified on 20th Sept 2010 by replacing the Indian Electricity Rules 1957.

In the current version as amended on 2018, there are total 116 Regulations divided in 10 Chapters, covering different aspects. In 2019 Chapter 11 was added to cover 'Safety Provisions for Electric Vehicle Charging Stations' with additional regulations from 117 to 123. Under the context of this document, following regulations are most important and call for special attention.



Regulation 12 (1)

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

In other words, this regulation is a synopsis of CEA Regulations targeting basic goal, to which other regulations correlate.



Regulation 29

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 recognised by the State Government.

This regulation gives mandate that except an authorized person, no other person, shall interfere with an electrical installation, for any kind of work, highlighting the risk involved.



3. Terminology

Ambient Temperature – Environmental temperature surrounding the installation

Busbar – Low impedance conductor to which several electric circuits can be separately connected

Bonding – Connected to establish electrical continuity and conductivity

Branch Circuit – The circuit conductor between final over current device protecting the circuit and outlets

Cable – Typically one or more insulated conductors enclosed with or without a common sheath or a metallic/nonmetallic protective insulating covering

Cable Bunch – Two or more cables installed without maintaining spacing

Cable Ducting System – A system of closed enclosures of non-circular sections for insulated conductors, cable and cords in electrical installations, allowing them to be drawn in and replaced.

Cable Tray System – A unit or assembly of units or sections and associated fittings forming a structural system used to securely fasten or support the cables/raceways.

Cable Trunking System – A system of closed enclosure 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.

Circuit – An assembly of electrical equipment in an electrical path through which electricity may flow with protection against over current.

Circuit Breaker – A device linked with all poles designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined over current without damaging itself when properly applied within its rating.

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.

Current Carrying Capacity – The maximum current, in amperes, that a conductor can safely carry, continuously under the conditions of use without exceeding temperature limit of the insulation

Derating – Calculations that reduce standard tabulated current carrying capacities for different conditions of use based on various factors.

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

Harmonics – A sinusoidal component of periodical wave having frequency that is an integral multiple of fundamental frequency.

Outlet – A point on the wiring system at which current is taken to supply an electrical equipment for utilisation.

Wire – A single core insulated solid or stranded conductor used to carry current.

Wiring System – Assembly made up of bare or insulated conductors or cables or bus bars and the parts which secure and if necessary, enclose the cables or bus bars.

5. Importance of Planning and Coordination



Architectural Planning for Electrical Work

Electric Supply and Installation is one of the prime building services. For wiring installation, there are some pre-requisites, which are needed to be considered at planning stage itself. As this service is integral part of any building, there are some requirements related to Architectural Plans and also Civil Construction. Following list contains such requirements. Architect and Electrical Consultant/Contractor shall discuss and mutually agree upon space requirements and type of construction from the point of view of electrical safety, fire and maintenance, post completion. Dependability of various electrical tasks with other activities under building services, shall also have place in project planning and bar-charts.

5.1 Points for Consideration in Architectural Plans/Civil Work



Earthing station/electrode

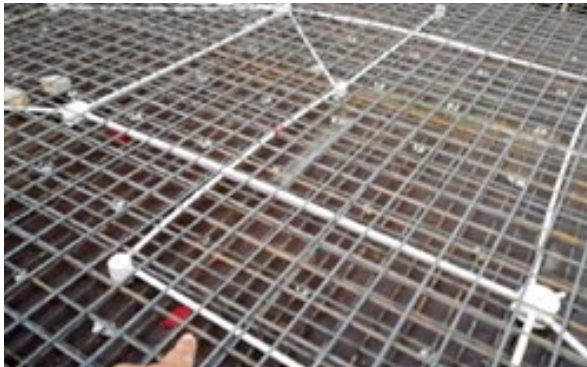


Interior design and Electrical Installation

- 
1. Routes and service entry points and segregation from other services.
 2. Cut-outs to avoid core cutting in RCC work.
 3. Shafts/Ducts/Trenches/Chambers for cables bus trunking.
 4. Location of Electrical Panels, for required clearances and accessibility.
 5. Electrical Meter Rooms.
 6. Detailed layout of electrical points considering illumination, ventilation (fans, exhaust fans), switch-boards, power outlets to suit location of appliances.
 7. Aesthetics/Interior Design without endangering Electrical Safety.
 8. Earthing System – location of earthing stations, their segregation and access.
 9. Fire rating of civil work items like doors, walls, in respect of electrical installation.
 10. Walls/partitions and their thickness to accommodate concealed parts of Electrical Installation.
 11. Strength/stability of civil structure to take static, dynamic load of heavy electrical equipment.
 12. Water related safeguards from possible seepages/leakages, dampness, splash (bathrooms/washrooms), etc.
 13. Heating, Ventilation and Air-conditioning (HVAC).
 14. Protection of electrical apparatus from ingress of polluted air, dust, solid objects.
 15. General clearances.

5.2 Coordination with Civil Works and other Utility Services

It is very important to maintain proper coordination with other works. This is for smooth, convenient and speedy progress of electrical work aligned with other project activities. It is also to avoid damages to the installed portion and the conflicts over accommodating different services at particular locations, e.g. areas above false ceiling, corridors/passages, service ducts, terrace, etc. Precisely timed bar-charts comprising all project activities and observing time schedule to get the work done in proper sequence will eliminate undesired situations in work progress.



Concealing of conduits before casting of RCC work

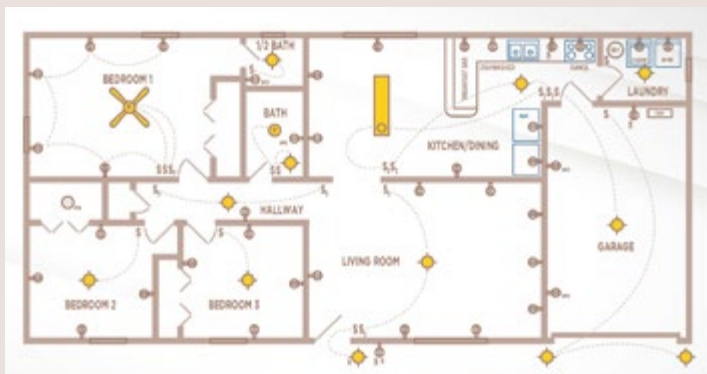


Consideration of load of cable tray system

6. Electrical Design

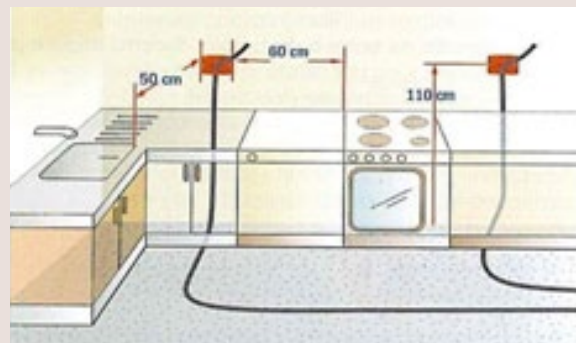
Precise electrical design is a base of electrical safety. It is an important tool to prevent/mitigate possible electrical hazards and save lives, prevent devastation of property caused by fires incidences initiated due to short-circuits/thermal mismanagement. The following points are important:

1. Assessment of electrical load based on use, type, pattern, daily and seasonal load cycle, continuous/fluctuating, diversity, with anticipation for future requirements, etc.
2. Bifurcation of load into general purpose, essential services, emergency services, critical services
3. Power source - main, emergency/standby with time lag, without time lag or uninterrupted and planned capacity under each category.
4. Preparation of electrical layouts considering use, functionality, installation, maintenance, etc., in coordination with other utility services, like LV system, with observation of safety norms, electromagnetic interferences (EMI), etc.



Preparation of Electrical Layout

5. Preparation of Single-Line-Diagram (SLD) for distribution network with details of, cables, switch gears, protections, and designed load.
6. Selecting wiring system
7. Preparing specifications for material to be used for electrical installation.
8. Allocating an appropriate location for electrical equipment and appliances



6.1 Wiring Systems – Types & Selection

Selection of wiring system is an important design aspect which is related to longevity of service life. It shall suite:

1. Type of use and users.
2. Situation of place, the base, on which the installation is to be carried out.
3. Factors of external influences* applicable to respective place.
4. Method of installation.

Important considerations further include type of conductor, insulation**, cores, enclosures/ support system, etc. From the point of view of thermal management, possible heat generation in the cable work and its dissipation, are the points of prime importance for assessing correct cross section of conductor.

***Note** – Reference can be taken from Annex ‘L’ of IS 732:2019 for factors of external Influences concerning wiring installations. Climatic condition of respective geographical region has a major role.

****Note** – Depending on geographical location wiring system shall be suitable for the limits prescribed for highest and lowest temperature. Maximum continuous operating temperature limit varies depending on type of insulation.

Note – Aesthetics is also a point of interest for the architect, interior designer and the user. But shall be considered ‘without compromising safety’.

6.2 Method of Installation – Situation

Method of installation in relation to the situation concerned; e.g., location where wiring is to be installed, the base on/under/within which the conductor/cable is to be installed, are classified as under:

1. Surface mounted.
2. Embedded in structure (Concealed).
3. Free in air.
4. Window frames/Architraves/non-accessible.
5. Building voids- accessible/non-accessible.
6. Buried in ground.

6.3 Method of Installation – Wire/Cable, Support/Enclosure

Method of installation in relation to type of wire/cable e.g., bare conductor, insulated conductor, sheathed conductor, single core/multi-core and contingent system to enclose/protect/support the wires/cables; along with fittings and accessories. It can be:

1. Conduit system – surface/concealed
2. Trunking
3. Clipped direct
4. Raceways
5. Ducting
6. Ladder, Tray, Brackets, etc.



Within reach? Need additional care?

Note – It shall be kept in mind that, in the case of concealed wiring additions, alterations are difficult and have limitations. So, for concealed-type wiring installation, adequate planning with foresight of future requirements is necessary. Else post completion additions and alteration in installation often leads to defective and unsafe work, performed by non-qualified person.

6.4 Current Carrying Capacities – Assessment

The current to be carried by any conductor for sustained periods during normal operation, consideration for short time over current, leakages, fault conditions to sustain effective operation of various protections shall be such that the temperature limit depending on type of insulation (refer point No. 6.6) is not exceeded. Under the context, it shall be noted that heat dissipation is an important factor, which depends on type of wiring and method of installation. Based on this, cross-sectional area of conductor shall be selected very judiciously. It shall be noted that for the same cross section current carrying capacity reduces to 50% depending on the situation. While selecting cross-sectional area; points related to voltage drop, temperature at terminals, harmonics, etc. shall also be taken into account. Following considerations are, thus, important to assess the current carrying capacity of cable with respect to particular situations as under:

1. Location
2. Type of wiring selected
3. Situation (base on which/in which) installation is proposed
4. Based on above, check under which group the reference method of Installation fits in.

6.4.1 Reference method of installation

To assess current carrying capacity of cable under various situations, methods of installations have been classified in to 10 groups as given under in Table 1 and, if different methods are applied for a circuit, the lowest current carrying capacity shall be considered.



Table – 1: Method of Installation (Ref: for details with figures see Table 20 from Annex S IS 732:2019)

Sr. No.	Reference method	Particulars
1	A1	Insulated conductors in conduit in thermally insulated wall ¹ /in mouldings/architraves/window frames
2	A2	Multi-core cable in conduit in thermally insulated wall ¹
3	B1	Insulated conductors in conduit/trunking on wooden wall/on or concealed in masonry wall ² , suspended in trunking/in building void
4	B2	Multi-core cable in conduit/trunking on wooden wall/on or concealed in masonry wall ² /flooring, suspended in trunking, in building or ceiling void/duct in void/in masonry/open or closed cable channel
5	C	Single-core or multi-core cable on a wooden wall ³ imperforated tray/on or directly in masonry wall/ceiling Cable on floor or under ceiling may also be considered under this category with slight reduction in current carrying capacity.
6	D1	Single core cable/Multi-core cable in conduits/ducts in the ground ⁴
7	D2	Multi-core cables designed to be buried directly in the ground ⁵ with or without added mechanical protection, e.g., half round RCC pipe
8 9 10	E F 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 ⁶

Note 1 : Wall consisting of outer weatherproof skin, thermal insulation and inner skin of wood or similar material having thermal conductance at least 10 W/m². 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 metal or PVC.

Note 2 : Conduit 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 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. This subject is under consideration.

Note 3 : Cable mounted on a wooden wall shall be 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.

Note 4 : Cables drawn into 100 mm diameter 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.

Note 5 : Cables 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.

Note 6 : 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.

6.4.2 Insulation of Cables

Select appropriate type of insulation PVC (polyvinyl chloride)/XLPE (Cross-linked Polyethylene)/EPR (Ethylene Propylene Rubber), to check allowable temperature limit. See Table 2 below:

Table – 2 Maximum operating temperature for types of insulation of cables

Type of Insulation	Temp. limit °C ¹
Thermoplastic (PVC)	70 at conductor
Thermosetting (XPLE/EPR rubber)	90 at conductor ²
Mineral (Thermoplastic PVC) covered or bare exposed to touch	70 at sheath
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	
Note: 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's specifications	

Note 1 : MI (Mineral Insulated cables have not been considered in the guidelines)

Note 2 : 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, else, above limits shall be observed.

Note 3 : In absence of manufacturer's specifications, FR, FRLSH, HFFR category shall be considered under PVC.

Note 4 : for FS cables, manufacturer's specifications shall be considered.

6.4.3 Number of Cores

Number of cores influence current carrying capacity of conductors.

In consideration of 6.4.1 to 6.4.3, IS 732:2019, gives current carrying capacities for standard cross-sectional areas under various tables (for details, refer Tables 21 to 32 from Annex S of IS 732:2019) This method gives precise values but one may find it somewhat complicated, as different permutations and combinations have to be checked to assess current carrying capacity. A simplified concise version of these tables is given in Annexure I. classified in to 10 groups as given under Table 1.

6.5 Derating/Correction Factor

On the values of current carrying capacity given in Annexure I; further derating/correction factors will be applicable as below.

6.5.1 Ambient Temperature Factor

1. Applicable for A1, A2, B1, B2, C, E, F, G methods of installation:

The current carrying capacity shown in Annexure I, are based on value of ambient temperature at **30°C**, for the installations other than below ground and **20°C** for installations, below ground. For such installations, as per the ambient temperature of respective geographical area, correction factor will apply. Refer Annexure III & IV.

2. Applicable for D1, D2 methods of installation:

Check and apply soil thermal resistivity correction factor in case of cables to be laid directly underground with soil resistivity other than 2.5 K-m/W (see Annexure V)



6.5.2 Group Reduction Factor

With the number of circuits or number of multi-core cables, current carrying capacity reduces. This reduction factor shall be applied on the value given under Annexure I. Reference shall be taken from Annexure II.

6.5.3 Effects of Harmonic Currents

Non-linear loads distort sinusoidal waveform and cause harmonic currents damaging supply quality. Some of the commonly seen equipment causing harmonic distortion are, fluorescent luminaries with electronic ballast, LED luminaries, computers, VVVF drives, inverter technology based electrical gadgets. The effects shall be considered as below:

1. Neutral Current

The magnitude of neutral current due to third harmonic causes significant effect on current carrying capacity of the cables in the circuit. So, 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 in ascertaining the current-carrying capacity of the circuit. Under the situation, where neutral current is likely to be higher than the line current, cable size shall be selected on the basis of neutral current.

2. Size of Cable

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. If the neutral current is more than 135 % 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.

3. Reduction factors due to Harmonics

In balanced three-phase circuits, where neutral currents due to the line currents, having a harmonic content does not get cancelled, reduction factors shall be applied. (See Table 3 below). If only two of the three phases are loaded, the neutral conductor will carry the harmonic currents in addition to the unbalanced current. Such a situation can lead to overloading of the neutral conductor.

If significant (i.e., more than 15 %), higher harmonics, for example, 9th, 12th, etc. are expected, then, lower reduction factors are applicable. Where there is an unbalance between phases of more than 50 %, then, lower reduction factors may be applicable.

The tabulated reduction factors, when applied to the current-carrying capacity of a cable with three loaded conductors, will 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 line conductors into account.

Table 3– Reduction factors for harmonic currents in four-core and five-core cables

Third harmonic content of line current %	Reduction factor	
	Size selection is based on line current	Size selection is based on neutral current
0-15	1.0	—
15-33	0.86	--
33-45	--	0.86
45	--	1.0

Note 1. The third harmonic content of the line current is the ratio of the third harmonic current and the fundamental current (first harmonic), expressed in %.

Note 2. The reduction factors only applies to cables where the neutral conductor is within a four-core or five-core cable system and is of the same material and cross-sectional area as the line conductors. These reduction factors have been calculated based on third harmonic currents.

Examples of applying reduction factors

Consider a three-phase circuit with a design load of 32A to be installed in conduit and concealed in masonry wall using four PVC insulated cables, installation method B. From Annexure I, a 6 mm² cable with copper conductors has a current-carrying capacity of 34A and hence is suitable if harmonics are not present in the circuit.

Example 1 If 20% third harmonic is present, then a reduction factor of 0.86 is applied and the design load becomes:

$$\frac{32}{0.86} = 37.2 \text{ A}$$

For this load a 10 mm² cable is necessary.

Example 2 If 40 % third harmonic is present; the cable size selection is based on the neutral current which is:

$$32 \times 0.4 \times 3 = 38.4 \text{ A}$$

and a reduction factor of 0.86 is applied, leading to a design load of:

$$\frac{38.4}{0.86} = 44.65 \text{ A}$$

For this load a 10 mm² cable is suitable.

Example 3 If 50 % third harmonic is present; the cable size is again selected on the basis of neutral current which is:

$$32 \times 0.5 \times 3 = 48 \text{ A}$$

In this case, the reduction factor is 1 and a 16 mm² cable is required.

Note - 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.

6.5.4 Voltage-drop in Consumers' Installation

The voltage drop between origin of an installation/point of supply and any load point shall have limitations as given in the following Table 4.

Table 4 – Voltage drop limitation (in percentage to the nominal voltage as per IS 12360)

Type of installation	Lighting	Other
A – low voltage installation supplied directly from public low voltage distribution system	3%	5%
B – low voltage installation supplied from private LV supply ^a	6%	8%
^a As far as possible, it is recommended that voltage drop within final circuits do not exceed those indicated in installation type A When the main wiring system of installation is longer than 100m these voltage drops may be increased by 0.005% per meter exceeding 100m, without this supplement being greater than 0.5% Voltage drop is determined from the demand by the current using equipment, applying diversity factor where applicable, or from the values of the design current of circuits		
Note 1 : Greater voltage drop may be accepted; - for motor during starting period - for other equipment having high inrush current Note 2 : Following temporary conditions are excluded; - Voltage transients - Voltage variation due to abnormal operation Note 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 the equipment is operating correctly.		

6.6 Conductor and Cross-sectional area

6.6.1 Conductor

For the safety of any electrical installation, thermal management is very important. Heat, the greatest enemy, has to be looked upon with a vigil, where it could be generated and where it could be accumulated. In most of the electrical accidents of electrocutions and fires, commonly seen causes are, electrical leakages leading to failure of insulation, heating and sparking at the point of contacts / terminals. Under this perspective, to mitigate possibilities of accident, copper is best option. Inherent properties of copper supersede that of aluminium. Safety, concerns during the service life of electrical installation and the maintenance issues are much less where copper is used. Coefficient of thermal expansion in case of Aluminium is 35% more than copper. So, over the period of time, development of mechanical forces due to

higher coefficient of thermal expansion, contacts getting loose, possibilities of oxide formation, leading to generation of heat, resulting into development of leakages and sparking are more when aluminium conductor is used. NBC has therefore recommended use of only copper conductor for cable sizes up to 16 mm².

Note – Loose contacts are major cause of heat generation leading to sparking and fire. Under routine maintenance; checking of all contacts up to branch circuits, switchboards may not take place. Hence, to mitigate the possibilities of fire hazard, copper conductor is recommended.

6.6.2 Cross-sectional Area

1. One of the very important tasks in design of electrical installation is assessing cross-sectional areas of conductor at various levels of distribution. For assessment of the cross-sectional area of conductor, following factors shall be considered:

- (i) designed/estimated load under normal conditions and maximum current (including anticipated future requirement);
- (ii) current carrying capacity* of the conductor under the respective situation and method of installation.
- (iii) derating/correction factor as per allowable voltage drop;
- (iv) derating/correction factor as per harmonic disturbances;
- (v) fault level withstand capacity, correlating to the protection;

Note – *It shall be noted that for the same cross section of conductor, variation in safe current carrying capacity is quite large. Typically, it will be seen that under Annexure I, current carrying capacity of 1.5 mm² copper conductor varies from 13A to 26A, depending on situation & method of installation.

2. Minimum Nominal Cross-sectional Area

Without prejudice to the above recommendations, the nominal cross section area of phase conductors in A.C. circuits and live conductor in D.C. circuits shall not be less than values specified in Table 5 below due to mechanical reasons:

3. Cross-sectional area of neutral conductor

- (i) In single phase circuits as well as three phase circuit with line conductor up to 16 mm², type and cross-section of neutral conductor shall be equal to line conductor.

- (ii) Also, where harmonic distortion is likely and THD does not exceed 33%; cross sectional area of neutral conductor shall be at least equal to the area of line conductor.
- (iii) If THD exceeds 33%, cross-sectional area of neutral conductor shall be increased in accordance with 6.5.3 above.
- (iv) For poly phase circuits, where cross sectional area of line conductor is greater than 16 mm², copper cross-sectional area of neutral conductor may be lower (but not less than 50%) 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% of the line conductor current;
 - (c) the neutral conductor is protected against over currents; and
 - (d) cross sectional area in not less than 16mm².

Table 5 – Minimum Nominal Cross-sectional area of Conductors

Type of wiring	Use of circuit	Conductor and cross section
Fixed Installation Cables and insulated conductors	Lighting circuits ¹ Power outlet ² 6A	1.5 mm ² Cu
	Power circuits Power outlet ³ 6A Power outlet ⁴ 16A Appliance ⁵ ≤ 2kW	2.5 mm ² Cu
	Appliance ⁶ < 3kW	4.0 mm ² Cu
	Appliance ⁷ < 6kW	6.0 mm ² Cu
	Signaling and controlling circuits	*0.5 mm ² Cu
	For any other application	*0.5 mm ² Cu
	Extra low voltage circuits	0.5 mm ²
Note* 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 mm² is permitted. Note1 Maximum looping - 2 boards, subject to load < 1 kW / 24 points Note2 Maximum 4 Nos., subject to total load < 1 kW Note3 Maximum 8 Nos., subject to total load < 2 kW Note4 Maximum 2 Nos., subject to total load < 2 kW Note5 1 No, subject to total load < 2 kW / AC < 1TR Note6 1 No, subject to total load < 3 kW / AC < 2 TR/3TR(3-PH) Note7 1 No, subject to total load < 6 kW / AC < 3 TR (1-PH)		

Aluminium conductor cables in sizes less than 16 mm² cause termination problems leading to heating at the terminals and enhancing the possibility of a fire. For conductor sizes less than or equal to 16 mm², only copper conductor cables should be used.

4. Cross-sectional Area of Protective Conductor

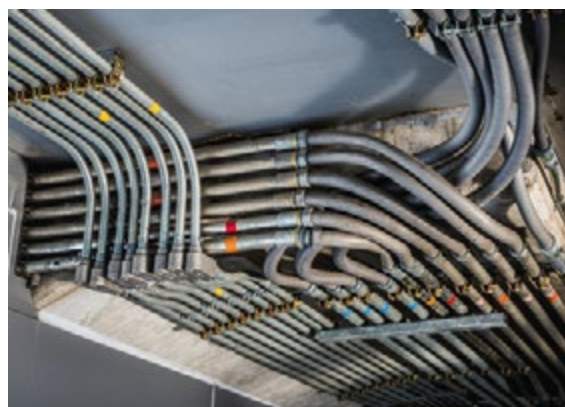
Cross-sectional area of protective conductor shall not be less than the appropriate value shown in following Table 6.

Table 6 – Cross-section area of Protective Earth conductor (PE)

Cross-section area of phase conductor S mm ² (Cu)	Minimum cross-section area of Protective Earth conductor mm ²
S<16	S
16<S<35	16
S>35	Refer Clause 12.2.2.1 of IS 3043
Note 1 – Applicable for same metal. If different metal is used, it shall have same ampacity. If exact size is not available, choose nearest next size. Note 2 – The values shown above are generally applicable. For precise size, Clause 12.2.2.1 of IS 3043 or Clause 5.4.3.1.3 of IS 732:2019 may be referred. For IT and TT system of earthing, compatibility may be verified in consideration with earth fault loop impedance	

6.7 Conduits and Conduit Systems

Conduits and conduit systems are used to support and provide environmental, mechanical protection to wires/cables and form an integrated part of wiring system. Conduits used in wiring installations shall comply with the standards published by BIS under IS 9537 series of standards and the Conduit Systems shall comply with IS 14930 series of standards.



6.7.1 Classification of Conduits

Conduits are classified and coded (12 digits) as per following points:

- | | |
|---|---|
| 1. Material (metal / non-metal), | 7. Electrical (continuity, insulating), |
| 2. Connections / extensions, | 8. Ingress (solid / water), |
| 3. Mechanical (light / medium / heavy), | 9. Corrosive properties, |
| 4. Impact resistance, | 10. Tensile Strength, |
| 5. Temperature range, | 11. Flame Resistance, and |
| 6. Bending, | 12. Suspended Load Capacity. |

6.7.2 Selection

Conduits shall be selected based on factors of external influences like, climatic conditions, pollution leading to corrosion, mechanical protection, fire behaviour, required skill-set for erection, etc. Metal conduits provide good mechanical protection and don't catch/spread fire but are susceptible to corrosion and require skilled workmen having experience for installation. Galvanised conduit is an option, but cost, erection time, and requirement of specialised skill stand at high level. However, PVC conduits are non-corrosive, do not require much skill, erection is easier; but have inferior fire related properties. uPVC conduits are also being used which have high resistance to corrosion, UV effect. These conduits have smooth surfaces which makes drawing of wires easier but bending is not as convenient as PVC conduits.

6.7.3 Size of conduit, Fill factor / Space factor

1. Size of conduit is an important consideration as it correlates with the thermal effects of insulation of cable and the limiting temperature. More the cables/crowding within conduit, more is generation of heat and problems related to dissipation of heat. Improper dissipation of heat and its accumulation cause adverse effects on insulation. Hence, limits are set called as 'space factor' or 'fill factor'. This factor can be worked out using two different methods. Under one method, values are assigned to cables based on individual cross-section called cable factor, and to conduits based on type of conduit and internal cross section, called conduit factor. It shall be seen that aggregate value of cable factor to be pulled through conduit shall be less than conduit factor.
2. Alternatively, as per NEC, recommended fill factors (portion of cross section within conduit which can be occupied by cable/s), can be considered as below:
One cable 53% | Two cables 31% | Three or more cables 40%

To assess number of cables according to size and numbers, it is necessary to refer internal cross-section of conduit and external cross-sections of cables. References may be taken from;

Tables below:

- (a) Table 7 – Dimensions of Rigid Steel Conduits for inside cross section of metal conduits (Ref. clause **7.1 of IS 9537-2**),
- (b) Table 8 – Dimensions of Non-metallic conduits (PVC) (Ref. clause **7.1 of IS 9537-3**)
- (c) Table 9 – Dimensions of Single Core Non-Sheathed Cables with Rigid Conductor Class 1 or Class 2 for maximum overall diameter of cables (Ref. Clauses **16.1.2** and **16.1.3 of IS 694**).

Note – Between pull boxes, for every two deviations in direction of up to 90°, area of conduit shall be considered less by 15%, and there shall be no further deviation.

Table 7 – Dimensions of Rigid Steel Conduits
(Ref. clause 7.1 of IS 9537 (Part 2):1981)

Nominal size of Conduit	Outside diameter	Maximum wall thickness	Internal cross-sectional area of conduit
mm	mm	mm	mm ²
16	16	1.8	121
20	20	1.8	211
25	25	1.8	360
32	32	1.8	633
40	40	2.2	995
50	50	2.2	1633
63	63	2.2	2697

Table 8 – Dimensions of non-metallic Conduits (PVC)

(Ref. clause 7.1 of IS 9537(Part 3):1983)

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
16	16	13.7	147	13.0	133	12.2	117
20	20	17.4	238	16.9	224	15.8	196
25	25	22.1	384	21.4	360	20.6	333
32	32	28.6	642	27.8	607	26.6	556
40	40	35.8	1007	35.4	984	34.4	929
50	50	45.1	1598	44.3	1541	43.2	1466
63	63	57.0	2552				

Table 9 – Dimensions of Single Core Non-Sheathed Cables with Rigid Conductor Class 1 or Class 2 (Ref. Clauses 16.1.2 and 16.1.3 of IS 694:2010)

Nominal Cross Sectional Area of Conductor	Class of Conductor	Thickness of Insulation	Maximum overall Diameter	Cross sectional Area of Cable
mm ²		mm	mm	mm ²
0.5	1	0.6	2.3	4.15
0.75	1	0.6	2.5	4.91
1	1	0.6	2.7	5.73
1.5	1	0.7	3.2	8.04
1.5	2	0.7	3.3	8.55
2.5	1	0.8	3.9	11.95
2.5	2	0.8	4	12.57
4	1	0.8	4.4	15.21
4	2	0.8	4.6	16.62
6	1	0.8	5	19.64
6	2	1	5.2	21.24
10	1	1	6.4	32.17
10	2	1	6.7	35.26
16	1	1.2	7.8	47.78

Note – Class 1 is solid Conductor and class 2 is stranded Conductor

Example

To find suitable Heavy PVC conduit for:

Number of cables (stranded):

2x1.5mm² (2 runs)

2x 4.0 mm² (1 run)

1x 1.5 mm² (3 run)

Number of bends 2 Nos. of 90°

To find Size of conduit:

Cross-sectional area of cables from Table 9

Class 2 - 1.5 mm² - 8.55 mm²

Class 2 - 4.0 mm² - 16.62 mm²

Fill area = (7x8.55) + (2x16.62)
= 93.03 mm²

Since number of cables are 9, Fill factor – 40%

$\frac{93.03}{0.4} = 232.73$ say 233

Nearest and next cross-sectional area of conduit from Table 8 as referred above and considering 2 bends of 90° area to be reduced by 15%

196 mm² 20 mm conduit

333 mm² 25 mm conduit

Less 15%

333 x .85 = 283.5 mm² It is more than 233 mm².

So suitable conduit will be 25 mm

Note – Limiting of number of cables within conduit may increase number of runs of conduits but shall be observed to avoid possible risk of deterioration of insulation.

6.8 Trunking/Ducting

In surface type wiring system, PVC trunking (also called casing and capping), is most popularly used. It shall comply with IS 14927/IEC 61084. Trunking and ducting are available in various standard sizes as in **Table 10** below.

6.8.1 Trunking sizes, Fill factor

1. Standard Dimensions

Table 10 – Dimensions of Trunking/Ducting

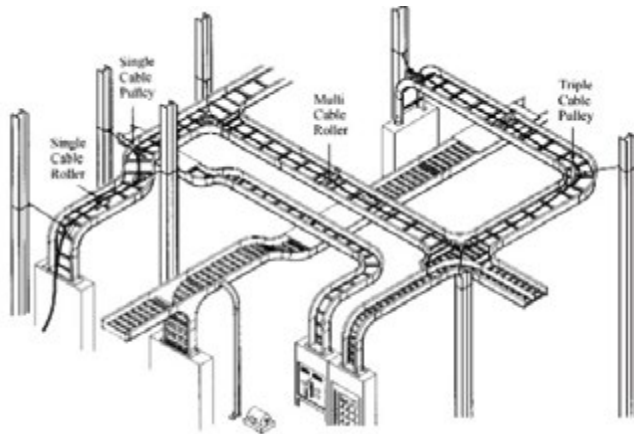
Size (outer) mm	Wall thickness mm	Approximate Internal cross section mm ²
12x12	1.2	119.5
16x12	1.2	153.0
16x16	1.2	196.0
25x12	1.2	239.1
25x16	1.2	307.4
25x25	1.2	510.8
38x16	1.3	474.4
38x25	1.3	793.0
50x16	1.5	611.0
50x50	1.5	2209
75x75	1.8	5098
100x50	1.8	4473
100x40	2.5	3333
200x30	2.5	5000
225x25	1.6	4687
225x38	1.6	7125
250x25	1.6	5103
250x38	1.6	7916
300x25	1.6	6250
300x30	2.5	7500
300x38	1.6	9500

2. Fill Factor

The last column shows internal cross section. On an average, fill factor of 40% shall be considered for cables to run through trunking.

6.9 Cable Tray and Ladder system

The assembly/structure in the form of Tray and Ladder for horizontal and vertical runs of the cables is one of the cable-management tools especially for bunch of cables (Sheathed/armoured), whether power or LV system in an organised way. This is open to air system, hence is advantageous from the point of view of thermal management. This system is to support the cables and is not intended to provide mechanical protection. For larger size cables, this system is suitable. The system shall conform IS/IEC 61537.



6.10 Duct/Channels/Raceways

Under this cable management system, cables are enclosed in metallic/non-metallic material. Hence unlike Tray/Ladder, this system provides protection against mechanical damages. This system can be surface, concealed or flush to the surface as per situation and requirement.



7. Electrical Distribution

Proper design of electrical distribution system assures safety, quality of supply and mitigates chances of power interruption due to faults within the installation. Appropriate sectionalising with adequate protection shall be the important consideration to avoid outages and blackouts. The scope of distribution considered is from the point of supply to the utility point. Following points shall be noted in this regard.



7.1 Single Line Diagram (SLD)

A detailed single line diagram shall be prepared showing distribution from point of supply to the final branch circuit and to the switch board/s connected on it. It shall include main switch/control panel, main distribution board, sub distribution boards, MCCBs, MCBs, and other protections RCDs/RCBOs, SPDs, etc. and the cables from source, main, sub-main, circuit main till final branch circuit. Technical details such as capacity, rating, ways, type, size and also connected and designed load shall be mentioned for every respective item. Each component, circuit, shall be given identification number/mark, for tracking of fault or to check possibilities of proposed changes in future.

7.2 Point Wiring – General Light and Power

The portion of wiring starting from switchboard to the outlet point to which an electrical appliance, fitting is connected comes within the scope of point wiring. This outlet may be for light/fan/or any equipment/appliance. Outlet of light point may be extended to number of light fixtures, subject to limitation of load and points. In case of 16 A power point, it starts from MCB to the power plug outlet.

1. Conductor Size – Phase, Neutral, Protective Earth (PE)

Conductor size for point wiring of lighting points shall not be less than 1.5 mm² and for power points, 2.5 mm². Protective Earth (PE) shall be of same size and metal as that of phase conductor. Table 5 shows minimum size of conductor, which shall be referred for selection of conductor size for point wiring.

Regulations do not make it mandatory to provide PE to fixed lighting fixtures and fans unless manufacturer provides the fixture with earth terminal. Also, for class II equipment PE is not necessary. But, in anticipation of possibility of change in future, e.g., the fixture with an earth terminal, it may not be easy to pull additional PE cable through the existing conduits. Hence, it is recommended that all points shall be provided with PE conductor connected at the earth terminal provided on 3-plate ceiling-rose or 3-pin power socket. Refer Table 6 for size of PE conductor.

2. Switch Boards

Supply to every switch board shall be fed through an independent branch circuit. Additional one board may be looped with subject to the limit set for number of points / maximum load on the circuit. The circuit feeding supply to the switch-board shall not be more than one, with an exception of circuit through inverter. The circuit number shall be marked on board. Care shall be taken to connect all single pole 1-way / 2-way switches on phase conductors only. Neutral shall not get isolated except on 2-pole switch having phase and neutral terminal. All connecting bare leads within box shall not remain exposed outside the portion of terminal. It is recommended to provide plug outlet on all boards or at least having more than 2 points, so as to ensure availability of neutral and PE which facilitates testing and modifications, where necessary.



3. Branch Circuit

Limit of 24 points or 1000W whichever is higher shall be observed per lighting circuit and 2 Nos. of power points or 3000W per power circuit. For assessment of load, where actual load as per manufacturer's product specifications is not available, following Tables 11 and 12 may be referred for lighting and power load respectively and maximum out of two (as per manufacturer's specifications and that given in table) shall be considered.

Table – 11 Lighting load

Connected utility on the outlet of point wiring	Load consideration in W
Light point*	50
Fan point	75
Power outlet 6A	100
Note 1 - *Shows load of conventional light point, which includes incandescent lamps / Tube light with ballast of any types. For energy saving LED light or equivalent, less wattage may be considered. In non-residential establishments where series of lights are controlled by single switch, actual load shall be taken into consideration. Note 2 - Fan shall include all types / sweeps / exhaust Note 3 - If actual rating of appliance is known, it may be taken into consideration subject to envisaged changes.	

Table 12 – Power load

Connected utility on the outlet of point wiring	Load consideration in W
Bathroom	
Storage type water heater	2000
Instant hot water geyser	3000
Dry balcony	
Washing Machine	2000
Dish washer	1500 / 2000
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	700 / 1000
Other	
A.C 1TR /1.5 TR / 2 TR	1250 / 1500 / 2000
Room heater	1000
Computer	150
TV	100
Iron	800 / 1000

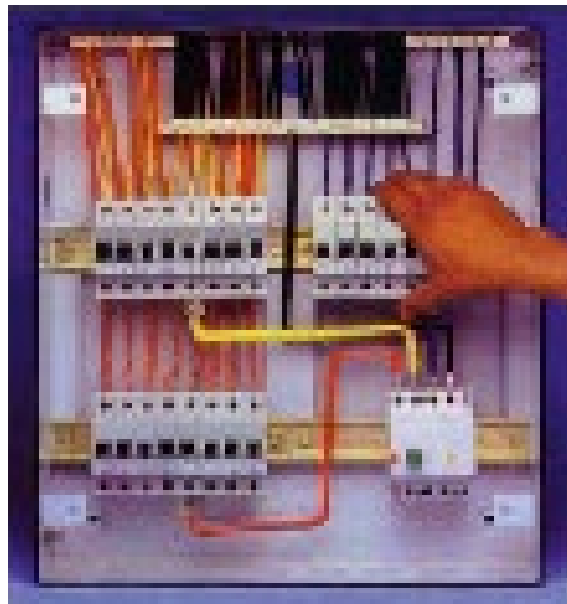
Minimum cross-sectional area of conductor shall not be less than 1.5 mm² for lighting circuits and 2.5 mm² for power circuits and shall be protected with a MCB of appropriate type (B, C, D) and capacity. There shall be provision of separate circuit for each room/area enclosed with a door and common areas like passages, lobby, and toilets. For all boards providing supply only for plug outlets, there shall be separate circuit. In case of power loads, apart from the condition of maximum allowed load and points; provision of separate circuit shall be made for every water heater, air-conditioner. It shall be observed that neutral of every circuit

remains independent and shall never loop with any other circuit. In case of points on emergency power supply circuits having backup of inverter/UPS, for every circuit neutral shall be run separately from the source and shall not be looped with any other circuit.

7.3 Mains/Sub-mains

Precise load consideration is first step to assess the current and further select conductor size as per the situation and method of construction. Following points shall be considered to work out the load.

1. Connected load
2. Simultaneous maximum load during time of day/diversity
3. Type of load; resistive/inductive/non-linear
4. Balancing of load where three phase supply is provided.



For all emergency/critical services to maintain a continuous supply, there shall be an arrangement of ring circuits.

7.4 Distribution Boxes (DB)

DB is one of the key locations from where safety can be monitored. Proper streamlining of distribution is possible through DB. Variety of DBs are available to suite the requirement. Following points shall be considered:

1. Adequate spacing within DB to accommodate cables,
2. Capacity of busbar
3. Links for termination of neutral and PE conductors
4. Apart from MCBs, mounting facilities for RCDs, RCBOs, SPDs, of required No. of poles.
5. Confirmation with IS 13032.
6. Same make and brand of the DB, MCBs and other protections within DB.

7.4.1 Location of DB

Location of DB shall be in conspicuous place like passages/common areas and shall be at high level on wall but at accessible position (within reach of hands without an aid of ladder/raised stand). In the areas of large expanse, location at load center shall be preferred.

7.5 Switch gears, Breakers and Protective Devices

Provision of correct device of precise rating*and key location is most important aspect to prevent any mishap, in respect of electrical installation involving risk of life and fire. Distribution system shall be so designed that every circuit is protected against overload and short-circuit. RCD is mandatory. It shall be so located that identification of fault can be tracked easily with minimum downtime without affecting non-defective portion of electrical installation. Installation shall also be protected against voltage surge by making provision of SPDs.

***Note** – Precise rating shall be worked out not just on size of conductor but on the basis of safe current carrying capacity of conductor, prospective short circuit current under respective situation and method of construction as given in Annexure- I. It shall be noted that for particular cross section of conductor, current carrying capacity reduces up to 50% depending on situation and method of construction.

1. Miniature Circuit Breakers (MCB)

Selection of MCB shall be done based on its current rating, breaking capacity, number of poles and tripping characteristics. Following table may be referred for choosing type B,C,D of MCB to suite the type of load. For resistive type of load like water heater B type MCB may be used. For load causing high inrush current at starting like air-conditioner, C type MCB shall be used. Devices having very high inductive loads/SMPS power supply, D type MCB shall be suitable. Short circuit current rating if not available, MCB of maximum breaking capacity (9kA/10 kA) shall be selected.

Table – 13 Tripping Ranges

Type	Range (Instantaneous)		
B	Above 3 I _n up to and including 5 I _n (tripping time t > 0.1 s)		
C	Above 5 I _n up to and including 10 I _n (tripping time t > 0.1 s)		
D	Above 10 I _n up to and including 20 I _n ^a (tripping time t > 0.1 s)		
^a For special cases value up to 50 I _n may also be used			
Tripping time for current I _n less than that shown above will be approximately as shown below			
Type	Current (I _n)	Time (t)	Result
B, C, D	1.13 I _n	t < 1h (I _n < 63A) t < 2h (I _n > 63A)	No trip when cold
B, C, D	1.45 I _n	t < 1h (I _n < 63A) t < 2h (I _n < 63A)	Trip when not cold
B, C, D	2.55 I _n	1 s <t< 60 s (I _n < 32A) 1 s <t< 120 s (I _n > 32A)	Trip when cold



2. Isolators

Externally, Isolators and MCBs look alike except the difference in colour of knob. But it shall be kept in mind that an Isolator is just isolating device, and do not trip/provide any protection against overload and short-circuits. These are meant to operate manually. Its use is not advisable especially when the back-up circuit protection is not nearby. Under fault conditions, there are chances that the contacts may get welded, making the situation prone to Fire.

3. Moulded Case Circuit Breakers (MCCB)

Use of MCBs has limitation in respect of current rating and breaking capacity. (generally available, current rating of MCB - up to 63 or 125A max. and breaking capacity, 10 kA). MCCBs are available in much higher rating up to 1600A and 85 kA Breaking capacity. These are available both having fixed as well as variable setting of tripping range. Application of MCCBs is generally seen at places other than domestic installations.

4. Residual Current Devices (RCD)

Residual Current Device which provides protection against electrical shock due to leakage currents, are available in 30mA/100mA/300mA rating. For human protection use of 30mA RCD is mandatory. Study reports have revealed that persistent leakage currents of higher magnitude have led to fire initiation. Hence it is recommended that use of 300mA RCD shall be made at point of supply for all LT installations. RCDs shall conform IS 12640-1:2016

Note 1 - Function of RCD can be availed combined with MCB providing overload and short-circuit protection through a device RCBO. (IS 12640-2)

Note 2 - To avoid nuisance tripping proper location and sectionalised distribution is recommended. In case of three phase distribution system, per phase isolation DBs provide facility to install RCD for each phase at source, which do not interrupt supply of healthy phases.

Note 3 - Functionally RCD/ELCB/RCCB is same

5. Surge Protective Devices (SPD)

Installations and the equipment, susceptible to adverse effects due to voltage surges shall be provided with SPD. This device provides protection from switching, lightning surges. It shall conform to IEC 61643-1. These devices come in three types, 1, 2, and 3.



(a) Type 1 - It protects electrical installations against direct lightning. It prevents current originating from lightning stroke in to spreading from earth conductor to wiring network.

(b) Type 2 – It is installed at low voltage electrical DBs to prevent over voltage surge spreading in downstream Wiring Installation.

(c) Type 3 – These are used to install near sensitive equipment, which act as a secondary protection to Type 2.

6. Air Circuit Breakers (ACB)

Use of ACBs is done in Electrical Installations with heavy loads and Industrial Installations. ACBs overcome limitations of MCCBs and are rugged. They can meet requirements of higher current rating and breaking capacity. Time delays in instantaneous tripping is possible hence discrimination can be achieved for tripping sequence. Circuit breakers shall conform to IS/IEC 60947.



7. Panel Boards

A Panel board also called Switchboard is an assembly consisting of switching devices ranging up to 6300A and 100 kA; along with associated control, measuring, indicating, and protective equipment for distribution of electric power. It shall conform to IS/IEC 61439 series. Switchboards can be of wall-mounted or floor-mounted structures clad in metallic or non-metallic enclosure. Fixed or withdrawable facility can be provided and can also be installed outdoor with provision of appropriate class of Ingress Protection. Panels can be made extendable with modular type construction where, add-ons can be possible.



8. MATERIAL

8.1 Procurement

The material to be procured and used for electrical Installation shall strictly be:

1. As per the technical specifications given in design sheet/schedule, provided by Design Consultant/Licensed Electrical Contractor.
2. Shall conform to relevant Indian Standard or International Standard where Indian standards are not available
3. *Shall be and be qualified for Routine Test/Acceptance Test/Type Test with satisfactory test results.

*Note - May apply to the larger projects/important or sensitive installations. Related documentation shall be preserved and treated as record.

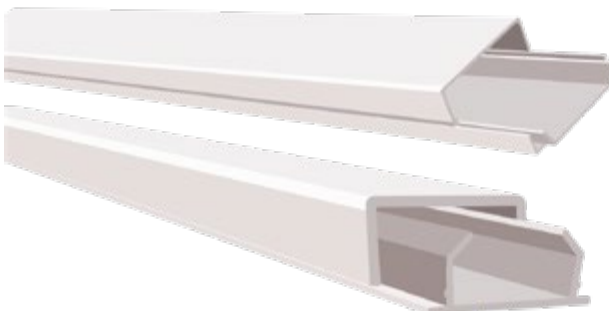
4. Basic material and its accessories/components shall be of same make and brand.

8.2 Transportation and Storage

Transportation and storage of material shall be done with due care so that it doesn't damage or lose its properties till the time of erection.



Flexible conduits



Trunking



Conduits & Accessories



9. INSTALLATION

Strict and vigilant supervision of skilled technician along with, proper documentation/certification of hidden work shall be considered to be the most important requirement of any electrical installation work. It shall be kept in mind that best quality material and design will be rendered useless if the work is not executed properly.

9.1 Layouts and Routing

Layouts and routing as per design and sequence of activities shall be strictly followed to maintain coordination with other services, e.g., LV system, gas pipeline, etc. Schedule as per work activity chart shall be observed to avoid conflicts between various services. Working drawings/shop drawings shall be prepared before the work execution. For the concealed portion of work, provision of alternate route, ring routes may be considered to avoid possible choke-up of conduits. Record/as built drawings shall be prepared and preserved as record

9.2 Installation of Conduits and Boxes

Conduit routing shall be, preferably, parallel and closer to vertical and horizontal room edges. Crossings shall be avoided. Shortest routes may be allowed under flooring/over ceiling. Sharp bends shall be avoided and shall not be more than two between pull-on boxes. Provision of separate conduits per phase shall be observed for single phase distribution, LV system with required spacing. Fixing/laying shall be done with standard accessories. Conduits, accessories shall be rigidly fixed with each other and on the base and wall/ceiling surface. (Refer the Table 14 below for provision of supports). PVC conduits shall be made rigid at all joints with resin. Bending shall be done to restricted angle with proper tools without affecting mechanical properties. In case of metal conduits, burr shall be removed open and threaded portion shall be covered with anticorrosive paint, Junctions boxes shall be made rigid with pipe by using check-nuts. In case of concealed wiring within wall/RCC structure, strict supervision shall be done to avoid displacement due to vibrator (while casting RCC portion). Proper fixing shall be done to avoid displacement on the portions above false ceiling, voids, etc. Drawing the fish wires through conduits may be considered to facilitate pulling of cables. Switch-board boxes at the point of terminations shall be rigidly fixed on at the end of conduit. And, in case of concealed wiring, it shall be so fixed as to match/flush with finished wall surface.

Table 14 – Spacing of Supports for Conduits

Sr. No.	Nominal Size of conduit mm	Maximum distance between supports in meters					
		Rigid Metal		Rigid PVC		Pliable	
		Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
1	Up to 16	0.75	1.0	0.75	1.0	0.3	0.5
2	> 16 up to 25	1.75	2.0	1.5	1.75	0.4	0.6
3	> 25 up to 40	2.0	2.25	1.75	2.0	0.6	0.8
4	> 40	2.25	2.5	2.0	2.0	0.8	1.0

9.3 Installation of Trunking

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, if they do not come into contact with the conductors, cables or are isolated from live parts and are not capable of transmitting a fault current. Where there is such possibility, fixing may be done with screws, however, such screws shall be used with PVC plugs and shall be so designed to withstand the mechanical stresses occurring during installing and normal use. If there is provision of segregation of circuits, same shall be adequately secured. Accessible metal parts of system components which are liable to become live in event of failure of insulation, shall have provision to connect with earthing system.

9.4 Installation of Trays and Ladders

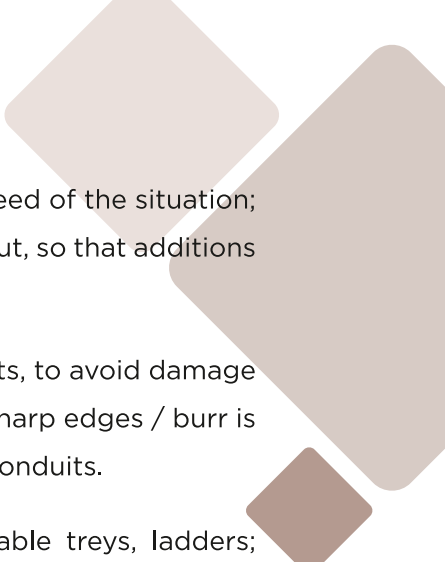
In such type of installation, while involving cantilever construction, structural load is an important point of consideration for support brackets as well as the civil construction on which system is to be installed. Bends shall be fabricated considering minimum bending radii of highest size of cable. Support System shall be strong enough to bare load in anticipation with possible additional load in future. Any deflection if is likely to occur, shall be within limit. Construction shall be done by the workmen having required experience. Manufacturer's instructions, if any, shall be followed.

9.5 Installation of Cable Raceways

For open raceways, the guidelines given for construction of Trays and Ladders may be considered. For concealed type raceways, e.g., within flooring, it is very important to coordinate work with civil work, while maintaining levels with finished civil work. Especially, in respect of Pull-on/Junction Boxes, in anticipation with finished civil work, accessibility and prevention from ingress, are important points. Supervisor on job shall be vigilant while executing the work.

9.6 Installation of Wires/Cables

Cables can be installed as per various methods described above in Table 1 under point 6.4.1. Good workmanship and strict supervision are necessary as lapses/mistakes may lead to disaster in future. Restrict safe current carrying capacity as per design and prevent damage to the insulation during installation/drawing of wires, which depends on the skilled workmanship. Following points shall be noted:

- 
1. **Additions and alterations** – Considering possible need in future, or need of the situation; there shall be adequate means/access for cables to draw in and pull out, so that additions and modifications may be possible.
 2. **Preventing Insulation damage** – While drawing wires through conduits, to avoid damage to the insulation, it shall be confirmed that at the point of junctions; sharp edges / burr is cleaned and use of bushing is made at the inlet and at exit ends of conduits.
 3. **Preventing displacement** – In case of installation at places like cable treys, ladders; supports and ties provided at suitable intervals and design considerations in respect of spacing shall be maintained.
 4. **Weight on terminals** – Care shall be taken to provide clamps, so that the weight of cable does not cause any tension, especially, at the point of termination.
 5. **Twisting** – Twisting of cables shall be prevented
 6. **Bending** – Limits of bending radii shall be observed.
 7. **Protective Conductor** – Continuity of protective conductor shall be maintained without dependency on support system.
 8. **Bunching** – Number of cables allowed within conduits as per fill factor shall be strictly observed.

Note – Busbar Trunking system which is a good option to avoid mess of cable work is not considered in the scope of this document.

9. **Proximity to other services** – There shall be segregation between circuits having different band voltages, LV (>50 up to 1000 V) and Extra low voltage (up to 50 V). Circuits of different services within same voltage band shall also be segregated. Emergency supply circuits and critical service circuits shall be routed separately. In case of proximity to non-electrical services, care shall be taken from the point of view of indirect contact, heat, condensation, gas, etc.
10. **Colour-Coding, Marking and Identification** – For identification of cables and conductors, IS 11353 gives guidance on uniform system of marking and identification of conductors and apparatus terminals. (See Table 15 below). Every single core non-flexible cable and every core of twin or multi-core non-flexible cable used as fixed wiring shall be identifiable throughout its length. This applies to all wiring up to the final distribution board, and also for circuit wiring, (red may be used for any phase).

Table – 15 Correlation between Alphanumeric Notation Graphical Symbol and Colours

(Ref. Table A of IS 11353:1985)

Designation of Conductors		Identification	
		Alphanumeric	Colour
Supply AC system	Phase 1	L1	Red
	Phase 2	L2	Yellow
	Phase 3	L3	Blue
	Neutral	N	Black
Apparatus AC system	Phase 1	L1	Red
	Phase 2	L2	Yellow
	Phase 3	L3	Blue
	Neutral	N	Black
Single Phase AC system	Phase	L	Red
	Neutral	N	Black
	Protective Conductor	PE	Green and Yellow
Earth		E	Other than above

11. Labelling/Tagging

During installation and before completion, every circuit and components of switchgear shall be labelled with tag and ferrule as per the identification mark as shown in SLD. In respect of cables, tag shall be provided at both, incoming and outgoing ends. This is important to track fault, check capacity to accommodate additions/alterations in the existing electrical installation.

12. Terminations – At termination point, connection between cables/cable and terminals shall be sufficiently tight and durable to ensure continuity and least voltage drop. Use of appropriate type of lugs shall be made with all strands properly inserted so that no charring or hot spot is created. Terminations shall be in intrinsically safe enclosures.

13. Underground cable work – LT Cable to be laid underground shall be laid on riddled soil/sand bed of minimum 75mm below and minimum 75 mm above covered with bricks/half round RCC pipes. Cable across the road shall be through duct/full round RCC/G.I./HDPE pipe. Minimum depth shall be 750 mm and 1000 mm for route along the road and across the road respectively. (depth is the distance between top road/ground surface and the top of the cable below ground). Cables shall be marked with identification marks/tapes and route markers shall be erected throughout the length. Clearances of the cables from other services shall be as given in **Table 16**:

Table – 16 Clearances for underground cables (Ref. Clause 6.3.3 of IS 1255: 1983)

Category of cable / service	Clearance
Power cable to Power cable	Not specific but shall suite de-rating factor
Power cable to control cable	200 mm
Power cable to communication cable	300 mm
Power cable to Gas / Water main	300 mm
NOTE - Inductive influence of power cable on sensitive control cable shall be checked	

9.7 Installation of DBs, Control Panels, Switch gears and Protections

DBs, and Control Panels shall be installed as per the finalised drawing. Any deviation due to unforeseen reasons shall be approved without compromising safety. Accessibility for maintenance and safety clearances shall be observed. Earthing of extraneous conductive parts of DBs, and Panels shall be checked. Every breaker/switchgear shall be properly marked as per SLD. Related notices shall be displayed at suitable locations. Insulating mats where mandatory shall be provided. Adequate ventilation/requirement of positive pressures, possibility of water leakages shall be checked. Shrouding of terminals shall be provided where necessary.

10. Verification and Testing

Every installation during erection and after completion before commissioning for use shall be verified to confirm the work has been executed as per approved design and meets safety norms mandated as per the statutory provisions. The initial verification shall be carried out visually and tested without supply on and then with supply on. Under IS 732:2019 detailed guidelines and Formats have been given for verification as below:

1. Annex MM of IS 732:2019 – Initial Verification
2. Annex QQ of IS 732:2019 – Description of the Installation for Verification
3. Annex RR1 of IS 732:2019 – Form for Inspection
4. Annex RR2 of IS 732:2019 – Check points
5. Annex SS of IS 732:2019 – Report of Verification



11. Handing Over

Handing over of installation to the owner / user shall be done with following documents.

1. Documentation related to the electrical supply application made with the Electrical Supply Company., load sanction along with the payment receipts.
2. SLD (Single Line Diagram)
3. Test Report of the Installation.
4. Warranties/Guarantees, papers related to AMC
5. Instruction, list of liabilities and trouble-shooting chart
6. Emergency services



Annexure I

Current-carrying capacity in amperes (ref. Table 41, Annex T of IS 732:2019)

Reference methods in Table B.52.1	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

Annexure I

Current-carrying capacity in amperes (contd.)

Reference methods in Table B.52.1	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 (mm²) 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.

Current-carrying capacities in amperes (ref. Table 42, Annex T of IS 732:2019)

Installation methods	Size mm ²	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	18.4	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

Annexure II

Reduction factors for groups of several circuits or of several multi-core cables

(to be used with current-carrying capacities given in Annexure I) (ref. Table 43 Annex T of IS 732:2019)

Item	Arrangement	Number of circuits or multi-core cables								
		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	–	–	–

Annexure III

Correction factor for ambient air temperatures other than 30°C to be applied to the current-carrying capacities for cables in the air (ref. Table 33 Annex S of IS 732:2019)

Ambient Temperature °C	Insulation	
	PVC	XLPE/EPR
10	1.22	1.15
15	1.17	1.12
20	1.12	1.08
25	1.06	1.04
30	1.00	1.00
35	0.94	0.96
40	0.87	0.91
45	0.79	0.87
50	0.71	0.82
55	0.61	0.76
60	0.50	0.71
65	-	0.65
70	-	0.58
75	-	0.50
80	-	0.41
85	-	-
90	-	-
95	-	-

Annexure IV

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
(ref. Table 34 Annex S of IS 732:2019)

Ground temperature °C	Insulation	
	PVC	XLPE and EPR
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

Annexure V

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 D1/D2 (ref. Table 35 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

NOTE:

- 1) The correction factors given have been averaged over the range of conductor sizes and types of installation included in Tables 21 to 24 of Annex S of IS 732:2019. The overall accuracy of correction factors is within 5 %.
- 2) The correction factors are applicable to cables drawn into buried ducts; 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, they may be calculated by methods given in the IEC 60287 series.
- 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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