Earthing and Protection

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National Crime Records Bureau Reports

- 2000+ death every year in fire due to electrical fault
- 10000+ death due to electrocution
- Plus many more unreported cases
- Loss of crores of rupees due to damage to property

Can we stop this ?

Caused of Electrical Accidents

Reason

- Faulty and fried wiring
- Too many equipment in Extension cords
- Faulty electrical appliances
- Outdated circuit breakers
- Light fixtures and decorations
- Electrical switches and outlets
- Unattended charging points

Result

- Insulation failure
- Over current
- Heat and fire
- Electrocution

Protection

Basic Protection

- Insulation of Live Parts
- Barriers or Enclosure

Fault Protection

- Automatic Disconnection of supply
- Double insulation
- Separation
- ELV

Fire prevention

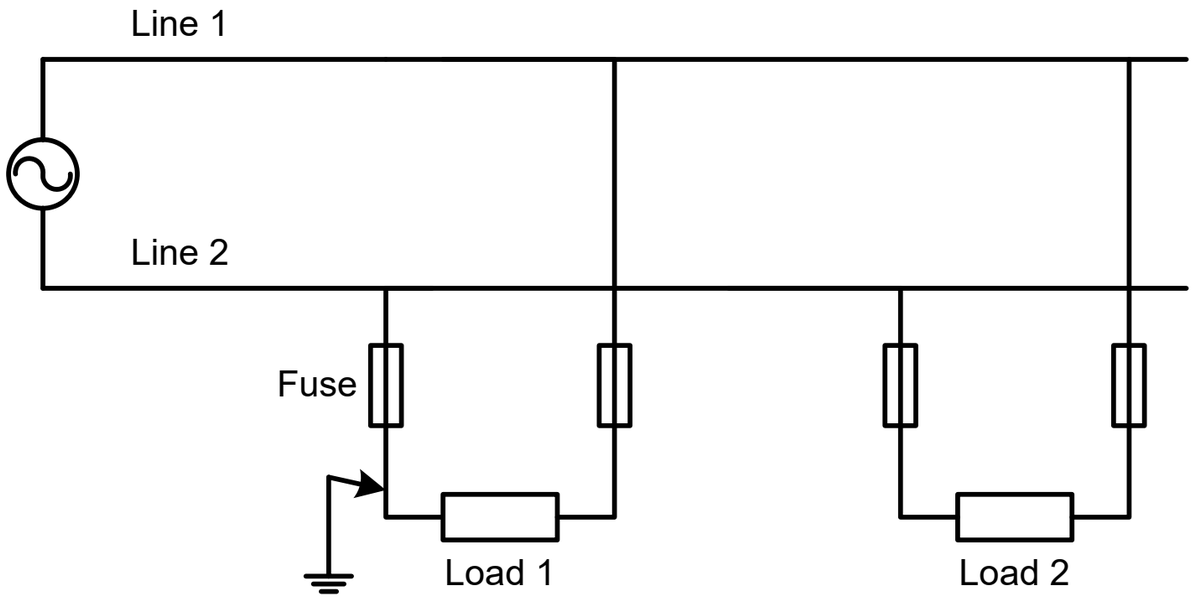
- Smoke / Fire detection
- Fire Suppression
- Smoke / Fire sealing
- Evacuation
- Rules and regulations

More than 95% of the accidents can be avoided if the supply is disconnected within the stipulated time

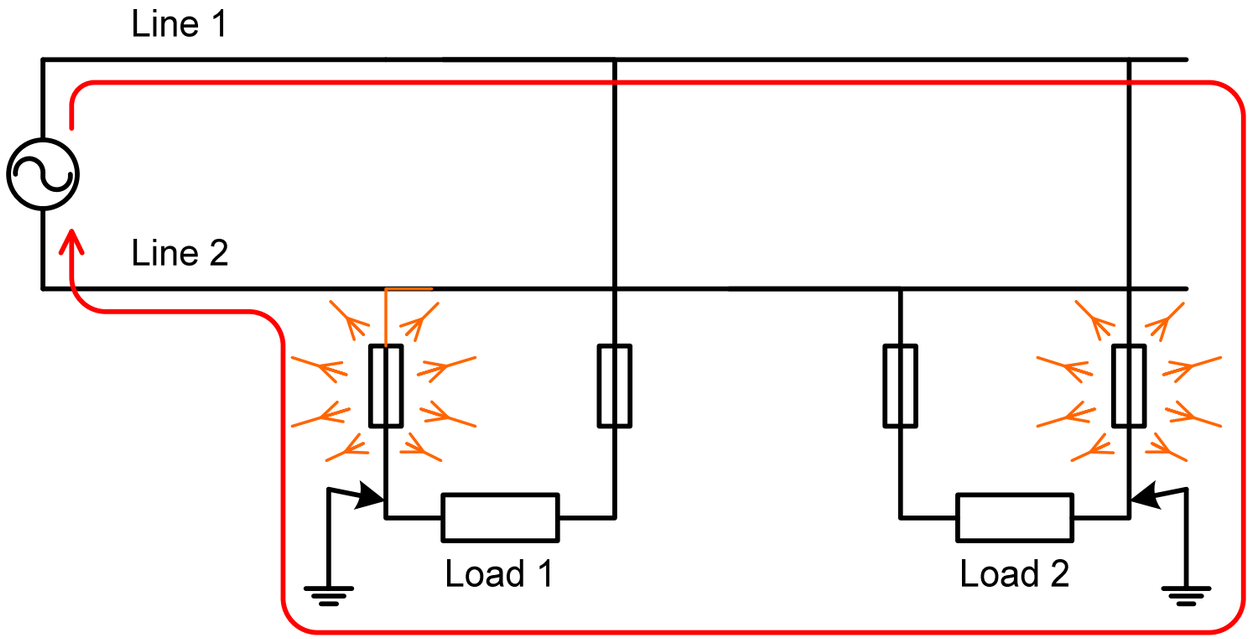
Standards

- **IS 732** – Code for practice for Electrical Wiring Installations
- **IS 3043** – Code for Practice of Earthing
- **NBC** – National Building Code 2016
- **IEEE 142**
- **IEC 364**

Earthing Fundamentals



Earthing Fundamentals



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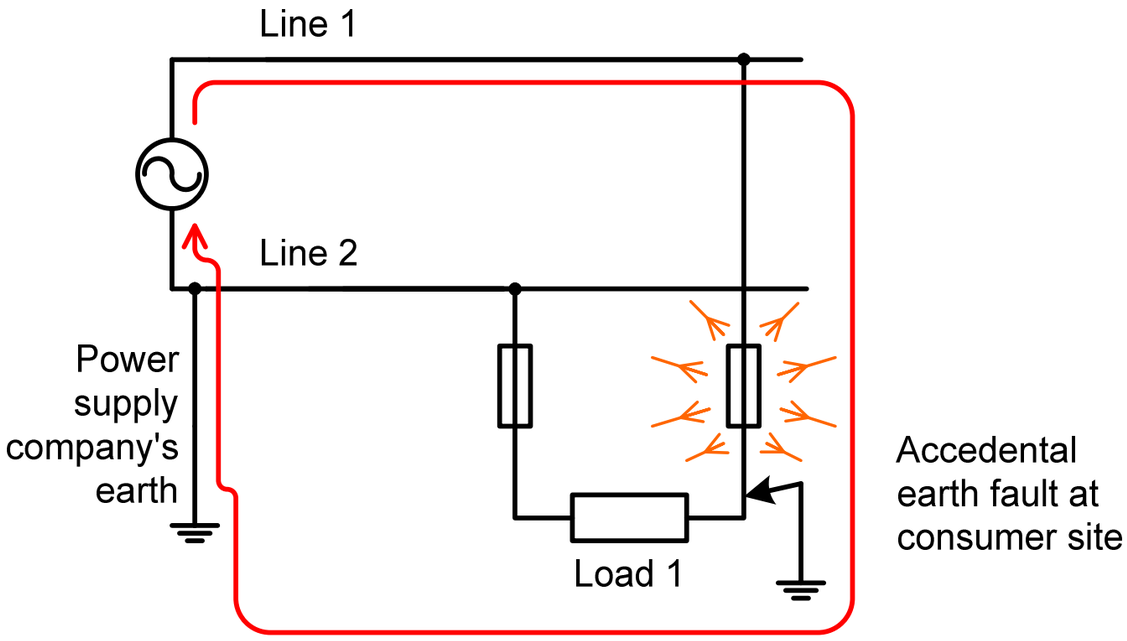

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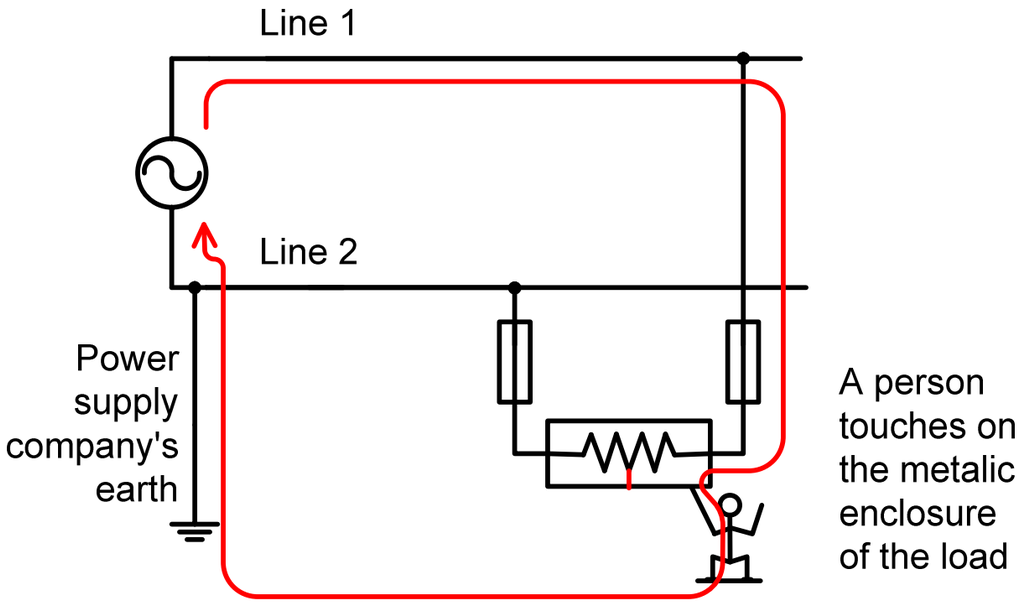


Need for Earthing

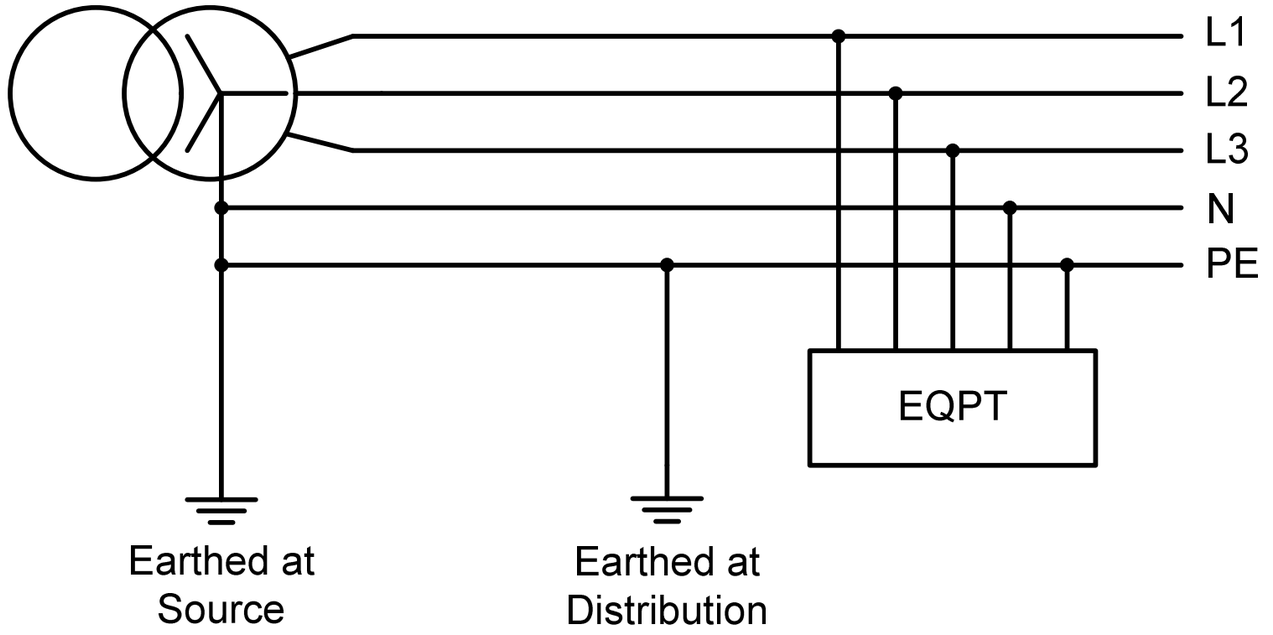
- Earthing for safety
  (Automatic disconnection of power supply)
- Voltage Reference of System (Neutral)
- Dissipation of Lightning current
- Base for Equipotentialisation
- Shielding against Electromagnetic interference

Types of Earthing

- TN
  - TN-S
  - TN-C
  - TN-C-S
- TT
- IT

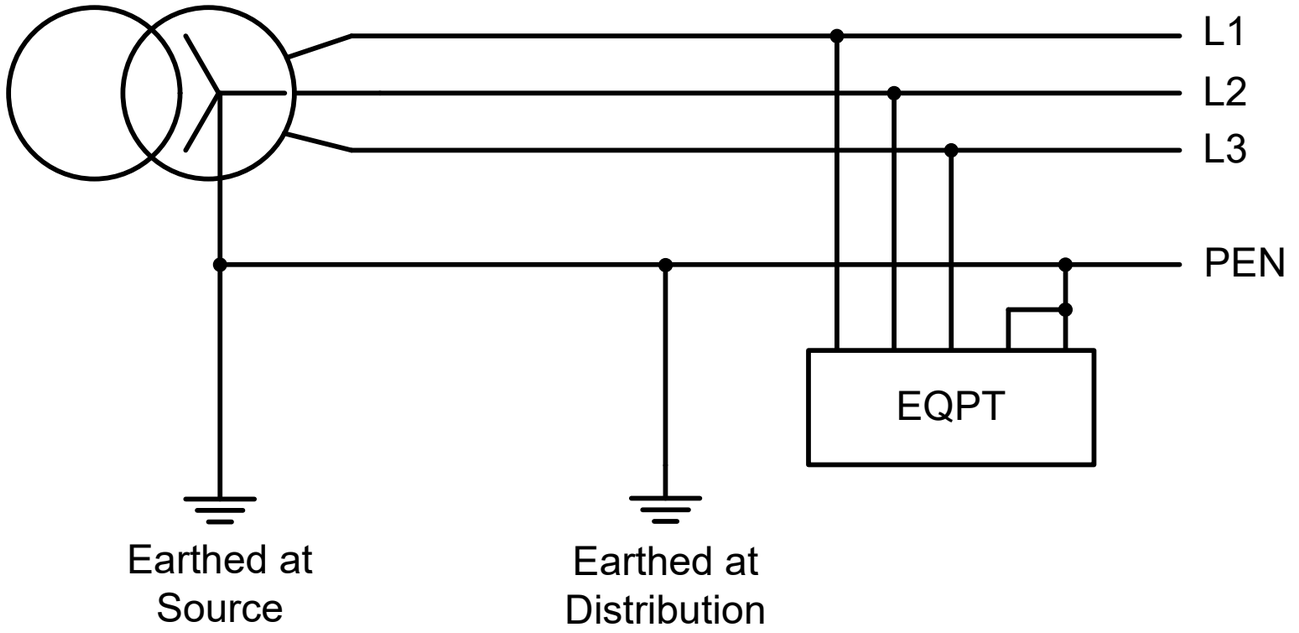
T – Terre (soil)
N - Neutral
S – Separate
C – Combined
I - Isolated

TN-S System



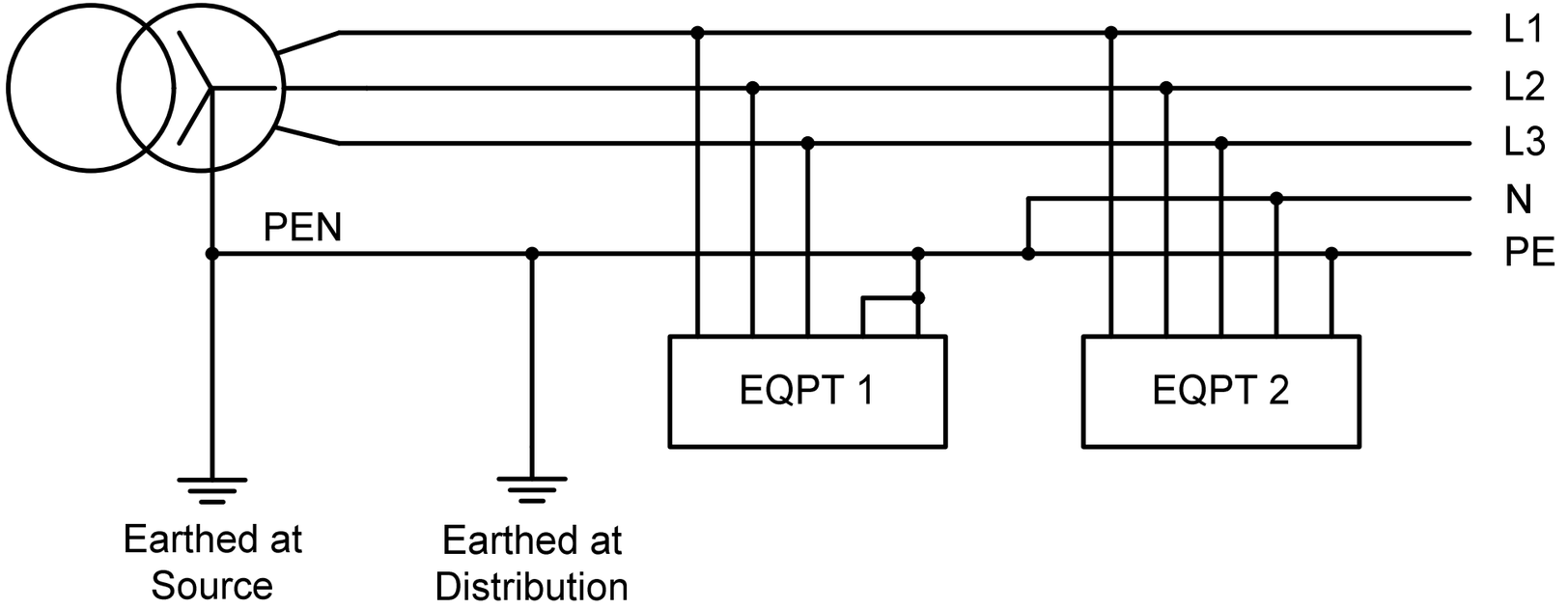
There is a separate **Protective Earthing** line

TN-C System



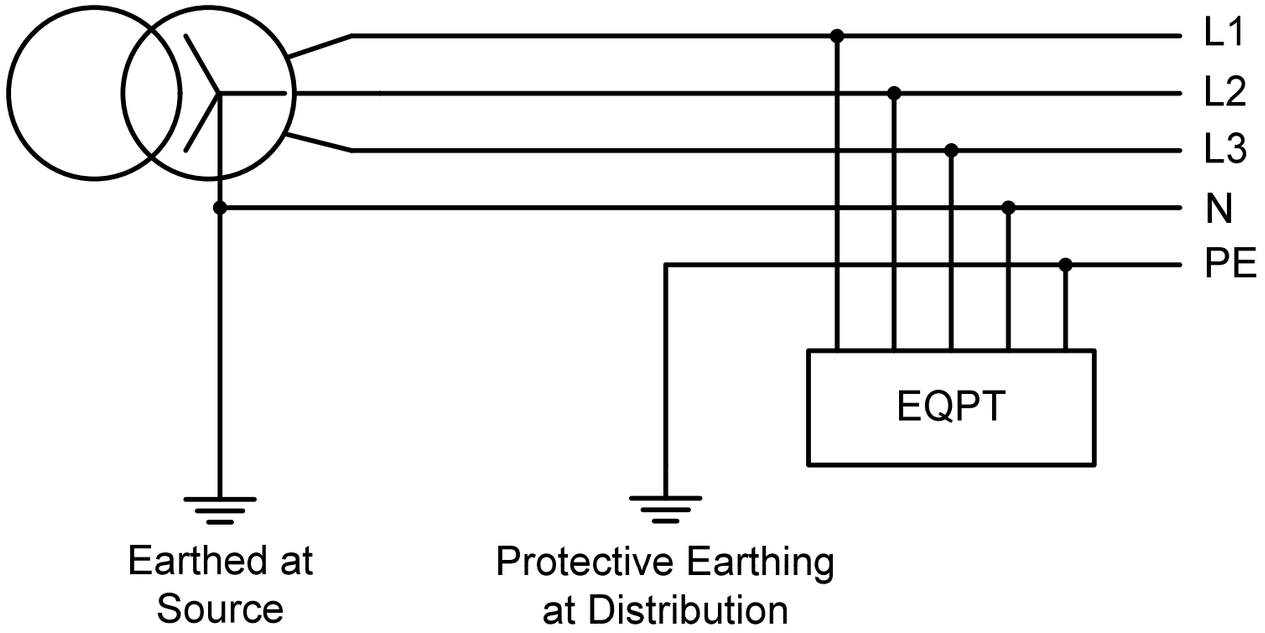
Protective Earth and Neutral are **Combined**

TN-C-S System



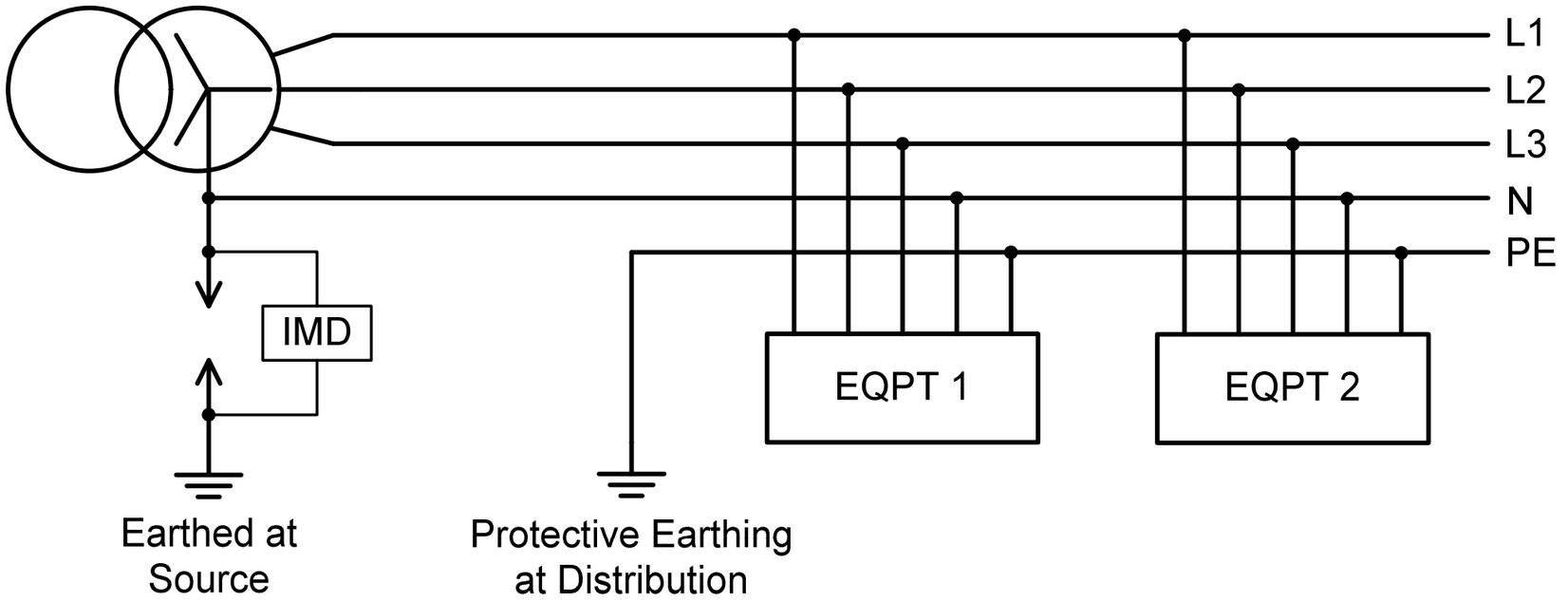
Separate PE and N for one section and combined PE and N for the other section

TT System



Earth current flows through ground only

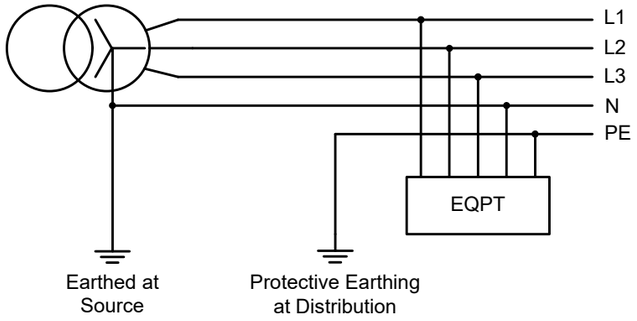
IT System



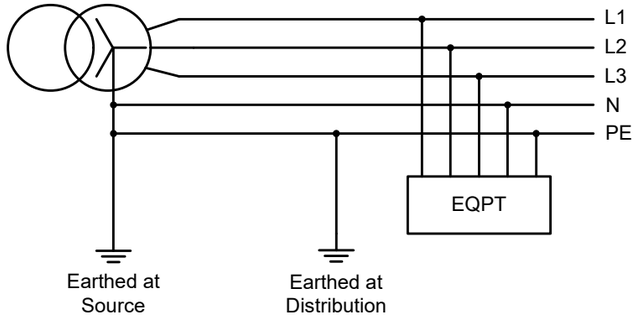
No direct grounding at source side; insulation monitoring is essential

Compare Earthing Systems

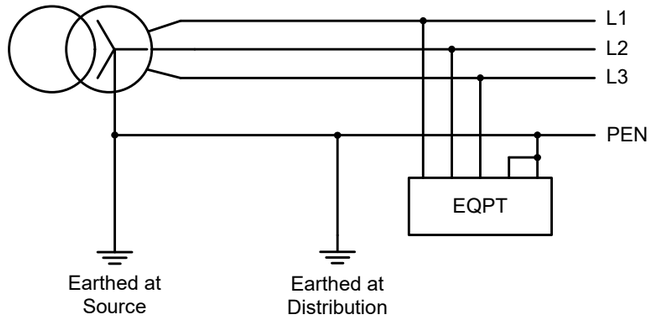
TT



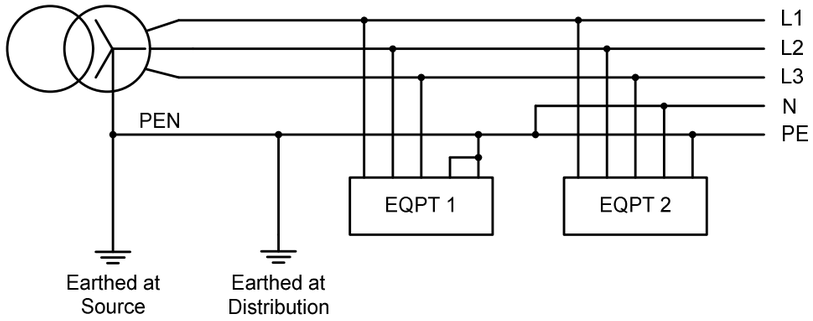
TN-S



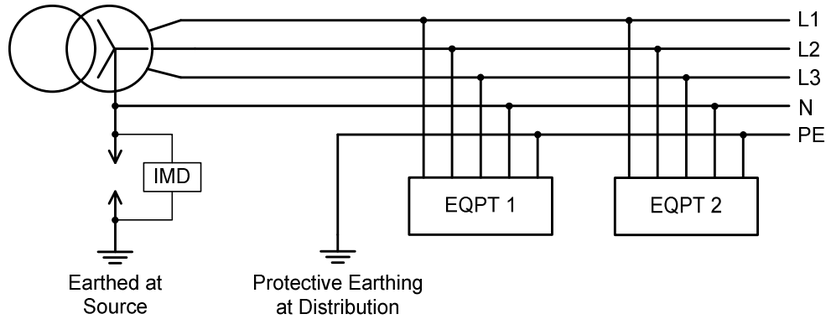
TN-C



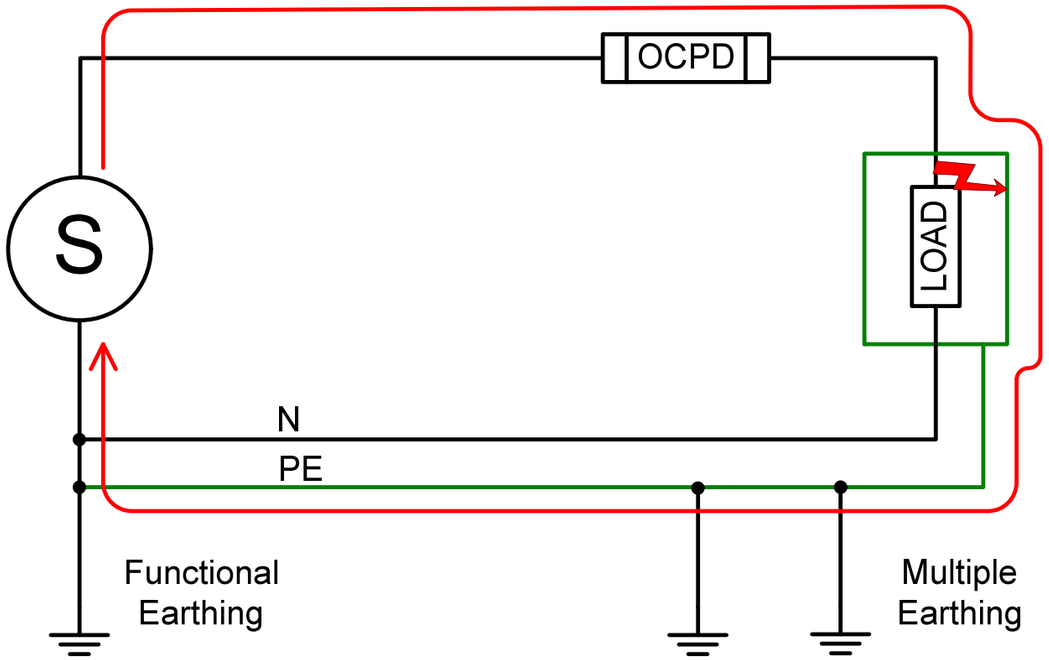
TN-C-S



IT



TN-S System Loop Impedance



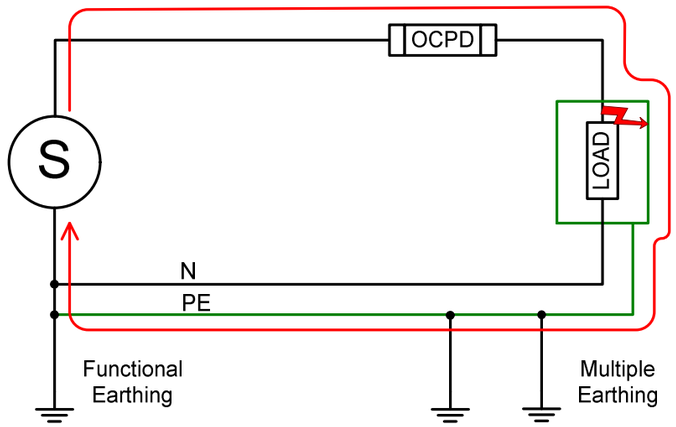
$$\text{Loop impedance, } Z_s = \frac{U_0}{I_a}$$

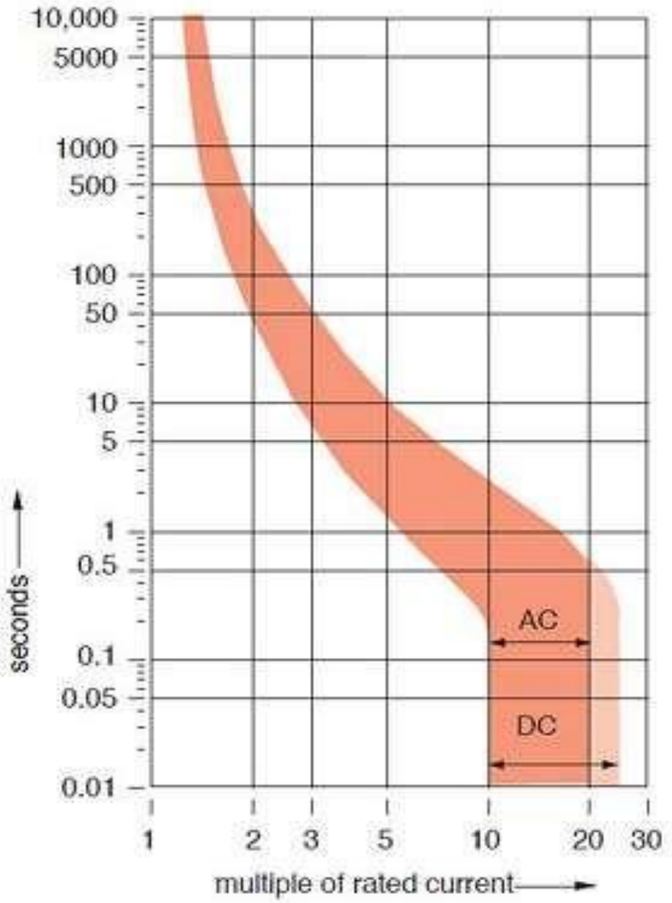
Where

U_0 = conventional voltage limits

I_a = current ensuring the automatic operation of disconnecting device

Importance of Loop Impedance

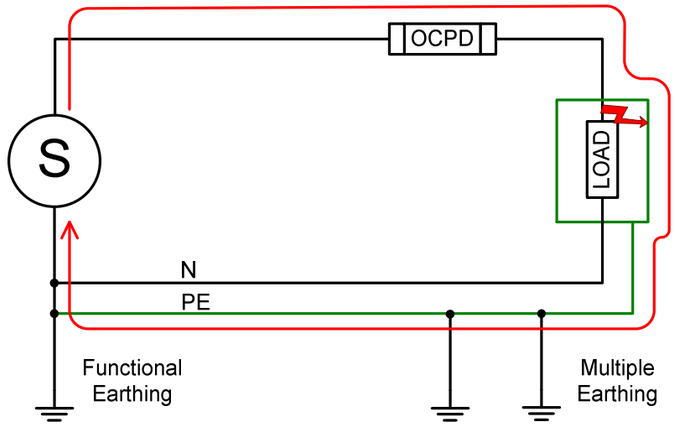




Voltage = 240V OCPD – 250A MCCB

Z_s	I_{sc}	Action	Remark
1.0 Ω	240 A	Device will not trip	Unsafe
0.5 Ω	480 A	Device will trip delayed	Unsafe
0.1 Ω	2400 A	Device will trip quickly	Safe

Disconnection time as per IS 3043



220 volts fault

0.17 sec for dry condition

0.035 sec for wet condition

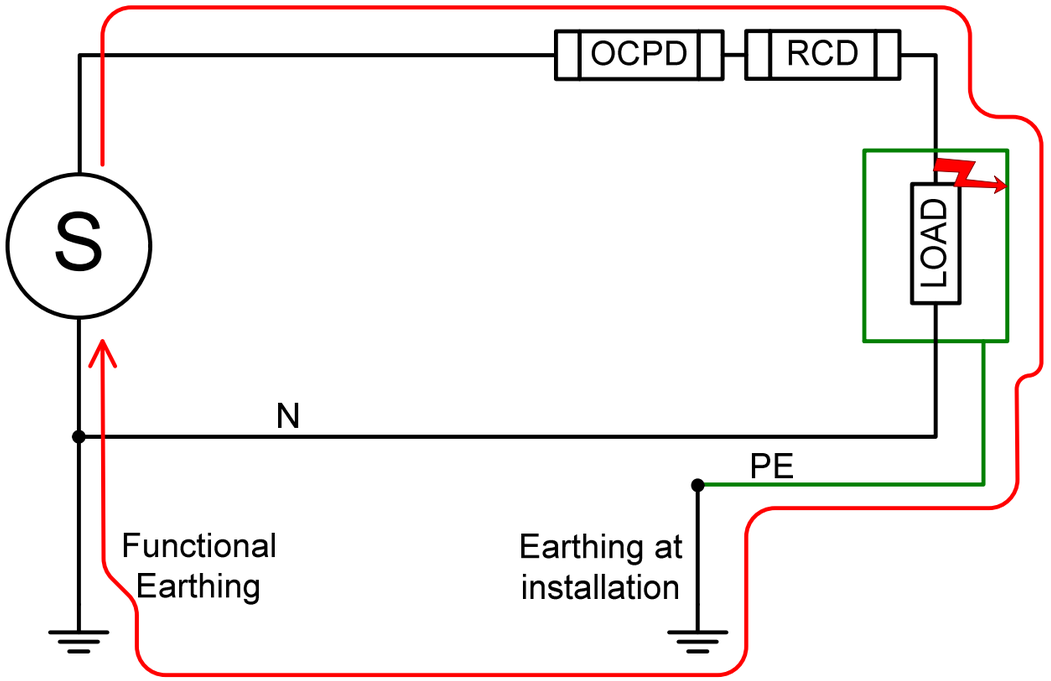
TABLE 8 DISCONNECTING TIMES FOR DIFFERENT TOUCH VOLTAGES

PROSPECTIVE TOUCH VOLTAGE U_c	CONDITION 1*			CONDITION 2†		
	Z_1	I	t	Z_2	I	t
(V)	(Ω)	(mA)	(s)	(Ω)	(mA)	(s)
25	—	—	—	075	23	5
50	1 725	29	5	925	54	0·47
75	1 625	46	0·60	825	91	0·30
90	1 600	56	0·45	780	115	0·25
110	1 535	72	0·36	730	151	0·18
150	1 475	102	0·27	660	227	0·10
220	1 375	160	0·17	575	383	0·035
280	1 370	204	0·12	570	491	0 020
350	1 365	256	0·08	565	620	—
500	1 360	368	0·04	560	893	—

*Dry or moist locations, dry skin and significant floor resistance.22

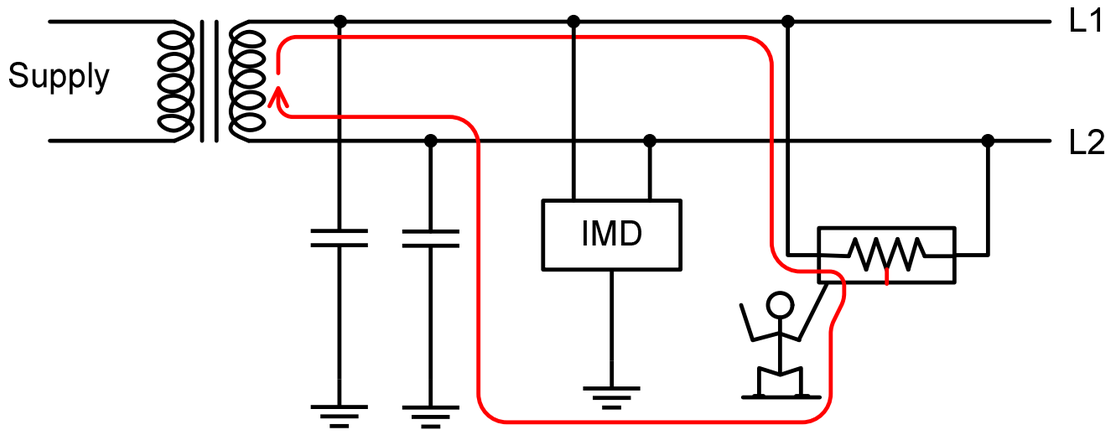
†Wet locations, wet skin and low floor resistance.

Loop Impedance in TT System



Loop impedance is high; So RCD protection is essential

IT System



- As input to unearthed IT systems, either a transformer or an independent power source, such as a battery or a generator are used.
- No high fault current flows in the event of a short circuit to exposed conductive part or an earth fault.
  As required by the standards, an insulation monitoring device is mandatory in an IT system.
- In an unearthed system, a first fault does not interrupt the system power supply and therefore increases the availability of the system.

Comparison of Earthing Systems

	TT	IT	TN-S	TN-C	TN-C-S
Earth fault loop impedance	High	Highest	Low	Low	Low
RCD preferred?	Yes	N/A	Optional	No	Optional
PE conductor cost	Low	Low	Highest	Least	High
Risk of broken neutral	No	No	High	Highest	High
Safety	Safe	Less Safe	Safest	Least Safe	Safe
Safety risks	High loop impedance	Double fault, overvoltage	Broken neutral	Broken neutral	Broken neutral
Advantages	Safe and reliable	Continuity of operation, cost	Safest	Cost	Safety and cost

Applications

Type	Applications
TT	Over head power distribution for residential / commercial from a common Transformer. Every installation shall have an RCD and an earth electrode at Origin of installation
TN-S	Industrial / commercial / IT Buildings with electronic systems and Transformer with in facility (transformer operated by the owner)
TN-C	Over Head Power Distribution up to Origin of an Installation.
TN-C-S	Over head power distribution for residential / commercial from a common Transformer. RCD and earth electrode at origin of installation are optional.
IT	Hospitals / IT installation for a building or part of a building. Not suitable for different buildings with same supply

Overcurrent Protective Devices (OCPD)

FUSE

MCB

MCCB

ACB

Tripping occurs due to overload, short circuit or earth fault.
For quick disconnection approx. 10 times rated current shall flow

220 volt fault Disconnection time in final circuit:

Dry condition – 0.170 sec

Wet condition – 0.035 sec

Residual Current Protective Devices

ELCB

Voltage sensing Earth Leakage Circuit Breaker

Now obsolete

RCCB

Residual Current Circuit Breaker

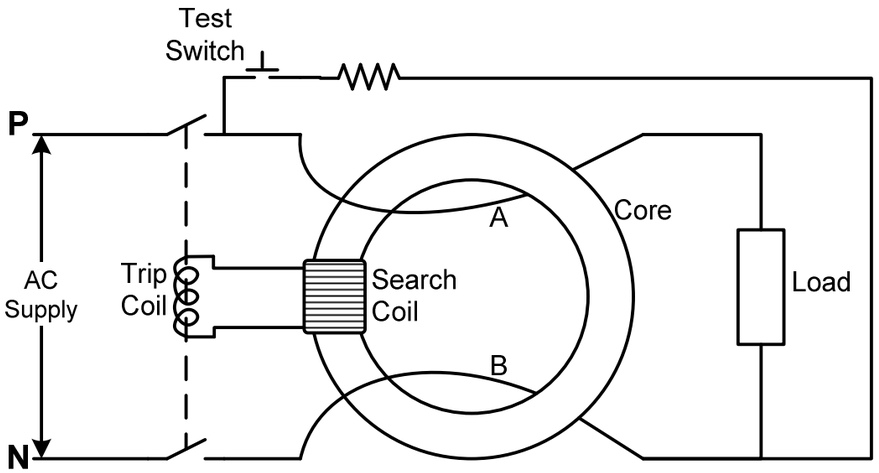
RCBO

Residual Current Breakover

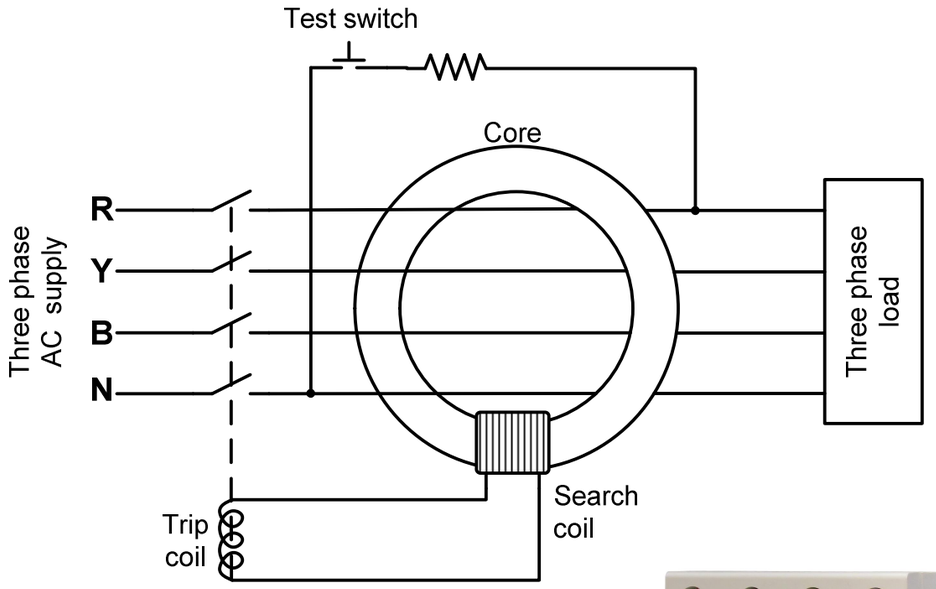
RCCB + MCB

RCCB Principle

2 Pole - RCCB



4 Pole - RCCB



Electric Shock Levels

- Electrical Sensation
  - 0.3 mA to 0.4 mA
- Perception Let-Go
  - 0.7 mA to 1.1 mA
- Maximum Let -Go Level
  - 10 mA (Female)
  - 16 mA (Male)
- Fibrillation Level
  - 50 mA for 0.2 Secs (female)
  - 75 mA for 0.5 Secs (Male)

Automatic disconnection of supply should happen before the prescribed time

Definitions

- **Reference Earth** — the conductive mass of the earth, whose electric potential at any point of this mass of earth is taken as zero with reference to an earthing system of electrical power system or electrical installations in a building.
- **Earthing system -** arrangement of connections and devices necessary to earth equipment or a system separately or jointly.
- **Earth Electrode** — A conductor or group of conductors in intimate contact with and providing an electrical connection to earth.
- **Earth grid –** earth electrode in the form of two over lapping groups of buried, parallel, horizontal electrodes usually laid approximately at right angle to each other with the electrodes bonded at each intersection. Earth grid provides common ground for electrical devices and metallic structures.
- **Earth Electrode Resistance** — The resistance to earth of an earth electrode or earth grid.

Definitions

- **Earth Fault Loop Impedance** — The impedance of the earth fault current loop (phase-to-earth loop) starting and ending at the point of earth fault.
- **Earth Leakage Current** — A current which flows to earth or to extraneous conductive parts in a circuit which is electrically sound.
- **Earthing Conductor** — A protective conductor connecting the main earthing terminal to an earth electrode or to other means of earthing.
- **Electrically Independent Earth Electrodes** — Earth electrodes located at such a distance from one another that the maximum current likely to flow through one of them does not significantly affect the potential of the other(s).
- **Equipotential Bonding** — Electrical connection putting various exposed conductive parts and extraneous conductive parts at a substantially equal potential.

Definitions

- **Functional Earthing** — Connection to earth necessary for proper functioning of electrical equipment
- **Neutral Conductor** — A conductor connected to the neutral point of a system and capable of contributing to the transmission of electrical energy.
- **PEN Conductor** — A conductor combining the functions of both protective conductor and neutral conductor.
- **Earth Potential –** Electric potential with respect to general mass of earth which occurs in, or on the surface of the ground around an earth electrode when an electric current flows from the electrode to earth.
- **Earth Potential rise** – Voltage between an earthing system and reference earth

Definitions

- **Equipotential Line or Contour** — The locus of points having the same potential at a given time.
- **Mutual Resistance of Grounding Electrodes** — Equal to the voltage change in one of them produced by a change of one ampere of direct current in the other and is expressed in ohms.
- **Earth Grid** — A system of grounding electrodes consisting of inter-connected connectors buried in the earth to provide a common ground for electrical devices and metallic structures.

  NOTE — The term 'earth grid' does not include 'earth mat'.
- **Earth Mat** — A grounding system formed by a grid of horizontally buried conductors and which serves to dissipate the earth fault current to earth and also as an equipotential bonding conductor system.

Definitions

- **PME** - Protective multiple earthing
- **CNE** - Combined neutral and earth
- **PEN -** A conductor combining the functions of both protective conductor and neutral conductor
- **MET –** Main Earthing Terminal

Statutory Provisions

- All equipment of voltages of 250 volts to 650 volts shall be earthed by two separate and distinct connections with earth.
- Each earth system shall be so devised that the testing of individual earth electrode is possible.
- As far as possible, all earth connections shall be visible for inspection.
- No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and the live conductors, shall be inserted on any supply system.
  - This, however, does not include the case of a switch for use in controlling a generator or a transformer or a link for test purposes.

Reason for Accidents

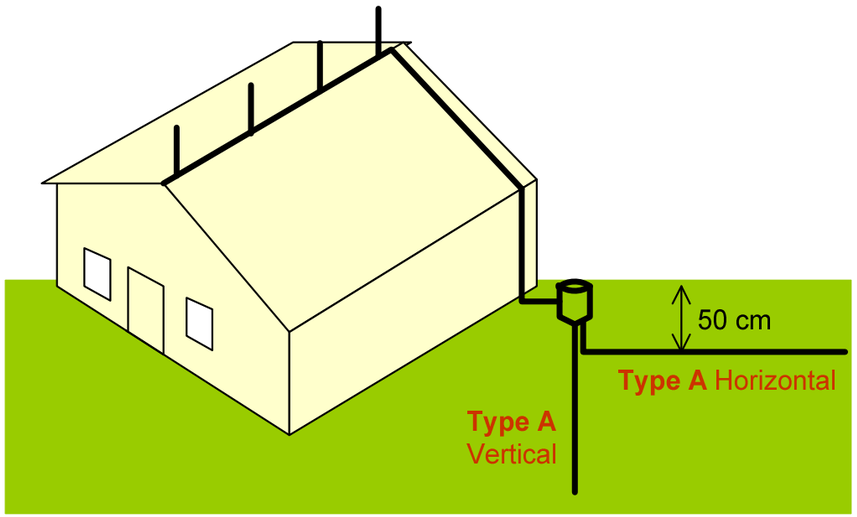
- Houses/shops/buildings etc - L.V public electricity distribution
  - Safety regulations and standards are not understood by Utilities. As a result TT network is used without RCD
  - Conditions of ADS (automatic disconnection of supply) are not followed by utilities. As a result protective device wont trip during fault.
  - ADS will not work when powered from Generators / UPS / Inverters due to insufficient fault current.

Reason for Accidents

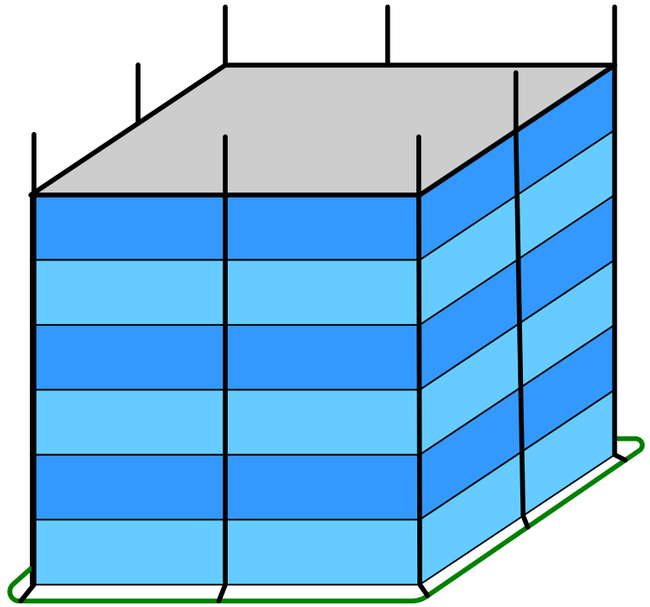
- Industrial / commercial / multistoried buildings (HT supply)
  - Safety regulations and standards are not understood. As a result TT network is used instead of TN-S with PME
  - Sources such as Transformer and DG – Neutral are earthed in soil separately creating high impedance path for fault current as a result primary protective device will never operate during fault.
  - MET and equipotentialisation is unknown and not followed.
  - Loop impedance test and ADS (Auto disconnection of supply) is not carried out.
  - ADS will not work when powered from Generators / UPS / Inverters due to insufficient fault current.

Earthing for Lightning Protection

Type A

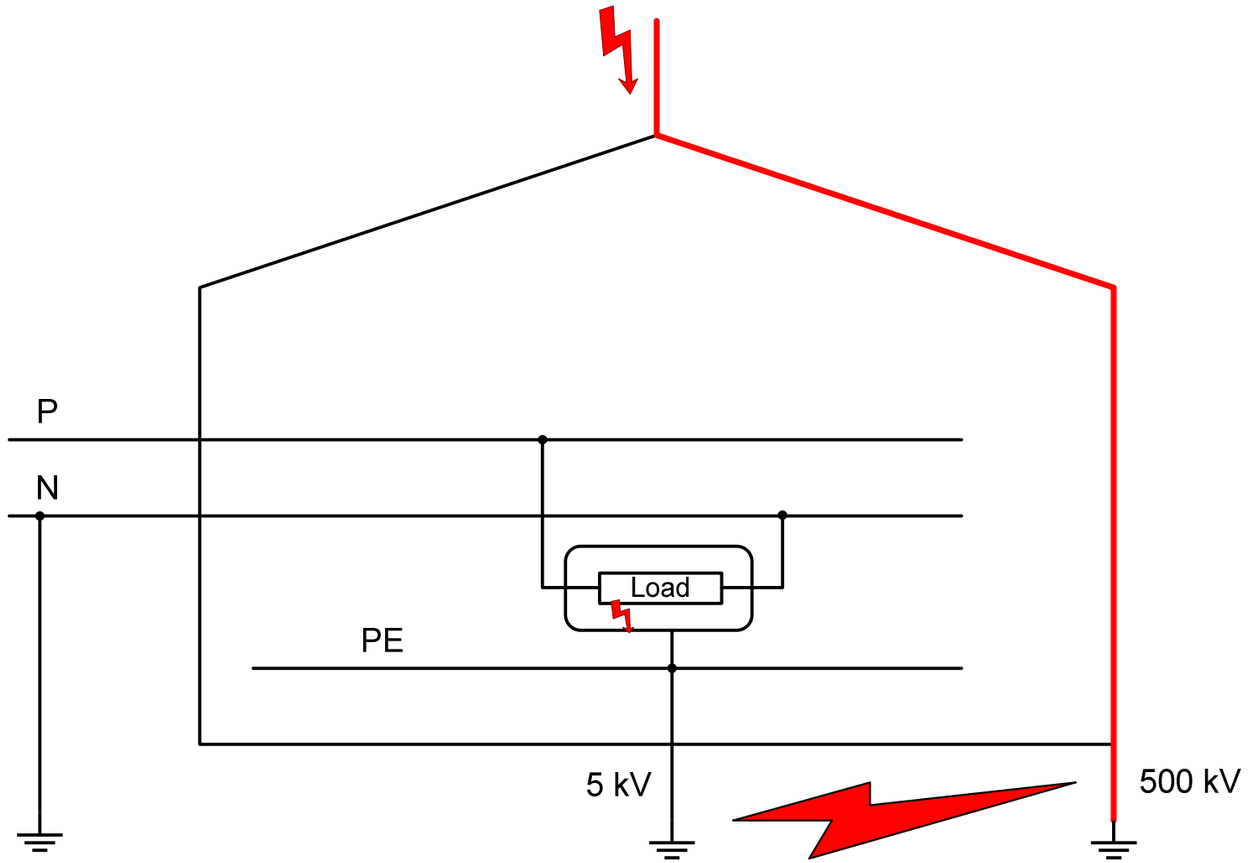


Type B



Type B Arrangement
(Ring Conductor)

Earthing for Lightning Protection



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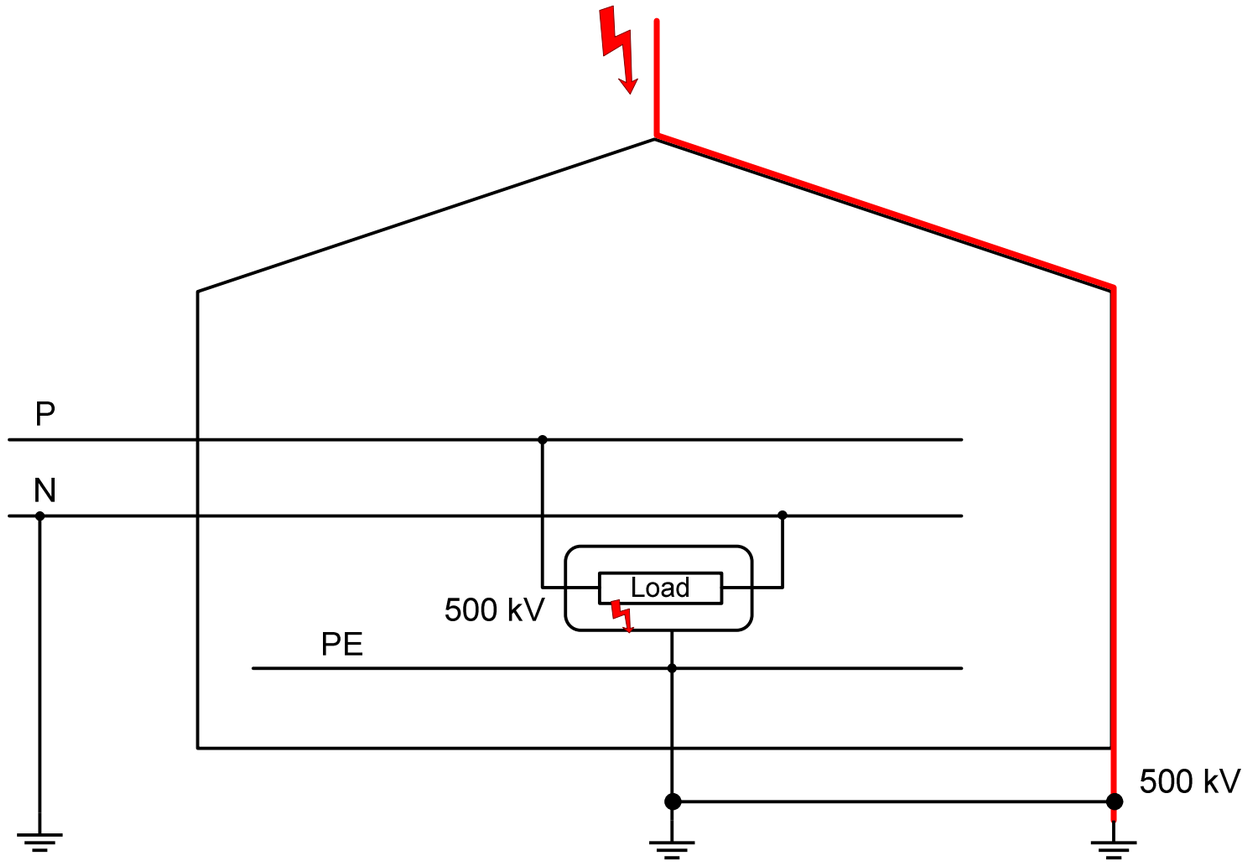
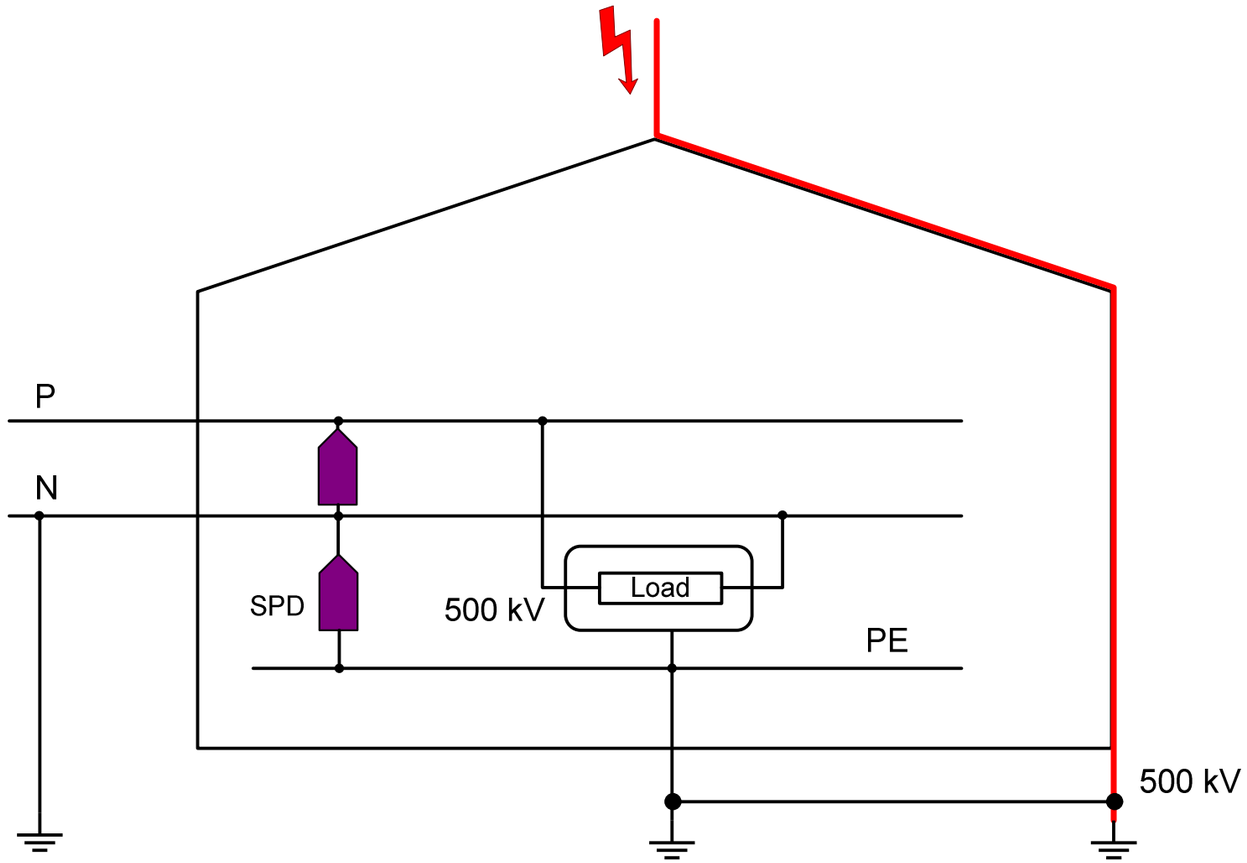
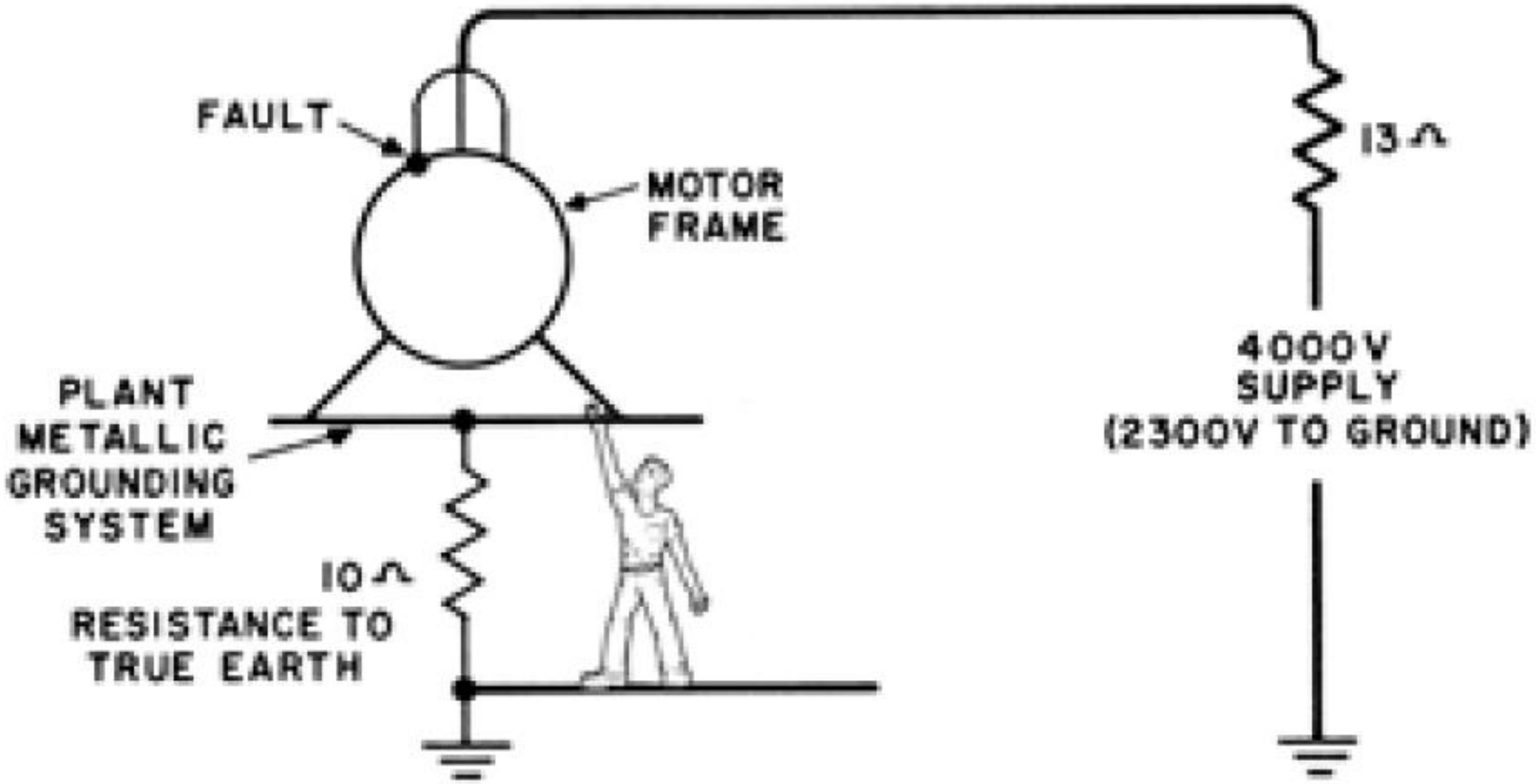


Earthing for Lightning Protection



Significance of Earth Resistance



Earth Electrodes

Pipe Earthing

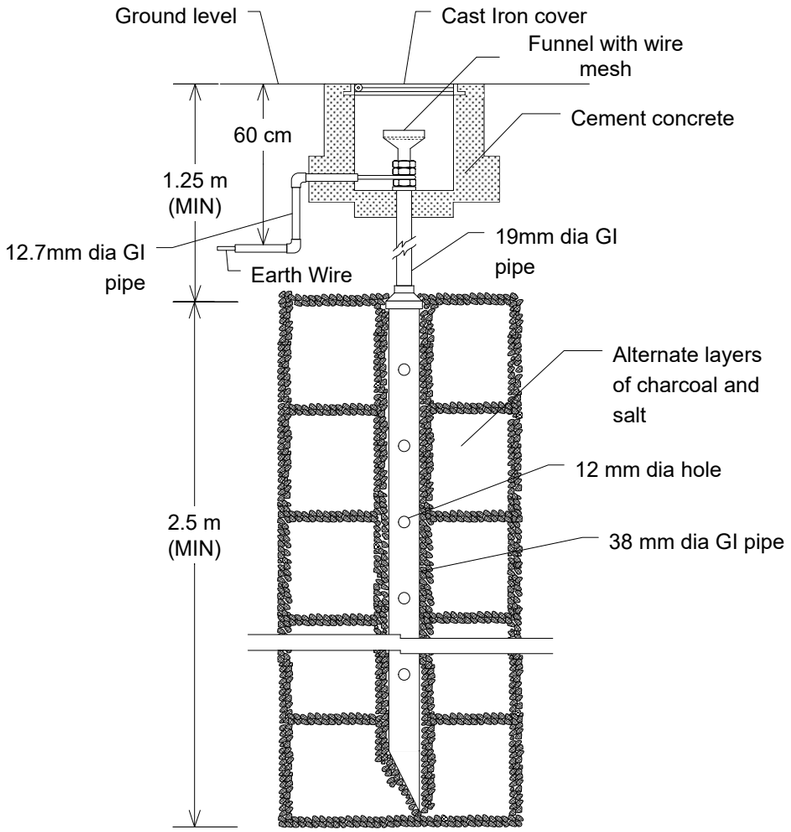
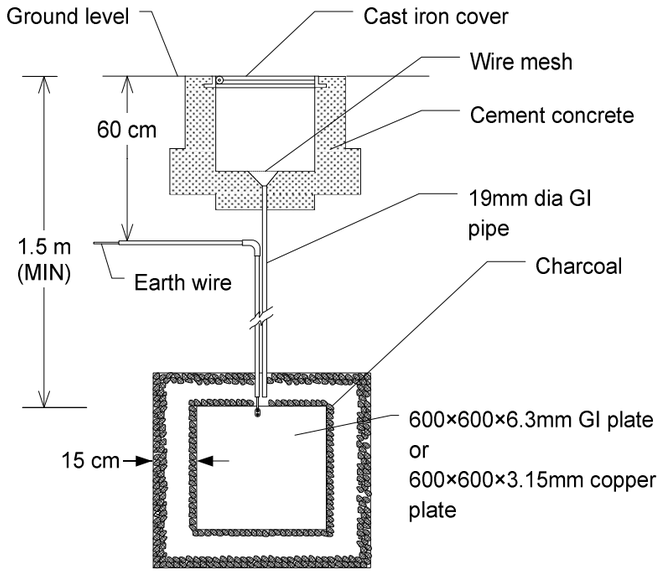
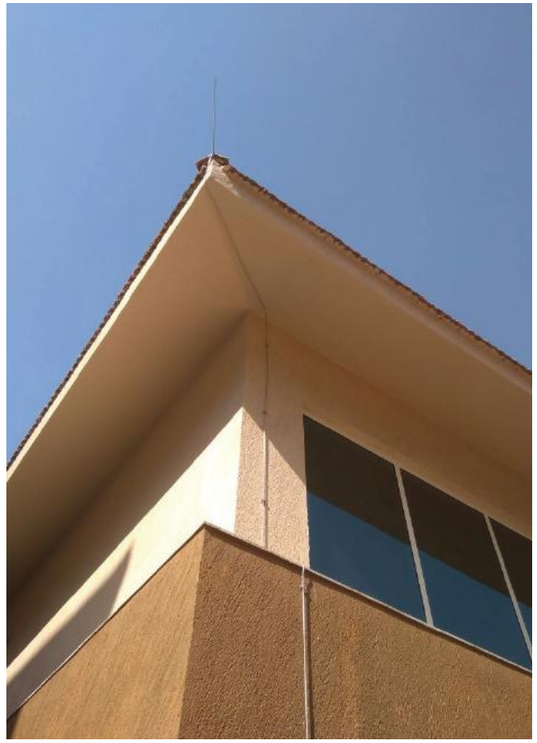


Plate Earthing



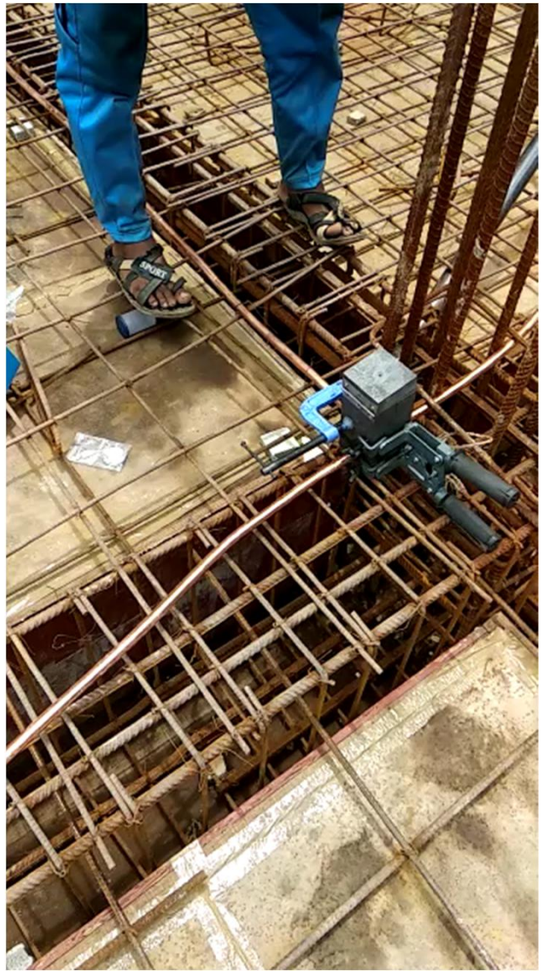
New developments are coming up

Planning for Earth Terminal

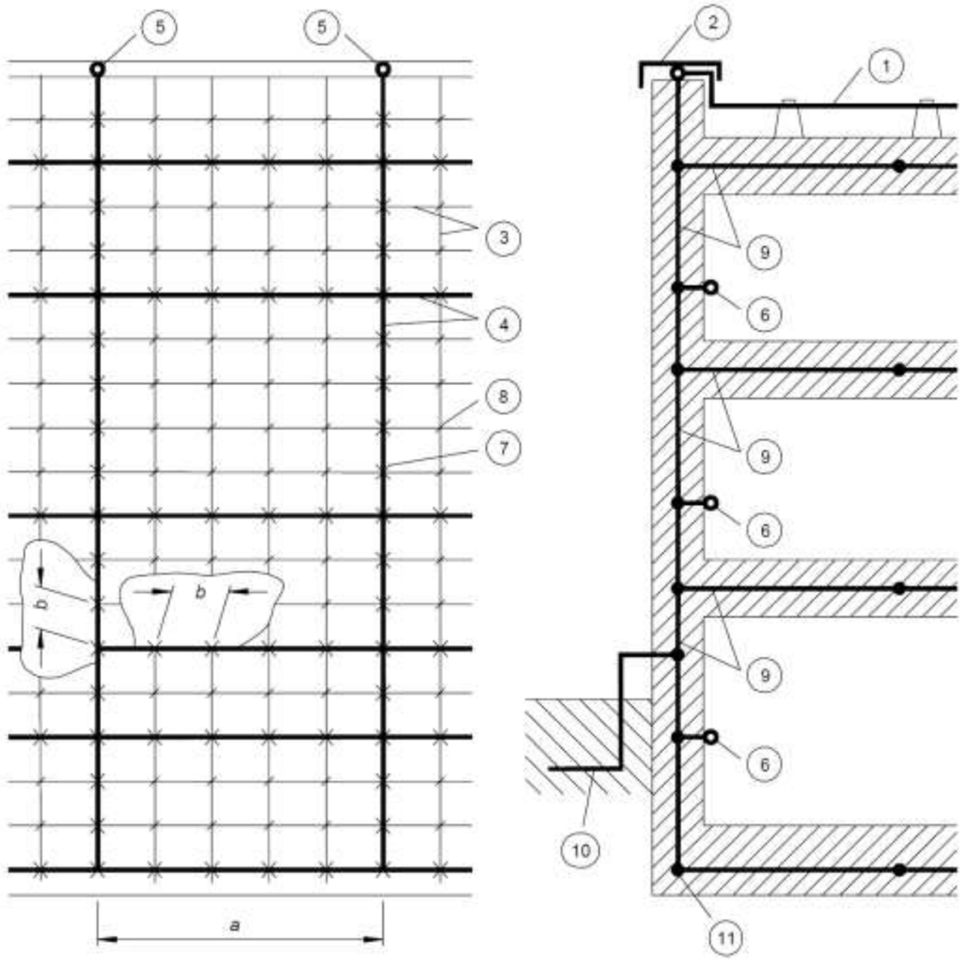


Aesthetics, Effectiveness and maintenance requirements are to be considered

Structural Earthing

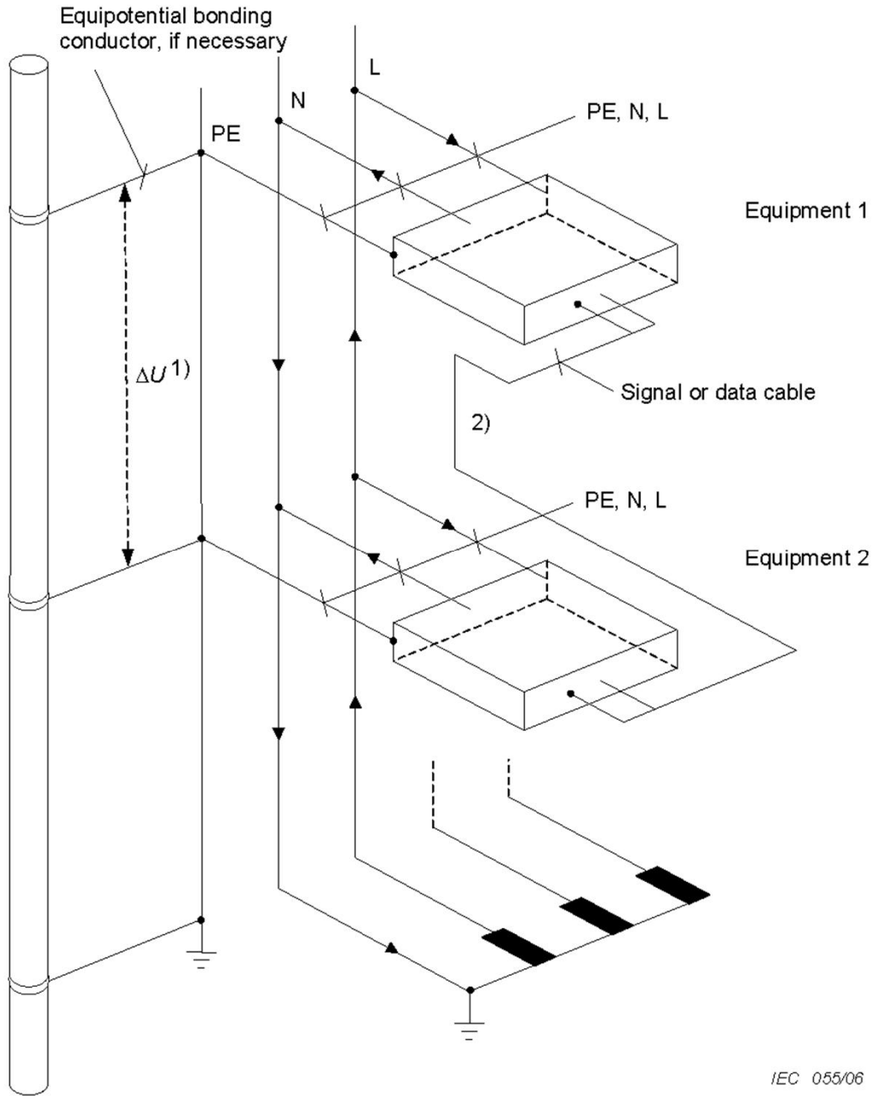


Structural Earthing



1. air-termination conductor
2. metal covering of the roof parapet
3. steel reinforcing rods
4. mesh conductors superimposed on the reinforcement
5. joint of the mesh conductor
6. joint for an internal bonding bar
7. connection made by welding or clamping
8. arbitrary connection
9. steel reinforcement in concrete (with superimposed mesh conductors)
10. ring earthing electrode (if any)
11. foundation earthing electrode

Equipotential bonding



Thank You