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SAFETY IN ELECTRICAL
LOW VOLTAGE INSTALLATIONS

Vol.3: Inspection of Electrical LV Installations



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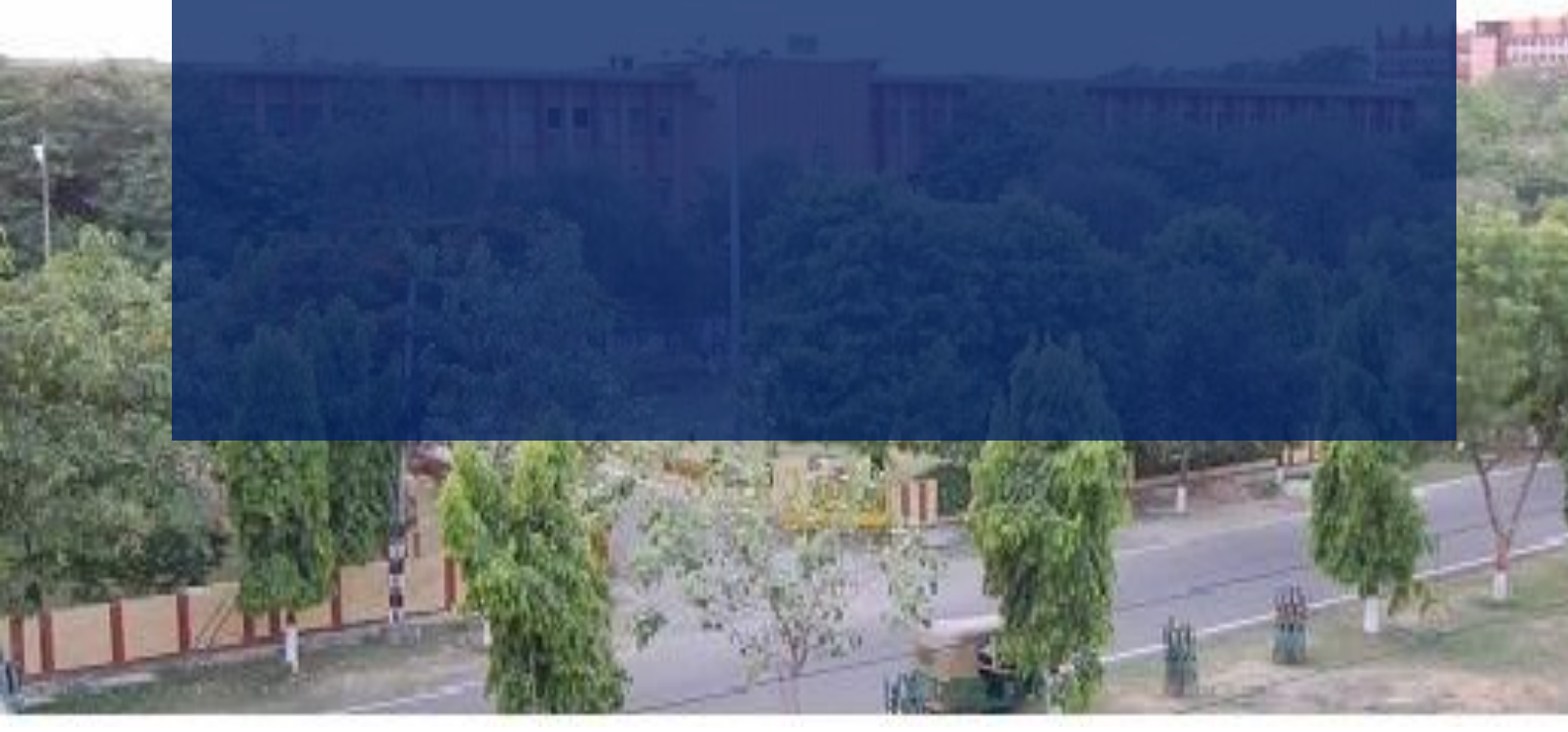
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RAILWAY ELECTRICAL ENGINEERS AND TECHNICIANS DEALING WITH LV INSTALLATIONS

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Indian Railways
Centre for Advanced Maintenance Technology
MAHARAJPURA, GWALIOR - 474005

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(आई.एस.ओ. 9001–2015 प्रमाणित संस्थान)
CENTRE FOR ADVANCED MAINTENANCE TECHNOLOGY
Ministry of Railways
DD Nagar, Maharajpur, Gwalior - 474005
(ISO 9001-2015 Certified Organisation)



जितेंद्र सिंह आई आर एस एम ई
Jitendra Singh IRSME
प्रधान कार्यकारी निदेशक
Principal Executive Director

FOREWORD

Our motto of preparing these documents under the series "**Safety in Electrical Low Voltage Installations**" is to reduce fire cases due to electrical faults and electrocution on Indian Railways. These publications are based on Indian standards and codes in simplified and practically implementable manner.

This volume-3 on "**Inspection of Electrical LV Installations**" has been prepared by CAMTECH, Gwalior under the series of documents "Safety in Electrical Low Voltage Installations" and under this series two volumes i.e. Vol-1: "Basics of LV Earthing System" and Vol-2: "Selection and application of LV Protective Devices" have already been prepared & published. It is recommended to go through Vol. 1 & Vol. 2 for better understanding of this third volume.

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

I am sure that this booklet along with earlier volumes will be useful for electrical design and maintenance engineers and technicians for updating their knowledge, improving the reliability and safety of electrical installations as well as precious human lives. This will be also helpful in reducing the electrical failures on account of electrical failures.

Date: 31.03.2022
Place: CAMTECH/Gwalior

Jitendra Singh
Principal Executive Director

PREFACE

As per directives of Railway Board, CAMTECH, Gwalior has studied the requirements of safety in low voltage electrical installations by referring various Indian Standards on the subject and with the help of experts in this domain. CAMTECH, Gwalior is preparing series of Booklets on “Safety in Electrical Low Voltage Installations”. Under this series two volumes have already been prepared & published.

Our prime object is to disseminate the knowledge among the electrical engineers and technicians about protective earthing, selection and application of protective devices and various provisions/ requirements for selection of size of conductors and equipment to ensure safety and reliability as well in LV installations.

This volume-3 on “Inspection of Electrical LV Installations” under the document “Safety in Electrical Low Voltage Installations” has been prepared to give users various requirements and important key points to be followed for different protections like shock protection, fire protection, protection against external influences, etc., on LV installation based on Indian standard IS 732: 2019, IS 3043:2018.

This volume consists the requirements for protection against electric shock, to limit propagation of fire, protection against thermal effect and protection against over current (overload & Short circuit). This also covers sizing of conductors/ protective conductors, requirements of isolation switching and identification of conductors etc.

This will help electrical engineers & technicians to understand the requirements of safe electrical LV installations & help them in inspection of electrical installations to ensure safety and reliability.

Technological up-gradation & learning is a continuous process. Please feel free to write to us for any addition/ modification in this booklet. We shall highly appreciate your contribution in this direction.



Date: 30.03.2022
Place: CAMTECH/Gwalior

(Himanshu Maheshwari)
Jt. Director /Electrical

ACKNOWLEDGEMENT

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My sincere thanks to Shri Vivek Dixit, CEE (RS)/Western Railway for his continuous motivation, guidance, suggestions, insightful comments, and hard questions which guided us to make this publication simpler for users to understand.

My sincere thanks to Shri S. Gopa Kumar, Member in various Electro Technical committees of BIS for his technical guidance and support throughout the process of making this publication. He has helped us in understanding the Indian and international standards, various concepts of protection, comments and clearing our doubts which we faced during the making of this publications.

I thank my team members Shri Bal Chandra Agrawal, SSE, Shri Arvind Chaturvedi, SSE & Smt. Sangeeta Shrivastava JE/IT for their continuous study, hard work, sincere efforts & dedication to make this publication.



Himanshu Maheshwari
Jt. Director /Electrical

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ISSUE OF CORRECTION SLIP

The correction slips to be issued in future for this booklet will be numbered as follows:

CAMTECH/EL/2021-22/Inspection- Vol.3/1.0/C.S. # XX date---

Where “XX” is the serial number of the concerned correction slip (starting from 01 onwards).

Sr.No.	Date of Issue	Page No. & Iten No. Modified	Remarks

OBJECTIVE OF PUBLICATION

To prepare guidelines which can educate the Indian Railway (IR) engineers and technicians dealing with low voltage electrical installations and other IR officials about various provisions given in IS standards pertaining to IS 3043-2018, IS 732:2019.

DISCLAIMER

It is clarified that the information given in this booklet does not supersede any existing provisions of Indian Standards (IS) on the subject, related matters, and other existing provisions laid down by the Railway Board, RDSO. This is not a statuary document and instructions given are for the purpose of guidance only. If at any point contradiction is observed, then Indian Standards, regulations issued by Government bodies, Railway Board/RDSO guidelines shall be referred. This Booklet covers requirements for general Electrical LV installations based on IS 732:2019 and for special requirements/ locations respective standards may be referred.

ABBREVIATION

Abbreviation	Full Form
AC	Alternating Current
AFDD	Arc Fault Detection Device
BRC	Bonding Ring Conductor
CEA	Central Electricity Authority
CEAR	Central Electricity Authority Regulations
CNE	Combined Neutral and Earth
DB	Distribution Board
DC	Direct Current
EE	Earth Electrode
EMC	Electro Magnetic Compatibility
FELV	Functional Extra Low Voltage
SELV	Separated Extra Low Voltage
ELCB	Earth Leakage Circuit Breaker
IE	Indian Electricity
IEC	International Electro-technical Commission
IS	Indian Standard
IP	International Protection
LPS	Lightning Protection System
MDB	Main Distribution Board
MET	Main Earthing Terminal
N	Neutral
OCPD	Over Current Protective Device
PEN	Protective and Neutral conductor combined
PEL	Protective and Line conductor combined
PELV	Protective Extra Low-Voltage
PEM	Protective and Mid-point conductor combined
PME	Protective Multiple Earthed
PNB	Protective Neutral Bonding
RCD	Residual Current Device
RCM	Residual current monitor
SEBT	Supplementary Equipotential Bonding Terminal
SPD	Surge Protection Device
T	Terre (French word for earth)

INTRODUCTION

This volume 3 on inspection of electrical LV installation is prepared to give users various requirements and important key points to be followed for different protections like shock protection, fire protection, protection against external influences, etc., on LV installation based on Indian standard IS 732: 2019, IS 3043:2018. This booklet can be considered as simplified version of IS 732:2019 for Inspections of LV installations.

A ready-to-use check sheet for inspection of existing or new electrical installation is also enclosed at the end of this booklet for direct use by the concerned supervisors with brief requirements and further referred with reference from Vol 1, 2 & 3 of Safety in electrical LV installations prepared by CAMTECH, Gwalior for better understanding.

INSPECTION OF ELECTRICAL LV INSTALLATIONS

PURPOSE OF INSPECTION

Every new installation or change (addition or changes) to an existing installation shall be verified during erection as far as reasonably practicable and on completion, before being put into service.

Initial Inspection shall precede testing and shall be done prior to energizing the installation. The purpose of inspection is to ensure following aspects:

i. Checking of Wiring & Earthing system
ii. Checking of Protection system
iii. To ensure that the electrical equipment fixed in the installation are correctly selected and erected according to IS 732:2019 and as per the manufacturer's installation guidelines duly ensuring safety requirements
iv. To ensure that the electrical equipment fixed in installation are not in visibly damaged condition which may impair safety.

POINTS TO BE CHECKED DURING INSPECTION

(Ref: Para 6.2.2.3 of IS 732:2019)

Following points shall be checked while inspection of low voltage electrical installations where relevant:

i. Provisions for protection against electric shock
ii. Provisions for protection to limit propagation of fire and protection against thermal effects like provision of fire barriers and other precautions.
iii. Selection of conductors according to current-carrying capacity and voltage drop
iv. Selection and setting of protective and monitoring devices.
v. Presence and correct location of suitable isolating and switching devices
vi. Connection of single-pole switching devices in the line conductors
vii. Selection of equipment and protective measures appropriate to external influences
viii. Correct identification of line, neutral and protective conductors (earth wires)
ix. Identification of circuits, overcurrent protective devices, switches, terminals, etc and presence of circuit diagrams, warning notices or other similar information
x. Adequacy of termination and connection of cables and conductors
xi. Presence and adequacy of protective conductors (earth wires), including main and supplementary equipotential bonding conductors (5.4)
xii. Accessibility of equipment for convenience of operation, identification and maintenance

CHAPTER 1

PROTECTION AGAINST ELECTRIC SHOCK

The fundamental rule of protection against electric shock, is that "hazardous live parts must not be accessible and accessible conductive parts must not be hazardous live, neither under normal conditions nor under single fault conditions".

The protection under normal conditions is provided by basic protective provisions (Insulation/ Separation) and protection under single fault conditions is provided by fault protective provisions (Protective devices like MCB, MCCB, Fuse, RCCB, etc).

Protection against electric shock is provided by an enhanced protective provision (RCCB), which provides protection under normal conditions and under single fault conditions.

Different protective measures shall have no influence on each other i.e. failure of one protective measure should not impair the other protective measures.

In each part of an installation one or more protective measures shall be applied, taking into account of the conditions of external influence. The following protective measures are generally recommended against electric shock:

a) Automatic disconnection of supply
b) Double or reinforced insulation
c) Electrical separation for the supply of one item of current-using equipment
d) Extra Low Voltage (SELV and PELV)

Automatic disconnection of supply is the most commonly used protective measure in low voltage electrical installations.

1.1 PROTECTIVE MEASURES FOR AUTOMATIC DISCONNECTION OF SUPPLY

(Ref: para 4.2.11 of IS 732: 2019)

The basic protection under normal conditions is provided by **basic insulation of live parts** or by **barriers or enclosures**, which is intended to prevent **direct contact** (for details see para 8 of vol.1_Basics of LV Earthing System) with live parts.

Fault protection is provided by **protective equipotential bonding** (for details see para 7.1 of vol.1_Basics of LV Earthing System) and **automatic disconnection of supply** in case of a fault to prevent shock hazards **(indirect contact) (**for details see **-para 8.1 of vol.1**_Basics of LV Earthing System**).**

Where specified, additional protection is provided by a voltage independent Residual Current Protective Device (RCCB) in a.c. systems with a rated residual operating current not exceeding 30 mA. This will provide additional protection in the event of failure of the provision for basic protection and/or the provision for fault protection or carelessness by users.

System voltage independent RCCB not exceeding 30 mA shall be used for domestic and similar application.

Residual current monitors (RCMs) may also be used to monitor residual currents in electrical installations. RCMs produce an audible or audible & visual signal when a preselected value of residual current is exceeded to warn the user.

1.1.1 Requirements for fault protection
(Ref: para 4.2.11.3 of IS 732: 2019)

1.1.1.1 Protective Earthing and Protective Equipotential Bonding
(Ref: para 4.2.11.3.1 of IS 732: 2019)

1.1.1.1.1 Protective Earthing
(Ref: para 4.2.11.3.1.1 of IS 732: 2019)

Exposed conductive parts (refer para 7.6 of vol.1_Basics of LV Earthing System for more details) shall be connected to a protective (earth) conductor under the specific conditions for each type of system earthing (Refer volume-1_Basics of LV Earthing System para 6.0 for more details on system Earthing like TN {TN-S, TN-C, TN-C-S}, TT and IT).

Simultaneously accessible exposed conductive parts shall be connected to the same earthing system individually, in groups or collectively i.e. MET/Sub MET.

Conductors for protective earthing shall comply with para 5.4 of IS 732: 2019 and para 17 of IS 3043: 2018. Each circuit shall have a protective (earth) conductor and shall be connected to the relevant earthing terminal (i.e. MET/Sub MET).

1.1.1.1.1.1 Protective Earthing in TN system
(Ref: para 4.2.11.4 of IS 732: 2019)

In TN systems, the neutral point of the power supply system shall be earthed. If a neutral point is not available or not accessible, a line conductor shall be earthed. Exposed conductive parts of the installation shall be connected by a protective (earth) conductor to the main earthing terminal of the installation which shall be connected to the earthed point of the power supply system.

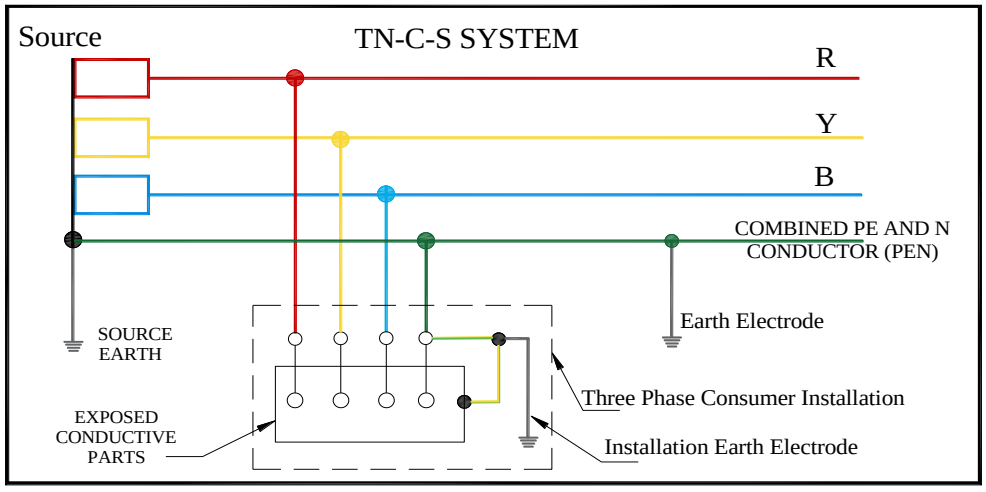


Figure 1: TN-C-S System

In TN systems the integrity of earthing of the installation depends on the reliable and effective connection of the source PEN (TN-C-S, TN-C) or PE (TN-S) conductors to earthing point/terminal of the installations.

In TN system with PME, earthing at additional points, distributed as evenly as possible will ensure that the potentials of protective conductors (earth wires) remain as near as possible to that of earth in case of a fault (snapping of Neutral). Protective conductors (earth wires) shall also be connected to other effective earth connections if exist in the installations i.e Earth Electrode or Concrete embedded Electrode.

Extraneous-conductive-parts shall not be used as PEN conductors.

In large buildings such as high – rise buildings, where additional earthing of protective conductors (earth wires) is not possible for practical reasons, **protective equipotential bonding** shall be done between protective conductors (earth wires) and extraneous-conductive-parts which has a similar function.

No switching or isolating device shall be inserted in the PEN conductor.

Source Protective conductor (PE and PEN) should be earthed where they enter any buildings or premises taking account of any diverted neutral currents.

In a fixed installation like TN-C-S, in incoming supply single conductor may serve both as a protective (earth) conductor and as a neutral conductor (PEN conductor) provided that the following requirements are satisfied:

- PEN conductor may only be used in fixed electrical installations **and shall have a cross-sectional area not less than 10 mm² copper or 16 mm² aluminium for mechanical strength** (Ref para 5.4.3.4.1 of IS 732 : 2019). The size mentioned above is for incoming service cable/Wires. **In case of armoured cable, this size recommendation does not apply**.

IS/IEC 60079-14 does not permit the use of a PEN conductor in explosive atmospheres.

- The PEN conductor shall be insulated for the rated voltage of the line conductor.
- **Metallic enclosures of wiring systems shall not be used as PEN** conductor, except for bus-bar trunking systems complying with IS 8623 (Part 2) and for power track systems complying with IEC 61534-1. (Ref para 5.4.3.4.2 of IS 732 : 2019).
- If, from any point of the installation, the neutral and protective functions are provided by separate conductors, Then neutral conductor shall not be **connected** to any other earthed part of the installation. (Ref para 5.4.3.4.3 of IS 732:2019).
- It is permitted to form more than one neutral conductor and more than one protective (earth) conductor from the PEN conductor respectively.
- The PEN conductor shall be connected to the terminal or bar intended for the purpose of protective conductors (earth wires) (**see figure-2 below),** unless there is a **specific terminal or bar intended for the connection of the PEN** conductor (examples are given in figure 3 and 4 below).

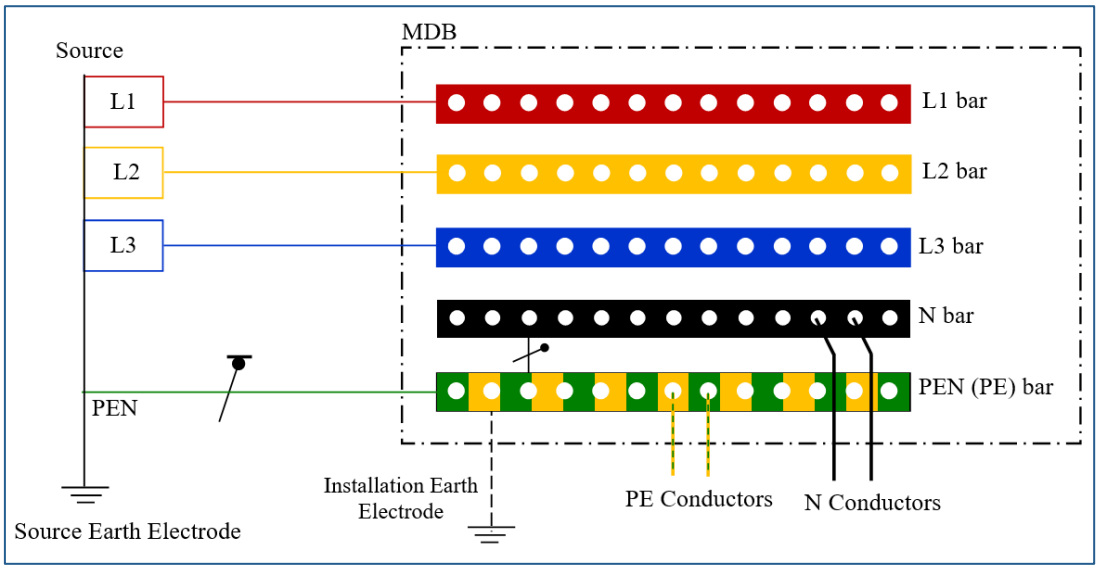


Figure 2: PEN terminated at MET

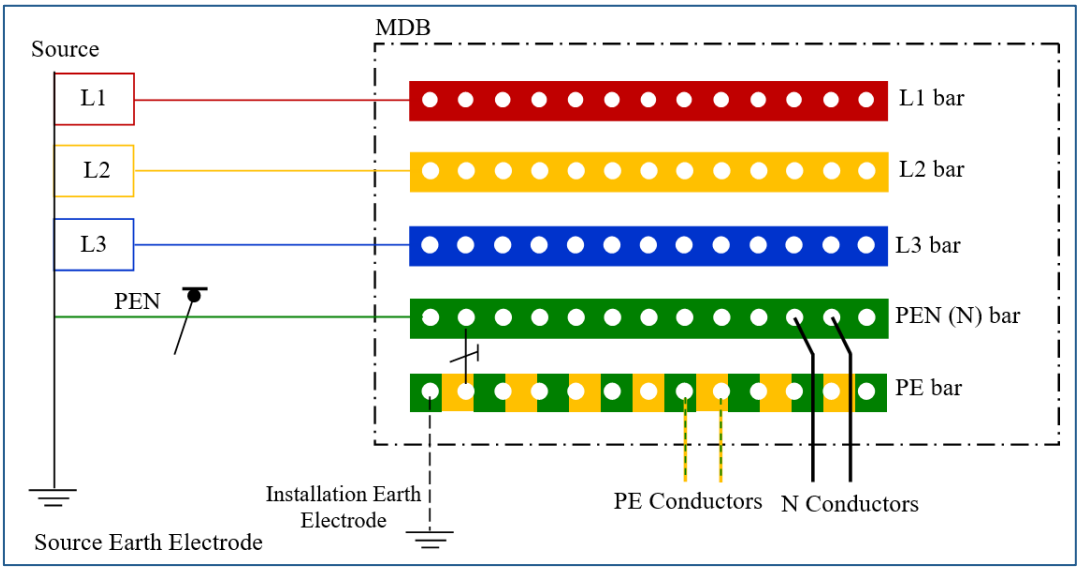


Figure 3: PEN terminated at N bar

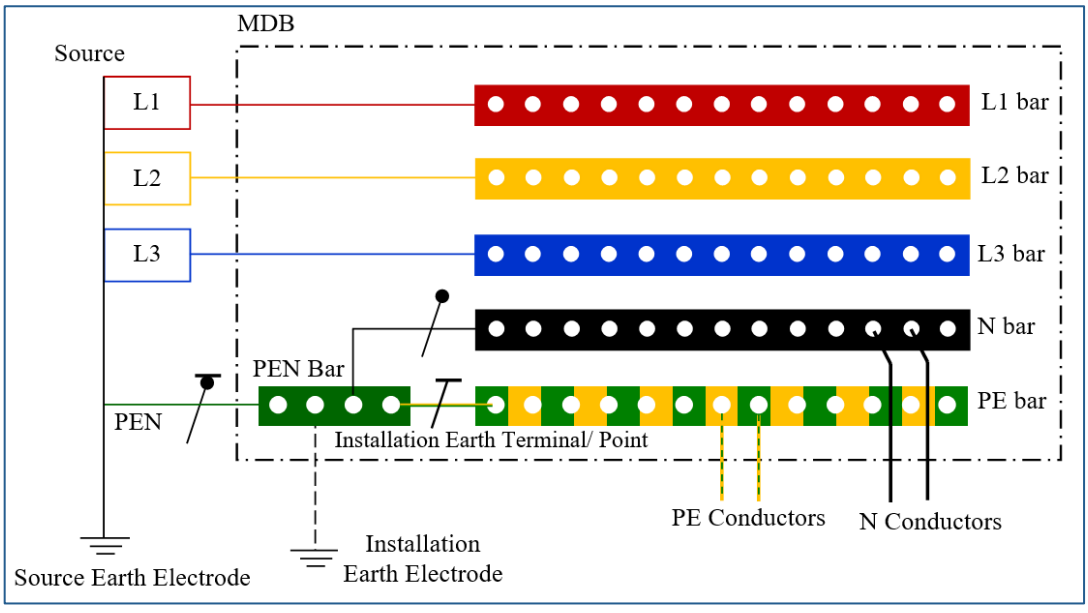


Figure 4: PEN terminated at separate PEN bar

All exposed & extraneous conductive parts of an installation are connected through protective (earth) conductors. All the protective conductors/connections run separately inside consumer's premises and connected to main earthing terminal (MET) and then to the PEN conductor.

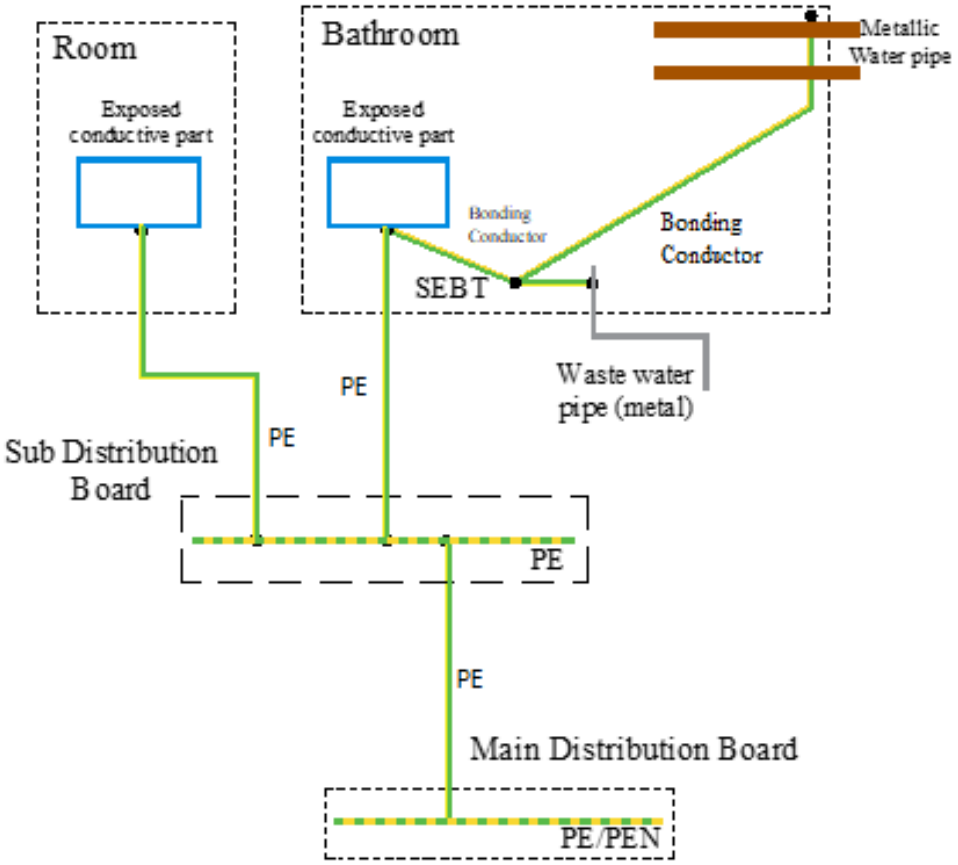


Figure 5: Connections of Exposed and extraneous conductive parts

1.1.1.1.1.2 Protective Earthing in TT system

(Ref: para 4.2.11.5 of IS 732: 2019)

TT system has one or more points of the source of energy directly earthed and the exposed and extraneous conductive parts of the installation are connected to a local earth electrode. Source and installation earth electrodes are electrically independent.

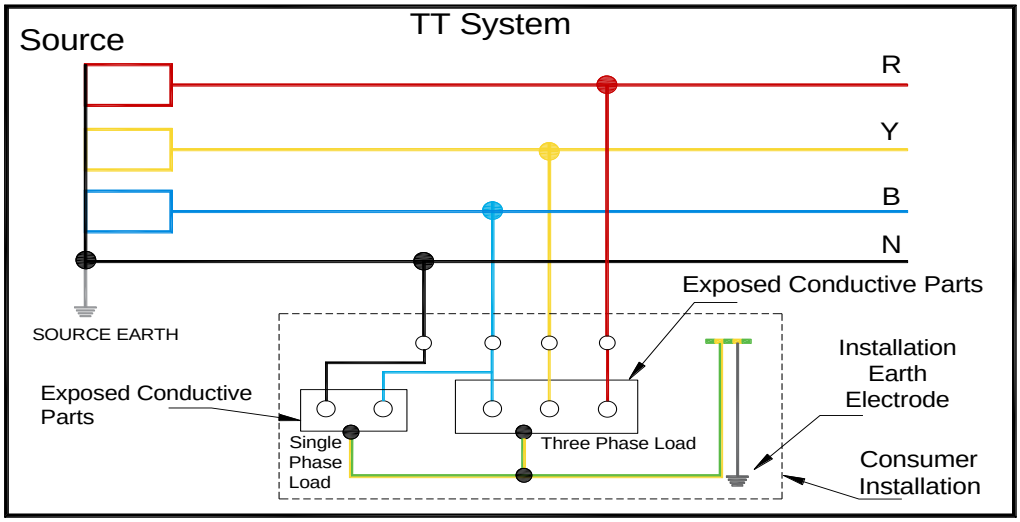


Figure 6: TT System

All exposed conductive parts collectively protected by the same protective device shall be connected by the protective conductors (earth wires) to an earth electrode common to all those parts. Where several protective devices are utilized in series, this requirement applies separately to all the exposed-conductive-parts protected by each device to an earth electrode common to all those parts.

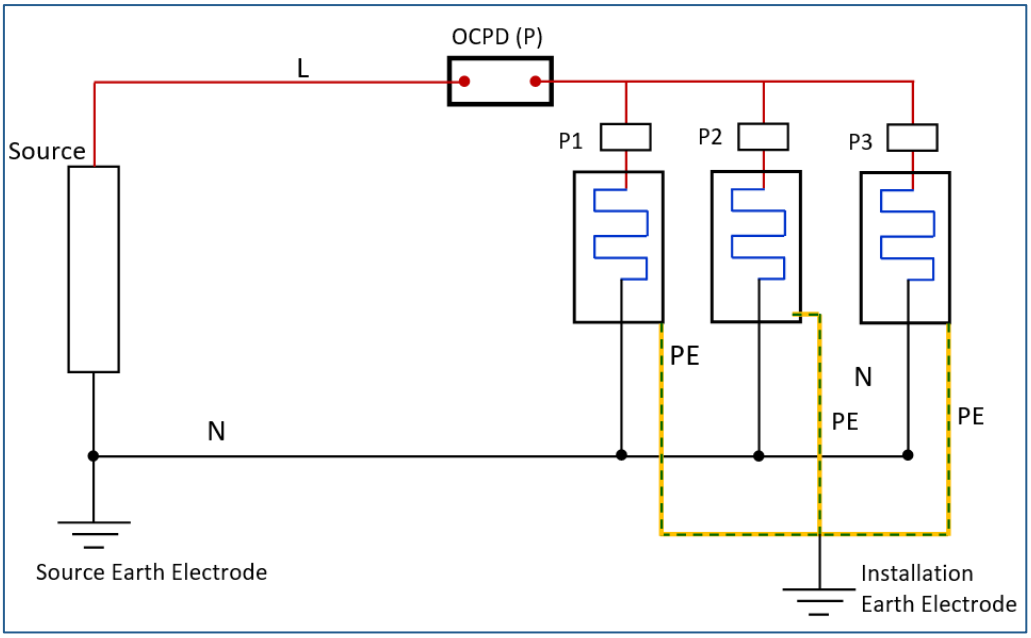


Figure 7: Series Protective scheme in TT System

1.1.1.1.1.3 Protective Earthing in IT system

(Ref: para 4.2.11.6 of IS 732: 2019)

IT system is used where continuity of supply is desired as safety services, fire services, medical (operation theatre, ICUs etc.). In this systems, live parts of the source (power supply system) shall be insulated from earth or connected to earth through a sufficiently high impedance. This connection may be made either at the neutral point of the system or at an artificial neutral point. The exposed conductive parts of the installation are connected to electrically independent earth electrodes. (For more details about **IT system** refer volume-1_Basics of LV Earthing System para 6.3.)

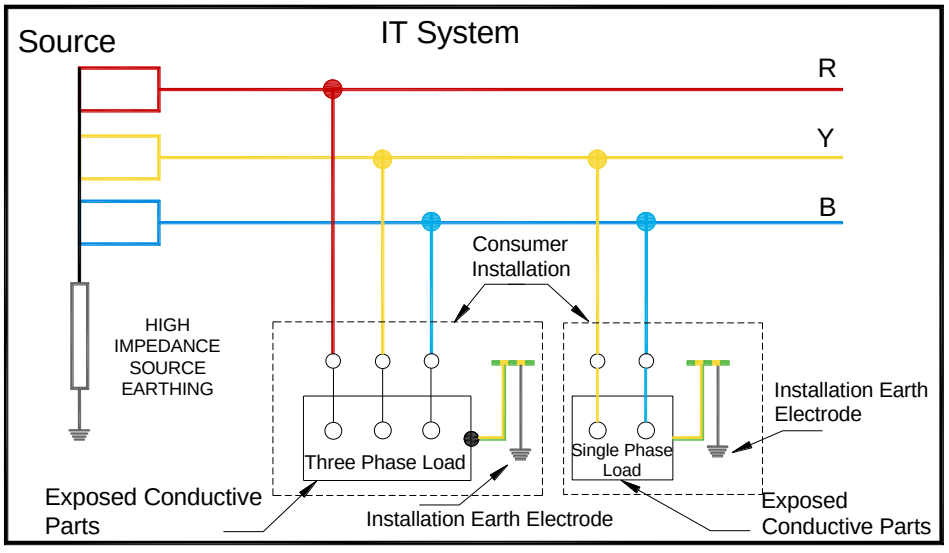


Figure 8: IT System

All exposed conductive parts of an installation are connected to an earth electrode though protective earth conductors via **MET (Main Earthing Terminal)**. Refer volume-1_Basics of LV Earthing System para 7.3.



Figure 9: Main Earthing Terminal (MET)

In IT system, when single fault with exposed conductive part or with earth, the fault current is low and therefore automatic disconnection is not achieved through protective device.

In case of IT system Residual Current Monitors (RCMs) or insulation monitoring relays may be used to monitor residual currents or insulation degradation in electrical installations. These devices produce an audible or audible & visual signal when a preselected value is exceeded to warn the users.

1.1.1.1.2 Protective Equipotential Bonding

(Ref: para 4.2.11.3.1.2 of IS 732: 2019)

In each building the all earthing conductors, main earthing terminal (MET) and the following conductive parts shall be connected to the protective equipotential bonding:

a. metallic pipes supplying services into the building, for example, gas, water;
b. structural extraneous conductive parts, if accessible in normal use, metallic central heating and air-conditioning systems;
c. and metallic reinforcements of constructional reinforced concrete, if reasonably practicable.

In every installation where protective equipotential bonding is used, a main earthing terminal shall be provided and the following shall be connected to it:

a. protective bonding conductors
b. earthing conductors
c. protective conductors
d. functional earthing conductors, if relevant.

It is not intended to connect every individual protective (earth) conductor directly to the main earthing terminal where they are connected to this terminal by other protective conductors. Where more than one earthing terminal is provided, they shall be interconnected.

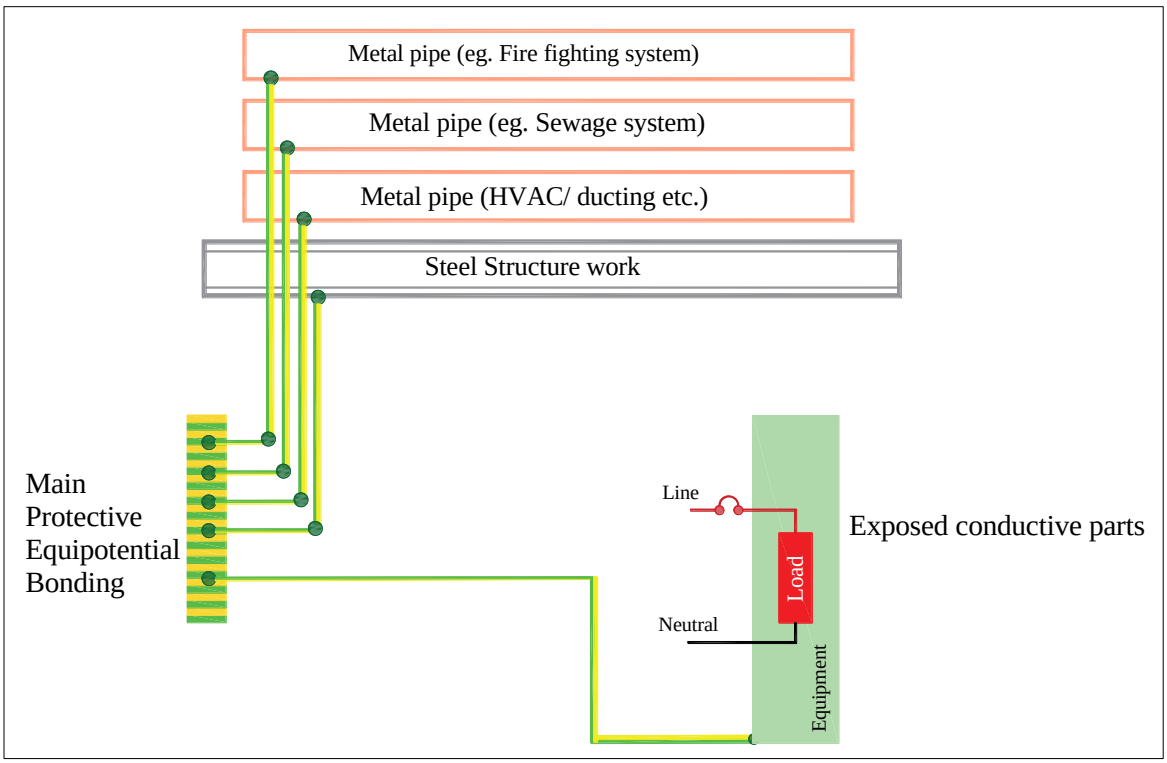


Figure 10: Equipotential Bonding with all exposed/extraneous conductive parts

Where such conductive parts originate outside the building, they shall be bonded as close as practicable to their point of entry within the building. Conductors for protective equipotential bonding shall comply with para 5.4 of IS 732:2019 and para 17 of IS 3043:2018.

1.1.1.2 Maximum Time for Automatic Disconnection in case of a Fault

(Ref para 4.2.11.3.2 of IS 732:2019)

A protective device shall automatically interrupt the supply of the line conductor in the circuit/equipment in event of a **fault of negligible impedance between the line conductor and an exposed conductive part or a protective (earth) conductor (**i.e. Earth wire in the circuit/equipment within the disconnection time as mentioned below:

i. The maximum disconnection time stated in Table below shall be applied **to final circuits** (Ref 4.2.11.3.2.2 of IS 732:2019).

Table 1: Maximum Disconnection Times

System	50 V < U_0 ≤ 120 V s		120 V < U_0 ≤ 230 V s		230 V < U_0 ≤ 400 V s		U_0 > 400 V s	
	a.c.	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.	d.c.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
TN	0.8	Note 1	0.4	5	0.2	0.4	0.1	0.1
TT	0.3	Note 1	0.2	0.4	0.07	0.2	0.04	0.1
Where in TT system the disconnection is achieved by an overcurrent protective device and the protective equipotential bonding is connected with all extraneous-conductive-parts within the installation, the maximum disconnection times applicable to TN systems may be used. U_0 is the nominal a.c. or d.c. line to earth voltage.								

Notes:

1. Disconnection may be required for reasons other than protection against electric shock.
2. Where disconnection is provided by an RCCB, see Note to 4.2.11.4.4, Note 4 to 4.2.11.5.3 and Note to 4.2.11.6.4 of IS 732:2019.

Explanation of table: For 230 V final circuit in TN & TT system the maximum disconnection time given for protective device to interrupt the supply during fault is 0.4 sec & 0.2 sec respectively.

ii. For distribution circuits in TN & TT systems, a disconnection time shall not exceed 5s & 1s respectively. (Ref 4.2.11.3.2.3, 4.2.11.3.2.4 of IS 732:2019)

If automatic disconnection according to above cannot be achieved in the time required by (i) or (ii) as appropriate, supplementary protective equipotential bonding shall be provided.

Supplementary protective equipotential bonding
(Ref: para 4.2.15.2 of IS 732:2019)

Supplementary protective bonding may involve the entire installation, a part of the installation, an item of apparatus, or a location.

Supplementary protective equipotential bonding shall include all simultaneously accessible exposed conductive parts of fixed equipment and extraneous conductive parts including where practicable the main metallic reinforcement of constructional reinforced concrete. The equipotential bonding system shall be connected to the protective conductors (earth wires) of all equipment including those of socket outlets.

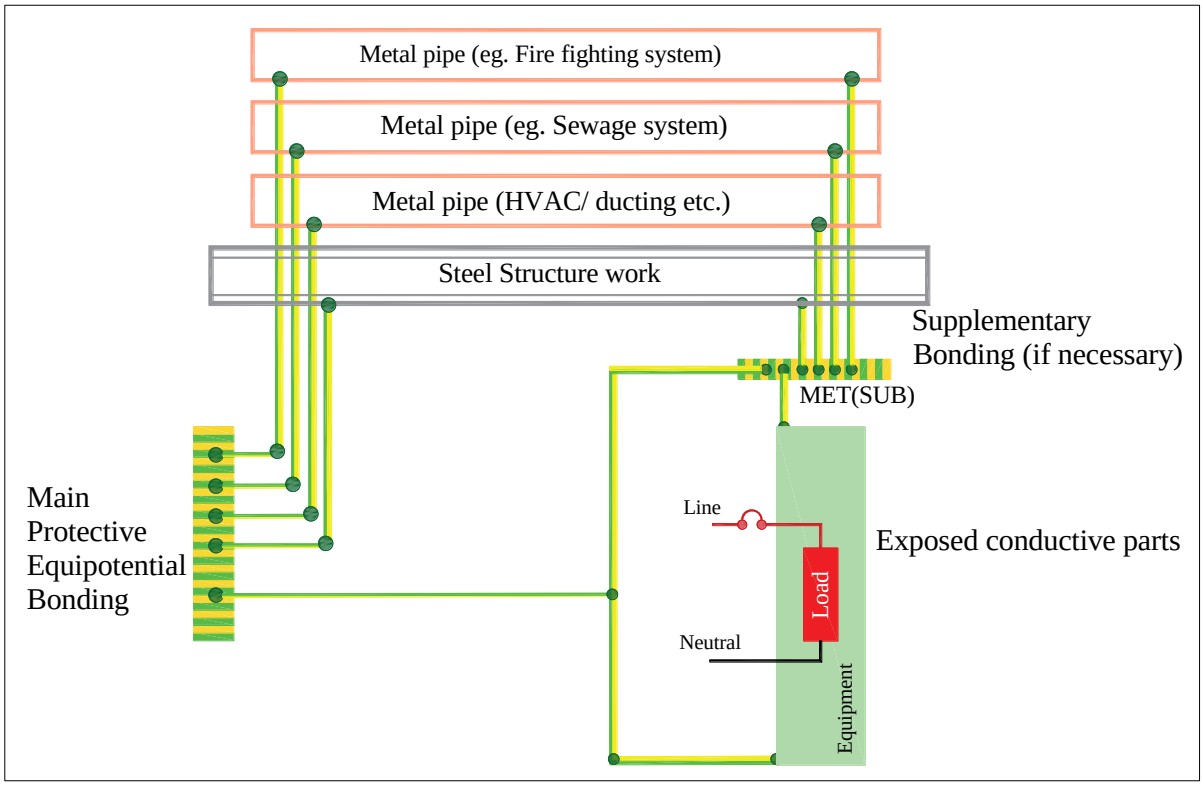


Figure 11: Supplementary protective equipotential bonding

1.1.1.3 Additional Protection Requirements

(Ref: para 4.2.11.3.3 and para 4.2.15.1 of IS 732: 2019)

System voltages independent Residual Current protective Device **(RCCB)** with a rated residual operating current **not exceeding 30 mA** shall be used in an AC system as an additional protection in the event of failure of the provision for basic protection and/or the provision for fault protection or carelessness by users. This will ensure safety of users from earth leakage. It shall be provided

a. **At the incoming supply of every sub-distribution board** having one or more outgoing circuits with fixed installation and socket-outlets. Ex. Domestic and similar applications
b. Mobile equipment ex Portable gen-set, and hand held equipment.

The use of such devices is only an additional protection and not recognized as a sole means of protection and does not obviate the need to apply one of the protective measures such as Automatic disconnection of supply, Double or reinforced insulation, Electrical separation for the supply of one item of current-using equipment and Extra Low Voltage (SELV and PELV).

For shock protection, RCCB not exceeding 30 mA shall be used as additional protection at the incomer of every sub-distribution board having one or more outgoing circuits with fixed installation and socket-outlets.

1.1.1.3.1 Additional Protection for TN System

(Ref para 4.2.11.4.5 of IS 732: 2019)

In TN systems, Over Current Protective Devices (OCPDs) devices shall be used for fault protection (protection against indirect contact) and for additional protection Residual Current Protective Devices (RCCBs) may be used.

A residual current protective device (RCCB) cannot be used in TN-C system as protective and neutral functions are provided by the single conductor inside the installation.

Where an RCCB is used in a TN-C-S system, PEN conductor shall not be used on the load side of RCCB. The connection of the protective (earth) conductor to the PEN conductor shall be made on the source side of the RCCB as shown below:

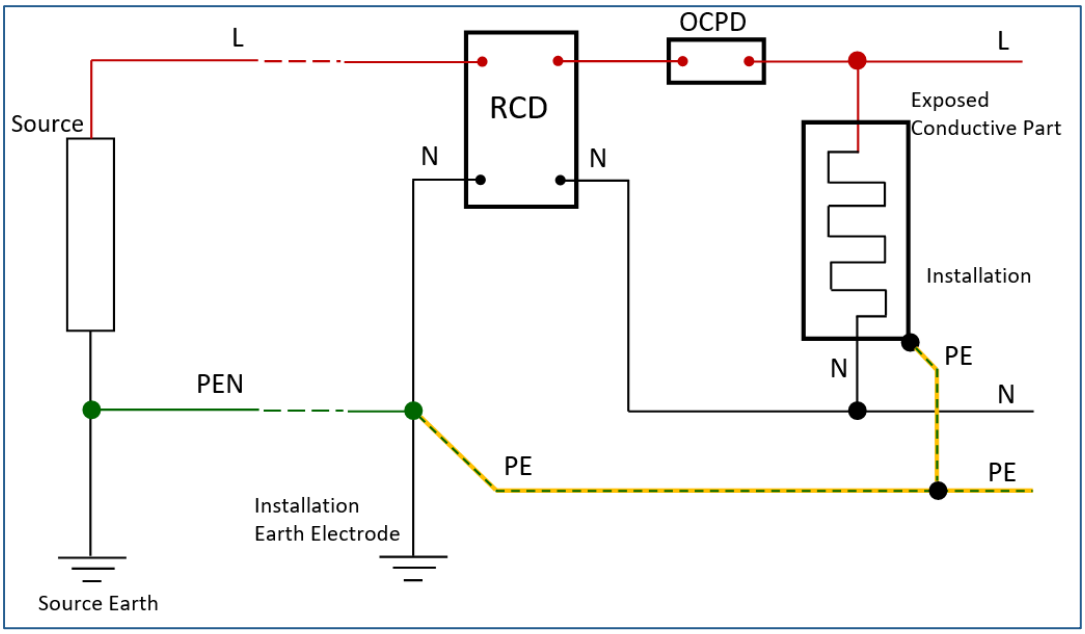


Figure 12: RCCB connection in TN-C-S System

Where an RCCB is used in a TN-S system, as the neutral and protective functions are performed by separate, the RCCB shall be connected as shown below:

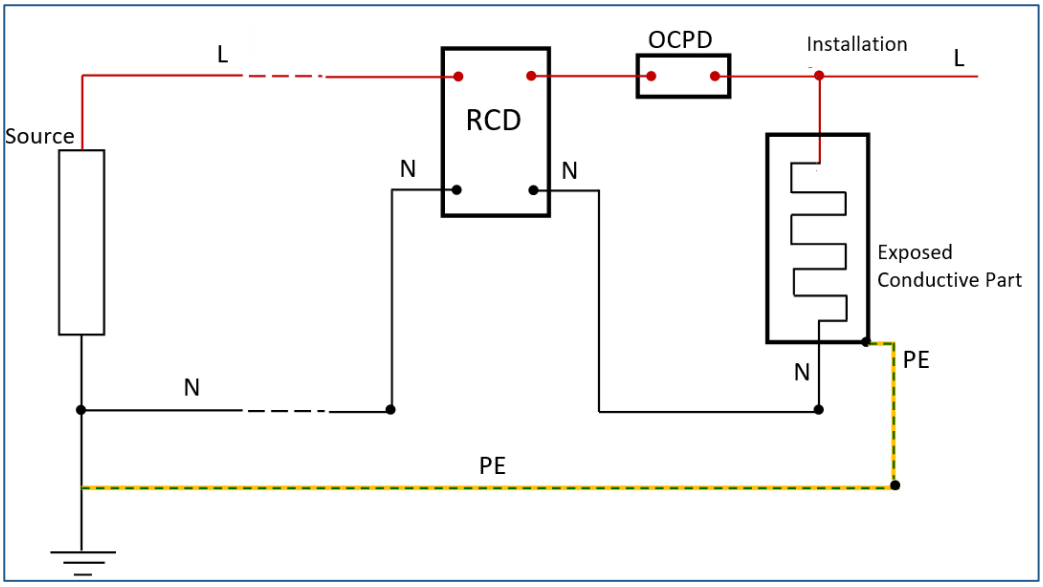


Figure 13: RCCB connection in TN-S System

1.1.1.3.2 Additional Mandatory Protection for TT System

(Ref para 4.2.11.5.2 and 4.2.11.5.3 of IS 732: 2019)

In TT systems, RCCB is mandatory for earth fault protection. Where an RCCB is used, the circuit should also be protected by an overcurrent protective device. Earth fault loop impedance is generally high enough in TT system and fault current will not be sufficient to operate the overcurrent protection device in case of earth faults and then RCCB will take care of earth faults.

In TT systems, RCCB is mandatory for earth fault protection in addition to over current protection.

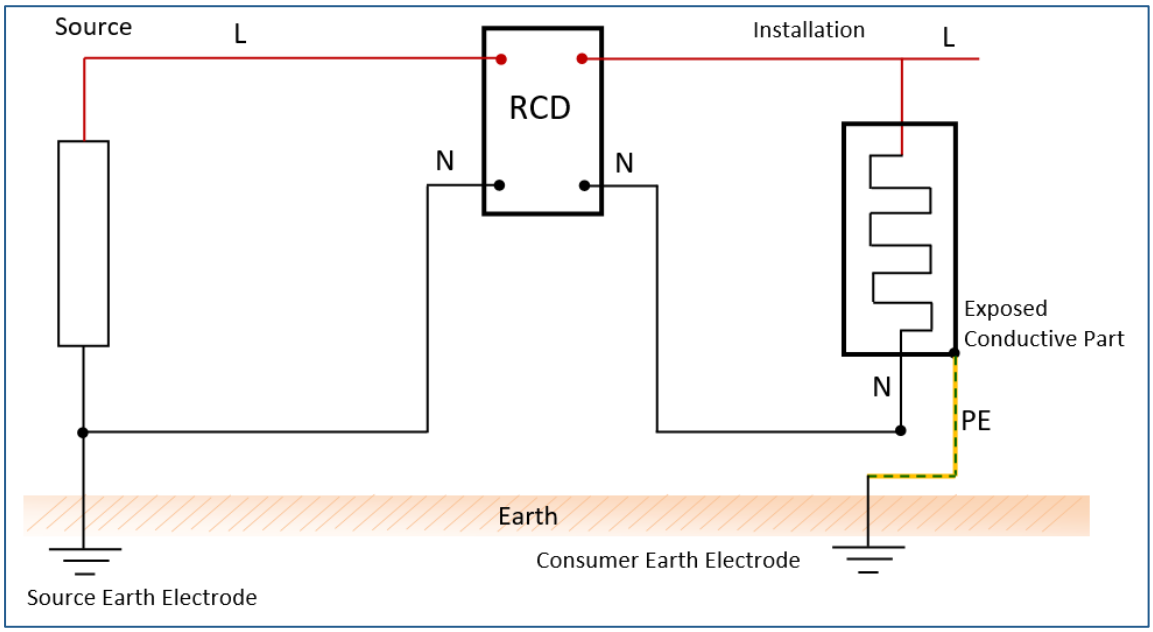


Figure 14: RCCB connection in TT System

As we can see from table-2 below (Ref table 14 of IS 3043; 2018), the earth electrode resistance may be as high as 1666 ohms if RCCB is provided.

Table 2: Maximum Earth Electrode Resistance for Different Types of Circuit Breakers

Type of Breaker	Operating Current (mA)	Maximum Earth Electrode Resistance (Ω)
RCCB	300	166
RCCB	30	1666
	--	500

Where an RCCB is used for fault protection, the following conditions shall be fulfilled:

a. the disconnection time as required by **1.1.1.2** mentioned earlier and
b. $R_A \times I_{\Delta n} \leq 50\,V$

where
R_A = the sum of the resistance (in Ω) of the earth electrode and the protective (earth) conductor for the exposed conductive-parts, and
$I_{\Delta n}$ = the rated residual operating current of the RCCB.

1.1.1.3.3 Protection for IT System

(Ref para 4.2.11.6.3 of IS 732: 2019)

In IT systems the following monitoring devices and protective devices may be used for protection.
a) insulation monitoring devices (IMDs)
b) residual current monitoring devices (RCMs)
c) Insulation fault location systems
d) overcurrent protective devices; and
e) residual current protective devices (RCCBs)

If 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. It is recommended that a first fault be eliminated with the shortest practicable delay.

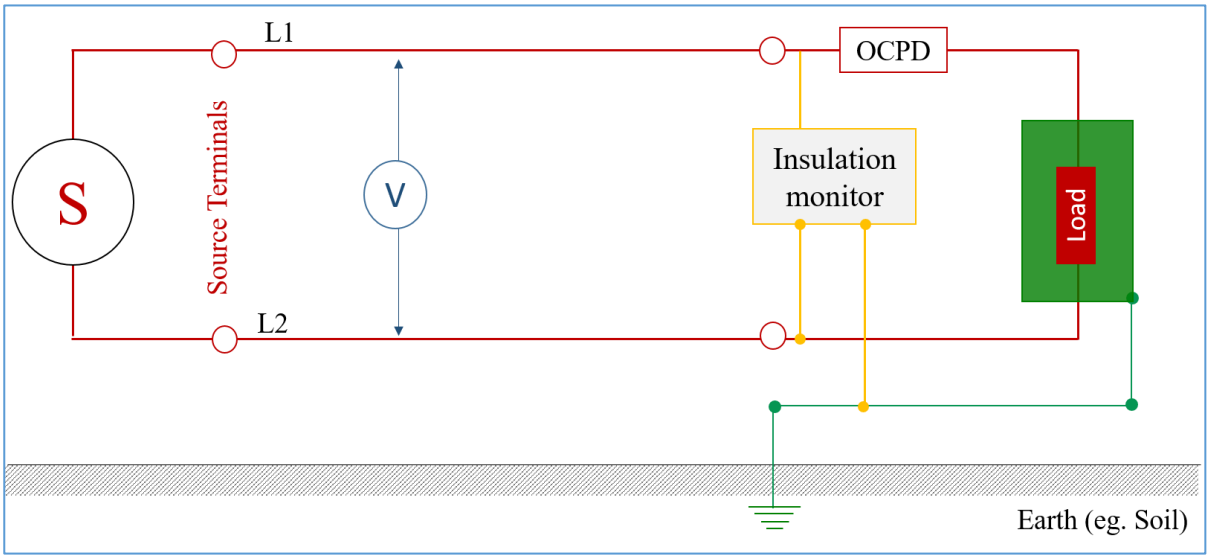


Figure 15: Insulation Monitor in IT system

Except where a protective device is installed to interrupt the supply in the event of the first earth fault, an RCM or an insulation fault location system may 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 visual signals it is permissible for the audible signal to be cancelled, but the visual alarm shall continue as long as the fault persists.



Figure 16: Residual current monitoring (RCM)



Figure 17: insulation monitoring devices (IMDs)

Where a residual current operating device (RCCB) is used in IT system, tripping of the RCCB in event of a first fault cannot be excluded due to capacitive leakage currents.

1.1.1.3.4 Discrimination between RCCBs (Residual Current protective Devices)

(Ref para 5.3.6.3 of IS 732: 2019)

- **Discrimination between RCCBs installed in series is required for service reasons**, to provide continuity of supply to the parts of the installation not involved in the fault.
- This discrimination can be achieved by selecting and erecting RCCBs which will be required for protection to the different parts of the installation and disconnect from the supply of only that part of the installation that is located on the load side of the RCCB installed on the supply side and closest to the fault.
- To ensure discrimination between two RCCBs in series, these devices shall satisfy both the following conditions:
  a. the non-actuating time-current characteristic of RCCB located on the supply side (upstream) shall be higher than the total operating time-current characteristic of the RCCB located on the load side (downstream).
  b. the rated residual operating current on the device located on the supply side shall be higher than that of the residual current protective device located on the load side.

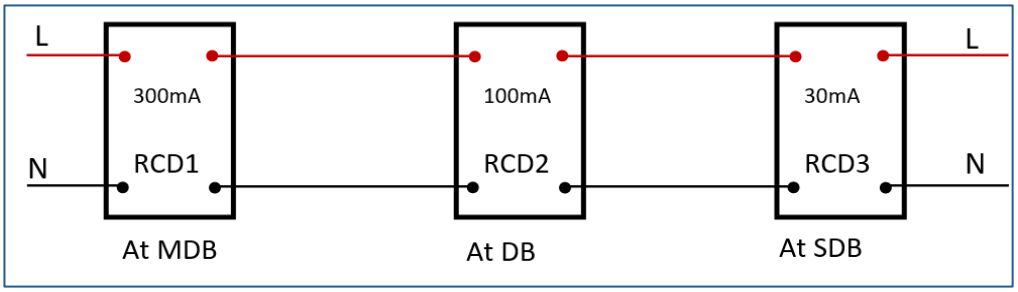


Figure 18: Discrimination between RCCBs

For Ensuring discrimination in operation of RCCBs, the rated residual operating current of the RCCB located on the supply side shall be at least three times that of the RCCB located on the load side.

1.2 PROTECTIVE MEASURE BY DOUBLE OR REINFORCED INSULATION

(Ref para 4.2.12 of IS 732: 2019)

i. Double or reinforced insulation is a protective measure intended to prevent the appearance of dangerous voltage on the accessible parts of electrical equipment in the event of failure of basic insulation. In this protective measure:
   a. Basic protection is provided by basic insulation, and fault protection is provided by supplementary insulation, or
   b. Basic and fault protection is provided by reinforced insulation between live parts and accessible parts.

ii. Where this protective measure is to be used as the sole protective measure (that is, where a whole installation or circuit is intended to consist entirely of equipment with double insulation or reinforced insulation), it shall be verified that the installation or circuit concerned will be under effective supervision in normal use so that no change is made that would impair the effectiveness of the protective measure.

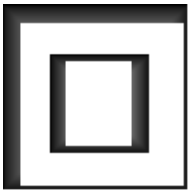
iii. This protective measure shall not be solely applied to any circuit that includes a socket-outlet or where a user may change items of equipment without authorization.

1.2.1 Requirements for basic protection and fault protection
(Ref para 4.2.12.2 of IS 732: 2019)

1.2.1.1 Requirement in Electrical equipment
(Ref para 4.2.12.2.1 of IS 732: 2019)

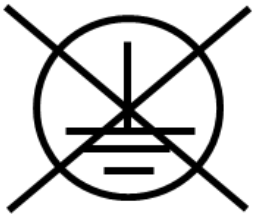
Where the protective measure, using double or reinforced insulation, is used for the complete installation or part of the installation, electrical equipment shall comply with one of the following:

i. Electrical equipment shall be Class II equipment having double or reinforced insulation, or equipment declared in the relevant product standard as equivalent to Class II. This type of equipment is identified by the symbol shown below. For more details of classes of equipment, refer volume-1_Basics of LV Earthing System, Annexure-1 item no. 3 to 6.



ii. Electrical equipment **having only basic insulation** shall be provided with supplementary insulation (like insulating enclosures) during the process of erecting electrical installation, provided a degree of safety equivalent to class II equipment and complying with para **1.2.1.2 below**.

iii. Electrical equipment **having uninsulated live parts** shall be applied with reinforced insulation during the process of erecting the electrical installation, provided a degree of safety equivalent to class II equipment and complying with para **1.2.1.2 below**. Such insulation being recognized only where constructional features prevent the application of double insulation.



NOTE for para ii & iii - This Equipment supplementary enclosures shall not be connected to protective earth and symbol shown below should be fixed in a visible position on the exterior and interior of the enclosure.

1.2.1.2 Enclosures for Electrical equipment
(Ref para 4.2.12.2.2 of IS 732: 2019)

The electrical equipment being ready for operation, all conductive parts separated from live parts by basic insulation only, shall be contained in an **insulating enclosure** with at least the degree of protection IP2X or IPXXB. For more details on IP (International Protection) code, refer annexure-3.

IP2X: This is the IP code necessary to prevent access to hazardous parts **with fingers** and protects the equipment inside the enclosure against ingress of solid foreign objects having a diameter of **12.5 mm and greater.** There is no water ingress protection.

IPXXB : This means protection against ingress of solid foreign objects and water is not required and access to hazardous parts is protected for incidental contact with fingers.

- The insulating enclosure shall not be move by conductive parts likely to transmit a potential.
- The insulating enclosure shall not contain **any screws or other fixing means of insulating material** which may be removed, during installation or maintenance and whose replacement by **metallic screws** or other fixing means could impair the enclosure's insulation property.

- Where the insulating enclosure must be moved by mechanical joints or connections (for example, for operating handles of built-in apparatus), these should be arranged in such a way that protection against shock in case of a fault is not impaired.
- Where lids or doors in the insulating enclosure can be opened without the use of a tool or key, all conductive parts, which are accessible if the lid or door is open, shall be behind an insulating barrier (providing a degree of protection not less than IPXXB or IP2X) preventing persons from coming unintentionally into contact with those conductive parts. This insulating barrier shall be removable only by use of a tool or key.

Conductive parts enclosed in the insulating enclosure shall not be connected to a protective (earth) conductor unless specific provision for this is made in the specifications for the equipment concerned. However, provision may be made for connecting protective (earth) conductor which necessarily run through the enclosure in order to serve other items of electrical equipment whose supply circuit also runs through the enclosure. Inside the enclosure, any such protective conductors and their terminals shall be insulated as though they were live parts, and their terminals shall be marked as **PE terminals**.

1.2.1.3 Installation of Electrical Equipment

(Ref para 4.2.12.2.3 of IS 732: 2019)

The installation of equipment mentioned in para **1.2.1.1** (fixing, connection of conductors, etc.) shall be done in such a way so as to maintain the protection available with equipment as per the equipment specification.

Except where **1.2 (ii)** applies, a circuit supplying items of Class II equipment shall have a circuit protective (earth) conductor run to and terminated at each point in wiring and at each accessory. So that if in future the replacement of Class II equipment by Class I equipment is done by the user the connection of earth wire can be done with Class I equipment.

1.2.1.4 Wiring systems for protection of double or reinforced insulation

(Ref para 4.2.12.2.4 of IS 732: 2019)

Wiring systems installed in accordance with para 5.2 of IS 732:2019 are considered to meet the requirements of **1.2.1** if:

a. the rated voltage of the wiring system shall be not less than the nominal voltage of the system and should be at least 300/500 V.

b. adequate mechanical protection of the basic insulation is provided by one or more of the following:

   i. the **non-metallic sheath** of the cable, or

   ii. **non-metallic trunking or ducting** complying with IS 14297 (Part 1) and IS 14927 (Part 2/Section 1), or non-metallic conduit complying with either IS 9537 or the IS 14930 (Parts 1 and 2).

1.3 PROTECTIVE MEASURE BY ELECTRICAL SEPARATION

(Ref para 4.2.13 of IS 732: 2019)

Electrical separation is a protective measure in which,

a. **basic protection** is provided by **basic insulation of live parts** or by **barriers and enclosures** in accordance with below paras **1.3.1.1 and 1.3.1.2** respectively, and

b. fault protection is provided by simple separation of the **separated circuit** from **other circuits and from earth.**

This protective measure shall be limited to the supply of one current-using equipment supplied from one **unearthed source** with simple separation except as permitted by **1.3.2** (**for more than one item of current-using equipment**).

1.3.1 Provisions for Basic Protection

(Ref para Annex 'A' of IS 732: 2019)

Provision for basic protection provides protection from shock under normal conditions and these are applied where specified as a part of the chosen protective measure. All electrical equipment under this category shall be provided with one of the basic protective provisions given below or the protective measure given in **1.2** mentioned earlier.

1.3.1.1 Protection by Basic Insulation of Live Parts

The basic insulation is intended to prevent contact with live parts.

- Live parts shall be completely covered with insulation which can only be removed by destruction.
- For equipment, the insulation provided shall comply with the relevant standard for the electrical equipment.

1.3.1.2 Protection by Barriers or Enclosures

Barriers or enclosures are intended to prevent contact with live parts.

- **Live parts shall be inside enclosures or behind barriers providing at least the degree of protection IPXXB or IP2X** except that, where larger openings occur during the replacement of parts, such as certain lamp holders or fuses, or where larger openings are necessary to allow the proper functioning of equipment according to the relevant requirements for the equipment:
  a. suitable precautions shall be taken to prevent persons or livestock from unintentionally touching live parts.
  b. it shall be ensured, as far as practicable, that persons will be aware that live parts can be touched through the opening and should not be touched intentionally; and
  c. the opening shall be as small as is consistent with the requirement for proper functioning and for replacement of a part.
- Horizontal top surfaces of barriers or enclosures which are readily accessible shall provide a degree of protection of at least IPXXD or IP4X. For more details on IP (International Protection) code, refer annexure-3.

IP4X: This is the IP code necessary to prevent access to hazardous parts **with wire** and protects the equipment inside the enclosure against ingress of solid foreign objects having a diameter of **1.0 mm and greater**.

IPXXD: This means protection against ingress of solid foreign objects and water is not required and access to hazardous parts is protected for incidental contact with wire.

- Barriers and enclosures shall be firmly secured in place and have sufficient stability and durability to maintain the required degrees of protection and appropriate separation from live parts in the known conditions of normal service, taking account of relevant external influences.
- Where it is necessary to remove barriers or open enclosures or to remove parts of enclosures, this shall be possible only;
  a. by the use of a key or tool, or
  b. after disconnection of the supply to live parts against which the barriers or enclosures afford protection, restoration of the supply being possible only after replacement or re-closure of the barriers or enclosures, or
  c. where an intermediate barrier providing a degree of protection of at least **IPXXB** or **IP2X** prevents contact with live parts, by the use of a key or tool to remove the intermediate barrier.
- If, behind a barrier or in an enclosure, equipment are installed which may retain dangerous electrical charges after they have been switched off (**capacitors,** etc.), a **warning label** is required. Small capacitors such as those used for arc extinction, for delaying the response of relays, etc. shall not be considered dangerous.

  NOTE — Unintentional contact is not considered dangerous if the voltage resulting from static charges fall below 120 V d.c. in less than 5 s after disconnection from the power supply.

1.3.2 Requirements for Fault Protection

(Ref para 4.2.13.3 of IS 732: 2019)

Fault Protection by electrical separation shall be ensured by compliance with following:

i. The separated circuit shall be supplied through a source with at least simple separation, and the voltage of the separated circuit shall not exceed **500 V.**

ii. Live parts of the separated circuit **shall not be connected at any point to another circuit or to earth or to a protective** (earth) **conductor.** To ensure electrical separation, arrangements shall be such that basic insulation is achieved between circuits.

iii. Flexible cables and cords shall be visible throughout any part of their length liable to mechanical damage.

iv. For **separated circuits the use of separate wiring systems is recommended**. If separated circuits and other circuits are in the same wiring system, multi conductor cables without metallic covering, insulated conductors in insulating conduit, insulated ducting or insulated trunking shall be used, provided that:
  a. the rated voltage is not less than the highest nominal voltage, and
  b. each circuit is protected against overcurrent.

v. The **exposed conductive parts of the separated circuit shall not be connected either to the protective** (earth) **conductor or exposed conductive parts of other circuits, or to earth**.

NOTE — If the exposed-conductive-parts of the separated circuit are liable to come into contact, either intentionally or fortuitously, with the exposed-conductive-parts of other circuits, protection against electric shock no longer depends solely on protection by electrical separation but on the protective provisions to which the latter exposed-conductive-parts are subject.

1.4 PROTECTIVE MEASURE: EXTRA-LOW-VOLTAGE PROVIDED BY SELV AND PELV

(Ref para 4.2.14 of IS 732: 2019)

Protection by extra-low-voltage is a protective measure which consists of either of two different extra-low-voltage systems:

– SELV (Separated Extra Low-Voltage); or

– PELV (Protective Extra Low-Voltage)

This protective measure requires:

a. limitation of voltage in the SELV or PELV system to the upper limit of Voltage Band-1 i.e. **50 V a.c. or 120 V d.c**.

b. protective separation of the SELV or PELV system from all circuits other than SELV and PELV circuits,

c. basic insulation between the SELV or PELV system and other SELV or PELV systems; and

d. for SELV systems only, basic insulation between the SELV system and earth.

CHAPTER 2

PROTECTION TO LIMIT PROPAGATION OF FIRE AND PROTECTION AGAINST THERMAL EFFECTS

2.1 PROTECTION AGAINST THERMAL EFFECTS

(Ref: para 4.3 of IS 732: 2019)

2.1.1 Protection Against Fire Caused by Electrical Equipment

(Ref: para 4.3.1 of IS 732: 2019)

Requirements:

i. 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.

ii. Electrical equipment shall not present a fire hazard to adjacent materials. The heat generated by electrical equipment shall not cause danger or harmful effects to the adjacent fixed material or to material which may be in proximity to such equipment in future.

Following effects may cause damage, injury or ignition:

- heat accumulation, heat radiation, hot elements,
- Failure of the safe functions of electrical equipment, e.g. protective devices such as protective switchgear, thermostats, temperature limiters, seals of cable penetrations and wiring systems may lead to overheat generation
- over current in a circuit leading to excess heat generation,
- insulation faults and/or arcs causing interference,
- harmonic currents leading to excess heat generation,
- lightning strikes
- over voltages
- inappropriate selection or erection of equipment.

Following instructions shall be followed in addition to relevant manufacturer's erection instructions in electrical Equipment:

i. Where **fixed electrical equipment which may attain surface temperatures** which could cause a fire hazard to adjacent materials, the following points to be ensured.

   a. The equipment should be mounted on or within materials of low thermal conductance so that it can withstand such temperatures or

   b. The Equipment should be protected by a screen from elements of building construction by materials of low thermal conductance so that it can withstand such temperatures or

   c. The Equipment should be **mounted so as to allow safe dissipation of heat** at a sufficient distance from any material on which such temperatures could have deleterious thermal effects, any means of support being of low thermal conductance.

ii. Where **arcs or sparks may be emitted** by permanently connected equipment in normal service, the equipment shall either:

a. be totally enclosed in arc-resistant material, or

b. be screened by arc-resistant material from nearby materials on which the emission could have harmful effects, or

c. be mounted so as to allow safe extinction of the emissions at a sufficient distance from nearby material upon which the emissions could have harmful effects.

Arc-resistant material used for this protective measure shall be non-ignitable, of low thermal conductivity, and of adequate thickness to provide mechanical stability. For example, a sheet made of fibre glass silicone of 20 mm thickness may be considered as arc-resistant.

iii Fixed equipment **causing a concentration of heat** shall be at a sufficient distance from any fixed object or building element so that the object or element, in normal conditions, is not subjected to a dangerous temperature. For example, a temperature in excess of its ignition temperature. Any information from the manufacturer of the equipment should be taken into account.

iv. Where electrical equipment in a single location **contains flammable liquid** in significant quantity (quantity > 25 Lts), adequate precautions shall be taken to prevent the spread of liquid, flame and the products of combustion (Flame, smoke & gas).

- Examples of such precautions include:
  a. a retention pit to collect any leakage of liquid and ensure extinction in the event of fire; Example: Pit around power Transformer for oil drainage, Tray in bottom of oil cooled compressor.
  b. installation of the equipment in a chamber of adequate fire resistance and the provision of sills or other means of preventing liquid spreading to other parts of the building, such a chamber being ventilated solely to the external atmosphere.
- It is desirable to switch off the supply at the onset of a fire.

v. The materials of enclosures installed around electrical equipment during erection shall withstand the highest temperature likely to be produced by the electrical equipment.

2.1.2 Precautions where Particular Risks of Fire Exist

(Ref: para 4.3.2 of IS 732: 2019)

- Electrical equipment shall not be provided in such locations except wiring system passing (no bare conductor) through these locations provided they have no connection along the route inside these locations and shall be protected against overcurrent. If any connection is necessary, that shall be placed in fire resistant enclosures.
- In case of Electrical equipment is required to be provided it shall be so selected and erected that its temperature in normal use and foreseeable temperature rise during a fault cannot cause a fire. These arrangements may be effected by the construction of equipment or its conditions of installation. Thermal cut-out devices shall have manual resetting only.

2.1.2.1 Conditions of evacuation in an emergency:

(Ref: para 4.3.2.2 of IS 732: 2019)

Engineering department in railways responsible for building construction, public gatherings, fire prevention, etc. may specify which BD condition is applicable. Buildings are classified according to conditions of evacuation in an emergency as BD1 to 4, refer Annexure-2, table-1 for more details.

Except BD1 for BD2 to BD4, following requirements shall be fulfilled:

- Wiring systems shall not encroach on escape routes unless the wiring in the wiring system is provided with sheaths or enclosures.
- Wiring systems encroaching on escape routes shall not be **within arm's reach** unless they are provided with protection against mechanical damage likely to occur during an evacuation.
- Wiring systems in escape routes shall be as short as practicable and shall **be non-flame propagating.** Compliance with this requirement may be achieved by using the following products:
  a. Cables fulfilling tests under fire conditions of IEC 60332- 1-2, and appropriate fire conditions as per IEC 60332-3-21, 22, 23, 24 and 25;
  b. Conduit systems classified as non-flame propagating according to IS 14930 (Parts 1 & 2);
  c. Cable trunking systems classified as non-flame propagating according to IS 14297 (Part 1) and IS 14927 (Part 2/ Section 1);
  d. Cable tray systems and cable ladder systems classified as non-flame propagating according to IEC 61537; and
  e. For power-track systems: the IEC 61534 series.
- Wiring systems that are **supplying safety circuits** shall have a **resistance to fire rating** of either the time authorized by regulations for building elements or **1 hr** in the absence of such a regulation.

  Wiring within escape routes shall have a limited rate of smoke production (Ex. FRLS wires).
- Switchgear and control gear devices, except certain devices to facilitate evacuation, shall be accessible only to authorized persons. If they are placed in passages, they shall be **enclosed in cabinets or boxes constructed of non-combustible or not readily combustible material**. This clause does not prohibit plastic enclosures that are not readily combustible.

  In conditions **BD3 and BD4** and in escape routes, electrical equipment containing **flammable liquids** shall not be installed.

2.1.2.2 Locations with Risks of Fire due to the Nature of Processed or Stored Materials

(Ref: para 4.3.2.3 **and 4.3.2.4** of IS 732: 2019)

Locations with risks of fire due to the nature of processed or stored materials are classified as **BE2** for more details refer Annexure-2, table 2.

In conditions BE2 following requirements shall be fulfilled:

- Light fitting shall be kept at an adequate distance from combustible materials. If no other information is given by manufacturers, spotlights and projectors shall be installed at the following minimum distances (in all directions) from combustible materials:

S.N.	Luminaires (Watt)	Minimum distances from combustible materials (m)
a.	100 W	0.5 m
b.	100 W to 300 W	0.8 m
c.	300 W to 500 W	1.0 m
d.	above 500 W	Greater distances can be necessary

- Lamps and other components of luminaires shall be protected against **foreseeable mechanical stresses.** Such protective means shall not be fixed on lamp holders unless they form an integral part of the luminaire. Modifications to luminaires are not acceptable.
- A luminaire with a lamp that could **eject flammable materials** in case of failure shall be installed with a safety **protective shield** for the lamp in accordance with the manufacturer's instructions.
- Luminaires suitable for **direct mounting** on normally **flammable surfaces** were earlier marked with the symbol  according to IS 10322. With the publication of IEC 60598-1 : 2008, luminaires suitable for direct mounting have no special marking and only **luminaires not suitable for mounting on normally flammable surfaces** are marked with symbols:  and/or  .
- Measures shall be taken to **prevent an electrical enclosure of equipment such as a heater or resistor** from exceeding the following temperatures.

  a) 90 °C under normal conditions, and

  b) 115 °C under fault conditions.

  Where materials such as dust or fibres sufficient to cause a fire hazard could accumulate on an enclosure of electrical equipment, adequate measures shall be taken to prevent that enclosure from exceeding the temperatures stated above.
- **Switchgear for protection, control and isolation** shall be placed **outside these locations** unless it is in an enclosure providing a degree of protection appropriate for such a location of at least IP4X or, in the presence of dust, IP5X or, in the presence of conductive dust, IP6X, except where circuits are supplied at SELV or PELV applies.
- Except where wiring and wiring systems are **embedded in non-combustible material**, then only non-**flame propagating wiring** systems shall be used. As a minimum, equipment shall be selected in accordance with the following requirements:

  a. Cables shall satisfy the test under fire conditions specified in the IEC 60332 series. Where the risk of flame propagation is high, e.g. in long vertical runs of bunched cables, cables should meet the flame propagation characteristics of the appropriate part in the IEC 60332-3 series.

  b. Conduit systems shall satisfy the test for resistance to flame propagation specified in IS 14930 (Parts 1 and 2);

  c. Cable trunking systems and cable ducting systems shall satisfy the test for resistance to flame propagation specified in IS 14297 (Part 1) and IS 14297 (Part 2/Section 1);

  d. Cable tray systems and cable ladder systems shall satisfy the test for resistance to flame propagation specified in IEC 61537 series; and

  e. Power track systems shall satisfy the test for resistance to flame propagation specified in IEC 61534 series.

- Wiring systems which passes through these locations (BE2), but are not necessary for the use of the locations, shall satisfy the following conditions:

  a. they have no connection along the route inside the locations (BE2), unless these connections are placed in fire-resistant enclosures;

  b. they are protected against overcurrent (overload or short circuit) by protective devices located at outside and on the supply side of these locations

  c. Circuits originating inside these locations, shall be protected against overcurrent (overload or short circuit) by protective devices located at their origin and

d. bare conductors shall not be used.

- In locations where combustible dust may be present, air intake for forced-air heating shall be from outside locations. The temperature of the outgoing air shall not be such as to cause fire in the location.
- Motors which are automatically or remotely controlled, or which are not continuously supervised, shall be protected against **excessive temperature rise by temperature responsive devices,** unless specifically designed to be inherently heat-limiting.
- Every luminaire shall:

  a. be appropriate for the location;

  b. be provided with an enclosure providing a degree of protection of at least IP4X or, in the presence of dust, IP5X or, in the presence of conductive dust, IP6X;

  c. have a limited surface temperature in accordance with IEC **60598-2-24**; and

  d. be of a type that prevents lamp components from falling from the luminaire.

  In locations where there may be fire hazards due to dust or fibres, luminaires shall be installed so that dust or fibres cannot accumulate in dangerous amounts. Luminaires should also comply with relevant parts of the IEC 60598 series.

- **Final circuits and current-using equipment shall be protected against insulation faults as follows:**

  a. In TN and TT systems, RCCBs with a rated residual operating **current $I_{\Delta n}$ 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. Alternatively, RCCBs with a rated residual operating current as specified in (a) may be used. In the event of a second fault, **see para 2.1** above for disconnection times.

  a) Mineral insulated cables and bus bar trunking systems are not considered likely to cause a fire from insulation faults and therefore need not be protected. Cables with metallic coverings are recommended. The metallic covering should be connected to the protective (earth) conductor.

- Circuits supplying BE2 locations, shall be protected against overload and short-circuit by protective devices located outside and on the supply side of these locations. Circuits originating inside the locations shall be protected against overcurrent by protective devices located at their origin.
- PEN conductors are not allowed in BE2 locations, except for circuits passing through such locations and having no connection between their passing PEN conductor and any conductive part in the locations.

  Every circuit supplying equipment in BE2 locations shall be provided with a means of isolation from all live supply conductors such that no live supply conductor can remain closed when one or more others are open. This may be achieved, for example, by a mechanically linked switch/circuit-breaker.

2.1.2.3 Fire propagating structures (CB2)

(Ref: para 4.3.2.5 of IS 732: 2019)

- In CB2 structures where the shape and dimensions facilitate the spread of fire, precautions shall be taken to ensure that the electrical installation cannot propagate a fire (for example, chimney effect).
- Buildings are classified according to Building design as CB1 to 4. For more details, refer Annexure-2, table-4.

2.1.2.4 Selection and erection of installations in locations with endangering of irreplaceable goods

(Ref: para 4.3.2.6 of IS 732: 2019)

The locations include buildings or rooms with assets of significant value, like national monuments, museums and other public buildings **such as railway stations** and airports, buildings or facilities such as laboratories, computer centres and certain industrial and storage facilities.

In such locations, electrical equipment shall be so selected and erected that its temperature in normal use and foreseeable temperature rise during a fault cannot cause a fire. In addition, following measures may also be considered:

a. installation of mineral insulated cables according to IEC 60702-1.
b. Installation of cables with improved fire-resisting characteristics in case of a fire hazard, and complying with IEC 60331-1 or IEC 60331-21 or similar.
c. Installation of cables in non-combustible solid walls, ceilings and floors.
d. Installation of cables in areas with constructional partitions having a fire-resisting capability for a time of **30 min or 90 min**, the **latter in locations housing staircases** and needed for an emergency escape.

Where these measures are not practicable, enhanced fire protection may be possible by use of reactive fire protection systems.

It is recommended that special measures to be taken to protect against the effects of arc faults in final circuit in above locations. In ac circuits the use of arc fault detection devices (AFDD) will satisfy the above mentioned recommendations. If used, an AFDD shall be placed at the origin of the circuit to be protected.

2.1.3 Protection against Burns

(Ref: para 4.3.3 of IS 732: 2019)

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 given below. All parts of the installation in normal service likely to attain temperatures exceeding the limits stated in this table even for short periods, shall be guarded so as to prevent any accidental contact.

However, the values in table do not apply to equipment specifically designed as per IS for handling higher temperatures.

Table 3: Temperature Limits in Normal Service for Accessible Parts of Equipment within Arm's Reach

Accessible Parts	Material of Accessible Surfaces	Maximum Temperatures degree C
Hand-held means of operation	Metallic	55
	Non-metallic	65
Parts intended to be touched but not hand-held	Metallic	70
	Non-metallic	80
Parts which need not be touched for normal operation	Metallic	80
	Non-metallic	90

In BA2 (Nursery school for children) lower temperatures may be applicable.

2.1.4 Protection against Overheating

(Ref: para 4.3.4 of IS 732: 2019)

2.1.4.1 Forced air heating systems

(Ref: para 4.3.4.1 of IS 732: 2019)

- 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.

  Example: - As in the cases of RMPUs of AC Coaches in Railways, heaters can only be activated after running of blowers which is acknowledged by VANE Relay. RMPU also have two temperature limiting devices thermostat and ESTI (Fuse link in heater element) independent of each other.

2.1.4.2 Appliances producing Hot Water or Steam

(Ref: para 4.3.4.2 of IS 732: 2019)

- 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 Indian 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.

2.1.4.3 Space Heating Appliances

(Ref: para 4.3.4.2 of IS 732: 2019)

- The frame and enclosure of space heating appliances shall be of non-combustible material.
- In 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 which are not touched by the heat radiation 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.

2.2 SELECTION AND ERECTION OF WIRING SYSTEMS TO MINIMIZE THE SPREAD OF FIRE

(Ref: para 5.2.10 of IS 732: 2019)

2.2.1 Precautions within a fire-segregated compartment

(Ref: para 5.2.10.1 of IS 732: 2019)

The risk of spread of fire shall be minimized by the selection of appropriate materials and erection in accordance **the following**.

- Wiring systems shall be installed so that the general building structural performance and fire safety are not reduced.
- Cables complying with, at least, the requirements of IEC 60332-1-2 and products classified as non-flame propagating may be installed without special precautions. In installations where a particular risk is identified, cables complying with the more onerous tests for bunched cables described in the IEC 60332-3 series may be necessary.
- Cables not complying, as a minimum, with the resistance to the flame propagation requirements of IEC 60332-1-2 shall, if used, be limited to short lengths for connection of appliances to permanent wiring systems and shall, in any event, not pass from one fire-segregated compartment to another.
- Products classified as non-flame propagating as specified in IS 8623 (Part 2), IEC 61537 and in the series: IS 14297 (Part 1) and (Part 2/ Section 1), IS 14930 (Parts 1 & 2) and IEC 61534, may be installed without special precautions. Other products complying with standards having similar requirements for resistance to flame propagation may be installed without special precautions.
- Parts of wiring systems other than cables not classified as non-flame propagating, as specified in IS 8623 (Part 2), IEC 60570, IEC 61537 and in the following series: IS 14297 (Part 1) and (Part 2/Section 1), IS 14930 (Parts 1 & 2) and IEC 61534, but which comply in all other respects with the requirements of their respective product standards shall, if used, be completely enclosed in suitable non-combustible building materials.

2.2.2 Sealing of Wiring System Penetrations

(Ref: para 5.2.10.2 of IS 732: 2019)

i. Where a wiring system passes through elements of building construction such as floors, walls, roofs, ceilings, partitions or cavity barriers, the openings remaining after passage of the wiring system shall be sealed according to the degree of fire resistance (if any) prescribed for the respective element of building construction before penetration.

ii. Wiring systems which penetrate elements of building construction having specified fire resistance shall be internally sealed to the degree of fire resistance of the respective element before penetration as well as being externally sealed as mentioned in above para (i).

iii. Conduit systems, cable trunking systems and cable ducting systems classified as non-flame propagating according to the relevant product standard and having a maximum internal cross-section area of **710 mm²** need not be internally sealed provided that:

   a. the system satisfies the test of IS/ IEC 60529 for IP33 and

b. any termination of the system in one of the compartments, separated by the building construction being penetrated, satisfies the test of IS/IEC 60529 for IP33.

iv. No wiring system shall penetrate an element of building construction which is intended to be load bearing unless the integrity of the load bearing element can be assured after such penetration.

v. Sealing arrangements intended to satisfy **(i)** or **(ii) above,** shall resist external influences to the same degree as the wiring system with which they are used, and in addition, they shall meet all of the following requirements:

a. they shall be resistant to the products of combustion to the same extent as the elements of building construction which have been penetrated.

b. they shall provide the same degree of protection from water penetration as that required for the building construction element in which they have been installed.

c. the seal and the wiring system shall be protected from dripping water which may travel along the wiring system or which may otherwise collect around the seal unless the materials used in the seal are all resistant to moisture when finally assembled for use.

The above requirements of (v) may be satisfied if:

a. either cable cleats, cable ties or cable supports are installed within **750 mm** of the seal and are able to withstand the mechanical loads expected following the collapse of the supports on the fire side of the seal to the extent that no strain is transferred to the seal or

b. the design of the sealing system itself provides adequate support.

CHAPTER 3

PROTECTION AGAINST OVER CURRENT

Protective devices shall be provided to disconnect any overcurrent (due to overload or short circuit) 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.

3.1 REQUIREMENTS ACCORDING TO THE NATURE OF THE CIRCUITS

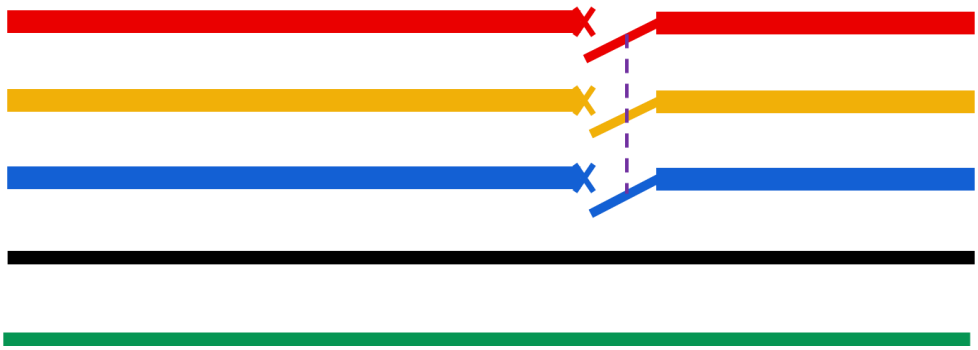
(Ref: para 4.4.2 of IS 732: 2019)

3.1.1 Protection of line conductors

(Ref: para 4.4.2.1 of IS 732: 2019)

i. Detection of overcurrent shall be provided for all line conductors, except where **(ii) below** applies. It shall disconnect the conductor in which the overcurrent is detected but not necessarily the disconnection of other live conductors.

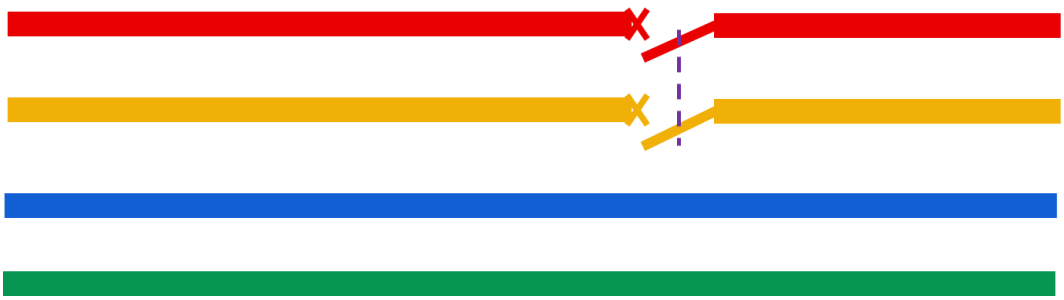
ii. If disconnection of a single phase may cause danger, for example in the case of a three-phase motor, appropriate precautions shall be taken.



iii. In a TT or TN system, for a circuit supplied by line conductors only 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. protection intended to detect unbalanced loads and intended to cause disconnection of all the line conductors in the same circuit or on the supply side, and

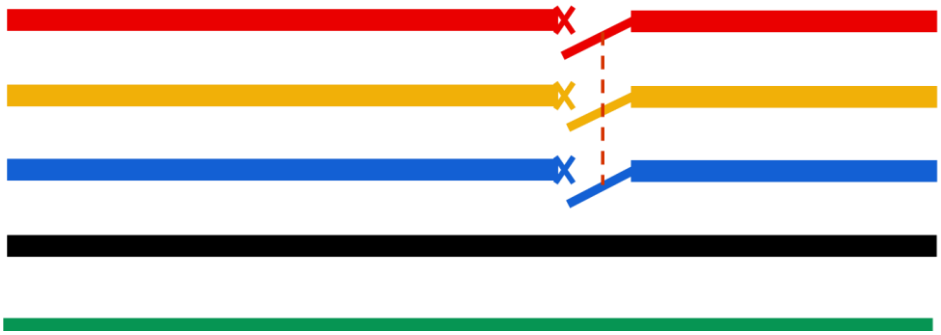
b. The neutral conductor is not distributed from an artificial neutral point of the circuits situated on the load side of the protective device mentioned in (a).



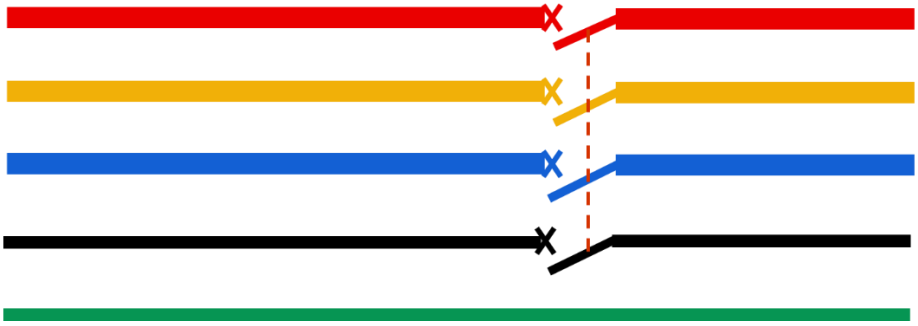
3.1.2 Protection of Neutral conductors
(Ref: para 4.4.2.2 of IS 732: 2019)

3.1.2.1 Protection of Neutral conductors in TT or TN systems
(Ref: para 4.4.2.2.1 of IS 732: 2019)

- Where the cross-sectional area of **the neutral conductor is at least equivalent** to the **line** conductors, and the current in the neutral is expected not to exceed the value in the line conductors, it is not necessary to provide **overcurrent detection** for the neutral conductor or a disconnecting device for that conductor.



- Where the cross-sectional area of the **neutral conductor is less than that of the line conductors**, it is **necessary to provide overcurrent detection** for the neutral conductor, **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.



In both the above cases neutral conductor shall be protected against short-circuit current. This protection may be achieved by the overcurrent protective devices in the line conductors. In that case it is not necessary to provide overcurrent protection for the neutral conductor or a disconnecting device for that conductor.

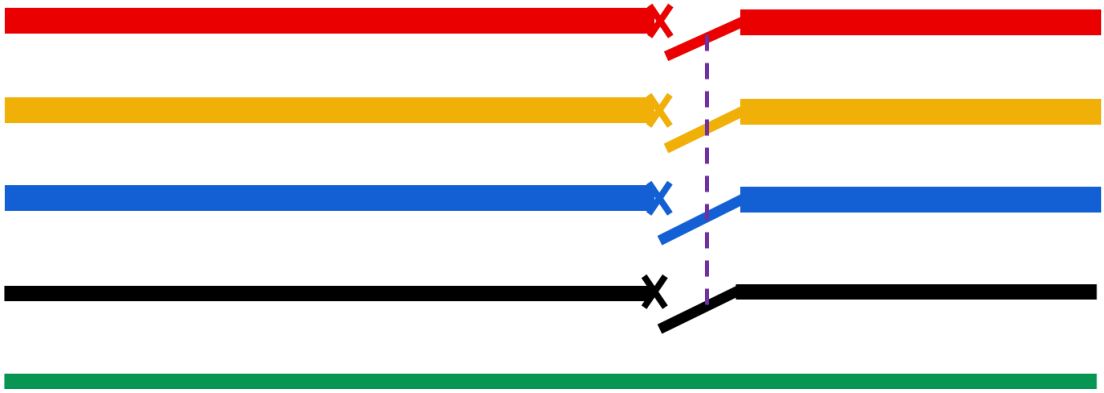
Where the current in the neutral conductor is expected to exceed the value in the line conductors, refer to 3.1.2.3 on harmonics currents.

Except for disconnection, the requirements for a neutral conductor apply to a PEN

3.1.2.2 Harmonic currents
(Ref: para 4.4.2.2.3 of IS 732: 2019)

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.



Where disconnection of the neutral conductor is required, neutral conductor shall not be disconnected before the line conductors and shall be reconnected at the same time as or before the line conductors.

3.2 PROTECTIVE DEVICES

3.2.1 Protective Devices for Both Overload and Short-circuit Current

(Ref: para 4.4.3.1 of IS 732: 2019)

Except the characteristics of short circuit protective devices, a device providing protection against both overload and short-circuit current shall be capable of breaking and, for a circuit breaker, making any overcurrent up to and including the prospective short-circuit current at the point where the device is installed.

3.3 PROTECTION AGAINST OVERLOAD CURRENT

(Ref: para 4.4.4 of IS 732: 2019)

3.3.1 Coordination between conductors and overload protective devices

(Ref: para 4.4.4.1 of IS 732: 2019)

The operating characteristics of a device protecting a cable against overload shall satisfy following two conditions:

i. $I_B \leq I_n \leq I_z$

ii. $I_2 \leq 1.45 \times I_z$

Where,

I_B = the design current for that circuit.

I_z = the continuous current-carrying capacity of the cable.

I_n = the rated current of the protective device. For adjustable protective devices, the rated current I_n is the current setting selected.

I_2 = the current ensuring effective operation in the conventional time of the protective device. This shall be provided by manufacturer or as given in the product standard.

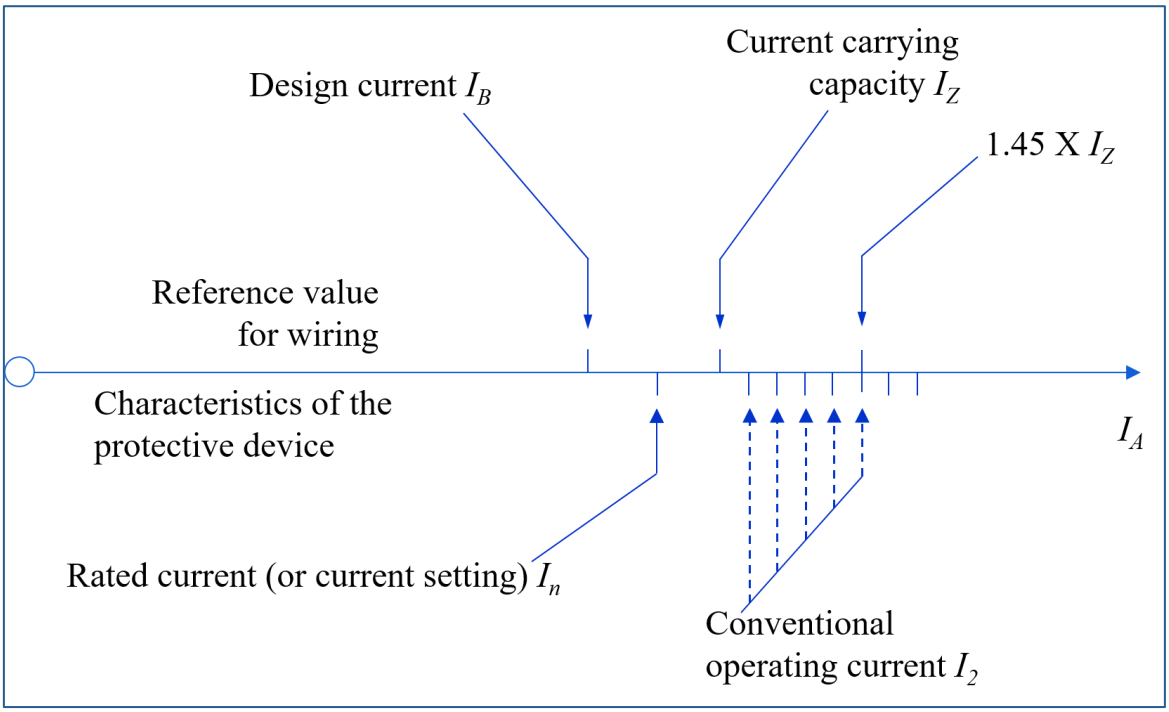


Figure 19: Illustration of condition (i) and (ii)

Protection in accordance with this clause may not ensure protection in certain cases, for example where sustained over currents less than I_2 occur. In such cases, consideration should be given to selecting a cable with a larger cross-sectional area.

Design current I_B can be considered as an actual current I_a after applying correction factors, i.e. maximum demand and diversity (Ref: para 4.1.5.6.1 of IS 732:2019).

Example: Calculation of Size of Conductor

- Consider a circuit/Installation in which design current (I_B) is 30A.
- Capacity of MCB & required current carrying capacity of wire are to be calculated.

1.	Design current (I_B) of a circuit/Installation	30A	
2.	Rated current of Protective device (MCB) (I_n) shall be	Minimum 32 A	30A MCB is not available
3.	Tripping current (I_2) in the conventional time of the protective device shall be	Minimum I_nx1.45= 46.4A	
4.	Required Current carrying capacity of wire (I_Z) shall be	Minimum 46.4 A	
5.	$I_B \leq I_n \leq I_Z$	I_B= 30A, I_n= 32A, I_Z =46.4	Equation 1 satisfied
6.	$I_2 \leq 1.45x I_Z$	I_2= 46.4A, (1.45xI_Z= 1.45x46.4 =67.28)	Equation 2 satisfied

Refer volume-2 chapter 5 for more details.

3.3.2 Position of devices for overload protection

(Ref: para 4.4.4.2 and Annex F of IS 732: 2019)

Devices for overload protection and devices for short circuit have to be installed for each circuit and generally need to be placed at the origin of each circuit.

i. A device ensuring protection against overload shall be placed at the point where a change, which causes a reduction **in the value of current-carrying capacity** of the conductors, except where (ii) below and omissions of devices for protection against overload 3.3.3 apply.

ii. An overload protective device P2 may be moved from the origin (O) of the branch circuit (B) provided that there is no other connection or socket-outlet on the supply side of P2 and fulfils **at least one of the** following two conditions:

a) It is protected against short-circuit current.

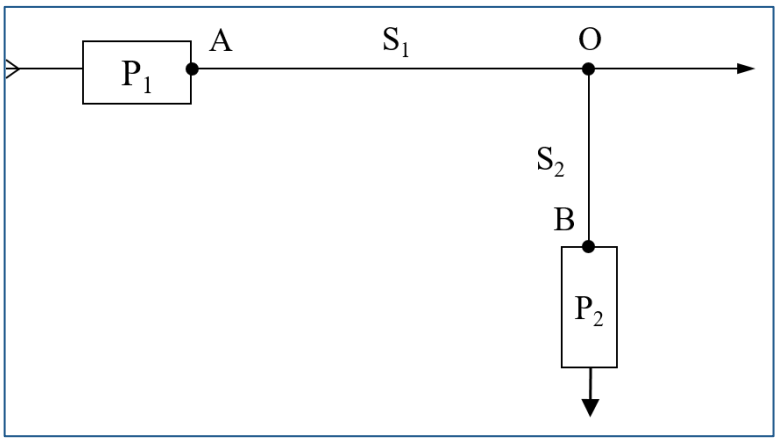


Figure 20: Overload Protective Device (P2) not at the origin of Branch Circuit (B)

P1, P2: Protective device, S1, S2: Cross sectional area of conductor (S1>S2), A, B: Location of Protective device, O: Origin of Branch Circuit

The overload protective device is to protect the wiring system.

Only electrical equipment may generate overload, therefore the overload protective device may be moved along the run of the branch circuit to any place provided short-circuit protection of the branch circuit remains operational.

b) Its length does not exceed 3 m,

An overload protective device P2 may be moved up to 3 m from the origin (O) of the branch circuit (B) provided that there is no other connection or socket-outlet on this length of the branch circuit, its length does not exceed 3 m, and the risk of short-circuit, fire and danger to person is reduced to a minimum for this length.

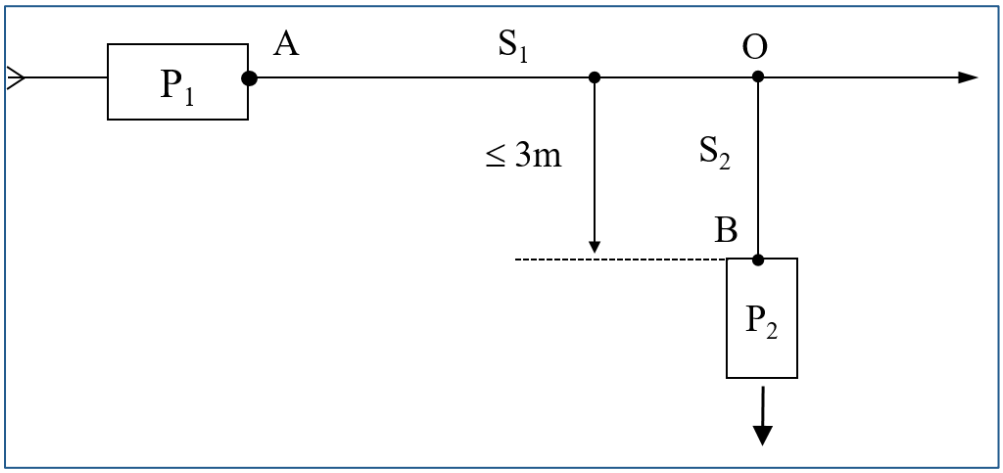


Figure 21: Overload Protective Device (P2) installed within 3 m of the origin of Branch Circuit (B)

It is accepted that for a length of 3 m, the branch circuit is not protected against short-circuit, but precautions have to be taken to ensure safety. In addition, it may be possible that the short-circuit protection of the supply circuit also provides short circuit protection to the branch circuit up to the point where P2 is installed.

3.3.3 Omission of devices for protection against overload

(Ref: para 4.4.4.3 of IS 732: 2019)

The various cases stated in this para 3.3.3 **shall not be applied to installations situated in locations presenting a fire risk or risk of explosion** or where the requirements for special installations and locations specify different conditions.

3.3.3.1 Devices for protection against overload need not be provided

a. for a conductor situated on the load side of a change which causes a reduction **in the value of current-carrying capacity**, that is effectively protected against overload by a protective device placed on the supply side (as shown in below figure, branch circuit S2 is protected against overload by P1)

b. for a conductor that is not likely to carry overload current, provided that **this conductor is protected against short-circuit current** and that it has neither branch circuits nor socket-outlets (as shown in below figure, branch circuit S3 is not likely to carry overload).

c. at the origin of an installation where the distributor provides an overload device and it affords protection to the part of the installation between the origin and the main distribution point of the installation where further overload protection is provided.

d. for circuits for telecommunications, control, signalling and the like (as shown in below figure) branch circuit S4 is for telecommunication, control, signalling.

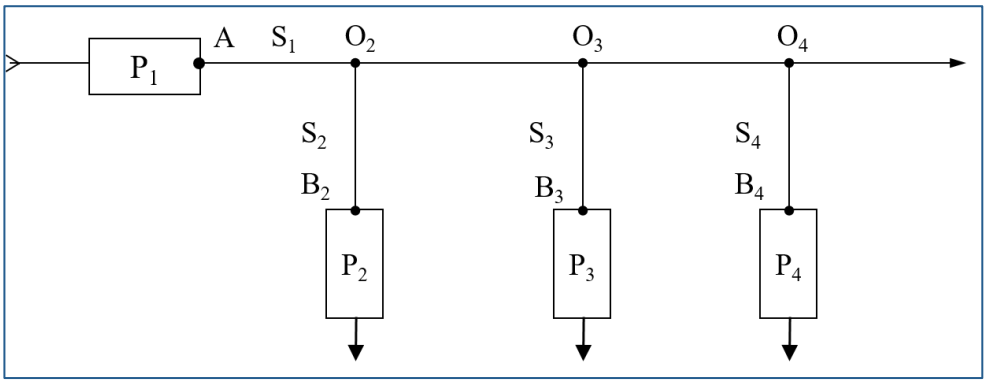


Figure 22: Illustration of cases where overload protection may be omitted

P2, P3 and P4 are the short-circuit protective devices for branch circuits S2, S3 and S4 respectively.

3.4 PROTECTION AGAINST SHORT-CIRCUIT CURRENT

(Ref: para 4.4.5 of IS 732: 2019)

Here the short circuit current means the current in case of short-circuit between conductors belonging to the same circuit.

3.4.1 Determination of prospective short-circuit currents

(Ref: para 4.4.5.1 of IS 732: 2019)

- The prospective short-circuit current at every relevant point of the installation shall be determined. This may be carried out either by calculation or by measurement.
- The prospective short-circuit current at the supply point may be obtained from the supply utility.
- External short circuit fault loop impedance (Z_e) may also be measured or calculated between Phase to phase (Z_{L-L}) for three phase and phase to neutral (Z_{L-N}) for single phase at the incoming supply point of MDB.
- Prospective highest short-circuit current (I_{cc} in kA) may be measured or calculated as per ohm's law.

$$Icc = \frac{Uo}{Z}$$

Where, Z_e= (Z_{L-L}) for 3 phase and (Z_{L-N}) for single phase,

U_o = Supply voltage (415 V for 3 phase and 240 V for single phase)

kA rating of protective devices shall be equivalent or more than highest short-circuit current at incoming supply to that point.

3.4.2 Position of short-circuit Protection Devices

(Ref: para 4.4.5.2 of IS 732: 2019)

A short-circuit protection device shall be placed at the point where a change which causes reduction to the current-carrying capacity of the conductors, except where (i), (ii) or 3.4.3 following applies:

(i) The various cases stated in the following sub **clause shall not be applied to installations situated in locations presenting a fire risk or risk of explosion** and where special rules for certain locations specify different conditions.

The short-circuit protection device may be placed other than as specified in para 3.3.2 earlier, 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, this condition may be obtained for example by reinforcing the protection of the wiring against external influences, see figure below:

c) not be placed close to combustible material.

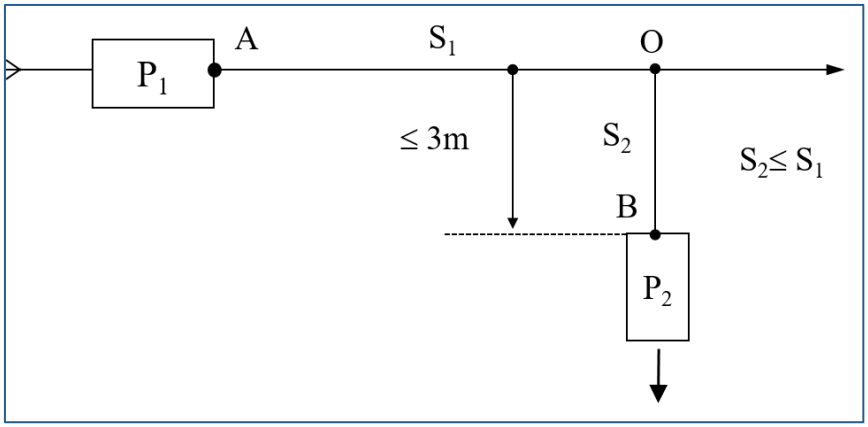


Figure 23: Limited change of position of short circuit protective device (P2) on a branch circuit

(ii) A protective device may be placed on the supply side of the reduced cross-sectional area or another change made, provided that it possesses an operating characteristic such that it protects the wiring situated on the load side against short-circuit.

The short-circuit protective device P2 may be installed at a point on the supply side of the origin (O) of the branch circuit (B) provided that, the maximum length between the origin of the branch circuit and the short-circuit-protective device of this branch circuit respect the specification proposed by the “triangular rule”.

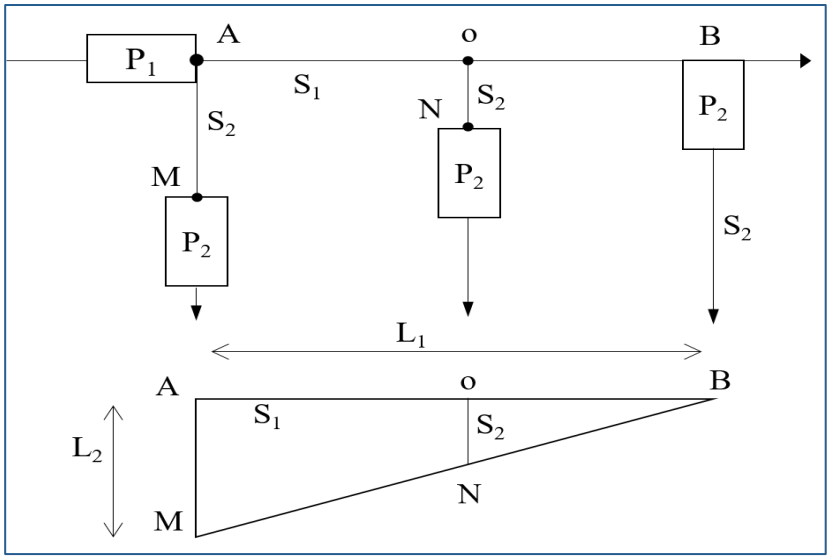


Figure 24: Short circuit protective device (P2) installed at a point on the supply side of the origin of a branch circuit

AB = is the maximum length L_1 of the conductor of the cross-sectional area S_1 protected against short-circuit by the protective device P_1 placed at A.

AM = is the maximum length L_2 of the conductor of the cross-sectional area S_2 protected against short-circuit by the protective device P_1 placed at A.

The maximum length of the conductor branched off at O, with the cross-sectional area S2, that is protected against a short-circuit by the protective device P1 placed at A, is given as length ON in the triangle BON.

This clause may be used in the case where only protection against short-circuit is provided.

These maximum lengths correspond to the minimum short-circuit capable of activating the protective device P1. This protective device protecting branch circuit S1 up to the length AB also protects the branch circuit S2. The maximum length of branch circuit S2 protected by P1 depends on the location where the branch circuit S2 is connected to S1.

The length of branch circuit S2 cannot exceed the value determined by the triangular diagram. In this case, the protective device P2 may be moved along branch circuit S2 up to the point N.

The above may also be applied in the case of three successive conductor runs of different cross sectional area.

3.4.3 Omission of devices for protection against short-circuit

(Ref: para 4.4.5.3 of IS 732: 2019)

Provided that both of the following conditions are simultaneously fulfilled:

- the wiring is installed in such a way as to reduce the risk of a short-circuit to a minimum and
- the wiring is not placed close to combustible material; short circuit protection devices need not be provided for applications such as:
    a. conductors connecting generators, transformers, rectifiers, accumulator batteries to the associated control panels, the protective devices being placed in these panels.
    b. circuits where disconnection could cause danger for the operation of the installations concerned,
    c. certain measuring circuits.
    d. at the origin of an installation where the distributor installs one or more devices providing protection against short-circuit to the part of the installation between the origin and the main distribution point of the installation where further short-circuit protection is provided.

3.4.4 Short-circuit protection of conductors in parallel

(Ref: para 4.4.5.4 of IS 732: 2019)

A single protective device may protect conductors in parallel against the effects of short-circuit provided that the operating characteristics of that device ensures its effective operation should a fault occur at the most onerous position in one of the parallel conductors.

Account shall be taken of the sharing of the short-circuit currents between the parallel conductors. A fault can be fed from both ends of a parallel conductor.

If operation of a single protective device is not effective, then one or more of the following measures shall be taken:

a. For two conductors in parallel, a short-circuit protective device shall be provided at the supply end of each parallel conductor.

b. For more than two conductors in parallel, short-circuit protective devices shall be provided at the supply and load ends of each parallel conductor.

3.4.5 Characteristics of short-circuit protective devices

(Ref: para 4.4.5.5 of IS 732: 2019)

i. The rated breaking capacity shall be not less than the prospective maximum short-circuit current at the place of its installation. A lower rated breaking capacity is permitted if another protective device having the necessary breaking capacity is installed on the supply side.

ii. For cables and insulated conductors, all current caused by a short-circuit occurring at any point of the circuit shall be interrupted in a time not exceeding that which brings the insulation of the conductors to the permitted limit temperature.

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 shall be greater than the value of the let-through energy (I^2t) quoted by the manufacturer of the protective device.

For short-circuits of duration up to 5 s, the time t, in which a given short-circuit current will raise the insulation of the conductors from the highest permissible temperature in normal duty to the limit temperature can, as an approximation, be calculated from the formula:

$$t = (k \times \frac{S}{I})^2)$$

where

t = the duration, in s;

S = the cross-sectional area, in mm^2;

I = the effective short-circuit current, in A, expressed as an r.m.s. value; and

k = a factor taking account of the resistivity, temperature coefficient and heat capacity of the conductor material, and the appropriate initial and final temperatures. For common conductor insulation, the values of k for line conductors are shown in table given below.

Table 4: Values of *k* for Conductors

Property/ Condition	Type of Conductor Insulation							
	PVC Thermoplastic		PVC Thermoplastic 90°C		EPR XLPE Thermosetting	Rubber 60 °C Thermosetting	Mineral	
							PVC sheathed	Bare unsheathed
Conductor cross-sectional area mm^2	≤ 300	>300	≤ 300	> 300				
Initial temperature °C	70		90		90	60	70	105
Final temperature °C	160	140	160	140	250	200	160	250
Conductor material:								
Copper	**115**	**103**	**100**	**86**	**143**	**141**	**115**	**135-115**[1)]
Aluminium	**76**	**68**	**66**	**57**	**94**	**93**	–	–
Tin-soldered joints in copper conductors	**115**	–	–	–	–	–	–	–

[1)] This value shall be used for bare cables exposed to touch.
NOTES 1. Other values of *k* are under consideration for: a. small conductors (particularly for cross-sectional areas less than 10 mm^2); b. other types of joints in conductors; c. bare conductors. 2. The nominal current of the short-circuit protective device may be greater than the current-carrying capacity of the cable. 3. The above factors are based on IEC 60724. 4. *See* Annex EE (**5.4**) for the calculation-method of factor *k*. of IS 732:2019

iii. For bus bar trunking and power track, one of the following requirements shall apply:

a. The rated short-time withstand current (I_{CW}) and the rated peak withstand current of a bus bar trunking or power track system shall not be lower than the prospective short-circuit current r.m.s. value and the prospective short circuit peak current value, respectively. The maximum time for which the ICW is defined for the bus bar trunking or power track system shall not be less than the maximum operating time of the protective device.

b. The rated conditional short circuit current of the bus bar trunking or power track system associated with a specific protective device, shall not be lower than the prospective short-circuit current.

3.5 COORDINATION OF OVERLOAD AND SHORT-CIRCUIT PROTECTION

(Ref: para 4.4.6 of IS 732: 2019)

3.5.1 Protection afforded by one device

(Ref: para 4.4.6.1 of IS 732: 2019)

A protective device providing protection against both overload and short-circuit currents shall fulfil the applicable requirements of over load protection and short circuit protection mentioned earlier in 3.3 and 3.4.

3.5.2 Protection Afforded by Separate Devices

(Ref: para 4.4.6.2 of IS 732: 2019)

The requirements over load protection and short circuit protection mentioned earlier in 3.3 and 3.4 apply to the overload protective device and the short-circuit protective device respectively.

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.

3.6 LIMITATION OF OVERCURRENT BY CHARACTERISTICS OF SUPPLY

(Ref: para 4.4.7 of IS 732: 2019)

Conductors are considered to be protected against overload and short-circuit currents where they are supplied from a source incapable of supplying a current exceeding the current-carrying capacity of the conductors (for example, certain bell transformers, certain welding transformers and certain types of thermoelectric generating sets).

CHAPTER 4

CURRENT-CARRYING CAPACITIES OF CONDUCTORS

4.1 CALCULATION OF CURRENT CARRYING CAPACITY

(Ref: para 5.2.6.1 to 5.2.6.5 of IS 732: 2019)

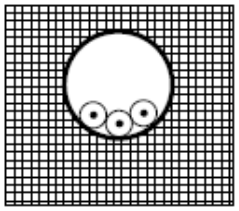
The current to be carried by any conductor for sustained periods during normal operation shall be such that the temperature limit of the insulation is not exceeded. The temperature limit for common types of insulations are given in below table (Ref: table 8 of IS 732: 2019):

Table: Maximum Operating Temperatures for Types of Insulation

Type of Insulation	Temperature Limit (degree C)
Thermoplastic (PVC)	70 at the conductor
Thermosetting (XLPE or EPR rubber)	90 at the conductor
Mineral (thermoplastic (PVC) covered or bare exposed to touch)	70 at the sheath
Mineral (bare not exposed to touch and not in contact with combustible material)	105 at the sheath

The above requirement may be satisfied if the current for insulated conductors and non armoured cables and having a nominal voltage up to 1 kV a.c. or 1.5 kV d.c. are calculated as per the tables given in Annex S with reference to table 19 of IS 732 : 2019, after applying necessary correction factors.

The brief on table 19 and table 21 to table 40 tables of Annex S are given in below table:

S. No.	Table No. & title	Brief about table	Example
1.	Table 19 : Examples of Methods of Installation Providing Instructions for Obtaining Current-Carrying Capacity	In this table different methods of installation of conductors are categorized like A1, A2, B1,B2,C,D1,D2,E,F,G etc. which are reference methods to obtain current carrying capacity mentioned in tables given in Annex S.	Insulated conductors or single-core cables in conduit in masonry is mentioned as B1 at sr. no. 59. Some other methods of installation are also covered under B1  category such as sr. no. 4,6,7,10,40,41,42, 43,44,45,46,47,50,52,54,55,56.
2.	Table 20 : Installation Reference Methods Forming Basis of Tabulated Current-Carrying Capacities	In this table according to installation method, which tables from table no. 21 to 40 to be referred for calculation	For B1 installation method, thermoplastic (PVC) insulated, 2 core cable of single circuit, current carrying capacity is given in table 21 col 4.

		of current carrying capacity and applicable correction/ reduction factors.	correction factor for ambient temperature from table 33 and group reduction factor from table 36 shall be chosen.
3.	Tables 21 to 32: Current-Carrying Capacities in Amperes for Methods of Installation as summarised in Table 20 according to different types of insulation methods, Copper or Aluminium etc. at reference ambient air temperature or ground temperature etc.	From table 21 to 32 Current-Carrying Capacities in Amperes for Methods of Installation as summarised in Table 20 according to different types of insulation methods, 2 or three loaded conductors, Copper or Aluminium shall be chosen accordingly.	For PVC insulated, **10 sq. mm** (nominal cross sectional area of conductor), two loaded copper conductors at ambient air temperature 30 degree C, and installation method B1, the current carrying capacity shall be chosen from table 21 col. 4 and it is **57 amp.**
4.	Table 33 : Correction Factor for Ambient Air temperatures other than 30 degree C to be Applied to the Current-Carrying Capacities for Cables in the Air	If ambient air temperature is less or more than 30-degree C for the cables in the air, then correction factor according to table 33 shall be multiplied in the current carrying capacity derived from table 21 to 32.	From example at sr. no.3 the current carrying capacity of 10 sq. mm PVC insulated, two loaded copper conductors at ambient air temperature 30-degree C, and installation method B1, derived from table 21 is 57 amps. If ambient air temperature is **40** degree C, then correction factor for PVC cable is 0.**87** and will be multiplied to current carrying capacity i.e. 57 x 0.87 = 49.59 = **50 amp.**
5.	Table 34 : Correction Factors for Ambient Ground Temperatures Other Than 20 degree C to be Applied to the Current-Carrying Capacities for Cables in Ducts in the Ground	If ambient ground temperature is less or more than 20-degree C for the cables in the ducts in the ground, then correction factor according to table 34 shall be multiplied in the current carrying capacity derived from table 21 to 32.	The current carrying capacity of 10 sq. mm PVC insulated, two loaded copper conductors at ambient temperature 20-degree C in ground, and installation method D1, derived from table 21 is **60 amp**. If ambient temperature in ground is 40 degree C, then correction factor for PVC cable is 0.77 and will be multiplied to current carrying capacity i.e. 60 x 0.77 = **46.2** amp.
6.	Table 36 : 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	If more than one circuit or more than one multi core cable are to be used in such arrangement which caused cable touching,	From example at sr. no.3 the current carrying capacity of 10 sq. mm PVC insulated, two loaded copper conductors at ambient air temperature 30 degree C, and installation method

	Cable, to be Used with Current-Carrying Capacities of Table 21 to Table 32	then reduction factor according to table 36 shall be multiplied in the current carrying capacity derived. from table 21 to 32.	B1, derived from table 21 is 57 amp. If 3 equally loaded circuits are installed in such arrangement which caused cable touching, then reduction factor for 3 circuits is 0.70 and will be multiplied to current carrying capacity i.e. 57 x 0.70 = 39.9 amp
7.	Table 37 : Reduction Factors for More Than One Circuit, Cables Laid Directly in the **Ground** – Installation **Method D2** in Table 21 to Table 24 Single-Core or Multi-Core Cables	If more than one circuit, cables are laid directly in the ground (installation method D2) used in such arrangement which caused cable touching or cable to cable specific clearance, then reduction factor according to table 37 shall be multiplied in the current carrying capacity derived. from table 21 or 24.	The current carrying capacity of 10 sq. mm PVC insulated, two loaded copper conductors at ambient temperature 20 degree C in Ground , and installation method D2, derived from table 21 is 64 amp. If 3 circuits are installed in such arrangement in directly laid in ground which caused cable touching (cable to cable clearance is NIL), then reduction factor for 3 circuits is 0.65 and will be multiplied to current carrying capacity i.e. 64 x 0.65 = 41.6 amp
8.	Table 38 : Reduction Factors for More Than One Circuit, Cables Laid in Ducts in the Ground — Installation Method D1 in Table 20 to Table 24	If more than one circuit, cables are laid in ducts in the ground (installation method D1) used in such arrangement which caused ducts touching or duct to duct specific clearance, multi core cable in single way ducts or single core cables in non magnetic single way ducts, then reduction factor according to table 38 shall be multiplied in the current carrying capacity derived. from table 21 or 24.	The current carrying capacity of 10 sq. mm PVC insulated, two loaded copper conductors at ambient temperature 20 degree C in Ground , and installation method D1, derived from table 21 is 60 amp. If 3 two core cables are installed in such arrangement in single way ducts which caused duct to duct touching (duct to duct clearance is NIL), then reduction factor for 3 cables is 0.75 and will be multiplied to current carrying capacity i.e. 60 x 0.75 = 45 amp
9.	Table 39 : Reduction Factors for Group of More Than One Multi-core Cable	If group of more than one multi-core cable is installed in trays (method E), then current carrying	The current carrying capacity of 10 sq. mm PVC insulated two core copper cable (two loaded conductors at ambient temperature 30 degree C in air,

	to be Applied to Reference Current-Carrying Capacities for Multi-core Cables in Free Air — Method of Installation E in Table 27 to Table 32	capacities for multi-core cables in free Air derived from table 27 to table 32 shall be multiplied by reduction factor according to table 39.	and installation method E, derived from table 29 is 70 amp. If two groups of 3 two core cables are installed in two perforated trays in such arrangement that vertical spacing between cable trays is minimum 300 mm, at least 20 mm between cable trays and wall. Cables are touching, then reduction factor for 3 cables is 0.80 and will be multiplied to current carrying capacity i.e. 70 x 0.80 = 56 amp
10.	Table 40 : 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 27 to Table 32	If group of more than one circuit of single-core cables is installed in trays (method F), then current carrying capacities for single-core cables in free Air derived from table 27 to table 32 shall be multiplied by reduction factor according to table 40.	The current carrying capacity of 25 sq. mm PVC insulated single core cables (two loaded conductors) at ambient temperature 30 degree C in air, and installation method F, derived from table 29 is 131 amp. If in two perforated trays each containing 2 three phase circuits i.e. 6 single core cables are installed in such arrangement that vertical spacing between cable trays is minimum 300 mm, at least 20 mm between cable trays and wall. Cables are touching, then reduction factor for this is 0.87 and will be multiplied to current carrying capacity i.e. 131 x 0.87 = 113.97 amp

4.1.1 Necessary Correction Factors

The following factors are considered and necessary correction factors are to be applied accordingly:

- **Ambient temperature** i.e. temperature of the surrounding medium when the cable or insulated conductor **are not loaded**. If it differs from 30 degree C in air and 20 °C in the ground in the intended location, the appropriate correction factor given in **Tables 33 and 34** shall be applied to the values of current-carrying capacity set out in **Tables 21 to 32** as explained in above table sr. no. 4 and 5.
- **Groups containing more than one circuit**, the group reduction factors given in **tables 36 to table 40 of IS 732:2019** shall be applied to the values of current-carrying capacity set out in **Tables 21 to 32** as explained in above table sr. no. 6 to 10 (theses are applicable to groups of insulated conductors or cables having the same maximum operating temperature).

- For **groups containing cables or insulated conductors having different maximum operating temperatures**, the current-carrying capacity of all the cables or insulated conductors in the group will be based on the **lowest maximum operating temperature** of any cable in the group, together with the appropriate group reduction factor.

4.1.2 Calculation of Number of Loaded Conductors

(Ref: para 5.2.6.6 of IS 732: 2019)

Number of loaded conductors i.e. the number of conductors those carrying load current.

- In **balanced poly-phase circuits, the associated neutral conductor is not considered as loaded conductor**. Under these conditions, a four-core cable is given the same current-carrying capacity as a three-core cable having the same conductor cross-sectional area for each line conductor.
- Four-core and five-core cables may have higher current-carrying capacities when only three conductors are loaded.
- Where the neutral conductor in a multicore cable carries current as a result of **an imbalance in the line currents,** the temperature rise due to the neutral current is **offset by the reduction in the heat generated by one or more of the line conductors**. In this case, the **neutral conductor size shall be chosen on the basis of the highest line current.**

  In all cases, the neutral conductor shall have a cross sectional area adequate to afford compliance with 4.1.1.
- Where the neutral conductor carries current caused by a **significant triple harmonic current in three-phase circuits without a corresponding reduction in load of the line conductors**, the **neutral conductor shall be taken as loaded conductor** in ascertaining the current-carrying capacity of the circuit. **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.**

4.1.3 Effect of Harmonic Currents and Reduction Factors

(Ref: para 5.2.6.6.3 and Annex V of IS 732: 2019)

Thermal effects due to the presence of third harmonic or multiples of 3 and the corresponding reduction factors for higher harmonic currents are given in **Annex V of IS 732:2019.**

In case there is current flowing in the neutral of a **balanced three-phase system**, these neutral currents are due to the line currents having a harmonic content which does not cancel in the neutral. The most significant harmonic which does not cancel in the neutral is **usually the third harmonic**. The magnitude of the neutral current due to the third harmonic may exceed the magnitude of the power frequency line current and will have a significant effect on the current-carrying capacity of the cables in the circuit.

The reduction factors given in below table (Ref; table 45 of IS 732:2019) apply to balanced three-phase circuits. The situation is more onerous if only two of the three phases are loaded. In this situation, the neutral conductor will carry the harmonic currents in addition to the unbalanced current which can lead to overloading of the neutral conductor. Equipment likely to cause significant harmonic currents are, for example, fluorescent lighting banks and d.c. power supplies such as those found in computers.

Table 5: 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 -35	0.86	--
35-45	--	0.86
45	--	1.0

Where the **neutral current is expected to be higher (more than 135 percent) than the line current then the cable size should be selected on the basis of the neutral current.** In this case 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.

Example:

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 23 of IS 732:2019, a 6 mm^2 cable with copper conductors with current-carrying capacity of 41 A is suitable if harmonics are not present in the circuit.

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

$$\frac{39}{0.86} = 45\ A$$

For this load (45A), a **10 mm^2** cable is necessary.

If 40 percent third harmonic is present, the cable size selection is based on the neutral current which is:

$$39 \times 0.4 \times 3 = 46.8\ A$$

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

$$\frac{46.8}{0.86} = 54.4\ A$$

For this load (45A), a **10 mm^2** cable is suitable.

Conductors which serve the purpose of protective conductors only (PE conductors) shall not be taken into consideration. PEN conductors shall be taken into consideration in the same way as neutral conductors.

4.1.4 Conductors in Parallel

(Ref: para 5.2.6.7 of IS 732: 2019)

Where two or more live conductors or PEN conductors are connected in parallel in a system, either a or b:

a. measures shall be taken to achieve equal load current sharing between them by selecting the conductors of the same material, same cross-sectional area, approximately the same length and shall have no branch circuits along the length, and either

- the conductors in parallel are multi-core cables or twisted single-core cables or insulated conductors, or

- the conductors in parallel are non-twisted single-core cables or insulated conductors in trefoil or flat formation and have a cross-sectional area less than or equal to **50 mm² in copper** or **70 mm² in aluminium,** or

- if the conductors in parallel are non twisted single-core cables or insulated conductors in trefoil or in flat formation and have a cross-sectional area **greater than** 50 mm² in copper or 70 mm² in aluminium, the special configuration necessary for such formations is adopted. These configurations consist of suitable groupings and spacings of the different phases or poles as shown below: (Ref: Annex Z of IS 732:2019).

b. Special consideration shall be given to the load current sharing to meet the requirements of 4.1.

Where adequate current sharing cannot be achieved or where four or more conductors have to be connected in parallel, consideration shall be given to the use of bus bar trunking.

4.1.5 Variation of Installation Conditions along a Route

(Ref: para 5.2.6.8 of IS 732: 2019)

Where the heat dissipation differs in one part of a route to another, the current-carrying capacity shall be determined so as to be appropriate for the part of the route **having the most adverse conditions.** This requirement can normally be neglected if heat dissipation only differs where the wiring is going through a wall of less than 0.35 m.

4.1.6 Single-core Cables with a Metallic Covering

(Ref: para 5.2.6.9 of IS 732: 2019)

The metallic sheaths and/or non-magnetic armour of single-core cables in the same circuit shall be connected together at both ends of their run. Alternatively, to improve current-carrying capacity, the sheaths or armour of such cables having conductors of cross sectional **area exceeding 50 mm²** and a non-conducting outer sheath may be connected together at one point in their run with suitable insulation at the unconnected ends, in which case the length of the cables from the connection point shall be limited so that voltages from **sheaths and/or armour to earth**:

a. do not cause corrosion when the cables are carrying their full load current, for example, by limiting the voltage to **25 V**, and

b. do not cause danger or damage to property when the cables are carrying short-circuit current.

4.2 VOLTAGE DROP IN CONSUMERS' INSTALLATIONS

(Ref: para 5.2.8 of IS 732: 2019)

In the absence of any other consideration, the **voltage drop between the origin of the consumer's installation and the equipment** should not be greater than that given in table below:

Table 6: Voltage Drop

Type of Installation	Lighting %	Other Users %
A – Low voltage installations supplied directly from a public low voltage distribution system	3	5
B – Low voltage installation supplied from private LV supply. For this as far as possible the voltage drop for final circuit shall not exceed those indicated in installation type A.	6	8

A greater voltage drop may be accepted for start-up time for motors and equipment with high inrush current subject to the voltage variations remain within the limit specified in the relevant equipment standard.

Temporary conditions such as voltage transients and voltage variation due to abnormal operation may be disregarded.

4.3 MINIMUM NOMINAL CROSS-SECTIONAL AREA OF CONDUCTORS FOR STANDARD CIRCUITS

(Ref: - Para 5.8.3 of section 9 part 1 of Draft NEC)

The nominal cross sectional area of line conductors in A.C. circuits shall not be less than values specified in below table due to mechanical reasons.

S.N.	Type of Circuit	Minimum Cross-Sectional Area of copper conductors	Remarks
1.	Lighting circuits	1.5 Sq.mm	Maximum 2 boards may be looped, subject to load < 1 kW or Maximum 24 points on two boards
2.	5/6A Socket	1.5 Sq.mm	Maximum 4 Nos. sockets, subject to total load < 1 kW
		2.5 Sq.mm	Maximum 8 Nos. sockets, subject to total load < 2 kW
3.	16A Socket	2.5 Sq.mm	Maximum 2 Nos. sockets, subject to total load < 2 kW
4.	Appliance $\leq$ 2kW	2.5 Sq.mm	1 No., subject to total load < 2 kW
5.	Appliance $\leq$ 3kW	4 Sq.mm	1 No., subject to total load < 3 kW
6.	Appliance $\leq$ 6kW	6 Sq.mm	1 No, subject to total load < 6 kW

4.3.1 Load on switch-board-lighting

(Ref:- Para 6.3.4 of section 9 part 1 of Draft NEC)

Considering not more than one circuit shall feed supply to Switchboard/s the total load of number of light, Fan, 5/6A plug outlets shall not exceed 30% of the maximum current carrying capacity of the circuit main (after considering all other factor) or 1000W or 24 points, whichever reaches its limit first.

CAHAPTER 5

ISOLATION, SWITCHING, CONTROL, PROTECTIVE AND MONITORING DEVICES

5.1 REQUIREMENTS FOR ISOLATION, SWITCHING AND CONTROL DEVICES

(Ref: para 5.3.1 of IS 732: 2019)

Every item for the purpose of isolation, switching, control or protection of electrical installation shall comply with the rules stated in the following clauses and the relevant rules in other parts of IS 732:2019.

i. The moving contacts of all poles of **multi-pole devices** shall be coupled mechanically to make and break together, except that contacts **solely intended for the neutral** may close before and open after the other contacts.

ii. Except isolation devices, single-pole devices shall not be inserted in the neutral conductor in multiphase circuits.

iii. In single-phase circuits single-pole devices shall not be inserted in the neutral conductor, unless a RCCB is provided on the supply side.

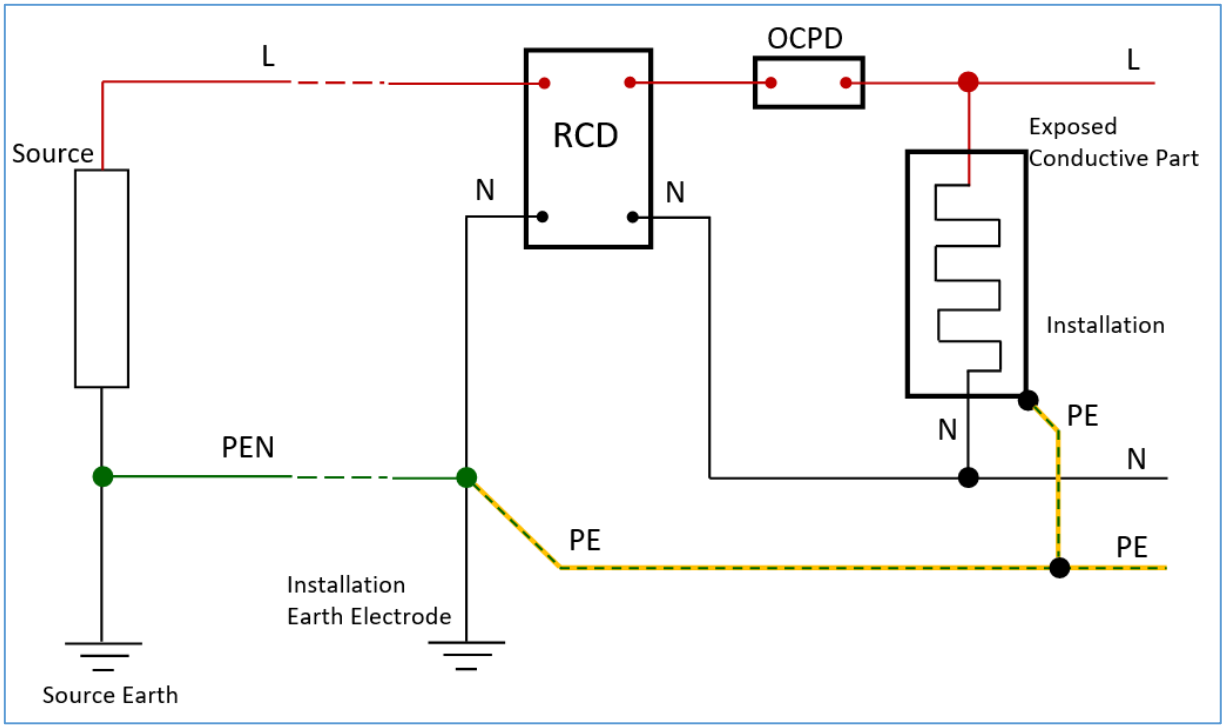


Figure 25: RCCB connection in Single phase circuit

5.2 PROTECTIVE DEVICES FOR AUTOMATIC DISCONNECTION OF SUPPLY TO PREVENT ELECTRIC SHOCK

(Ref: para 5.3.2 of IS 732: 2019)

5.2.1 Overcurrent Protective Devices

(Ref: para 5.3.2.1 of IS 732: 2019)

Already mentioned the requirements of over current protective devices in chapter 3 of this booklet.

5.2.2 Residual Current Protective Devices (RCCBs)

(Ref: para 5.3.2.2 of IS 732: 2019)

- A residual current protective device shall ensure the disconnection of all live conductors in the circuit protected.

  No protective (earth) conductor shall pass through the magnetic circuit of a RCCB.

- RCCB shall be so selected, and the electrical circuits shall be so subdivided, that any earth-leakage current which may be expected to occur during normal operation of the connected load(s) will not trip RCCB unnecessarily.
- RCCB may operate at any value of residual current in excess of 50 percent of its rated operating current.

  The use of a RCCB (even not exceeding 30 mA) in a circuit not having a protective (earth) conductor, is not a sufficient measure for protection against indirect contact.

- Connection to exposed conductive parts to earth wire is necessary for protection against electric shock.
- In TN system, connection of the exposed conductive parts to the protective (earth) conductor needs to be made on the source side of the RCCB.

  In TT system, if an installation is protected by a single RCCB, this RCCB shall be placed at the origin of the installation. If there is more than one origin, each origin shall be protected by separate RCCB.

- In IT system, if RCCB is provided and disconnection is not required on first earth fault, the **residual non-operating current of the RCCB shall be at least equal to the current which will circulate on the first fault phase to earth** of negligible impedance.

5.2.3 Insulation Monitoring Devices (IMD)

(Ref: para 5.3.2.3 of IS 732: 2019)

An insulation monitoring device continuously monitors the insulation of an electrical installation. It is intended to indicate a significant reduction in the insulation level of the installation to allow the cause of this reduction to be found before the occurrence of a second fault, and thus avoid disconnection of the supply.

Accordingly, it is set at a value lower than that specified in table given below appropriate to the installation concerned. **The setting of IMD can only be modified by the use of a key or tool.**

Nominal circuit voltage	Test voltage d.c. (V)	Insulation Resistance MΩ
SELV and PELV	250	≥ 0.5
Upto and including 500 V including FELV	500	≥ 1.0
Above 500 V	1000	≥ 1.0

5.3 DEVICES FOR PROTECTION AGAINST OVERCURRENT

(Ref: para 5.3.4 of IS 732: 2019)

5.3.1 Selection of Devices for Protection of Wiring systems against Overloads

(Ref: para 5.3.4.2 of IS 732: 2019)

The nominal current (or current setting) of the protective device shall be chosen in accordance with 3.3.1 mentioned earlier.

In certain cases, to avoid unintentional operation, **the peak current values of the loads** have to be taken into consideration. In the case of a cyclic load, the values of I_n and I_2 shall be chosen on the basis of values of I_B and I_z for the thermally equivalent constant load.

where

I_B = the current for which the circuit is designed

I_Z = the continuous current-carrying capacity of the cable

I_n = the nominal current of the protective device and

I_2 = the current ensuring effective operation of the protective device.

5.3.2 Selection of Devices for Protection of Wiring systems against Short Circuits

(Ref: para 5.3.4.3 of IS 732: 2019)

The details about protection devices against short circuit are already mentioned in 3.4 earlier in this booklet. Minimum and maximum short-circuit conditions for short-circuit duration up to 5 s shall be taken into account while selecting devices.

If it is specified for a protective device both a rated service short-circuit breaking capacity, and a rated ultimate short-circuit breaking capacity, it is permissible to select the protective device on the basis of the ultimate short-circuit breaking capacity for the maximum short-circuit conditions.

According to operational circumstances, it is desirable to select the protective device on the service short-circuit breaking capacity, for example, where a protective device is placed at the origin of the installation.

5.4 ASSOCIATION OF RCCB WITH OVERCURRENT PROTECTIVE DEVICES

(Ref: para 5.3.6.2 of IS 732: 2019)

i. Where a RCCB is incorporated or combined with a device for overcurrent protection, the characteristics of the assembly of protective devices (breaking capacity, operating characteristics in relation to rated current) shall satisfy the rules of overload current protective devices and short circuit protection devices.

ii. Where a RCCB is neither incorporated in, nor combined with a device for overcurrent protection, then:

- Appropriate overcurrent protection device shall be used with RCCB.
- RCCB shall be capable to withstand without damage the thermal and mechanical stresses in the event of a short-circuit occurring on the load side of the location where it is installed and
- RCCB shall not be damaged under these short-circuit conditions even when, due to unbalanced current or to current flowing to earth, the RCCB itself tends to open.

The stresses mentioned depend on the prospective short-circuit current at the point where the RCCB is installed, and the operating characteristics of the device providing short circuit protection.

5.5 DISCRIMINATION BETWEEN RCCBS

(Ref: para 5.3.6.3 of IS 732: 2019)

Discrimination between RCCBs installed in series may be required for safety as well as service reasons, to provide continuity of supply to the parts of the installation not involved in the fault, if any.

This discrimination can be achieved by selecting and erecting RCCBs which, while ensuring the required protection to the different parts of the installation, disconnect from the supply only that part of the installation that is located on the load side of the RCCB, installed on the supply side of the fault and closet to it.

Discrimination between RCCBs is already explained in 1.1.1.3.4 of this booklet.

5.6 ISOLATION AND SWITCHING

(Ref: para 5.3.7 of IS 732: 2019)

Non-automatic local and remote isolation and switching devices are required to prevent or remove dangers associated with electrical installations or electrically powered equipment and machines.

Isolation and switching measures are not alternatives to the protective measures against electric shock, thermal effects, overcurrent, voltage disturbances and electromagnetic disturbances.

Protective conductors (earth wires) in all systems shall not be isolated or switched.

In TN-S systems, the neutral conductor need not be isolated or switched.

In TN-C systems, the PEN (combined neutral and earth) conductor shall not be isolated or switched.

5.6.1 Isolation

(Ref: para 5.3.7.3 of IS 732: 2019)

i Every circuit shall be capable of being isolated from each of the live supply conductors.

ii If the service conditions allow, provisions may be made for isolation of a group of circuits by a common device.

iii Suitable means shall be provided to prevent any equipment from being unintentionally energized. Such precautions may include one or more of the following measures:

a. padlocking

b. warning notices and

c. location within a lockable space or enclosure.

Short-circuiting and earthing may be used as a supplementary measure.

iv A warning notice shall be placed on item of equipment or enclosure which contains live parts connected to more than one supply. This shall be in such a position that any person gaining access to live parts will be warned of the need to isolate those parts from the various supplies unless an interlocking arrangement is provided to ensure that all the circuits concerned are isolated.

v Where necessary, suitable means shall be provided for the discharge of stored electrical energy.

5.6.1.1 Devices for Isolation

(Ref: para 5.3.7.3.2 of IS 732: 2019)

The devices for isolation shall effectively isolate all live supply conductors from the circuit concerned. The devices shall comply with following requirements:

i Device shall withstand in the new, clean and dry condition, when in the open position, across the terminals of each pole, the impulse voltage value given in table 12 of IS 732:2019 in relation to the nominal voltage of the installation.

ii. When tested, across the terminals of each pole, with a voltage value equal to **110 percent of the phase to neutral value corresponding to the nominal voltage** of the installation, have a leakage current across open poles **not exceeding 0.5 mA per pole in the new, clean and dry condition**, and **6 mA per pole at the end of the conventional service life of the device.** In the case of d.c. testing, the value of the d.c. voltage shall be the same as the r.m.s. value of the a.c. test voltage.

iii. The isolating distance between open contacts of the device shall be **visible or be clearly and reliably indicated by "off" or "open" marking.** Such indication shall only occur when the isolating distance between open contacts on each pole of the device has been attained. The marking may be achieved by the use of the symbols **"O" and "I" to indicate the open and closed** positions respectively.

Semiconductor devices shall not be used as isolating devices.

iv. Devices for isolation shall be designed and/ or installed so as **to prevent unintentional closure** which might be caused by shocks and vibrations.

v. Provision shall be made for securing offload isolating devices against inadvertent and unauthorized opening. This may be achieved by locating the device in a **lockable space or enclosure or by padlocking**. Alternatively, the off-load device may be interlocked with a load-breaking one.

vi. Means of isolation shall preferably be **provided by a multipole switching device** which disconnects all poles of the relevant supply but single pole devices situated adjacent to each other are not excluded.

vii. Isolation may be achieved by the following means:

a. Dis-connectors (isolators), switch-disconnectors, multipole or single-pole,
a. plugs and socket outlets,
b. fuse-links,
c. fuses and
d. special terminals which do not require the removal of a wire.

ix. All devices used for isolation shall be clearly identified by marking to indicate the circuit which they isolate.

5.6.2 Switching Off (for mechanical maintenance)

(Ref: para 5.3.7.4 of IS 732: 2019)

Electrically powered mechanical equipment / installations like cranes, lifts, escalators, conveyors, machine tools, pumps etc. which may include rotating machines, heating elements, electromagnetic equipment etc. and where mechanical maintenance may involve a risk of physical injury. Means for switching-off for mechanical maintenance of these installations are required.

Systems powered by other means, for example, pneumatic, hydraulic or steam, are not covered by these rules. In such cases, switching-off any associated supply of electricity **may not be a sufficient measure**.

Suitable means like padlocking, warning notices, location within a lockable space or enclosure shall be provided to prevent electrically powered equipment from becoming unintentionally reactivated during mechanical maintenance, unless the means of switching-off is continuously under the control of any person performing such maintenance.

5.6.2.1 Devices for Switching-off (for mechanical maintenance)

(Ref: para 5.3.7.4.2 of IS 732: 2019)

- Devices for switching-off for mechanical maintenance shall be inserted preferably in the main supply circuit.
- Where switches are provided, they shall be **capable of cutting off the full-load current** of the relevant part of the installation. They need not necessarily interrupt all live conductors.
- Interruption of a control circuit of a drive or the like is permitted only where, supplementary safeguards, such as mechanical restrainers, or requirements of an IS specification for the control devices used provide a condition **equivalent to the direct interruption of the main supply**.
- **Switching-off for mechanical maintenance may be achieved by means of:**
  a. multipole switches
  b. circuit breakers
  c. control switches operating contactors and
  d. plugs and sockets.
- **Such devices shall require manual operation.**
- The **clearance between open contacts of the device shall be visible** or be clearly and reliably indicated by “off” or “open” marking. Such indication shall only occur when the “off” or “open” position on each pole of the device has been attained. The marking may be achieved by the use of the symbols “O” and “I” to indicate the open and closed positions respectively.
- Devices for switching ‘OFF’ for mechanical maintenance shall be designed and/or installed so as to prevent unintentional switching ‘ON’ which might be caused by shocks and vibrations.
- Devices for switching-off for mechanical maintenance shall be placed and marked so as to be readily identifiable and convenient for their intended use.

5.6.3 Emergency Switching

(Ref: para 5.3.7.5 of IS 732: 2019)

Emergency switching means emergency switching ‘ON’ or emergency switching ‘OFF’.

i. Switching means shall be provided for emergency switching of any part of an installation where it may be necessary to control the supply to remove an unexpected danger in case of any emergency.

   Examples of installations where means for emergency switching are used:
   a. pumping facilities for flammable liquids
   b. ventilation systems

c. large computers
b. discharge lighting with high-voltage supply, for example neon signs
a. certain large buildings, for example department stores
b. electrical testing and research facilities
c. teaching laboratories
d. boiler-rooms
e. large kitchens

i. Where a risk of electric shock is involved, the emergency switching device shall cut off all live conductors except PEN or neutral conductor.

ii. Means for emergency switching, including emergency stopping, shall act as directly as possible on the appropriate supply conductors. The arrangement shall be such that one single action only will cut off the appropriate supply.

iii. The arrangement of the emergency switching shall be such that its operation does not introduce a further danger or interfere with the complete operation necessary to remove the danger.

iv. Where emergency switching includes the function of emergency, in the case of machines, emergency stopping is also required. Means of emergency stopping shall be provided where electrically produced movements may give rise to danger. For example, means for emergency stopping are used in escalators, lifts, elevators, conveyors, electrically driven doors, machine-tools and car-washing plants etc..

5.6.3.1 Devices for Emergency Switching

(Ref: para 5.3.7.5.2 of IS 732: 2019)

i. The devices for emergency switching shall be capable of breaking the full-load current of the relevant parts of the installation taking account of stalled motor currents where appropriate. Means for emergency switching may consist of:
   a. one switching device capable of directly cutting off the appropriate supply, or
   b. a combination of equipment activated by a single action for the purpose of cutting off the appropriate supply.

ii. For emergency stopping, retention of the supply may be necessary, for example, for braking of moving parts. Emergency switching may be achieved by means of:
   a. switches in the main circuit, and
   b. push-buttons and the like in the control (auxiliary) circuit.

iii. Hand-operated switching devices for direct interruption of the main circuit shall be selected where practicable.

iv. Circuit-breakers, contactors etc. operated by remote control shall **open on de-energization of coils**, or other equivalent **failure-to-safety** techniques shall be employed.

v. The means of operating (handles, pushbuttons etc.) devices for emergency switching shall be clearly identified, **preferably coloured red** with a contrasting background.

vi. The means of operating shall **be readily accessible** at places where a danger might occur and, where appropriate, at any additional remote position from which that danger can be removed.

vii. The means of operation of a device for emergency switching shall be capable of latching or being restrained in the "off" or "stop" position.

viii. The release of an emergency switching device shall not re-energize the relevant part of the installation.

ix. Devices for emergency switching, including emergency stopping, shall be so placed and marked as to be readily identifiable and convenient for their intended use.

5.6.4 Functional Switching (Control)

(Ref: para 5.3.7.6 of IS 732: 2019)

i. A functional switching device shall be provided for each part of a circuit **which may require to be controlled** independently of other parts of the installation.

A single-pole switching device shall not be placed in the neutral conductor.

ii. Functional switching devices need not necessarily control all live conductors of a circuit.

iii. In general, all current-using apparatus requiring control shall be controlled by an appropriate functional switching device. A single-functional switching device may control several items of apparatus intended to operate simultaneously.

Plugs and socket-outlets rated at not more than 16 A may be used for functional switching.

iv. Functional switching devices ensuring the **change-over of supply from alternative sources** shall affect all live conductors and shall not be capable of putting the sources in parallel, unless the installation is specifically designed for this condition. In these cases, no provision is to be made for isolation of the PEN or protective conductors.

5.6.4.1 Functional Switching Devices

(Ref: para 5.3.7.6.2 of IS 732: 2019)

i. Functional switching devices shall be suitable for the most onerous duty they may be called upon to perform.

ii. Functional switching devices may control the current without necessarily opening the corresponding poles. Semiconductor switching devices are examples of devices capable of interrupting the current in the circuit but not opening the corresponding poles.

iii. Functional switching may be achieved by means of switches, semiconductor devices, circuit-breakers, contactors, relays and plugs and socket-outlets up to 16 A.

Dis-connectors, fuses and links shall not be used for functional switching.

5.7 ADEQUACY OF CONNECTION OF CONDUCTORS

(Ref: para 5.2.9 of IS 732: 2019)

i Connections between conductors and between conductors and other equipment shall provide durable electrical continuity and adequate mechanical strength and protection.

ii The use of soldered connections should be avoided, except in communication circuits.

iii Terminals without the marking "r" (only rigid conductors), "f" (only flexible conductors), "s" or "sol" (only solid conductors) are suitable for the connection of all types of conductors.

iv All connections shall be accessible for inspection, testing and maintenance, except for the following:

a. joints designed to be buried in the ground

b. compound-filled or encapsulated joints

c. connections between a cold tail and the heating element as in ceiling heating, floor heating and trace heating systems

d. a joint made by welding, soldering, brazing or appropriate compression tool and

e. joint forming part of the equipment complying with the appropriate product standard.

v Where necessary, precautions shall be taken so that the temperature attained by connections in normal service shall not impair the effectiveness of the insulation of conductors connected to them or supporting them.

vi **Conductor connections (not only final but also intermediate connections) shall only be made in suitable enclosures,** for example, in connection boxes, outlet boxes, or in equipment if the manufacturer has provided space for this purpose. In this case, equipment shall be used where fixed connection devices are provided or provision has been made for the installation of connection devices. At the termination of final circuits conductors shall be terminated in an enclosure.

vii Connections and junction points of cables and conductors shall be relieved from mechanical stress. Strain relief devices shall be designed so as to avoid any mechanical damage to the cables or conductors.

viii Where a connection is made in an enclosure, the enclosure shall provide adequate mechanical protection and protection against relevant external influences.

ix In order to protect against the separation or spreading of individual wires of multi-wire, fine wire or very fine wire conductors, suitable terminals shall be used or the conductor ends shall be suitably treated.

Soldering of the whole conductor end of multi-wire, fine wire and very fine wire conductors is permitted if suitable terminals are used.

x Soldered (tinned) conductor ends on fine wire and very fine wire conductors are not permissible at connection and junction points which are subject in service to a relative movement between the soldered and the non-soldered part of the conductor.

xi Cores of sheathed cables from which the sheath has been removed and non-sheathed cables at the termination of conduit, ducting or trunking shall be enclosed.

CHAPTER 6

SELECTION OF EQUIPMENT AND PROTECTIVE MEASURES APPROPRIATE TO EXTERNAL INFLUENCES

6.1 EXTERNAL INFLUENCES

(Ref: para 5.1.2.2 and table 7 of IS 732: 2019)

External influences applicable to specific locations shall be kept in mind while selecting any electrical equipment. The selection of equipment according to external influences is necessary not only for proper functioning, but also to ensure the reliability of the measures of protection for safety.

The characteristics of equipment shall be determined accordingly either by a degree of protection or by conformity to tests. If the equipment does not, by its construction, have the characteristics relevant to the external influences of its location, then appropriate additional protections shall be taken in the erection of the installation. Such protection shall not adversely affect the operation of the equipment thus protected.

When different external influences occur simultaneously, they may have independent or mutual effect and the degree of protection shall be provided accordingly.

External influences according to table 7 of IS 732:2019 are listed below in 6.1.1 to 6.1.3:

6.1.1 Environmental conditions

i Ambient temperature
ii Atmospheric humidity
iii Altitude
iv Presence of water
v Presence of foreign solid bodies or dust
vi Presence of corrosive or polluting substances
vii Mechanical shock
viii Vibration
ix Presence of flora and/or moulds growth
x Presence of fauna
xi Electromagnetic, electrostatic, or ionizing influences
xii Solar radiation
xiii Seismic effects
xiv Lightning
xv Movement of air
xvi Wind

6.1.2 Utilization

i Capability of persons
ii Contact of persons with earth potential
iii Conditions of evacuation in an emergency
iv Nature of processed or stored materials

6.1.3 Construction of buildings

i Construction materials

ii Building design

6.2 SELECTION AND ERECTION OF WIRING SYSTEMS IN RELATION TO EXTERNAL INFLUENCES

(Ref: para 5.2.5 and table 7 of IS 732:2019)

i The selected installation method shall protect the wiring system against the expected external influences.

ii Particular care shall be taken at changes in direction and where wiring enters into equipment.

iii Wiring systems shall be suitable for any temperature between the highest and the lowest local ambient temperature and to ensure that the limiting temperature (maximum continuous operating temperature) in normal operation and the limiting temperature in case of a fault will not be exceeded.

iv One or more of the following methods shall be used to protect wiring systems from harmful effects of heat from external sources:

- heat shielding
- placing sufficiently far from the source of heat
- selecting of the wiring system components suitable for the additional temperature rise which may occur
- local reinforcement of insulating material, for example, by heat-resisting insulated sleeving.

v Wiring systems shall be protected against condensation or ingress of water. The wiring system shall comply with the IP degree of protection relevant to the particular location.

vi In general, the sheaths and insulation of cables for fixed installations, when intact, are considered as proof against penetration by moisture. Special considerations apply to cables liable to frequent splashing, immersion or submersion.

vii Where water may collect or condensation may form in wiring systems, provision shall be made for its escape.

viii Wiring systems shall be protected from the ingress of solid foreign bodies. The wiring system shall comply with the IP degree of protection relevant to the particular location.

ix In a location where dust in significant quantity is present (AE4), additional precautions shall be taken to prevent the accumulation of dust which could adversely affect the heat dissipation from the wiring system.

x Where the presence of corrosive or polluting substances, including water, is likely to give rise to corrosion or deterioration, parts of the wiring system likely to be affected shall be suitably protected or manufactured from a material resistant to such substances. Suitable protection for application during erection may include protective tapes, paints or grease.

Dissimilar metals, liable to initiate electrolytic action, shall not be placed in contact with each other unless special arrangements are made to avoid the consequences of such contact example bimetallic connections.

xi Materials liable to cause mutual or individual deterioration or hazardous degradation shall not be placed in contact with each other.

Wiring systems shall be protected from mechanical stress, for example, by impact, penetration or compression during installation, use or maintenance.

xii In fixed installations where impacts of medium severity (AG2) or high severity (AG3) can occur, protection shall be afforded by:

a. the mechanical characteristics of the wiring system, or
b. the location selected, or
c. the provision of additional local or general mechanical protection, or
d. by any combination of the above.

Examples are areas where the floor is likely to be penetrated and areas used by forklift trucks. Additional mechanical protection may be achieved by using suitable cable trunking/ducting or conduit systems.

xiii A cable installed under a floor or above a ceiling shall be run in such a position that it is not liable to be damaged by contact with the floor or the ceiling or their fixings.

xiv The degree protection of electrical equipment shall be maintained after installation of the cables and conductors.

xv Wiring systems supported by or fixed to structures of equipment subject to vibration of medium severity (AH2) or high severity (AH3) shall be suitable for such conditions, particularly where cables and cable connections are concerned.

Special attention should be paid to connections to vibrating equipment. Local measures may be adopted such as flexible wiring systems.

xvi The fixed installation of suspended equipment, for example, luminaires, shall be connected by cable with flexible cores. Where no vibration or movement can be expected, cable with non-flexible core may be used.

The use of lubricants containing silicone oil for threading in cables and conductors into conduit systems, ducting systems, trunking systems and tray and ladder systems is not allowed.

xvii Where buried in the structure, conduit systems or cable ducting systems, shall be completely erected between access points before any insulated conductor or cable is drawn in.

The radius of every bend in a wiring system shall be such that conductors or cables do not suffer damage and terminations are not stressed.

xviii Where the conductors or cables are not supported continuously due to the method of installation, they shall be supported by suitable means at appropriate intervals in such a manner that the conductors or cables do not suffer damage by their own weight, or due to electro-dynamic forces resulting from short-circuit current.

xix **Where the wiring system is subjected to a permanent tensile stress** (for example, by its own weight in vertical runs) a suitable type of cable or conductor with appropriate cross-sectional areas and method of mounting shall be selected in such a manner **that the conductors or cables do not suffer damage by unacceptable tensile stress.**

xx Wiring systems intended for the drawing in or out of conductors or cables shall have adequate means of access to allow this operation.

xxi Wiring systems buried in floors shall be sufficiently protected to prevent damage caused by the intended use of the floor.

Wiring systems which are rigidly fixed and buried in the walls shall be run horizontally, vertically or parallel to the room edges.

xxii Wiring systems in ceilings or in floors may follow the shortest practical route.

xxiii Wiring systems shall be installed so that mechanical stress to the conductors and connections is avoided.

xxiv Cables, conduits or ducts that are buried in the ground shall either be provided with protection against mechanical damage or be buried at a depth that minimizes the risk of such damage. Buried cables shall be marked by cable covers or a suitable marking tape. Buried conduits and ducts shall be suitably identified.

Mechanical protection may be achieved by using conduit systems buried underground according to IS 14930 (Parts 1 & 2) or armoured cables or other appropriate methods such as cover plates.

Cable supports and enclosures shall not have sharp edges liable to damage the cables or insulated conductors.

xxv Cables and conductors shall not be damaged by the fixing means.

xxvi Cables, busbars and other electrical conductors which pass across expansion joints shall be so selected and erected that anticipated movement does not cause damage to the electrical equipment, for example, by use of flexible wiring system.

xxvii Where wiring passes through fixed partitions, it shall be protected against mechanical damage, for example, metallic sheathed or armoured cables, or by use of conduit or grommets.

No wiring system should penetrate an element of building construction which is intended to be load-bearing unless the integrity of the load-bearing element can be assured after such penetration.

xxviii Where the conditions experienced or expected constitute a hazard (AK2-*Presence of flora and/or mould growth*), the wiring system shall be selected accordingly or special protective measures shall be adopted.

Possible preventive measures are closed types of installation (conduit or cable ducting or cable trunking), maintaining distances to plants and regular cleaning of flora in relevant wiring system.

xxix Where conditions experienced or expected constitute a hazard (AL2-*Presence of fauna-insects, birds, small animals)*, the wiring system shall be selected accordingly or special protective measures shall be adopted, for example, by

a. the mechanical characteristics of the wiring system, or
b. the location selected, or
c. the provision of additional local or general mechanical protection, or
d. by any combination of the above.

Solar radiation (*AN) and ultraviolet radiation*

xxxv Where significant solar radiation (AN2) or ultraviolet radiation is experienced or expected, a wiring system suitable for the conditions shall be selected and erected or adequate shielding shall be provided. Special precautions may need to be taken for equipment subject to ionizing radiation.

xxxvi The wiring system shall be selected and erected with due regard to the seismic hazards of the location of the installation.

xxxvii Where the seismic hazards experienced are low severity (AP2) or higher, particular attention shall be paid to the following:

a) the fixing of wiring systems to the building structure; and

b) the connections between the fixed wiring and all items of essential equipment, for example, safety services, shall be selected for their flexible quality.

xxxviii Where risks due to structural movement exist (CB3), the cable support and protection system employed shall be capable of permitting relative movement so that conductors and cables are not subjected to excessive mechanical stress.

xxxix For flexible structures or structures intended to move (CB4), flexible wiring systems shall be used.

CHAPTER 7

IDIENTIFICATION OF CONDUCTORS & SWITCHGEARS

7.1 GENERAL

i Labels or other suitable means of identification shall be provided to indicate the purpose of switchgear and control gear, unless there is no possibility of confusion.

ii Where the functioning of switchgear and control gear cannot be observed by the operator and where this mightcause a danger, a suitable indicator shall be fixed in a position visible to the operator.

7.2 IDENTIFICATION OF WIRING SYSTEMS

Wiring shall be so arranged or marked that it can be identified for inspection, testing, repairs or alteration of the installation. The details as per IS 11353- 1985 Reaffirmed 2017 are as under:

ALPHANUMERIC NOTATION, GRAPHICAL SYMBOLS AND COLOURS

Designation of Conductors		Identification by		
		Alphanumeric Notation	Graphical Symbol	Colour
Supply ac system	Phase 1	L1		Red
	Phase 2	L2		yellow
	Phase 3	L3		Blue
	Neutral	N		Black
Apparatus ac system	Phase 1	U		Red
	Phase 2	V		Yellow
	Phase 3	W		Blue
	Neutral	N		Black
Supply dc system	Positive	L+	+	Red
	Negative	L-	-	Blue
	Midwire	M		Black
Supply ac * system (single phase)	Phase	L		Red
	Neutral	N		Black
Protective conductor		PE		Green and Yellow
Earth		E		No colour other than the colour of the bare conductor. If insulated, the colour for insulation so chosen to avoid those listed above for designation of other conductors.

*For single phase ac systems, the colour of red and black are recommended if the circuit is in isolation. In cases where the single phase conductors are associated with the 3-phase system from which they are derived, the phase conductor shall use the same colour as that phase from which it is derived.

For lighting the red wire shall always feed the switch, and a red wire must be used from the switch to the lighting point.

The use of light blue colour for internal wiring is also not permitted.

7.3 IDENTIFICATION OF PROTECTIVE CONDUCTORS

(Ref: IS 11353- 1985 Reaffirmed 2017)

The protective conductor designated as 'PE' shall have bi-colour combination, green and yellow (green/yellow), for identification as protective conductor and for no other purpose.

Bare conductors or bus bars, used as protective conductors, shall be coloured by equally broad green and yellow stripes, each 15 mm up to 100 mm wide, close together, either throughout the length of each conductor or in each compartment or unit or at each accessible position. If adhesive tape is used, only bi-coloured tape shall be applied.

For insulated conductors, the combination of the colours, green and yellow, shall be such that, on any 15 mm length of insulated conductor, one of these colours covers 30 percent and not more than 70 percent of the surface of the conductor and other colour covering the remainder of that surface.

Where the protective conductor can be easily identified from its shape, construction or position, for example concentric conductor, then colour coding throughout its length is not necessary but the ends or accessible positions should be clearly identified by a symbol or the bi-colour combination green-and-yellow.

PEN conductors, when insulated, shall be marked by one of the following methods:

a. Green/yellow throughout their length with, in addition, light blue markings at the terminations, or

b. light blue throughout their length with, in addition, green/yellow markings at the terminations.

7.4 IDENTIFICATION OF NEUTRAL CONDUCTORS

(Ref: IS 11353- 1985 Reaffirmed 2017)

Black colour is intended for the neutral conductor.

If identification by colour is used, bare conductors or bus-bars, used as neutral, shall be either coloured by a black stripe, 15 mm to 100 mm wide in each compartment or unit or at each accessible position or coloured black throughout their length.

7.5 IDENTIFICATION OF BUSBARS

(Ref: IS 11353- 1985 Reaffirmed 2017)

It is recommended that individual busbars and similar conductors, whether insulated or not, should be identified where appropriate, by a graphical symbol or alphanumeric notation rather than by colours.

If, however, colours are used, the colours selected shall be in accordance with above table given in para 7.2. When busbars or similar conductors are insulated, the preferred colour for the insulation is black. Identification of the phases shall be done using stripes or bands or other suitable means of colours given in table in para 7.2 above.

7.6 IDENTIFICATION OF APPRATUS TERMINALS

(Ref: IS 11353- 1985 Reaffirmed 2017)

The purpose. of identifying apparatus terminals is to provide information regarding the function of the terminal or its location with respect to other terminals or for other purposes.

The identifying colour, graphical symbols or alphanumeric notation employing Latin alphabetical characters and Arbic numeral characters shall normally be applied to the corresponding apparatus terminal.

The alphabetical characters used for the marking of terminals on apparatus and conductors shall be capital (upper case) Latin characters only.

The letters I and O shall not be used for marking apparatus terminals.

For the internal wiring of apparatus and equipment, it is recommended that only one colour be used. This colour shall be so chosen that it is not one of the colours listed in table in para 7.2 above for designation of other conductors. The use of light blue colour for internal wiring of apparatus is also not permitted.

7.7 IDENTIFICATION OF PROTECTIVE DEVICES

The protective devices shall be arranged and identified in such a manner that the circuits protected may be easily recognized and it may be convenient to group them in distribution boards.

7.8 DIAGRAMS

Where appropriate, diagrams, charts or tables shall be provided, indicating in particular:

a. the type and composition of circuits (points of utilization served, number and size of conductors, type of wiring) and
b. the characteristics necessary for the identification of the devices performing the functions of protection, isolation and switching and their locations.

For simple installations the foregoing information may be given in a schedule.

i The symbols used shall be chosen from the IS 12032 series.

7.9 ACCESSIBILITY

All equipment, including wiring, shall be arranged so as to facilitate its operation, inspection, maintenance and access to its connections. Such facilities shall not be significantly impaired by mounting equipment in enclosures or compartments.

CHAPTER 8

PROTECTIVE CONDUCTORS (EARTH WIRES), INCLUDING MAIN AND SUPPLEMENTARY EQUIPOTENTIAL BONDING CONDUCTORS

8.1 GENERAL

(Ref: para 5.4.2.1 of IS 732:2019)

i The earthing arrangements may be used jointly or separately for protective and functional purposes according to the requirements of the electrical installation. **The requirements for protective purposes shall always take priority.**

ii Where provided, earth electrodes within an installation shall be connected to the main earthing terminal using an earthing conductor. An installation does not need to have its own earth electrode.

iii Where the supply to an installation is at high voltage, requirements concerning the earthing arrangements of the high voltage supply and of the low-voltage installation shall also comply with **4.5.2** of IS 732:2019.

iv The requirements for earthing arrangements are intended to provide a connection to earth which:

a. is reliable and suitable for the protective requirements of the installation
b. **can carry earth fault currents and protective** (earth) **conductor currents to earth without danger** from thermal, thermo-mechanical and electromechanical stresses and from electric shock arising from these currents
c. if relevant, is also suitable for functional requirements
d. is suitable for the foreseeable external influences, for example, mechanical stresses and corrosion.

v Consideration shall be given to the earthing arrangements where currents with high frequencies are expected to flow.

vi Protection against electric shock, shall not be adversely affected by any foreseeable change of the earth electrode resistance (for example, due to corrosion, drying or freezing).

8.2 EARTH ELECTRODES

(Ref: para 5.4.2.2 of IS 732:2019)

i The type, materials and dimensions of earth electrodes shall be selected to withstand corrosion and to have adequate mechanical strength for the intended lifetime.

ii For corrosion, the following parameters may be considered:

a. the soil *pH* at the site,
b. soil resistivity
c. soil moisture,
d. stray and leakage a.c. and d.c. current,
e. chemical contamination, and proximity of dissimilar materials.

iii The earthing arrangement shall not rely on a metallic pipe for flammable liquids or gases as the earth electrode and their buried length shall not be considered when dimensioning the earth electrode. But this requirement does not rule out the protective equipotential bonding via the main earthing terminal of such pipes.

8.3 EARTHING CONDUCTORS

(Ref: para 5.4.2.3 of IS 732:2019)

i Earthing conductors cross-sectional area shall be not less than 6 mm^2 for copper or 50 mm^2 for steel when in air. **Where a bare earthing conductor is buried in the soil, its dimensions and characteristics shall also be in accordance with the minimum size required for earth electrode embedded in soil or concrete as per table given below.**

Table 13 of IS 732 Minimum Size of Commonly Used Earth Electrodes, embedded in Soil or Concrete Used to Prevent Corrosion and Provide Mechanical Strength

Material and Surface (1)	Shape (2)	Diameter mm (3)	Cross-Sectional Area mm^2 (4)	Thickness mm (5)	Weight of Coating g/m^2 (6)	Thickness of Coating/ Sheathing μm (7)
Steel embedded in concrete (bare, hot galvanized or stainless)	Round wire	10				
	Solid tape or strip		75	3		
Steel hot-dip galvanized[3]	Strip[2] or shaped strip/plate – Solid plate – Lattice plate		90	3	500	63
	Round rod installed vertically	16			350	45
	Round wire installed horizontally	10			350	45
	Pipe	25		2	350	45
	Stranded (embedded in concrete)		70			
	Cross profile installed vertically		(290)	3		
Steel copper-sheathed	Round rod installed vertically	(15)				2 000
Steel with electro-deposited copper coating	Round rod installed vertically	14				250[5]
	Round wire installed horizontally	(8)				70
	Strip installed horizontally		90	3		70
Stainless steel[1]	Strip[2] or shaped strip/plate		90	3		
	Round rod installed vertically	16				
	Round wire installed horizontally	10				
	Pipe	25		2		
	Strip		50	2		
	Round wire installed horizontally		(25)[4] 50			

Material and Surface (1)	Shape (2)	Diameter mm (3)	Cross-Sectional Area mm^2 (4)	Thickness mm (5)	Weight of Coating g/m^2 (6)	Thickness of Coating/ Sheathing μm (7)
Copper	Solid round rod installed vertically	(12) 15				
	Stranded wire	1.7 for individual strands of wire	(25) [4] 50			
	Pipe	20		2		
	Solid plate			(1.5) 2		
	Lattice plate			2		
NOTE - Values in brackets are applicable for protection against electric shock only, while values not in brackets are applicable for lightning protection and for protection against electric shock.						

[1] Chromium ≥16 %, Nickel ≥5 %, Molybdenum ≥2 %, Carbon < 0.08 %.

[2] As rolled strip or slit strip with rounded edges.

[3] The coating shall be smooth, continuous and free from flux stains.

[4] Where experience shows that the risk of corrosion and mechanical damage is extremely low, 16 mm^2 can be used.

[5] 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 to avoid mechanical damage of copper during the installation process (for example, drilled holes or special protective tips) are taken according to the manufacturer's instructions.

ii Where no noticeable fault current is expected to flow through the earth electrode (for example, in TN systems or IT systems), the earthing conductor shall have a cross-sectional area not less than half the cross-sectional area of the largest protective earthing conductor within the installation and not less than 6 mm^2 copper; or 50 mm^2 steel.

iii The cross-sectional area of earthing conductors need not exceed 25 mm^2 Cu or an equivalent cross sectional area for other materials.

Aluminium conductors shall not be used as earthing conductors.

Where a lightning protection system is connected to the earth electrode, the cross-sectional area of the earthing conductor should be at least 16 mm^2 for copper (Cu) or 50 mm^2 for iron (Fe).

iv The connection of an earthing conductor to an earth electrode shall be soundly made and electrically satisfactory. The connection shall be by exothermic welding, pressure connectors, clamps or other suitable mechanical connectors.

Connection devices or fittings that depend solely on solder shall not be used independently, as they do not reliably provide adequate mechanical strength.

v Where vertical electrodes are installed, means may be provided to allow the inspection of the connection and there placement of the vertical rod.

8.4 MAIN EARTHING TERMINAL (MET)

(Ref: para 5.4.2.4 of IS 732: 2019)

i In every installation where protective equipotential bonding is used, a main earthing terminal (MET) shall be provided and the following shall be connected to it:
   a. protective bonding conductors
   b. earthing conductors
   c. protective conductors
   d. functional earthing conductors, if relevant.

ii It is not intended to connect every individual protective (earth) conductor directly to the MET where they are connected to this terminal by other protective conductors.

iii The MET of the building can generally be used for functional earthing purposes. For information technology purposes, it is then regarded as the connection point to the earth.

iv Where more than one earthing terminal is provided, they shall be interconnected.

v Each conductor connected to the MET shall be able to be disconnected individually. This connection shall be reliable and such that it can only be disconnected by means of a tool.

vi Disconnection means may conveniently be combined with the MET, to permit measurement of the resistance of the earth electrode.

8.5 PROTECTIVE CONDUCTORS

(Ref: para 5.4.3 of IS 732: 2019)

8.5.1 Minimum Cross-Sectional Areas of Protective Conductors

(Ref: para 5.4.3.1 of IS 732: 2019)

i The cross-sectional area of every protective (earth) conductor shall satisfy the conditions for automatic disconnection of supply and be capable of withstanding mechanical and thermal stresses caused by the prospective fault current during the disconnection time of the protective device.

ii The cross-sectional area of a protective (earth) conductor shall either be calculated in accordance with 5.4.3.1.2 of IS 732:2019 or selected in accordance with **table given below**.

Minimum Cross-Sectional Area of Protective Conductors (Table 14 of IS 732:2019)

Cross-sectional Area of Line Conductor, S	Minimum Cross-Sectional Area of the Corresponding Protective (earth) Conductor	
	If the protective (earth) conductor is of the same material as the line conductor	If the protective (earth) conductor is not of the same material as the line conductor
(1)	(2)	(3)
$S \leq 16$	S	$\frac{k1}{k2} \times S$
$16 < S \leq 35$	16[1)]	$\frac{k1}{k2} \times 16$
$S > 35$	$\frac{S^1}{2}$	$\frac{k1}{k2} \times \frac{S}{2}$

where k1 = is the value of k for the line conductor derived from the formula given in Annex EE of IS 732:2019 or selected from tables given in IEC 60364-4-43, according to the materials of the conductor and insulation; k2 = is the value of k for the protective conductor, selected from Tables 58 to Table 62 of IS 732:2019 as applicable.
1) For a PEN conductor, the reduction of the cross-sectional area is permitted only in accordance with the rules for sizing of the neutral conductor.

iii In **TT systems,** where the earth electrodes of the supply system and of the exposed conductive parts are electrically independent, the cross-sectional area of protective conductors need not exceed:
- **25 mm² copper**
- **35 mm² aluminium.**

iv The cross-sectional area of every protective (earth) conductor which does not form part of **a cable or which is not in a common enclosure with the line conductor shall be not less than:**
a. **2.5 mm² Cu or 16 mm² Al,** if protection against mechanical damage is provided and
b. 4.0 mm² Cu or 16 mm² Al, if protection against mechanical damage is not provided.

v **A protective** (earth) **conductor not forming part of a cable is considered to be mechanically protected if it is installed in a conduit, trunking or protected in a similar way.**

vi Where a protective (earth) conductor is common to two or more circuits, its cross-sectional area shall be selected in accordance with above **Table 14** so as to correspond to the cross-sectional area of the largest line conductor of the circuits.

8.5.2 Types of Protective Conductors
(Ref: para 5.4.3.2 of IS 732:2019)

i 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
d. metallic cable sheath, cable screen, cable armour, wire braid, concentric conductor, metallic conduit

ii The following **metal parts are not permitted for use as protective conductors or as protective bonding conductors**:
a. metallic water pipes
b. metallic pipes containing potentially flammable materials such as gases, liquids, powder

8.5.3 Electrical Continuity of Protective Conductors
(Ref: para 5.4.3.3 of IS 732:2019)

i Protective conductors shall be suitably protected against mechanical damage, chemical or electrochemical deterioration, electrodynamics forces and thermodynamic forces.

ii Every connection (for example, screwed connections, clamp connectors) between protective conductors or between a protective (earth) conductor and other equipment shall provide durable electrical continuity and adequate mechanical strength and protection.

iii **Screws for connecting protective conductors shall not serve any other purpose.**
Joints shall not be made by soldering.

iv **Joints in protective conductors shall be accessible for inspection and testing** except for:

a. compound-filled joints,
b. encapsulated joints,
c. joints in metal conduits, ducting and busbar trunking systems,
d. joints forming part of equipment, complying with equipment standards,
e. joints made by welding or brazing, and
f. joints made by compression tool.

iv. **No switching device shall be inserted in the protective conductor,** but joints which can be disconnected for test purposes by use of a tool may be provided.

v. Where electrical monitoring of earthing is used, **dedicated devices (for example operating sensors, coils, current transformers) shall not be connected in series in protective conductors**.

vi. **Exposed-conductive-parts of electrical equipment shall not be used to form part of the protective** (earth) **conductor for other equipment.**

8.5.4 Combined Protective and Functional Earthing Conductors

(Ref: para 5.4.3.5 of IS 732: 2019)

Where a combined protective and functional earthing conductor is used, it shall satisfy the requirements for a protective conductor. In addition, it shall also comply with the relevant functional requirements.

8.5.5 Currents in Protective Earthing Conductors

(Ref: para 5.4.3.6 of IS 732: 2019)

i. **The protective earthing conductor should not be used as a conductive path for current under normal operating conditions.** (for example, connection of filters for EMC- reasons).

ii. **Where the current exceeds 10 mA under normal operating conditions, a reinforced protective** (earth) **conductor shall be used (See para 8.5.7 of this booklet).**

8.5.6 Reinforced protective earthing conductors for protective earthing conductor currents exceeding 10 mA

(Ref: para 5.4.3.7 of IS 732: 2019)

For current-using equipment intended for permanent connection and with a protective earthing conductor current exceeding 10 mA the following applies:

i. Where the current-using equipment has only one protective earthing terminal, the protective earthing conductor shall have a cross-sectional area of at least 10 mm^2 Cu or 16 mm^2 Al, through its total run.

ii. Where the current-using equipment has a separate terminal for a second protective earthing conductor, a second protective earthing conductor of at least the same cross- sectional area as required for fault protection shall be run from a point where the protective earthing conductor has a cross-sectional area not less than 10 mm^2 Cu or 16 mm^2 Al.

iii. **Current-using equipment normally having high protective conductor current may not be compatible with installations incorporating RCCBs**.

8.5.7 Arrangement of Protective Conductors

(Ref: para 5.4.3.8 of IS 732:2019)

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 or be located in their immediate proximity.

8.6 PROTECTIVE BONDING CONDUCTORS

(Ref: para 5.4.4 of IS 732:2019)

8.6.1 Protective Bonding Conductors for Connection to MET

Protective bonding conductors for connection to the MET shall have a cross-sectional area not less than **half the cross-sectional area of the largest protective earthing conductor** within the installation and **not less than**:

a. 6 mm^2 copper or
b. 16 mm^2 aluminium or
c. 50 mm^2 steel.

The **cross-sectional area of protective bonding conductors for connection to the MET need not exceed 25 mm^2 Cu or an equivalent cross- sectional area for other materials**.

8.6.2 Protective Bonding Conductors for Supplementary Bonding

i. A protective bonding conductor connecting two exposed conductive parts shall have a conductance not less than that of the smaller protective conductor connected to the exposed conductive parts.

ii. A protective bonding conductor connecting exposed conductive parts to extraneous conductive parts shall have a conductance not less than half that of the cross-sectional area of the corresponding protective conductor.

iii. The minimum cross-sectional area of protective bonding conductors for supplementary bonding, and of bonding conductors between two extraneous conductive parts, shall be in accordance with para 8.5.1 of this booklet.

8.7 SUMMARY OF PROTECTIVE CONDUCTORS SIZING

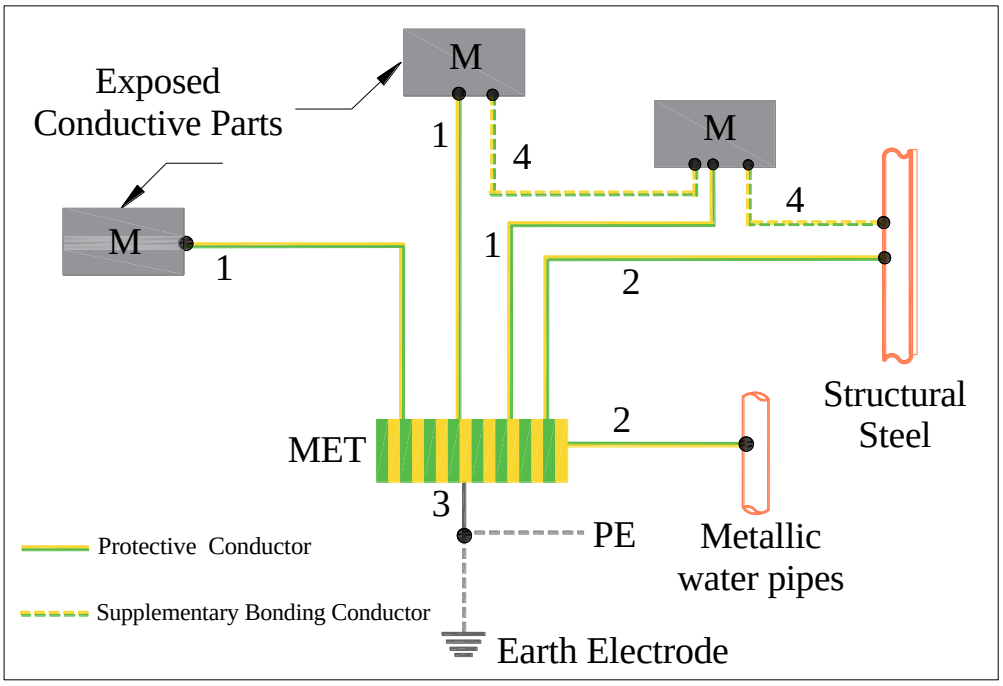


Figure 26: Equipotential bonding with all exposed/extraneous conductive parts

PE (Protective Earthing) Conductors	
M	Exposed Conductive parts of current using equipment
1	Circuit protective conductors
2	Main protective bonding conductor
3	Earthing conductor
4	Supplementary protective bonding conductor (if required)
1,2,3,4	Protective conductors

8.7.1 Circuit Protective Conductors (Earth Conductors) (Ref: para 5.4.3 of IS 732:2019)

Refer 8.5.1 above for details.

8.7.2 Earthing Conductor (Ref: para 5.4.2.3 & 5.4.4.1 of IS 732:2019)

Nominal cross-sectional area	When in Air	Minimum Size when buried in soil	In TN systems or IT systems		If lightning protection system is connected to the earth electrode	Remark
			Minimum Size	Maximum Size	Minimum Size	
Shall be equivalent to Circuit Protective Conductors as mentioned above	6 mm^2 for copper or 50 mm^2 for steel	As per table 13 of IS 732 equivalent to minimum size of earth electrode.	not less than half the cross-sectional area of the largest protective earthing conductor within the installation	25 mm^2 Cu or equivalent cross sectional area for other materials	16 mm^2 for copper or 50 mm^2 for steel	Aluminium conductors shall not be used.
Refer 8.3 of this chapter for more details						

8.7.3 Main Protective Bonding Conductors (Ref: para 5.4.4.1 of IS 732:2019)

Nominal cross-sectional area	Minimum Size	Maximum Size	Remark
not less than half the cross-sectional area of the largest protective earthing conductor within the installation	6 mm^2 copper or 16 mm^2 aluminium or 50 mm^2 steel.	25 mm^2 Cu or equivalent cross sectional area for other materials	Refer 8.6.1 of volume-3 for more details

8.7.4 Supplementary Protective Bonding Conductors (Ref: para 5.4.4.2 of IS 732:2019)

Minimum size	Between two exposed conductive parts	Between exposed conductive parts to extraneous conductive parts	Minimum size between two extraneous conductive parts	Remark
shall be in accordance with Circuit Protective Conductors as mentioned above	not less than that of the smaller protective conductor connected to the exposed conductive parts	not less than half that of the cross-sectional area of the corresponding protective conductor	shall be in accordance with Circuit Protective Conductors as mentioned above	Refer 8.6.2 of volume-3 for more details

ANNEXURE-1

TERMINOLOGY

1. **Ambient Temperature -** *"The temperature of the air or other medium where the equipment is to be used (or installed)."* It is assumed that the ambient temperature includes the effects of other equipment installed in the same location. The ambient temperature to be considered for the equipment is the temperature at the place where the equipment is to be installed resulting from the influence of all other equipment in the same location, when operating, not taking into account the thermal contribution of the equipment to be installed.
2. **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 to trip.
3. **Barrier V**— A part providing a defined degree of protection against contact with live parts, from any usual direction of access.
4. **Basic Insulation** — Insulation applied to live parts to provide basic protection against electric shock and which does not necessarily include insulation used exclusively for functional purpose.
5. **Basic Protection** — Protection against electric shock under fault-free condition. For low voltage installations, systems and equipment, basic protection generally corresponds to protection against direct contact that is "contact of persons or live parts".
6. **Bonding Conductor** — A protective conductor providing equipotential bonding.
7. **Buried Direct** — A cable laid in the ground in intimate contact with the soil.
8. **Bunched** — Cables are said to be bunched when two or more cables are contained within a single conduit, duct, ducting, or trunking or, if not enclosed, are not separated from each other.
9. **Busbar Trunking System** — A type-tested assembly, in the form of an enclosed conductor system comprising solid conductors separated by insulating materials.
10. **Circuit** —An assembly of electrical equipment supplied from the same origin and protected against overcurrent by the same protective devices. Certain types of circuit are categorised as follows:
11. **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.
12. **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.
13. **Category 3 Circuit** — A fire alarm circuit or an emergency lighting circuit.
14. **Circuit Breaker** — A mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions and also of making, carrying for as specified, and breaking currents under specified abnormal circuit conditions such as those of short circuit.
15. **Circuit Breaker Linked**— A circuit breaker the contacts of which are so arranged as to make or breakall poles simultaneously or in a definite sequence.
16. **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 installationin such a way that accessible conductive parts may notbecome live in the event of a failure of basic installation.

17. **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.
18. **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.
19. **Combustible** — Capable of burning.
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.
21. **Current Using Equipment** — Equipment which converts electrical energy into another form of energy, such as light, heat, or motive power.
22. **Design Current (of a Circuit)** — The magnitude of the current intended to be carried by the circuit in normal service.
23. **Discrimination** — Ability of a protective device to operate in preference to another protective device in series.
24. **Distribution Circuit (of Buildings)** — A circuit supplying a distributing board.
25. **Double Insulation** — Insulation comprising both basic insulation and supplementary insulation.
26. **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.
27. **Earth Fault Current** — A current resulting from a fault of negligible impedance between a line conductor and an exposed conductive part or a protective conductor.
28. **Earth Leakage Current** — A current which flows to earth, or to extraneous conductive parts, in a circuit which is electrically sound.
29. **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.
30. **Electric Shock** — A dangerous patho- physiological effect resulting from the passing of an electric current through a human body or an animal.
31. **Electrical Equipment (**abb: **Equipment)** — Any item for such purposes as generation, conversion, transmission, distribution or utilization of electrical energy, such as machines, transformers, apparatus, measuring instruments, protective devices, wiring materials, accessories, and appliances.
32. **Enclosure** — A part providing protection of equipment against certain external influences and, in any direction, protection against direct contact.
33. **External Influence** — Any influence external to an electrical installation which affects the design and safe operation of that installation.
34. **Fault** — A circuit condition in which current flows through an abnormal or unintended path. This may result from an insulation failure or a bridging of insulation. Conventionally the impedance between live conductors or between lives conductors and exposed or extraneous conductive parts at the fault position is considered negligible.
35. **Fault Current** — A current resulting from a fault.
36. **Fault Protection** — Protection against electric shock under single fault conditions. For low voltage

installation, systems and equipment, fault protection generally corresponds to protection against indirect 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."

37. **Final Circuit** — A circuit connected directly to current using equipment, or to socket outlets or other outlet points for the connection of such equipment.
38. **Fixed Equipment** — Equipment fastened to a support or otherwise secured.
39. **Flammability** — Ability of a material or productto burn with a flame under specified test condition.
40. **Functional Bonding Conductor** — Conductor provided for functional equipotential bonding.
41. **Functional Earthing** — Connection to earth necessary for proper functioning of electrical equipment.
42. **Functional Extra-Low Voltage (FELV)** — An extra-low voltage system in which not all of the protective measures required for SELV or PELV havebeen applied.
43. **Fuse** — A device which, by melting of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted bybreaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device.
44. **Hazardous-Live Part** — A live part which cangive, under certain condition of external influence, an electric shock.
45. **Indirect Contact** — Contact of persons orlivestock with exposed conductive parts made live bya fault and which may result in electric shock.
46. **Insulation** — Suitable non-conductive material enclosing surrounding or supporting a conductor.
47. **Isolation** — Cutting off an electrical installation,a circuit, or an item of equipment from every source ofelectrical energy.
48. **Isolator** — A mechanical switching device which,in the open position, complies with the requirements specified for the isolating function. An isolator is otherwise known as a disconnector.
49. **Leakage Current** — Electric current in an unwanted conductive path under normal operating conditions.
50. **Line Conductor** — A conductor of an a.c. systemfor the transmission of electrical energy other than a neutral conductor or a PEN conductor. This also means the equivalent conductor of a d.c. system unless otherwise specified in the Regulations.
51. **Live Part** — A conductor or conductive part intended to be energized in normal use including a neutral conductor but, by convention, not a PEN conductor.
52. **Main Earthing Terminal (MET)** — The terminal or bar which is the equipotential bonding conductor of protective conductors, and conductors for functional earthing, if any, to the means of earthing.
53. **Origin of an Electrical Installation** — The point at which electrical energy is delivered to an installation.
54. **Overcurrent** — A current exceeding the rated value. For conductors, the rated value is the current carrying capacity.
55. **Overcurrent Detection** —A method of establishing that the value of current in a circuit (or wall) such that in the event of direct contact exceeds apredetermined value for a specified time with a live part, a person standing on the floor (or touching the wall) cannot be traversed by a shock current flowing to the floor (or wall).
56. **Overload Current (of a Circuit)** — An overcurrent occurring in a circuit in the absence of an electrical

fault.

57. **PEL Conductor** —A conductor combining the function of both a protective earthing and a line conductor.
58. **PELV (Protective Extra-low Voltage)** — An extra-low voltage system which is not electrically separated from earth, but which otherwise satisfies allthe requirements for SELV.
59. **PEM Conductor** — A conductor combining the function of both a protective earthing conductor and a midpoint conductor.
60. **PEN Conductor** — A conductor combining the functions of both protective conductor and neutral conductor.
61. **Prospective Fault Current (I_{pf})** — The value of overcurrent 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 andan exposed conductive part.
62. **Prospective Touch Voltage** — The highest touchvoltage liable to appear in the event of a fault of negligible impedance in the electrical installation.
63. **Protective Conductor** — A conductor used forsome measures of protection against electric shock and intended for connecting together any of the followingparts:
    a. Exposed conductive parts,
    b. Extraneous conductive parts,
    c. The main earthing terminal, and
    d. The earthed point of the source, or an artificialneutral.
64. **Protective Conductor Current** —Electric current appearing in a protective conductor, such as leakage current or electric current resulting from an insulation fault.
65. **Protective Earthing** —Earthing of a point or points in a system or in equivalent for the purposes of safety.
66. **Rated Current** —Value of current used for specification purposes, established for a specified set of operating conditions of a component, device, equipment or system.
67. **Reinforced Insulation** — Single insulation applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in the relevant standard.
68. **Residual Current** — The algebraic sum of theinstantaneous values of current flowing through all live conductors of a circuit at a point of the electrical installation.
69. **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.
70. **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.
71. **Shock Current** —A current passing through the body of a person or an animal and having characteristics likely to cause dangerous patho- physiological effects.
72. **Short-Circuit Current** — An overcurrent resulting from a fault of negligible impedance betweenlive conductors having a difference in potential undernormal operating conditions.
73. **Simultaneously Accessible Parts** — Conductors or conductive parts which can be touched

simultaneously by a person or, where applicable by livestock. It should be noted that the word touched signifies any contact with any part of the body (hand, foot, head, etc).

74. CATEGORIES OF FUSES AS PER IEC 60269

Fuse type generally has two letters (i.e. aM, aR, gR, gG, gTr, etc.).

The first letter indicates the main operating mode:

a = associated fuse. It must be associated to another protective device as it cannot interrupt faults below a specified level. **Used in Short circuit protection only**.

g = general purpose fuse. It will interrupt all faults between the lowest fusing current (even if it takes 1 hour to melt the fuse elements) and the breaking capacity. **Used in Overload and short circuit protection.**

The second letter indicates the object to be protected:

G = cable and conductor protection, general

M = motor circuit protection

R or S= semiconductor protection

Tr = transformer protection

Fuse Type	Typical Industrial Applications
gG	General purpose fuse essentially for conductor protection
gM	Motor protection
aM	Motor circuit protection against short circuit only
aR	Fuse for semi conductor protection (IEC 269)
gTr	Transformer protection
gR, gS	Fuse for semi conductor protection and conductor protection

a. Fuse - links with gG characteristic are low voltage HRC fuse - links with blade contacts, intended for protection of wires, cables against overload and short circuit currents.

b. gG (general purpose, formerly gL) is the most common operating class in fuses. A gG class fuse will typically **blow within 2–5 seconds at five times the rated current**, and **within 0.1–0.2 seconds at ten times the rated current.**

ANNEXURE-2

CHARACTERISTICS OF EXTERNAL INFLUENCES

(Ref: Table 7 of IS 732: 2019)

Table-1: Classification of Buildings according to Conditions of evacuation in an emergency

BD	Conditions of evacuation in an emergency	
BD1 (Normal)	Low density/ easy exit	Low density occupation, easy conditions of evacuation Buildings of normal or low height used for habitation.
BD2	Low density/ difficult exit	Low density occupation, difficult conditions of evacuation. High-rise buildings
BD3	High density/ easy exit	High density occupation, easy conditions of evacuation. Locations open to the public (theatres, cinemas, departments stores, etc.)
BD4	High density/ difficult exit	High density occupation, difficult conditions of evacuation High-rise buildings open to the public (hotels, hospitals, etc.)

Table-2: Classification of Buildings according to Nature of processed or stored materials

BE	Nature of processed or stored materials	
BE1	No significant risks	Normal, this means that ordinary equipment will operate safely under the described external influences.
BE2	Fire risks	Manufacture, processing or storage of flammable materials including presence of dust. Barns, wood-working shops, paper factories.
		Characteristics Required for Selection and Erection of Equipment: • Equipment made of material retarding the spread of flame. • Arrangements such that a significant temperature rise or a spark within electrical equipment cannot initiate an external fire

Table-3: Classification of Buildings according to Constructional material

CA	Constructional materials	
CA1	Non combustible	• Normal, this means that ordinary equipment will operate safely under the described external influences.
CA2	Combustible	• Buildings constructed mainly out of combustible materials • Wooden buildings • Under consideration
		Characteristics Required for Selection and Erection of Equipment:
		• Precautions shall be taken to ensure that electrical equipment cannot cause the ignition of walls, floors or ceilings. This can be

		achieved by proper design, choice and installation of electrical equipment. • To avoid the ingress of solid foreign objects, boxes and enclosures installed in prefabricated hollow walls liable to be drilled during erection of the wall shall have a degree of protection of at least IP3X.

Table-4: Classification of Buildings according to Building design

CODE	External Influences	Conditions of shape and dimension of structure/ building
CB1	Negligible risks	• Normal, this means that ordinary equipment will operate safely under the described external influences.
CB2	Propagation of fire	• Buildings of which the shape and dimensions facilitates the spread of fire (for example, chimney effects). Like High-rise buildings and forced ventilation systems
		Characteristics Required for Selection and Erection of Equipment: • Equipment made of material retarding the propagation of fire including fires not originating from the electrical installation. • Fire barriers & Fire detectors may be provided.

Table-5: Classification of Buildings according to Capability of persons

BA	Capability of persons	
BA1	Ordinary	• Uninstructed persons. • Normal, this means that ordinary equipment will operate safely under the described external influences.
BA2	Children	Locations intended for presence of groups of children such as Nurseries. This class does not necessarily apply to family dwellings.
		Characteristics Required for Selection and Erection of Equipment: • Equipment of degrees of protection higher than IP2X. • Socket outlets shall be provided with at least IP2X or IPXXB and with increased protection according to IS 1293. • Inaccessibility of equipment with external surface temperature exceeding 80 degree C (60 degree C for nurseries and the like)

ANNEXURE-3

ELEMENTS OF IP (INTERNATIONAL PROTECTION) CODE AND THEIR MEANINGS

Element	Numerals or letters	Meaning for the protection of equipment	Meaning for the protection of persons
Code letters	IP	-	-
First characteristic numeral	X 0 1 2 3 4 5 6	Against ingress of solid foreign objects: Not required (non-protected) ≥ 50 mm diameter ≥ 12.5 mm diameter ≥ 2.5 mm diameter ≥ 1.0 mm diameter Dust-protected Dust-tight	Against access to hazardous parts with: Not required (non-protected) Back of hand Finger Tool Wire Wire wire
Second characteristic numeral	X 0 1 2 3 4 5 6 7 8	Against ingress of water with harmful effects: Not required (non-protected) Vertically dripping Dripping (15° tilted) Spraying Splashing Jetting Powerful jetting Temporary immersion Continuous immersion	-
Additional letter: optional	A B C D	-	Against access to hazardous parts with: Back of hand Finger Tool Wire
Supplementary Letter: optional	H M S W	Supplementary information specific to: High voltage apparatus Motion during water test Stationary during water test Weather conditions	-

ANNEXURE-4

CLASSIFICATION OF INSULATED CABLES/CONDUCTORS & FLEXIBLE CORDS

(*Ref: IS 8130: 2013, Reaffirmed 2018*)

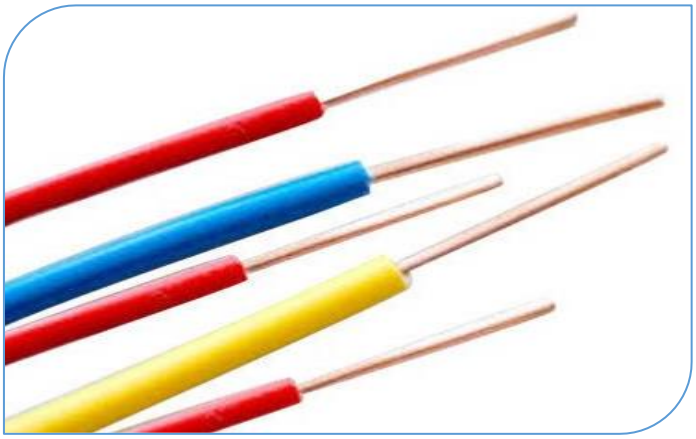
The conductors have been divided into four classes i.e. classes 1, 2, 5, 6 as follows:

Cables	Classes
Cables for fixed installations	Classes 1 and 2
The Flexibles	Classes 5 and 6
Copper welding cables	Class 6

Aluminium conductors for welding cables have not been assigned any class number.

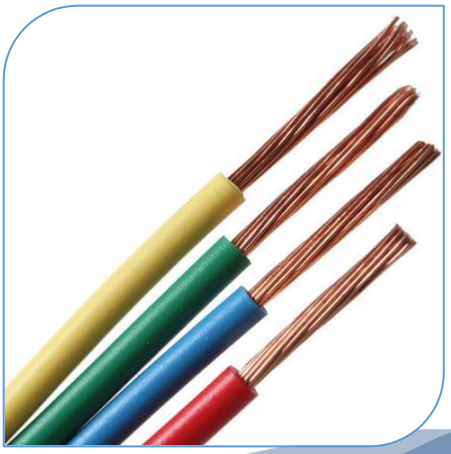
A. Solid Conductor (Class 1)

- The conductor consists of **single wire** of plain or tinned annealed copper or plain aluminium in accordance with table 1 of IS 8130: 2013.
- Solid copper conductor shall be of circular cross section.
- Solid aluminium conductor of sizes from 10 sqmm up to and including 35 sqmm shall be of circular cross section. Sizes 35 sqmm and above may be of either circular or shaped cross-section.



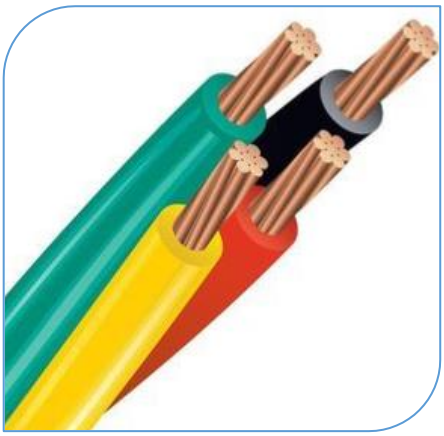
B. Stranded Circular Non-Compacted Conductors (Class 2)

- Conductor consists of plain or tinned annealed copper or plain aluminium.
- The wires in the conductor have the same nominal diameter before stranding.
- The number of wires in the conductor shall be not less than the appropriate minimum number given in table 2 of IS 8130: 2013.



C. Stranded Compacted Circular Conductors and Shaped Conductors (Class 2)

- Conductor consists of plain or tinned annealed copper or plain aluminium.
- The ratio of the diameters of two wires before stranding in the same conductor shall not exceed 2.
- The number of wires in the conductor shall be not less than appropriate minimum number given in table 2 of IS 8130: 2013.



D. Flexible Conductors (Classes 5 and 6)

- Conductor consists of plain or tinned annealed copper.
- The wires in the conductor have same nominal diameter before bunching.
- The diameter of the wires in any conductor shall not exceed the appropriate maximum value given in table 3 of IS 8130: 2013 for Class 5 and table 4 of IS 8130: 2013 for Class 6 conductors.



Comparison of Class 5 Vs Class 2 Copper Conductors (Tinned) in Final Circuit

Description	Class 5	Class 2
Size of wire used in sqmm	1.5	1.5
Average length of wire used for wiring in m	1000	1000
Average current in A	5	5
Total running hours per day	10	10
Temperature coefficient of copper	0.00393	0.00393
Reference Temperature deg. C	20	20
Actual Temperature (operating temp) deg. C	30	30
Resistance Ohm/km at 20 deg. C as per table 2 & 3 of IS 8130:2013	**13.7**	**12.2**
Resistance Ohm/km at actual temperature	14.24	12.68
Energy loss I^2Rt in kWh per day	**3.56**	**3.17**
Per month loss (kWh)	106.8	95.1
Per year loss (kWh)	1281.6	1141.2
Cost of energy per unit in Rs.	**5**	**5**
Cost of energy loss per year in Rs.	**6408**	**5706**

Difference (saving if class 2 copper is used) per year in Rs.	702	
Price of one coil	**1254**	**1392**
Initial investment for wire	**12540**	**13920**
Excess amount paid (Additional cost of class 2 wire)	**1380**	
Pay back period in years	**2 Years**	

CONCLUSION

It is clear from IS 8130 that Class 2 is for fixed installations and they are stranded conductors. Class 5 refers to flexible conductor. The core of class 5 conductor has more number of thin wires than class 2 to make it more flexible. As seen above the Class 5 conductors are having a higher resistance, they consume more power. And from above table, the **payback period is approx. 2 years and also** class 5 wire will have higher temperature in comparison to class 2 wire (higher losses) as a result payback will be even faster.

CHECKSHEET

FOR INSPECTION OF ELECTRICAL LOW VOLTAGE INSTALLATIONS

CHECKSHEET FOR INSPECTION OF ELECTRICAL LOW VOLTAGE INSTALLATIONS

(Ref: Para 6.2.2 of IS 732: 2019)

- Every installation shall be verified (inspection and testing) initially before energization and periodically during service.
- These verifications shall be done under supervision of JE/SSE and check-sheet shall be filled by JE/SSE.
- It is desirable that JE/SSE are conversant with following documents prepared by CAMTECH, Gwalior under the title "Safety in Electrical Low Voltage Installations" by simplification of Indian Standards and other relevant documents and the references of which are given in these check sheets for guidance.

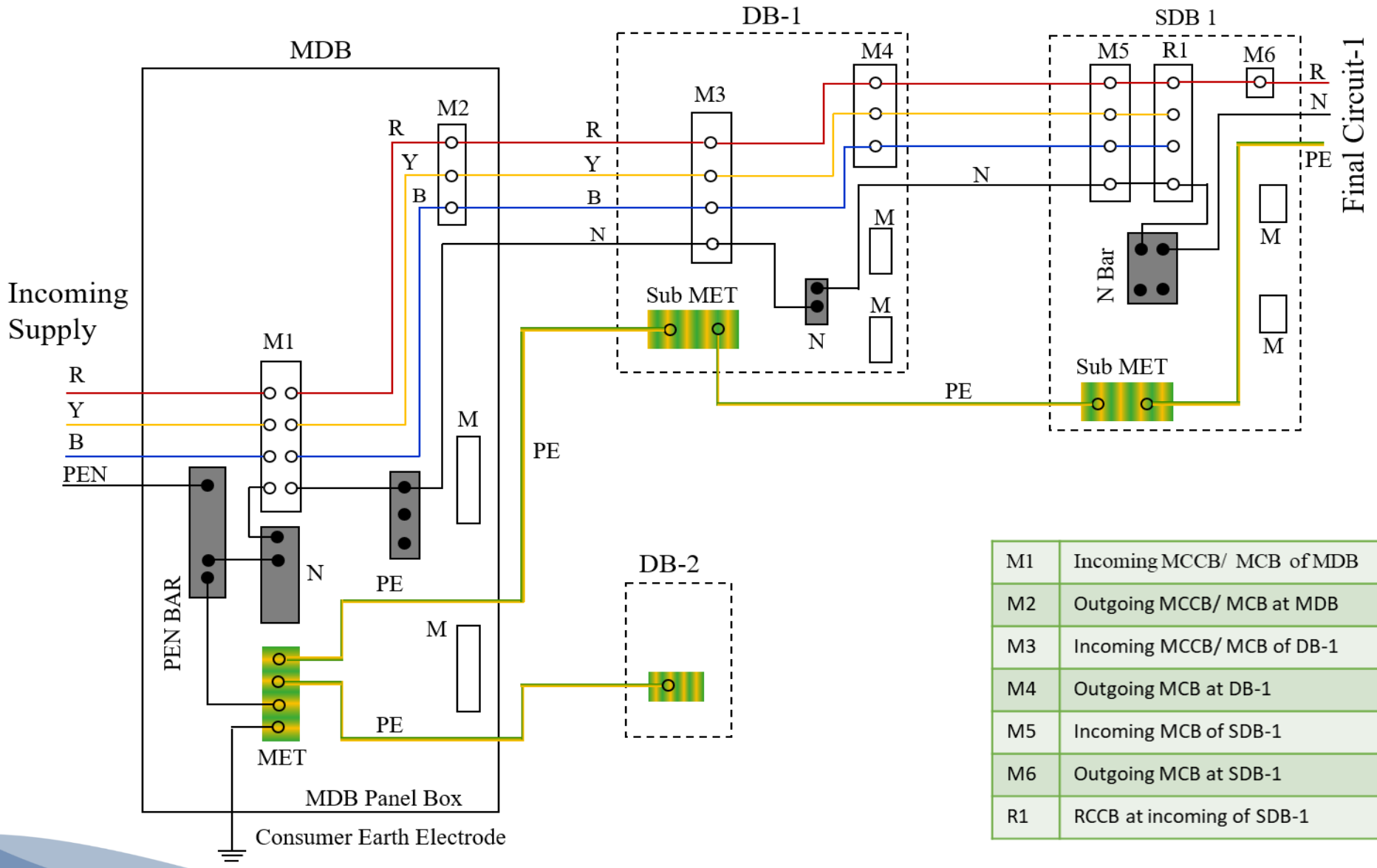
Vol. no.	Vol. Title	Reference given as
Vol. 1	Basics of LV Earthing System	Para no. of Vol. 1
Vol. 2	Selection and Application of LV Protective Devices	Para no. of Vol. 2
Vol. 3	Inspection of Electrical LV Installations	Para no. of Vol. 3

- This check sheet is prepared considering system earthing as TN-C-S (**with PME** in case of overhead bare conductor distribution system).
- **This check sheet is prepared based on IS 3043, IS 732 and NEC 2021. These guidelines are applicable for general building installations and does not supersede any existing provisions of Indian Standards, Railway Board, RDSO.**
- **For special installations, refer applicable standards.**

Key Notes: While designing an electrical installation:

1. First designed load on particular circuit (main circuit, distribution circuit or final circuit) is derived after applying diversity factor based on practical application.
2. The rating of overcurrent protective device (MCCB/MCB) is selected according the designed load on that circuit.
3. The type of MCB is selected according to type of load and earth fault current resulting from a fault of negligible impedance (dead earth) for automatic disconnection of supply within prescribed time (less than 0.1 sec) for shock prevention. This current is calculated from earth fault loop impedance and supply voltage of that phase at that particular point. Fault loop impedance tester is commonly used to measure these parameters.
4. The breaking capacity (kA) rating of MCCB/MCB is derived from prospective highest short circuit current resulting from a dead short between line to line (in three phase) / between line & neutral (in single phase). This current is calculated from short circuit loop impedance and voltage between line to line (in three phase) / between line & neutral (in single phase) at that particular point.
5. The conductor size is selected in coordination with MCCB/MCB after applying all correction factors like ambient temperature, grouping etc.

SINGLE LINE DIAGRAM OF INSTALLATION (With TN-C-S System)



M1	Incoming MCCB/ MCB of MDB
M2	Outgoing MCCB/ MCB at MDB
M3	Incoming MCCB/ MCB of DB-1
M4	Outgoing MCB at DB-1
M5	Incoming MCB of SDB-1
M6	Outgoing MCB at SDB-1
R1	RCCB at incoming of SDB-1

S.No.	Reference	Items to be checked	Check Points	Observation/Remark
1.		**Main Distribution Board (MDB)**	Shall be at the origin of the supply at Installation.	
1.1.		**Incoming supply at MDB**		
1.1.1.	Para 4.1 of IS 30 43 Para 6.0 of Vol. 1	Check type of system earthing of incoming supply i.e. TN-C, **TN-C-S**, TN-S, TT or IT	TN-C-S system is the most **common system** adopted by Electrical supply undertakings. **If it is not TN-C-S, some points of this check sheet may be invalid.**	
1.1.2.	--	Check supply type	i.e. single phase or three phase	
1.1.3.	Para 2.2 of Vol. 2	Nominal voltage, *U/U_o in volts*	240 V single-phase and 415 V three-phase ± 6%	
1.1.4.	--	Nominal frequency, f *in Hz*	50 Hz ± 3 percent	
1.1.5.	Para 2.8 of Vol. 2	A. External earth fault loop impedance, Z_e in ohm. B. External short circuit fault loop impedance in ohm	Measure (or calculate) between line and neutral (PEN) at the incoming supply point of MDB. Measure (or calculate) between Phase to phase (Z_{L-L}) for three phase and phase to neutral (Z_{L-N}) for single phase at the incoming supply point of MDB.	
1.1.6.	Para 2.8 of Vol. 2	Prospective highest short-circuit current, I_{cc} in kA	Measure or calculate highest short-circuit current, I_{cc} can be calculated as per ohm's law. Z= (Z_{L-L}) for 3 phase and (Z_{L-N}) for single phase, U_o = 415 V for 3 phase and 240 V for single phase $Icc = \frac{Uo}{Z}$	
1.2.		**Incoming supply cable/ conductors**		
1.2.1.	--	Type & Material of Conductor	PVC/ XLPE and Cu/ Al	
1.2.2.	--	No. of conductors/ cores		
1.2.3.	Para 5.2.6 of IS 732 Chapter 4 of Vol. 2	Size of incoming Line conductor.	The size of line conductor shall be as per design current of the installation. *The current-carrying capacity of a conductor depends upon the different parameters like size/ type of core/ type of insulation further it also depends upon other factors like method of installation of conductor, ambient temperature,	

S.No.	Reference	Items to be checked	Check Points	Observation/Remark
			grouping of conductors, Harmonic disturbances and voltage drop etc.	
1.2.4.	para 5.2.7.2.1 and 5.4.3.4.1 of IS 732 para 4.6 of Vol. 2 para 1.1.1.1.1.1 of Vol. 3	Size of incoming Neutral (PEN in TN-C-S) conductor	Neutral shall be **at least equal to the size of the line conductors**. **For mechanical strength**, size of PEN conductor shall not be less than **10 mm² copper or 16 mm² aluminium**. But this is not applicable in case of armoured cable.	
1.2.5.	para 5.4.3.4.3 of IS 732	Check provision of PEN bar, Neutral bar and Main earthing terminal (MET)/ bar at MDB.	Incoming PEN conductor shall be connected to PEN bar. One connection from it shall be connected to Neutral bar and one connection from it shall be connected to MET.	
1.2.6.	para 7.3 of Vol. 1	Check connection of Main Earthing Terminal/ bar to earth electrode.	MET shall be connected to Earth electrode by earthing conductor at the origin of the installation.	
1.2.7.	**para 5.4.4.1 of IS 732,** para 4.7 of Vol. 2	Check earthing conductor material (Cu or steel) and size (in mm^2).	Earthing conductor's size shall be not less than half of the size of the largest earth conductor (PE) within the installation and not less than **6 mm² for copper or 50 mm²** for steel.	
1.2.8.		Check soundness of earthing conductor connections at both ends.		
1.2.9.	para 7.0 of Vol. 1	Check equipotential bonding	All exposed & extraneous conductive parts of the installation shall be connected to MET through protective (earth) conductors.	
1.3.		**MDB Panel Box**	All live parts shall be are inside enclosures or behind barriers to avoid direct contact.	
1.3.1.	Annex 'A' of IS 732 para 1.3.1 of Volume 3	Check live parts for protection against direct contact	Live parts shall be inside panels (boxes) and shall restrict entry of finger (≥ 12.5 mm diameter).	
1.3.2.		Check top surface of the panel box	Accessible horizontal top surfaces of panels boxes shall restrict entry of wire (diameter of 1.0 mm and greater).	

S.No.	Reference	Items to be checked	Check Points	Observation/Remark
1.3.3.		Check covers/ doors of boxes	The covers/ doors shall be lockable and key/ or tool shall be required to open them or they can be opened only after disconnecting the supply.	
1.3.4.		Check cable entry/ exit points to avoid rubbing of cables/ conductors.	Rubber grommet or metallic fitting shall be provided at cable entry/ exit points.	
1.3.5.		Check empty entry/ exit holes	They shall be provided with dummy covers/ packing.	
1.3.6.		**Check Warning label**	**Danger Warning label** shall be provided outside the box and special warning, if **capacitors** are installed which may retain dangerous electrical charges even after they have been switched off.	
1.3.7.		Check all metallic parts of electrical panels including hinged covers are connected to an earth wire.	These earth wires shall be connected to earthing terminal of MDB/DB/SDB.	
1.4.	**para 5.3 of Vol. 2**	**Incoming MCCB/MCB of MDB**	MCCB or MCB may be provided as per requirement.	
1.4.1.		**Incoming MCCB (if provided)**		
1.4.1.1.	--	Nominal voltage rating in V	Same as or close to the incoming supply voltage	
1.4.1.2.	--	Nominal current rating (I_n) in A	It shall be selected as per the design load of the installation.	
1.4.1.3.	Para 4.4.2.2.1 of IS 732 Para 3.2.3.1 of Vol. 2	No. of poles (DP, FP)	Double Pole or Four Pole MCCB shall be provided respectively for single phase or three phase supply.	
1.4.1.4.	Para 3.2.3.2 of Vol. 2	Trip mechanism type of MCCB	Thermal magnetic type or microprocessor type* *Additional features like precise over load and short circuit setting, earth fault detection, LCD display etc. is available in microprocessor type.	
1.4.1.5.		Fixed type or adjustable setting thermal magnetic MCCB	May be selected as per site requirement.	

S.No.	Reference	Items to be checked	Check Points	Observation/Remark
			Both (over load and short circuit setting) fixed, both adjustable or single adjustable are available in the market,	
1.4.1.6.	para 3.2.1 of Vol. 2	kA rating (service short circuit breaking capacity, I_{cs})	kA rating of MCCB shall be equivalent or more than highest short-circuit current, I_{cc} in kA. Refer sr. no 1.1.6 above.	
1.4.2.		**Incoming MCB (if provided)**		
1.4.2.1.	Para MM 6.2.3.6.2 of Annex MM of IS 732 Para 3.1.2.3 & 5.3.2 of Vol. 2	Type of incoming MCB	B type MCB shall be provided at incoming of MDB/DB/SDB. For B type MCB instantaneous tripping (within 0.1 sec) current is 5 times of rated current (In).	
1.4.2.2.	Para 4.4.2.2.1 of IS 732 Para 3.1.2.2 of Vol. 2	No. of poles (SPN,TPN)	**SPN or TPN** shall be provided respectively for single phase or three phase supply.	
1.4.2.3.		Nominal voltage rating in V	As per supply voltage.	
1.4.2.4.		Nominal current rating (I_n) in A	The nominal current rating of MCB shall be selected as per the design load of the installation.	
1.4.2.5.	Para 3.1.2.1 of Vol. 2	Rated short-circuit capacity (I_{cn}) in kA	kA rating of MCB shall be equivalent or more than highest short-circuit current, I_{cc} in kA. Refer sr. no 1.1.6 above.	
1.5.		**MCCB/MCB for each outgoing circuit from MDB to DB**	Check for MCCB/MCB for each outgoing circuit from MDB to DB	
1.5.1.		**MCCB (if provided)**		
1.5.1.1.	--	Nominal voltage rating in V	Same as or close to the supply voltage	
1.5.1.2.	--	Nominal current rating (I_n) in A	It shall be selected as per the design load of that circuit.	
1.5.1.3.	Para 4.4.2.2.1 of IS 732 Para 3.2.3.1 of Vol. 2	No. of poles (DP, TP)	Double Pole or three Pole MCCB shall be provided respectively for single phase or three phase circuit.	
1.5.1.4.	Para 3.2.3.2 of Vol. 2	Type trip mechanism of MCCB	Thermal magnetic type or microprocessor type.	
1.5.1.5.		Fixed type or adjustable setting thermal magnetic MCCB	May be selected as per site requirement.	

S.No.	Reference	Items to be checked	Check Points	Observation/Remark
1.5.1.6.	Para 3.2.1 of Vol. 2	kA rating (Service Short Circuit Breaking Capacity, I_{cs})	kA rating of outgoing MCCB shall be equivalent to incoming MCCB kA rating.	
1.5.2.		**MCB (If provided)**		
1.5.2.1.	Para MM 6.2.3.6.2 of Annex MM of IS 732 Para 3.1.2.3 & 5.3.2 of Vol. 2	MCB Type	B type MCB shall be provided at outgoing from MDB to DB.	
1.5.2.2.	Para 4.4.2.2.1 of IS 732 Para 3.1.2.2 of Vol. 2	No. of poles (SP, TP)	**SP or TP** shall be provided respectively for single phase or three phase supply.	
1.5.2.3.	--	Nominal voltage rating in V	As per out going circuit voltage.	
1.5.2.4.	---	Nominal current rating (I_n) in A	The nominal current rating of MCB shall be selected as per the design load of the outgoing circuit. It shall also be equal or more than the rating of load side MCB (incomer MCB of DB).	
1.5.2.5.	Para 3.1.2.1 of Vol. 2	Rated short-circuit capacity (I_{cn}) in kA	It shall be equivalent to incoming MCCB/MCB kA rating of MDB.	
1.6.		**Outgoing conductor/ cable from MDB to DB**		
1.6.1.		Type and Material of Conductor	PVC/ XLPE and Cu/Al	
1.6.2.		No. of conductors/ core		
1.6.3.	para 5.2.6 of IS 732 chapter 4 of Vol. 2	Size of Line conductors	The size of line conductors shall be as per coordination with outgoing MCCB/MCB of this circuit at MDB. Refer sr. no. 1.2.3 for other factors. **The final current carrying capacity after applying all correction factors of the line conductors shall be at least 1.45 times of outgoing MCB rating or 1.3 times of outgoing MCCB rating of this circuit.**	

S.No.	Reference	Items to be checked	Check Points	Observation/Remark
1.6.4.	para 5.2.7.2 of IS 732 para 4.6 of Vol. 2	Size of Neutral conductor	The size of neutral conductor shall be at least equal to size of line conductors.	
1.6.5.	para 5.4.3.1 of IS 732:2019 para 8.5.1 of Vol. 3	PE (earth) conductor	Each outgoing circuit shall have a separate PE (earth) conductor, originating from MET at MDB to Earthing terminal at DB **For size of PE conductor (earth wire), refer 8.5.1 of this volume-3.**	
2.		**DISTRIBUTION BOARD (DB)**		
2.1.		**DB Panel Box**	Refer sr. no. 1.3 above.	
2.1.1.	para 2.8 of Vol. 2	A. External earth fault loop impedance, Z_e in ohm. B. External short circuit fault loop impedance in ohm	Measure (or calculate) earth fault Loop impedance between line and PE (earth point) at incoming point of DB. Measure (or calculate) short circuit loop impedance between Phase to phase (Z_{L-L}) for three phase and phase to neutral (Z_{L-N}) for single phase supply at the incoming point of DB.	
2.1.2.	para 2.8 of Vol. 2	Prospective highest short-circuit current, I_{cc} in kA	Measure or calculate highest short-circuit current at DB. Refer sr. no. 1.1.6 above.	
2.2.	V2- 5.3	**Check incoming MCCB/MCB of DB**	MCCB or MCB may be provided as per requirement.	
2.2.1.		**Incoming MCCB (if provided) at DB**		
2.2.2.		Nominal voltage rating in V	Same as or close to the circuit voltage	
2.2.2.1.		Nominal current rating (I_n) in A	It shall be selected as per the design load at this DB.	
2.2.2.2.	Vol.2 -3.2.3.1	No. of poles (DP, FP)	Refer sr. no. 1.4.1.3	
2.2.2.3.	Vol.2 -3.2.3.2	Type trip mechanism of MCCB	Refer sr. no. 1.4.1.4	
2.2.2.4.		Fixed type or adjustable setting thermal magnetic MCCB	Refer sr. no. 1.4.1.5	
2.2.2.5.	Vol.2 -3.2.1	kA rating (Service Short Circuit Breaking Capacity, I_{cs})	kA rating of MCCB shall be equivalent or more than highest short-circuit current, I_{cc} in kA at this DB incoming. Refer 2.1.2 above.	

S.No.	Reference	Items to be checked	Check Points	Observation/Remark
2.2.3.		**Incoming MCB (if provided) at DB**		
2.2.3.1.		Type of incoming MCB at DB	B type MCB shall be provided. Refer sr. no. 1.4.2.1 above.	
2.2.3.2.		No. of poles (SPN,TPN)	**SPN or TPN** shall be provided respectively for single phase or three phase supply.	
2.2.3.3.		Nominal voltage rating in V	As per incoming circuit voltage.	
2.2.3.4.		Nominal current rating (I_n) in A	The nominal current rating of MCB shall be selected as per the design load at this DB.	
2.2.3.5.	Vol.2 -3.1.2.4	Rated short-circuit capacity (I_{cn}) in kA	kA rating of MCB shall be equivalent or more than highest short-circuit current, I_{cc} in kA at this DB incoming. Refer sr. no. 2.1.2 above.	
2.3.		**Neutral bus bar/ terminal at DB**	Incoming neutral conductor and all outgoing neutral conductors shall be connected at this point.	
2.4.		**Earth bus bar/ terminal at DB**	Incoming PE conductor and all outgoing PE conductors shall be connected at this point.	
2.5.		**MCB for each Outgoing Circuit from DB to SDB**	Check for MCB at DB for each outgoing circuit	
2.5.1.		MCB Type	B type MCB shall be provided at outgoing from DB to SDB.	
2.5.2.		No. of poles	**SP or TP** shall be provided respectively for single phase or three phase supply.	
2.5.3.		Nominal voltage rating in V	As per out going circuit voltage.	
2.5.4.		Nominal current rating (I_n) in A	The nominal current rating of MCB shall be selected as per the design load of the outgoing circuit. It shall also be equal or more than the rating of load side MCB (incomer MCB of SDB).	
2.5.5.	Para 3.1.2.1 of Vol. 2	Rated short-circuit capacity (I_{cn}) in kA	It shall be equivalent to incoming MCCB/MCB kA rating of DB.	
2.6.		**Outgoing conductor/ cable from DB to SDB**		
2.6.1.		Type and Material of Conductor	PVC/ XLPE and Cu/Al	

S.No.	Reference	Items to be checked	Check Points	Observation/Remark
2.6.2.		No. of conductors/ core		
2.6.3.	Para 5.2.6 of IS 732 chapter 4 of Vol. 2	Size of Line conductors	The size of conductor shall be as per coordination with outgoing MCB of this circuit at DB. Refer sr. no. 1.2.3 for other factors. **The final current carrying capacity after applying all correction factors of the line conductors shall be at least 1.45 times of outgoing MCB rating of this circuit.**	
2.6.4.	Para 5.2.7.2 of IS 732 Para 4.6 of Vol. 2	Size of Neutral conductor	The size of neutral conductor shall be at least equal to size of line conductors.	
2.6.5.	Para 5.4.3.1 of IS 732:2019 Para 8.5.1 of Vol. 3	Size of PE conductor	Each outgoing circuit shall have a separate PE (earth) conductor, originating from earth terminal at DB to earth terminal at SDB. **For size of PE conductor (earth wire), refer 8.5.1 of this volume-3.**	
3.		**SUB DISTRIBUTION BOARD (SDB)**		
3.1.		**SDB Panel Box**	Refer sr. no. 1.3 above.	
3.1.1.	V2-2.8.2.5	A. External earth fault loop impedance, Z_e in ohm. B. External short circuit fault loop impedance in ohm	Measure (or calculate) earth fault Loop impedance between line and PE (earth point) at incoming point of SDB. Measure (or calculate) short circuit loop impedance between Phase to phase (Z_{L-L}) for three phase and phase to neutral (Z_{L-N}) for single phase supply at the incoming point of SDB.	
3.1.2.		Prospective highest short-circuit current, I_{cc} in kA	Measure or calculate highest short-circuit current at SDB. Refer sr. no. 1.1.6 above.	
3.2.	Vol.2- 5.3	**Check incoming MCB at SDB**		
3.2.1.		MCB Type (B, C or D)	B type MCB shall be provided at incoming of SDB. Refer sr. no. 1.4.2.1	
3.2.2.		No. of poles (SPN,TPN)	**SPN or TPN** shall be provided respectively for single phase or three phase supply.	

S.No.	Reference	Items to be checked	Check Points	Observation/Remark
3.2.3.	Vol.2 -……	Nominal current rating (I_n) in A	The nominal current rating of MCB shall be selected as per the design load at this SDB. **For load calculation at SDB, consider diversity factors as applicable on each final circuit.**	
3.2.4.	Vol. 2 -3.1.2.4	Rated short-circuit capacity (I_{cn}) in kA	kA rating of MCB shall be equivalent or more than highest short-circuit current, I_{cc} in kA at this SDB incoming. Refer sr. no. 3.1.2 above.	
3.3.	Vol.2 _3.4	**Check Residual current circuit breaker (RCCB) at incoming supply at SDB**	It is an additional protection, RCCB detests any difference between input and output currents i.e. it protects in case of any earth leakage, which is not detected by overcurrent protective devices.	
3.3.1.	Vol. 2 -3.4.2.1	Type (AC, A, or B)	**RCCB type depends on type of load:** Type AC: RCD tripping on alternating sinusoidal residual current suitable **for Resistive, Capacitive, Inductive loads** generally without any electronic components. Type A: tripping on alternating sinusoidal residual current and on residual pulsating direct current, suitable for **Single phase with electronic components, Single phase invertors, Induction hobs** etc. Type B: RCD for which tripping is achieved for residual pulsating direct currents super-imposed on a smooth direct current upto 10 mA or $4I_{\triangle n}$, whichever is the greater. **Suitable for three phase electronic equipment typically Inverters for speed control, Photo voltaic, etc.**	
3.3.2.	Para 4.2.11.3.3 of IS 732 Vol.3 **-1.1.1.3.**	Sensitivity ($I_{\Delta n}$) in mA	**System voltages independent RCCB not exceeding 30 mA shall be used.**	
3.3.3.		Nominal current rating (I_n) in A	It shall be equivalent to nominal current rating of incoming MCB at SDB.	

S.No.	Reference	Items to be checked	Check Points	Observation/Remark
3.3.4.	Vol. 3- 1.1.1.3	Check proper connection of RCCB	In single phase circuit, two pole RCCB shall be connected between phase and neutral and in three phase circuit four pole RCCB shall be connected across phases and neutral.	
3.4.		**Neutral bus bar/ terminal at SDB**	Incoming neutral conductor and all outgoing neutral conductors shall be connected at this point.	
3.5.		**Earth bus bar/ terminal at SDB**	Incoming PE conductor and all outgoing PE conductors shall be connected at this point.	
3.6.		**MCB for each final circuit (outgoing) at SDB**		
3.6.1.	Para MM 6.2.3.6.2 of Annex MM of IS 732 Para 3.1.2.3 & 5.3.2 of Volume 2	MCB Type (B, C or D)	**Suitable type of MCB to be selected based on first as per type of load and then time current characteristics of MCB according to external fault loop impedance.** **Instantaneous tripping (within 0.1 sec) currents for types of MCB:** **Type B -5 times of rated current (In)** **Type C -10 times of rated current (In)** **Type D -20 times rated current (In)**	
3.6.2.		No. of poles (SP, TP)	**SP or TP** shall be used respectively for single phase or three phase loads.	
3.6.3.		Nominal current rating (I_n) in A	The nominal current rating of MCB shall be selected as per the connected loads of the final circuit. **Standard loads for final circuits, refer para 5.1.1 of volume-2.**	
3.6.4.		Rated short-circuit capacity (I_{cn}) in kA	It shall be equivalent to incoming MCB kA rating of SDB. Refer 3.2.4 above.	
3.7.		**Outgoing conductors/ cable for final circuit**		
3.7.1.		Type and Material of Conductor	PVC/ XLPE and Cu/Al	
3.7.2.		No. of conductors		

S.No.	Reference	Items to be checked	Check Points	Observation/Remark
3.7.3.	Para 5.2.6 of IS 732 Chapter 4 of Vol. 2	Size of Line conductors	The size of line conductor shall be as per coordination with outgoing MCB of this final circuit. Refer sr. no. 1.2.3 for other factors. **The final current carrying capacity after applying all correction factors of the line conductors shall be at least 1.45 times of outgoing MCB rating of this final circuit.** **Refer 4.3 of this volume-3 for final circuits minimum conductor size.**	
3.7.4.	Vol. 2 -4.6	Size of Neutral conductor	The size of neutral conductor shall be at least equal to size of line conductors.	
3.7.5.	Para 5.4.3.1 of IS 732:2019 Para 8.5.1 of Vol. 3	Size of PE conductor	Each final circuit shall have a separate PE (earth) conductor, originating from earth terminal at SDB. **For size of PE conductor (earth wire), refer 8.5.1 of this volume-3.**	

REFERENCES

1. IS 3043-2018: Code of Practice for Earthing (Second Revision).
2. IS 732-2019: Code of Practice for Electrical Wiring Installations (Fourth Revision)
3. IS 9409-1980: Classification of Electrical and Electronic Equipment with Regard to Protection Against Electric Shock.
4. IS 8130-2013 (Reaffirmed 2018): Conductors for insulated electric cables and flexible cords — specification (Second Revision).
5. IS 11353-1985 (Reaffirmed 2017): Guide for Uniform System of marking and identification of conductors and apparatus terminals.
6. National Electrical Code 2011 [ETD 20: (Electrical Installation)

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Indian Railways, Centre for Advanced Maintenance Technology
In front of Hotel Adityaz, Airport Road, Maharajpura, Gwalior, Pin code – 474 005



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Maharajpura, Gwalior, M.P. 474 005