Earthing, Lightning & Surge Protection

Presented by

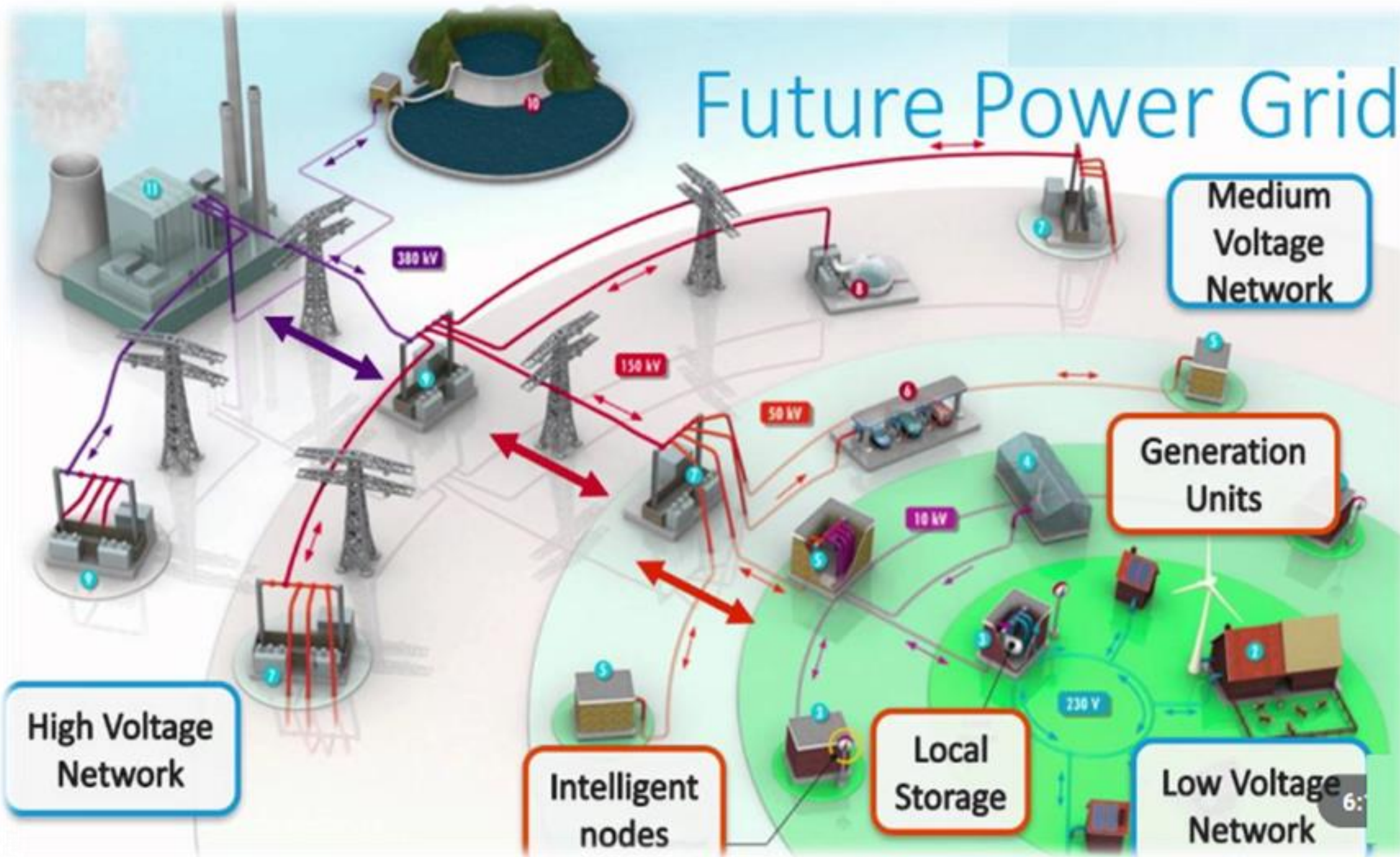
Mohamed A.Elhamied

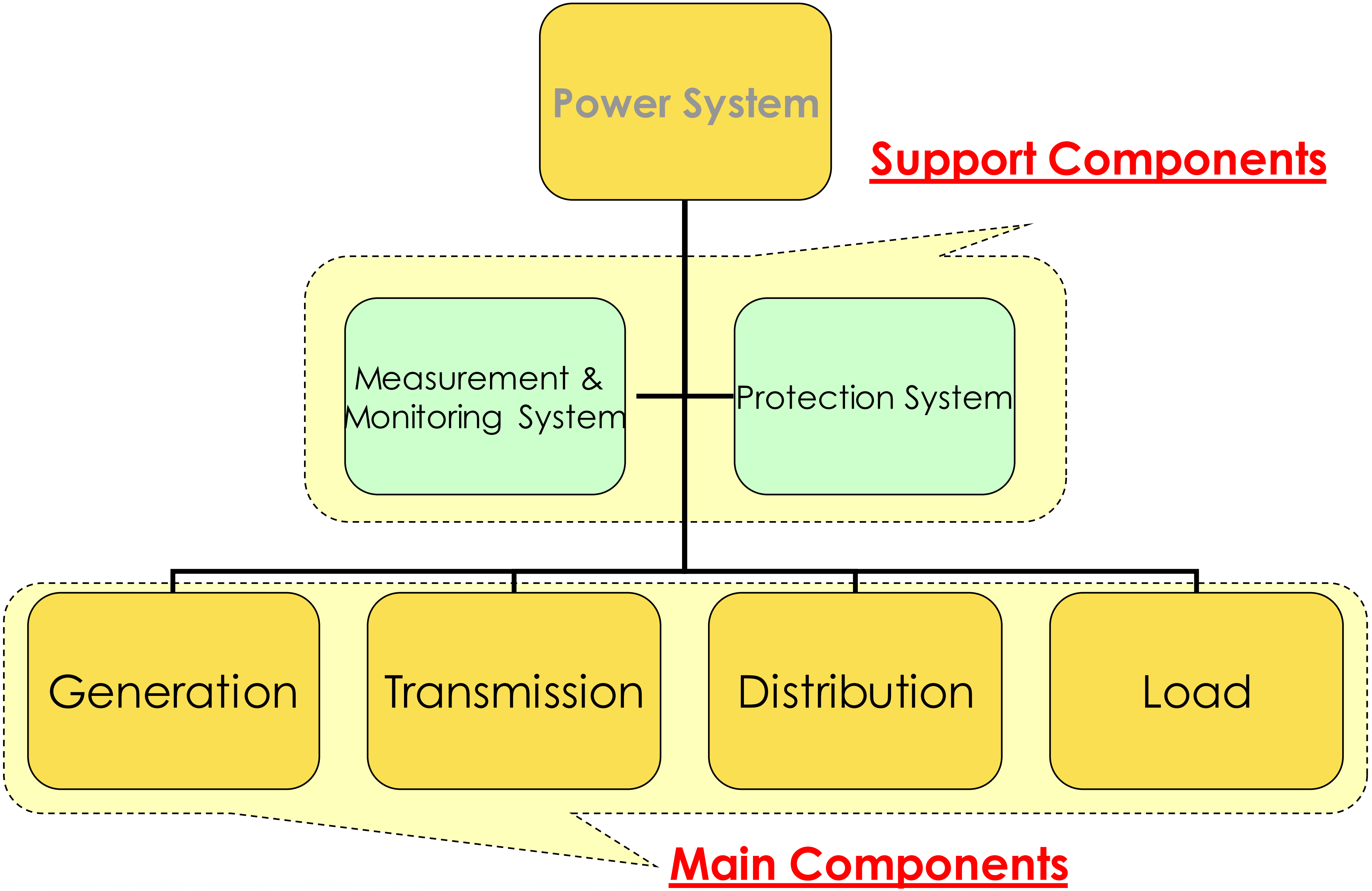
Earthing, Lightning & Surge Protection

Info.

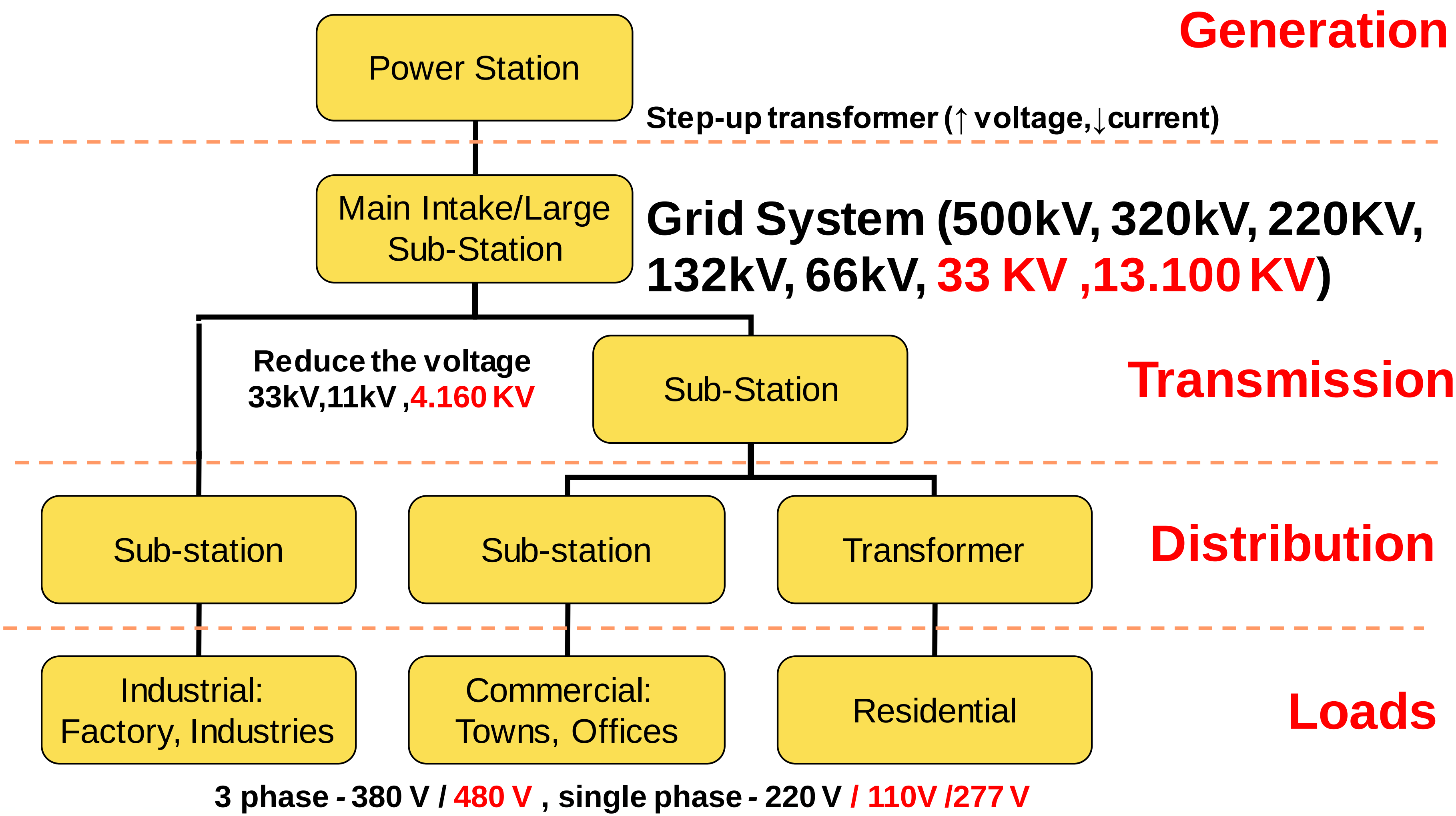
- Instructor: Eng. Mohamed A/Hamied
- We want you to enjoy this training course so please ask plenty of questions!
- There will be regular breaks and refreshments
- Relevant technical information is provided to support the training and may be used during the final assessment.
- Please turn off mobile phones or set to 'Silent!'

Introduction



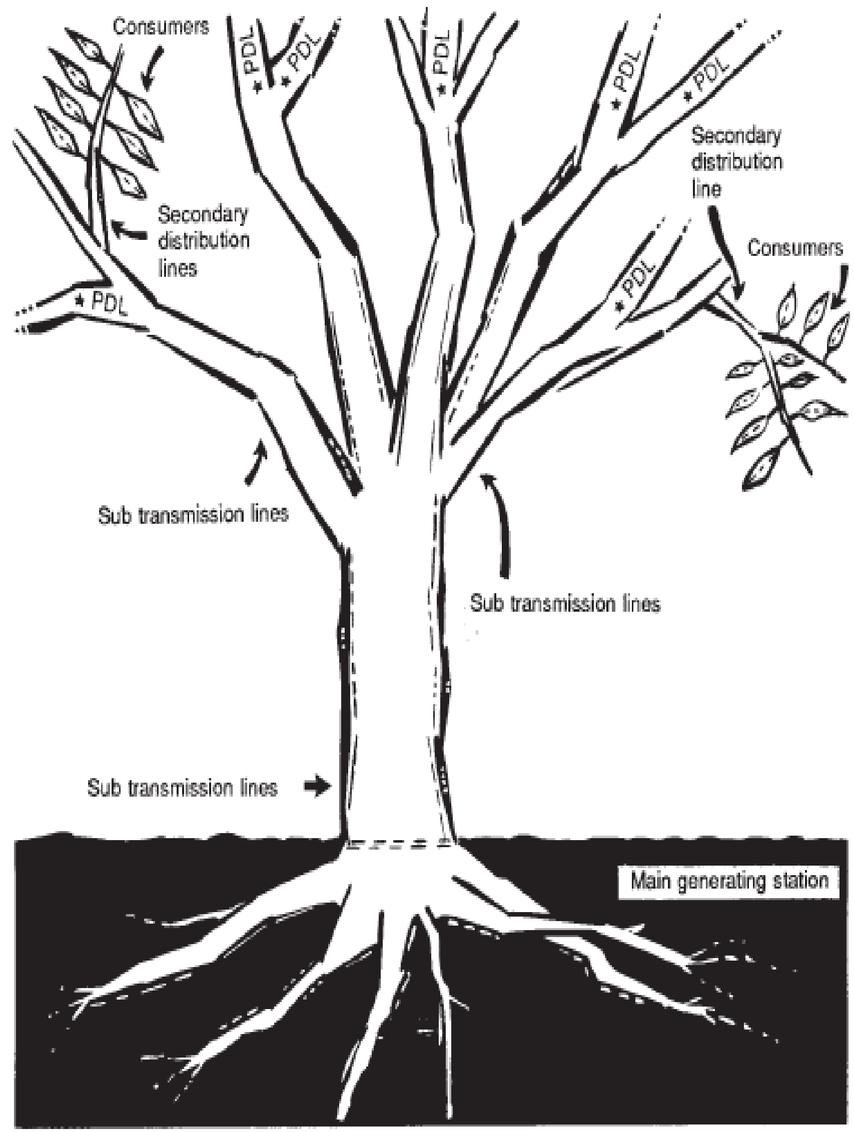

Power System
Support Components
Measurement & Monitoring System
Protection System
Generation
Transmission
Distribution
Load
Main Components

Power System Components



The Supply Source

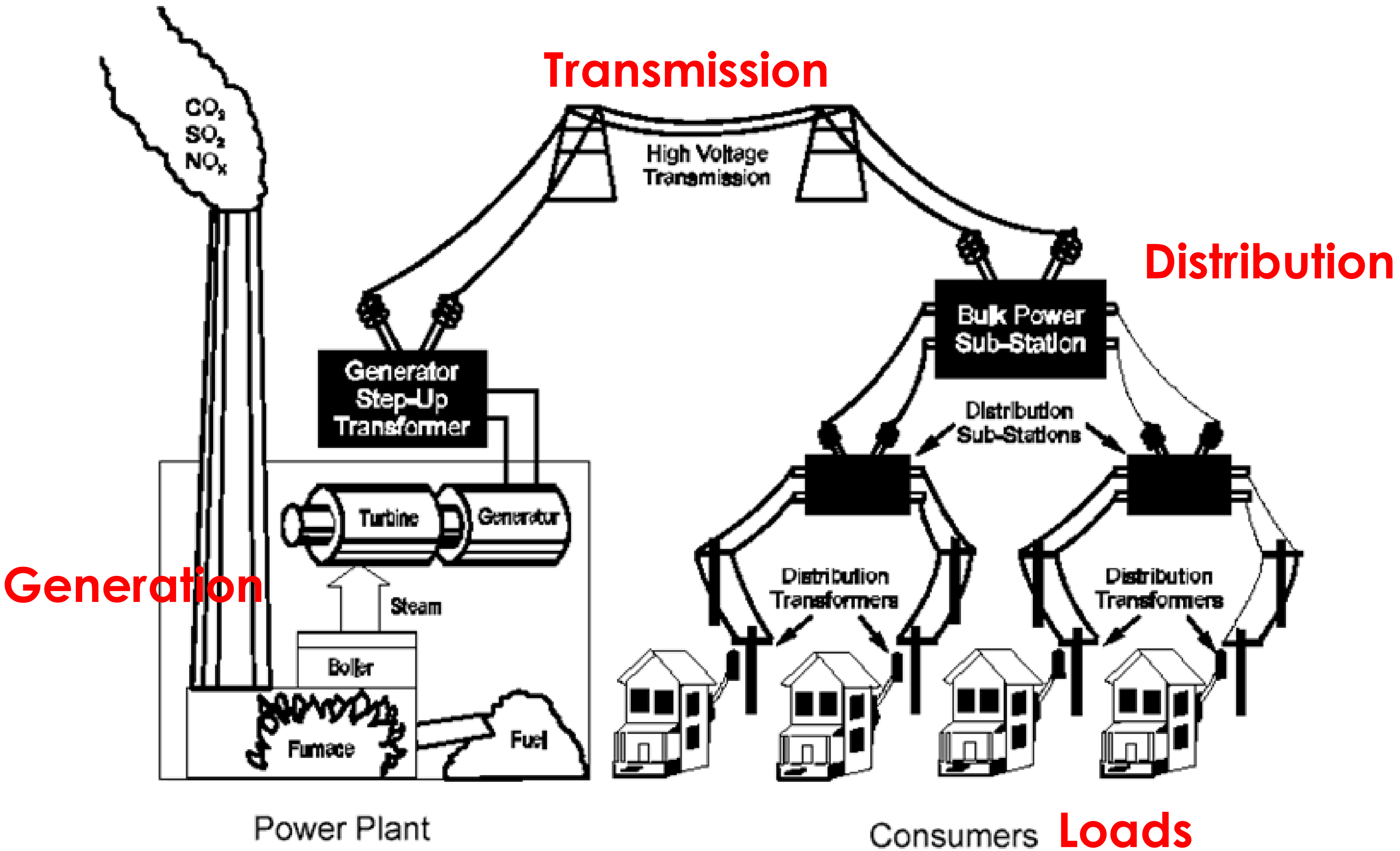
is the final stage in the delivery of electricity to end users. A distribution system's network carries electricity from the **transmission system (Power cables)and delivers it to consumers**. Typically, the network would include low voltage , medium-voltage and high voltage power lines, substations and pole-mounted transformers, low-voltage (less than 1 kV) distribution wiring and sometimes meters.



Tree of Electricity

Power System Component

1. Power Generation Source (Electrical Generator)
2. Step up transformer (in case of transfer power over along distance)
3. Overhead transmutation line or underground cables
4. Step down transformer (in case of transfer power over along distance)
5. Loads (important load as motor)
6. Circuit breaker , Earthing (protection)
7. UPS and battery (Accessory)



Transmission
Distribution
Generation
Loads
CO_2
SO_2
NO_x
High Voltage Transmission
Generator Step-Up Transformer
Turbine
Generator
Steam
Boiler
Furnace
Fuel
Bulk Power Sub-Station
Distribution Sub-Stations
Distribution Transformers
Distribution Transformers
Power Plant
Consumers

Standard Nominal System Voltages and Voltage Ranges

(From IEEE Standard 141-1993)

Voltage Class	Nominal System Voltage	
	Three-Wire	Four-Wire
Low voltage	240/120 240 480 600	208Y/120 240/120 480Y/277 —
Medium voltage	2400 4160 4800 6900 13,200 13,800 23,000 34,500 46,000 69,000	4160Y/2400 8320Y/4800 12000Y/6930 12470Y/7200 13200Y/7620 13800Y/7970 20780Y/12000 22860Y/13200 24940Y/14400 34500Y/19920
High voltage	115,000 138,000 161,000 230,000	— — — —
Extra-high voltage	345,000 500,000 765,000	— — —
Ultra-high voltage	1,100,000	—

From IEC 60038

System	*Nominal voltage (V_r) kV*
LV	$V_r \le 1$
MV	$1 < V_r \le 35$
HV	$35 < V_r \le 230$
EHV	$230 < V_r \le 800$
UHV	$V_m = 1050$ or 1200 kV (practised in USA)

Note

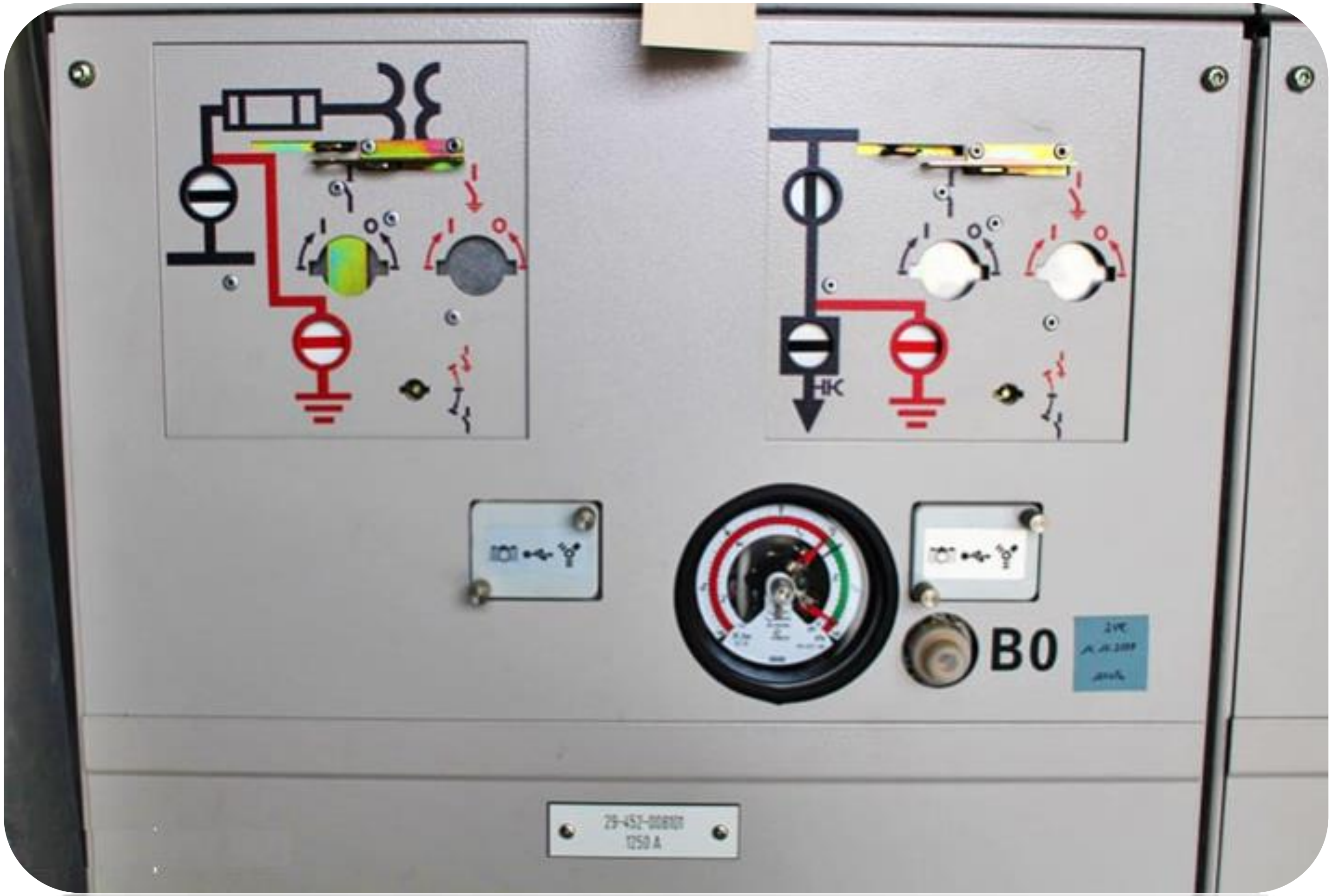
For all voltages above LV we have used the nomenclature as HV unless where the voltage range is specific such as for motors and generators we have used MV. Similarly we have identified,

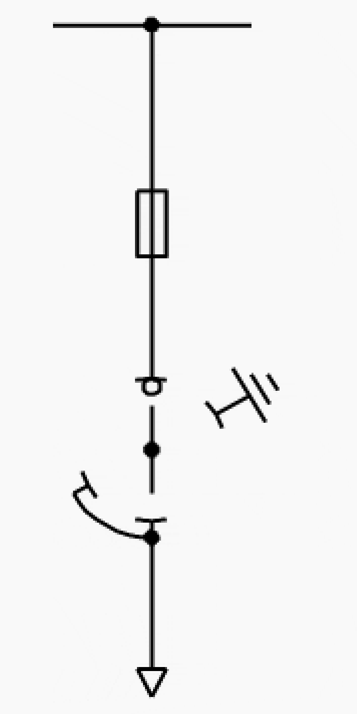
Transformer voltages as: Lower voltage side – LV

Higher voltage side – HV

Standard Nominal System Voltages and Voltage Ranges

Medium / High Voltage Earthing relation





Electrical Hazard

Hazards of Electricity

Shock Most common and can cause electrocution or muscle contraction leading to secondary injury which includes falls

Fires Enough heat or sparks can ignite combustible materials

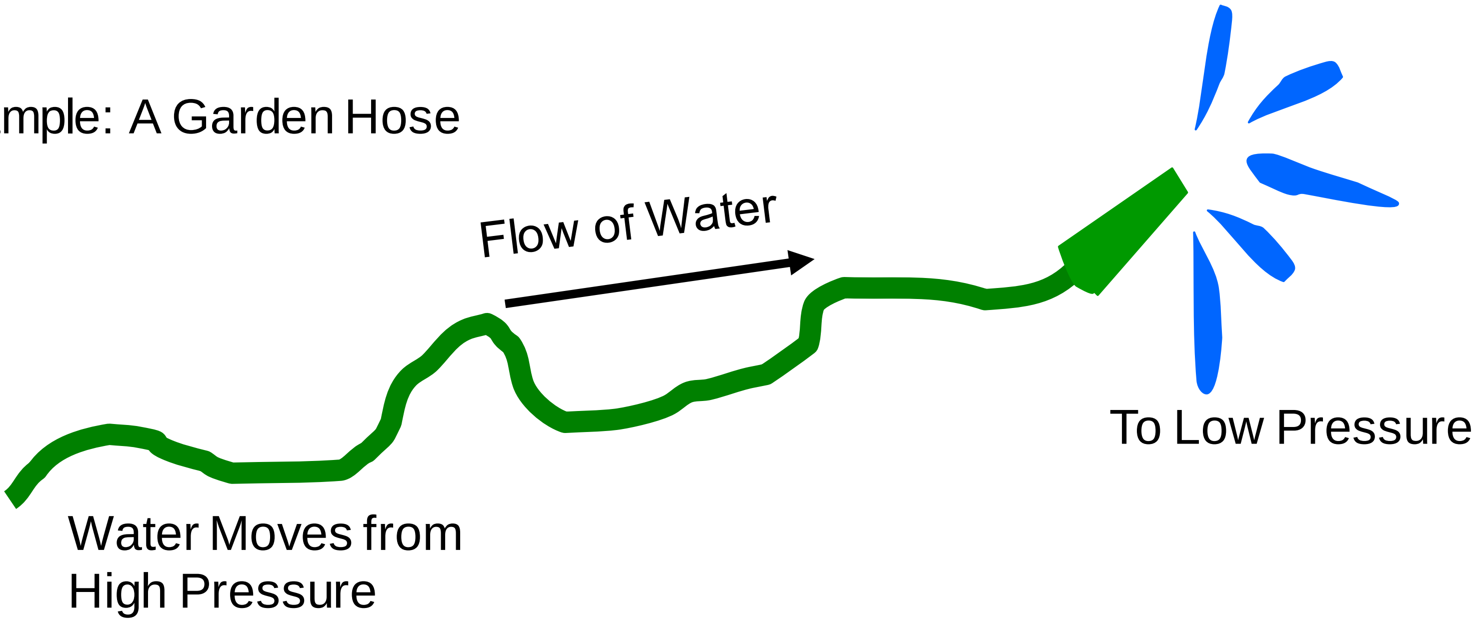
Explosions Electrical spark can ignite vapors in the air

Arc Flash can cause burns ranging from 14,000 degrees F. to 35,000 degrees F

Arc Blast In a short circuit event copper can expand 67,000 times. The expansion causes a pressure wave. Air also expands adding to the pressure wave

How Electricity Works

Example: A Garden Hose



The same thing occurs in an Electrical Wire

Current Moves from High Voltage

To Low Voltage

Electrical Shocks

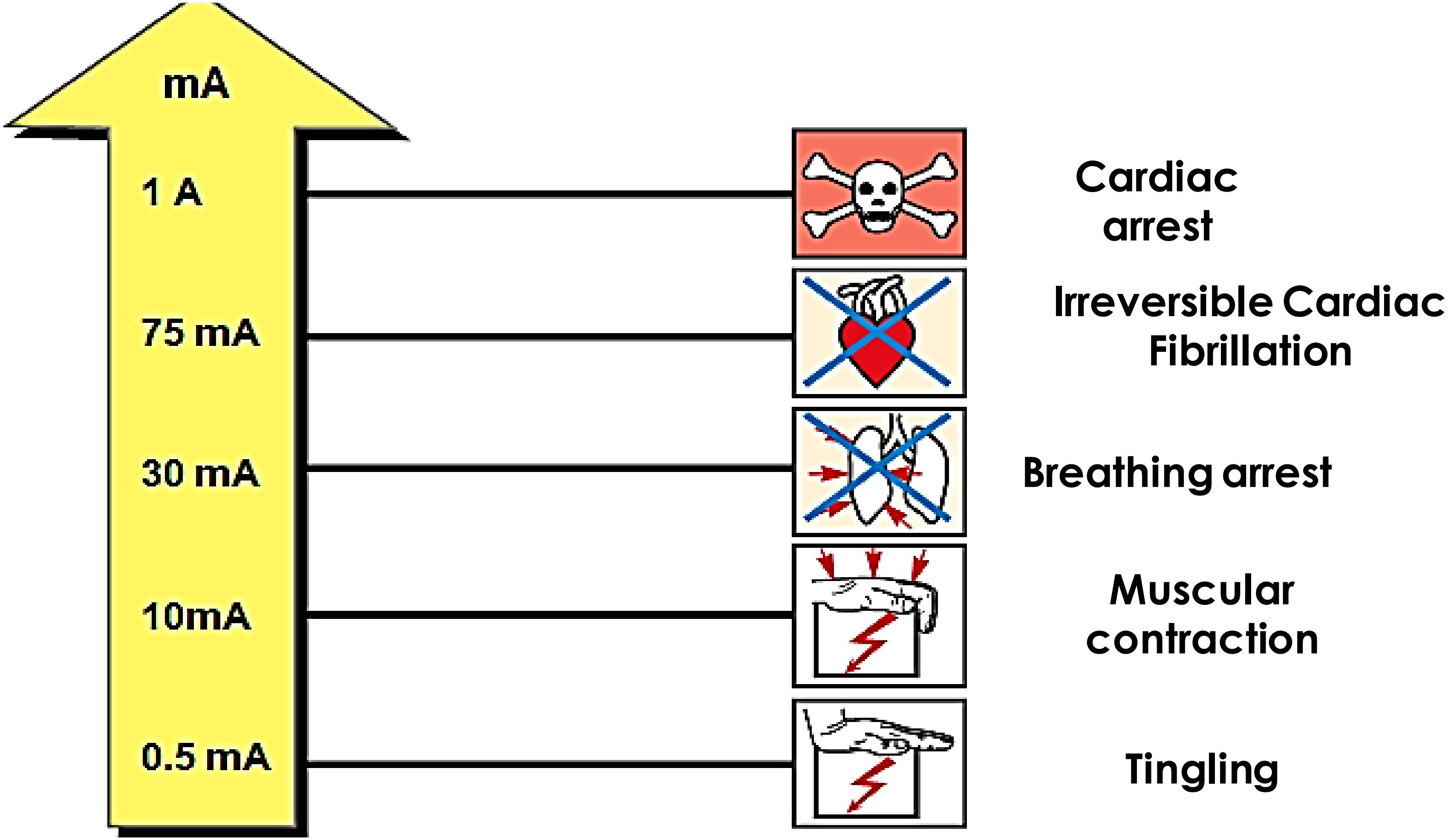
- Electricity travels in closed circuits, normally through a conductor
- Shock results when the body becomes part of the electrical circuit
- Current enters the body at one point and leaves at another

Note: Ground circuits provide a path for stray current to pass directly to the ground, and greatly reduce the amount of current passing through the body of a person in contact with a tool or machine that has an electrical short. Properly installed, the grounding conductor provides protection from electric shock.

IEC 60479-1: Effects of current on human beings and livestock.

BODILY EFFECT	DIRECT CURRENT	50 Hz AC
Slight sensation felt at hand(s)	Men = 1.0 mA	Men = 0.4 mA
	Women = 0.6 mA	Women = 0.3 mA
Threshold of perception	Men = 5.2 mA	Men = 1.1 mA
	Women = 3.5 mA	Women = 0.7 mA
Painful, but muscle control maintained	Men = 62 mA	Men = 9 mA
	Women = 41 mA	Women = 6 mA
Painful, unable to let go of wires (un-control of muscle)	Men = 76 mA	Men = 16 mA
	Women = 51 mA	Women = 10.5 mA
Severe pain, difficulty breathing	Men = 90 mA	Men = 23 mA
	Women = 60 mA	Women = 15 mA
Possible heart fibrillation after 3 seconds	Men = 500 mA	Men = 100 mA
	Women = 500 mA	Women = 100 mA

The Average Values



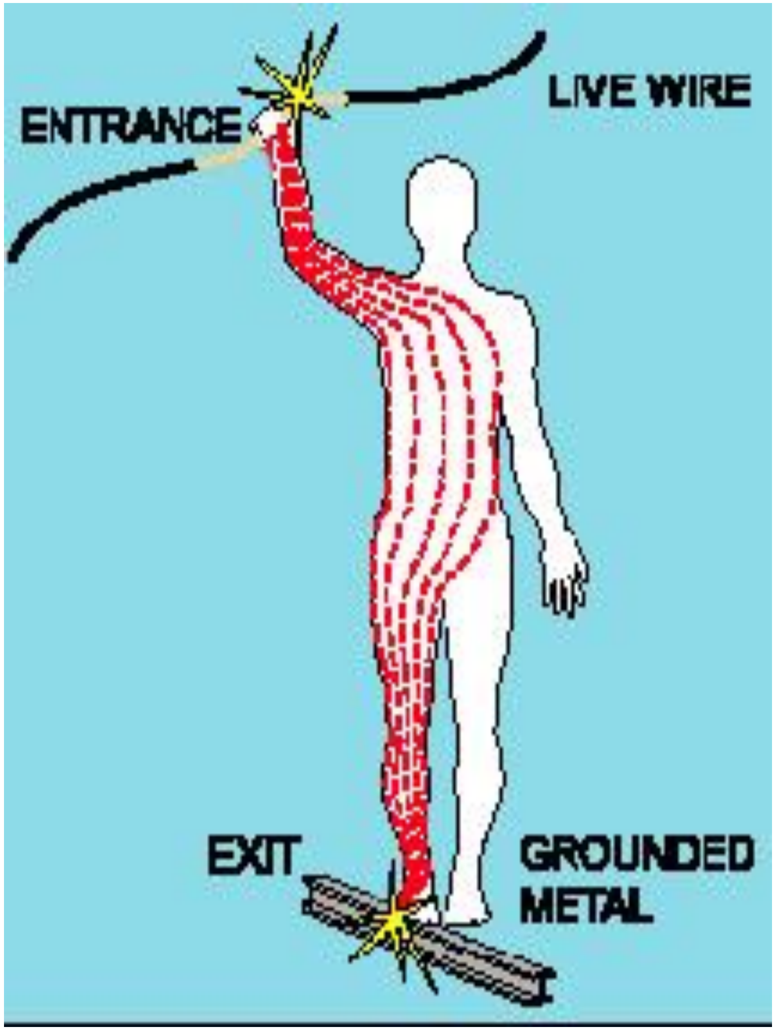
Electrical Burns

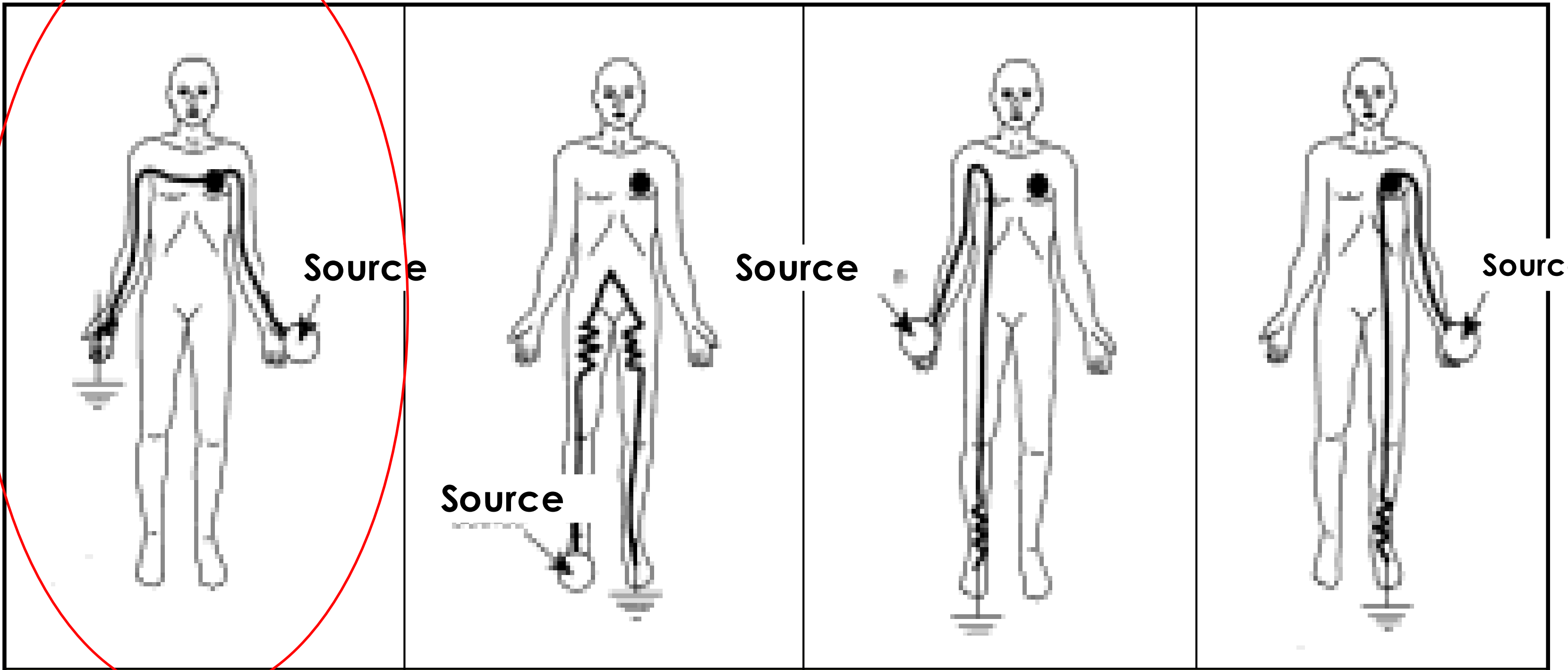
Falls


Describe identified hazards

Electrical Shock

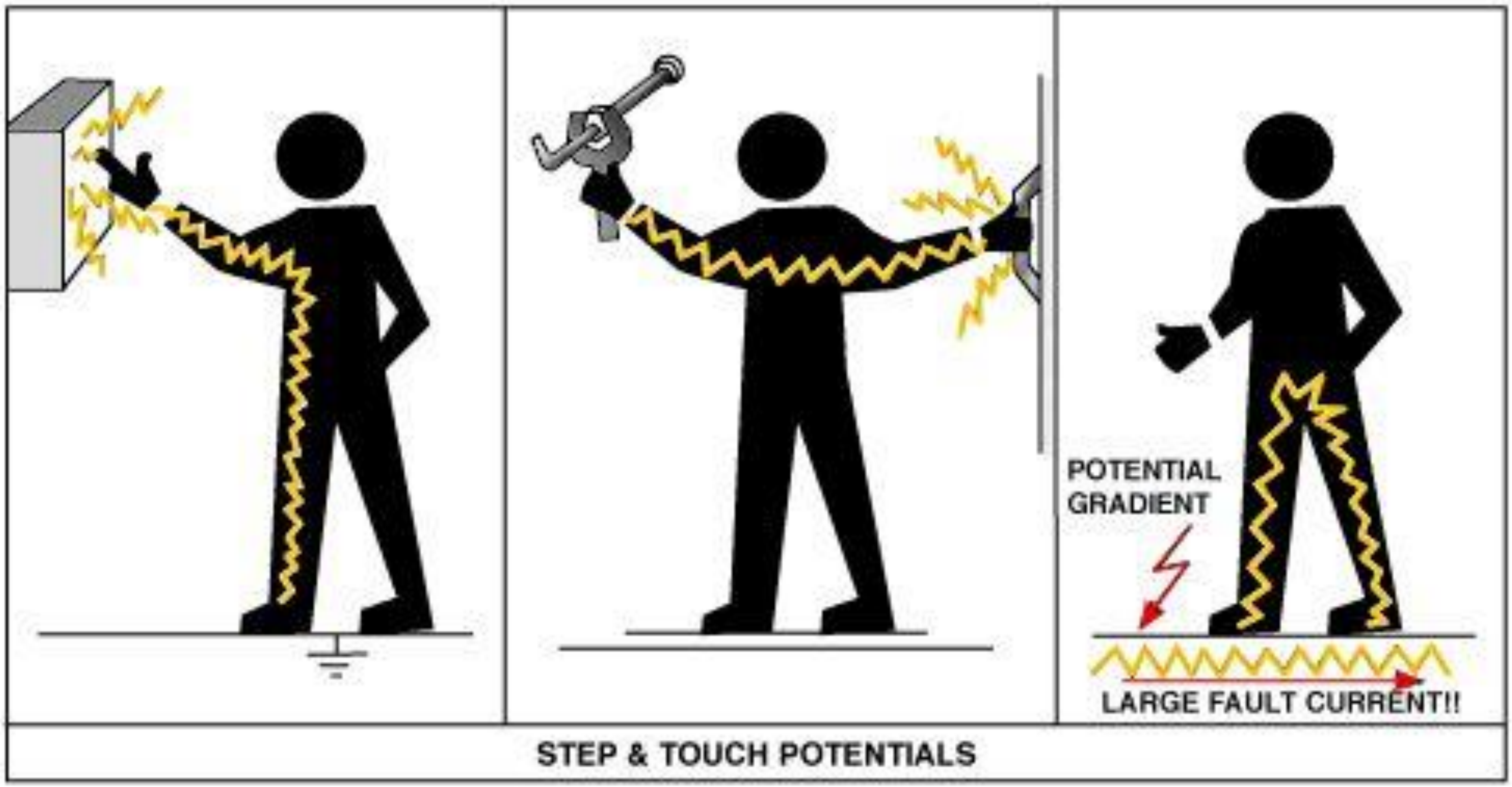
- Received when current passes through the body
- Severity of a shock depends on:
  - <u>Path</u> of current through the body
  - <u>Amount of current</u> flowing through the body
  - <u>Length of time</u> the body is in the circuit



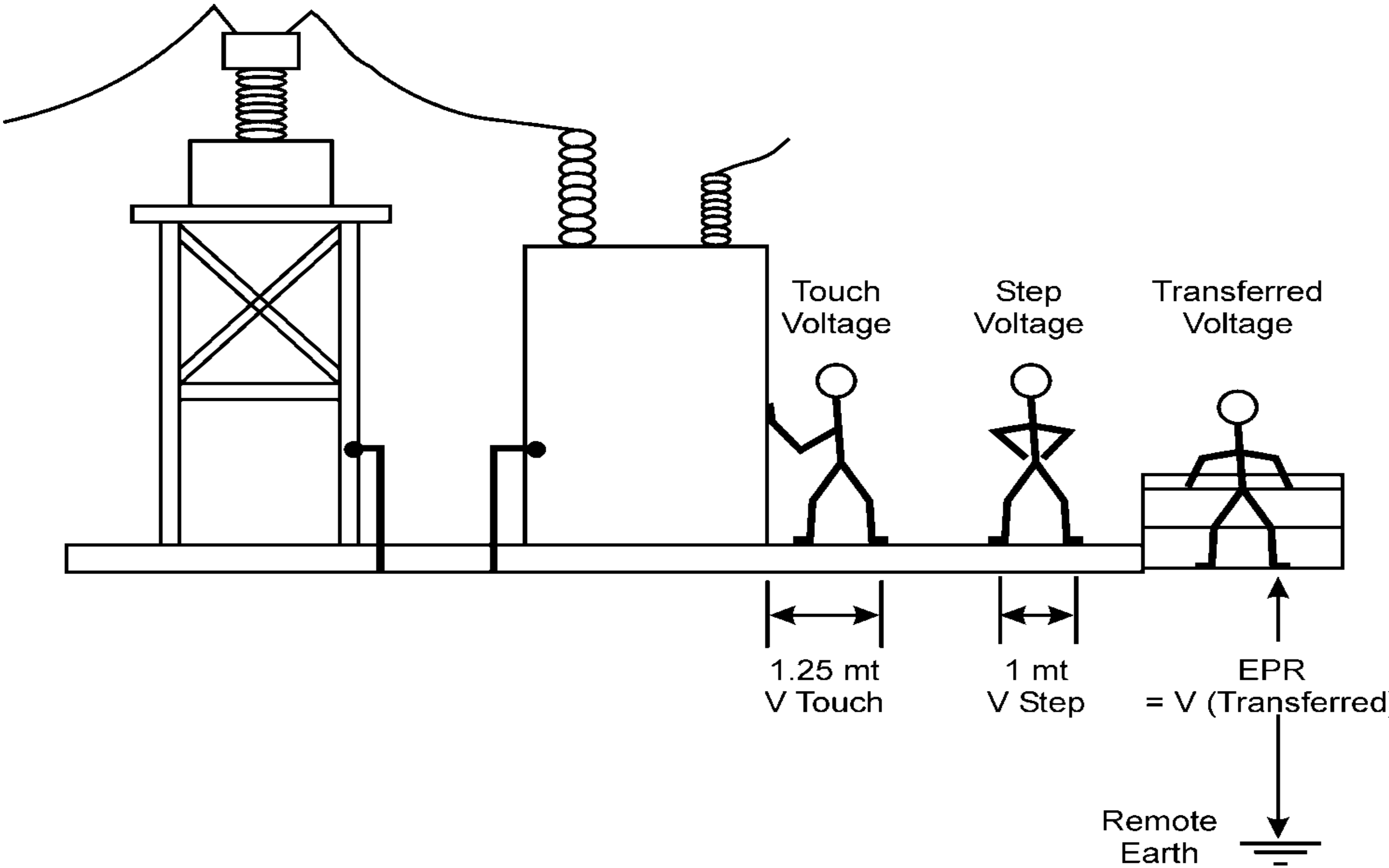


(A) Touch Potential	(B) Step Potential	(C and D) Touch / Step Potential

Current passing through the heart and lungs is the most serious


POTENTIAL GRADIENT
LARGE FAULT CURRENT!!
STEP & TOUCH POTENTIALS

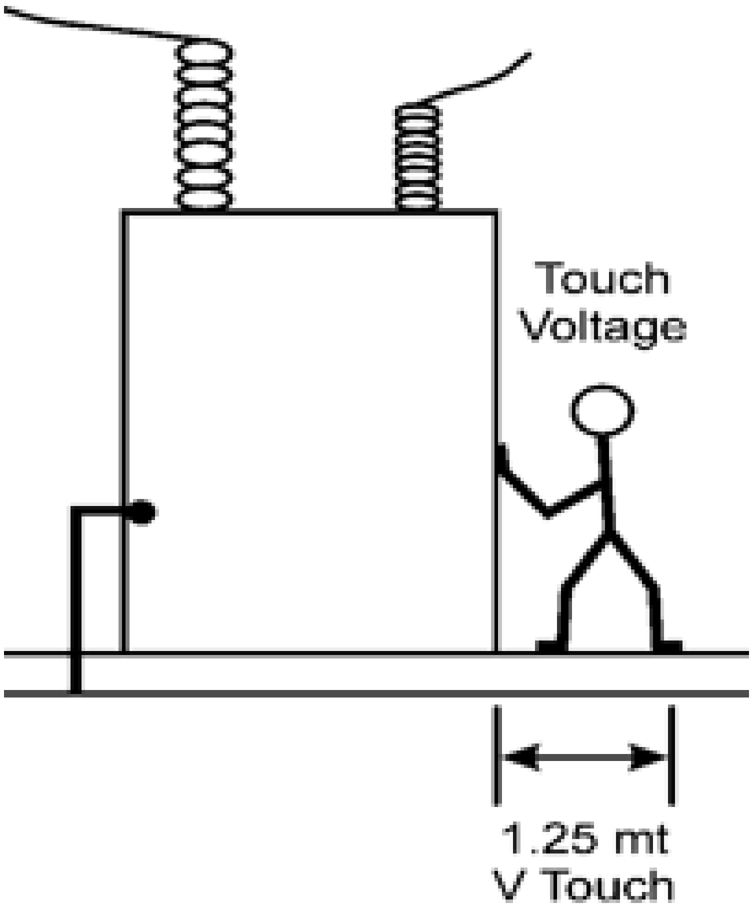
Touch, Step, Transferred Voltages



Touch Voltage

Permissible Touch Voltage

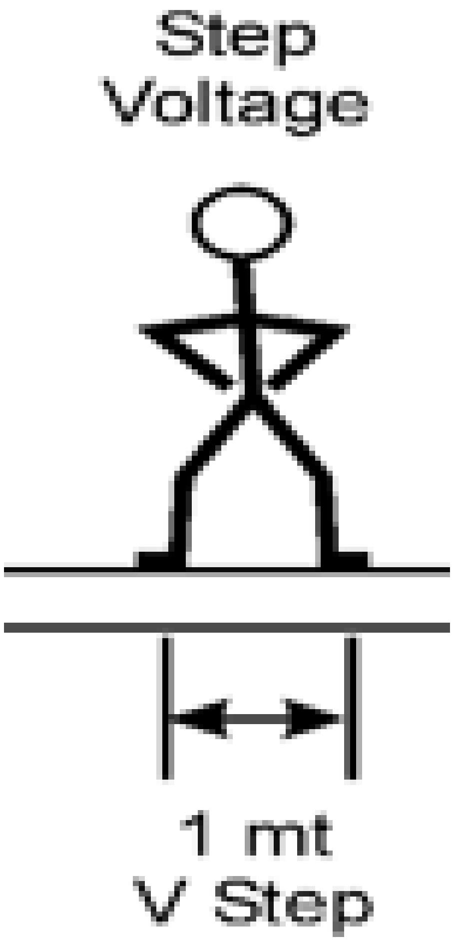
Voltage at any point of contact with uninsulated metal work Within **2.5 mtrs** from ground surface and Any point on ground surface within horizontal distance of **1.25 mtrs** from vertical projection of point of contact with uninsulated metal work



Step Voltage

Difference in surface potential experienced by a person bridging a distance of **1 mtr** with his feet apart, without contacting any other earthed object

Shall not exceed twice the value of Touch voltage



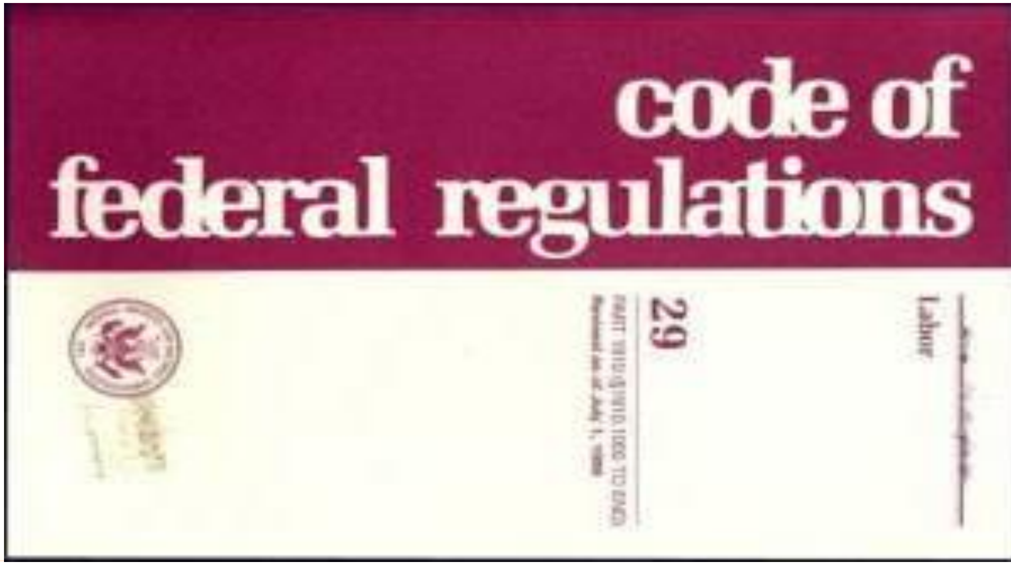
Controlling Electrical Hazards

Employers must follow the OSHA Electrical Standards and increased there skills with a lot of training

Electrical installation

Subpart K includes four proactive methods:

- **Electrical Isolation**
- **Equipment Grounding**
- **Circuit Interruption**
- **Safe Work Practices**



GROUNDING !!!!

Types of Grounding Systems According to IEC standard
Practically Grounding system

Types of Earthing/ Grounding Systems According to IEC standard

The international standards IEC60364, part 4, and Reference 10.

The five methods are abbreviated:-

1. IT **Unearthed or High impedance earthed neutral**
2. TT **Grounding / Earthed neutral**
3. TNC **Combined Neutral earthing / grounding**
4. TNS **Separate Neutral earthing /grounding**
5. TNCS **Separate & combined Neutral earthing / grounding**

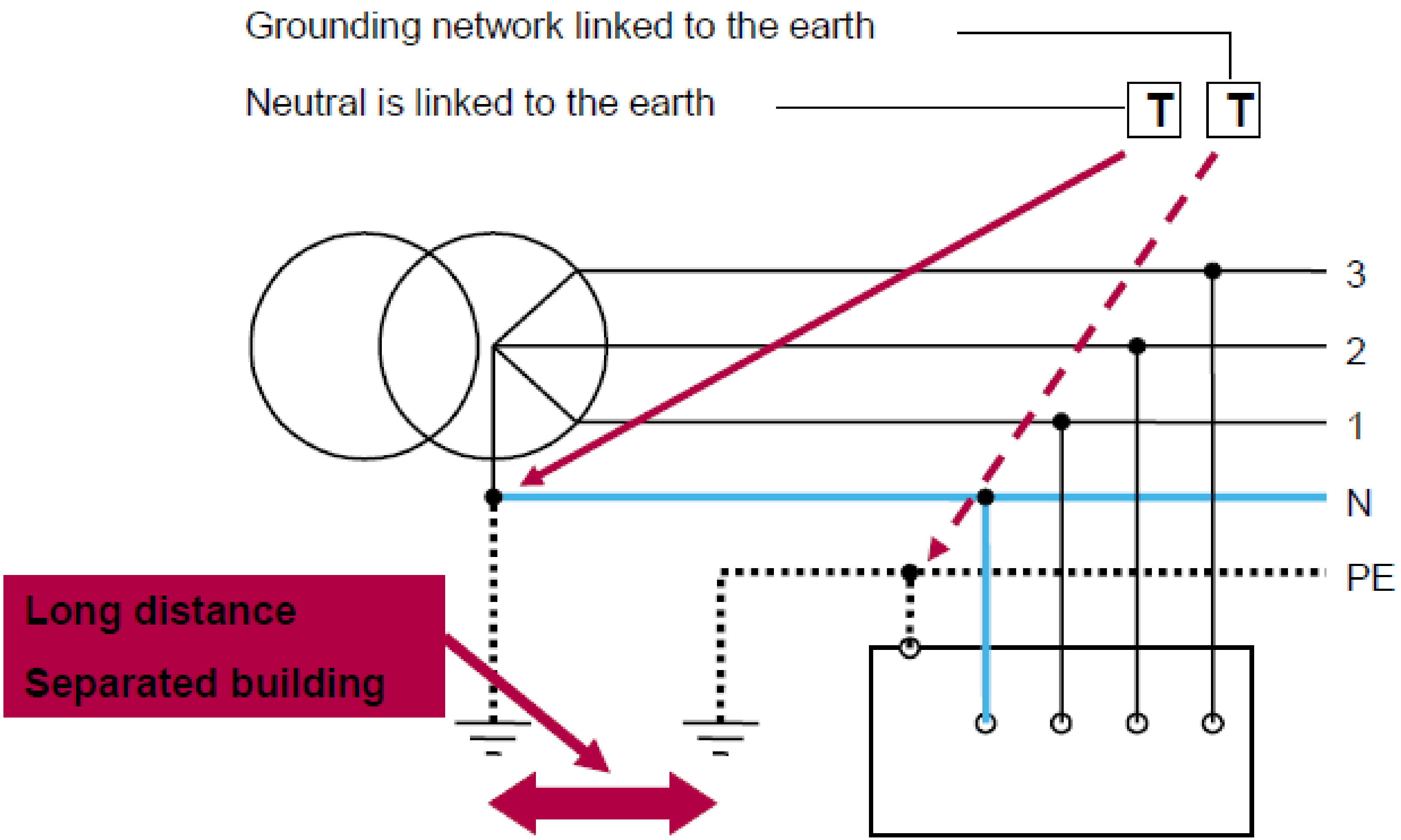
T = Earth (from the French word Terre)

N = Neutral

S = Neutral and Ground are **S**eparated

C = Neutral and Ground are **C**ommon

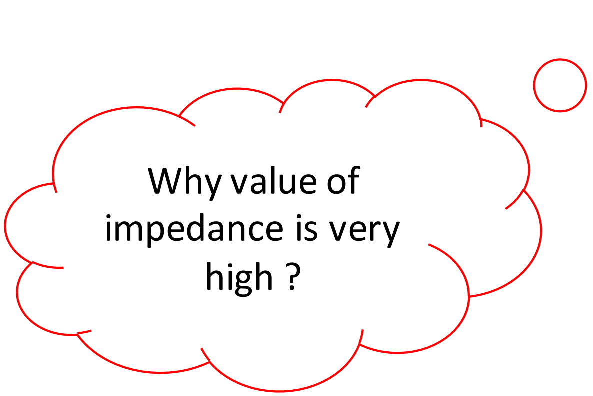
I = Neutral is **I**solated

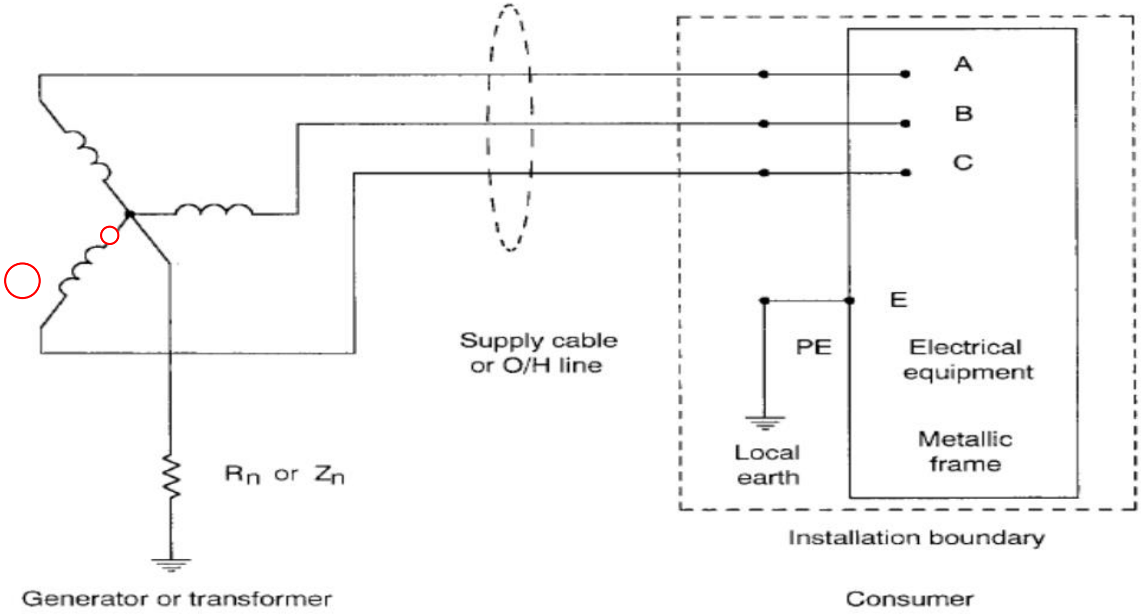


Grounding network linked to the earth
Neutral is linked to the earth
T
T
3
2
1
N
PE
Long distance
Separated building

1- IT isolated Earthing/ Grounding or (Unearthed) or (High impedance earthed neutral)

In an IT **earthing arrangement**, there is either no **earthing** at the supply, or it is done via a high impedance connection. This type of **earthing** is not used for distribution networks but is frequently used in substations and for independent generator-supplied systems





The exposed conductive parts of **loads** are interconnected, either altogether, or in groups.

Each interconnected group is connected to an earth electrode.

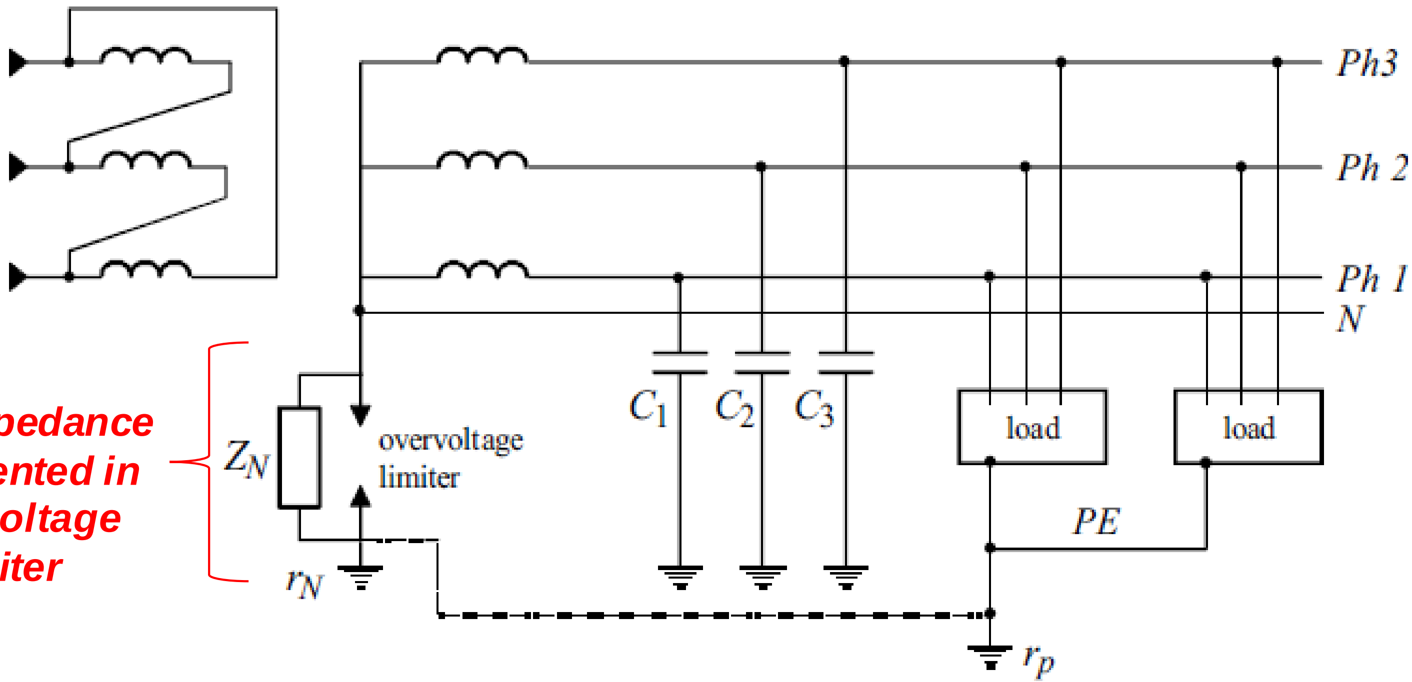
It is possible for one or several exposed conductive parts to be separately earthed.

WHY IT ?

Installing an **overvoltage limiter between the neutral point of the MV/LV transformer and earth is compulsory**.

If the neutral is not accessible, the overvoltage limiter is installed between one phase and earth. It protects the low voltage network against rises in voltage due to flashover between the transformer medium voltage and low voltage windings.

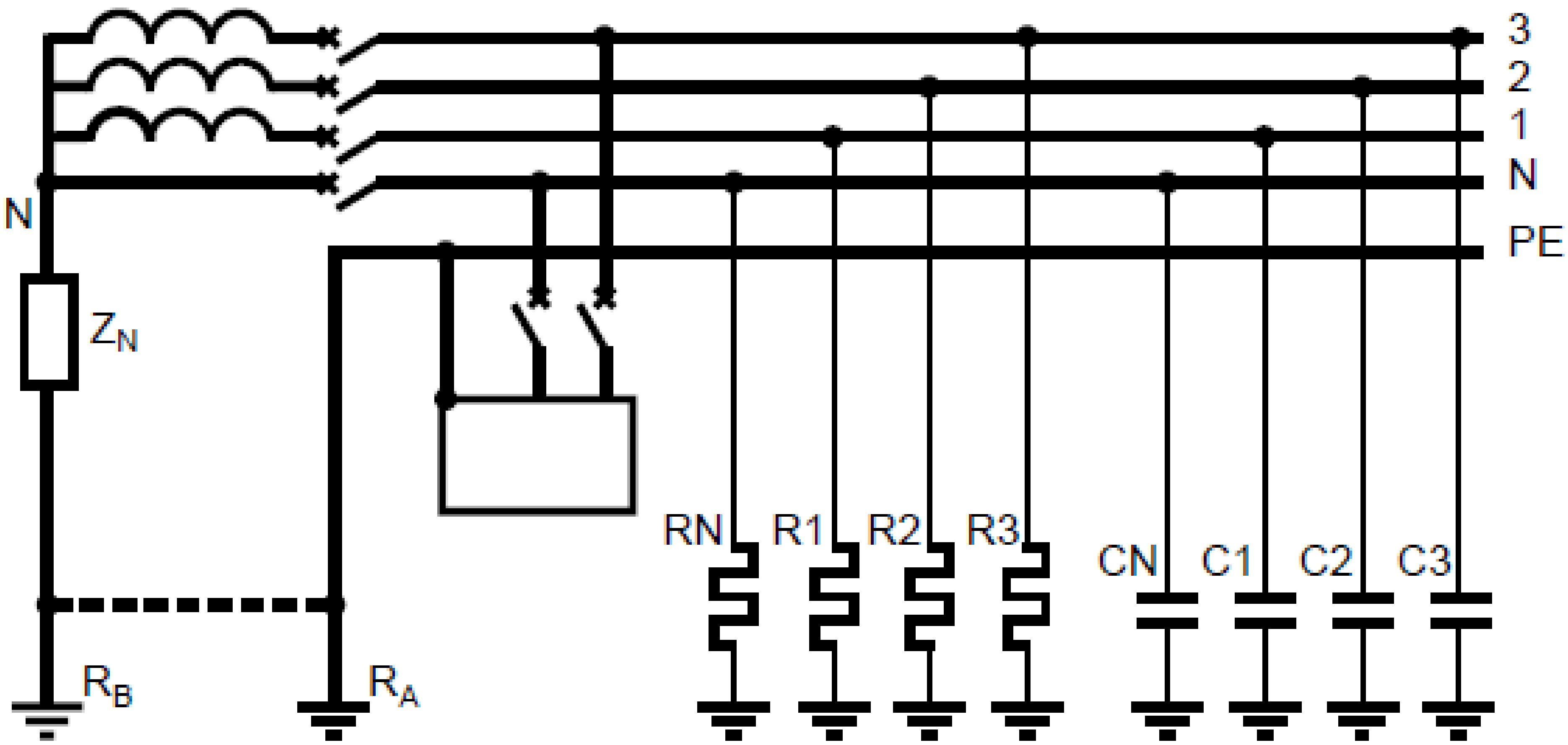
IT Application Power transformer



high impedance represented in High voltage limiter

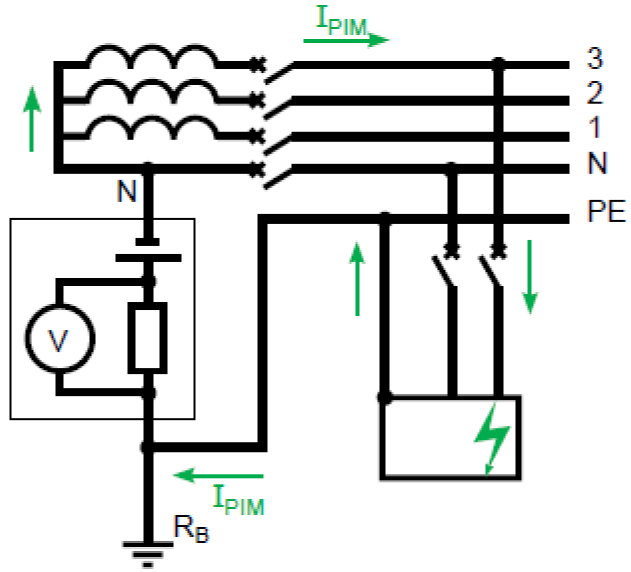
unearthed or high impedance earthed neutral (IT earthing system) in low voltage

Equivalent system for a network with unearthed or impedance-earthed neutral



Permanent insulation monitors, history and principles

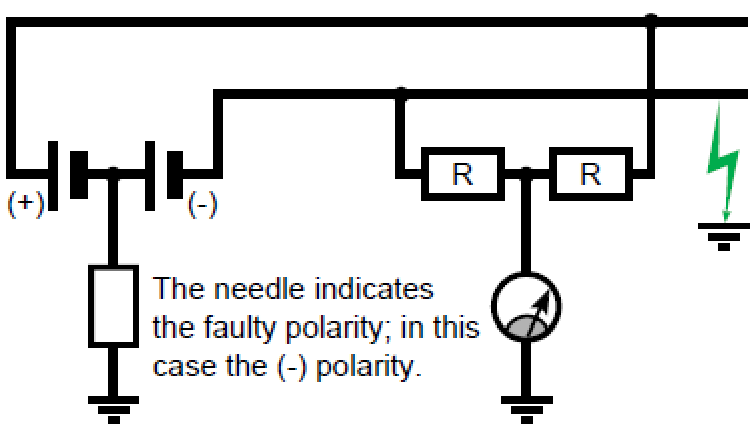
For AC network



For a DC network

(supplied by batteries or by DC generator).

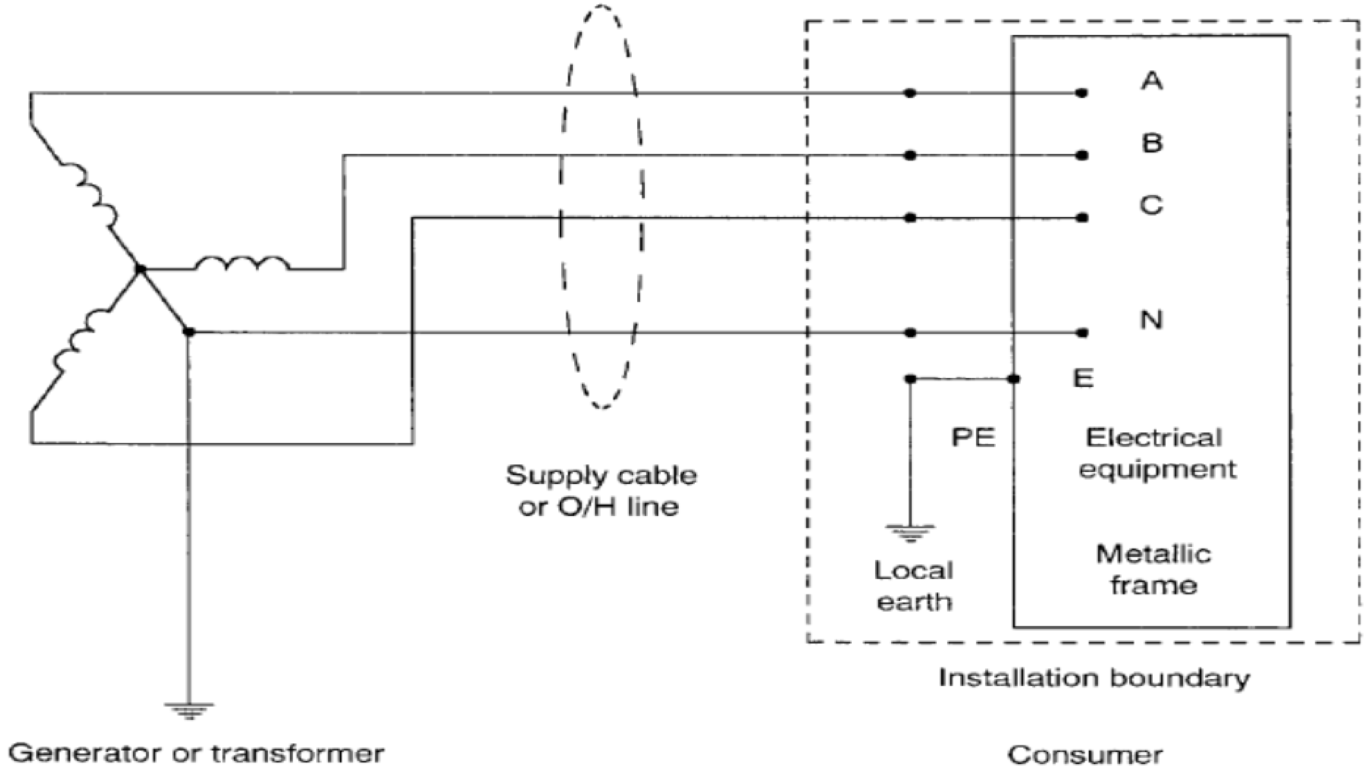
The technique of the voltmeter balance was the first to be used, and indeed is still used today.



2- Grounding / Earthing neutral (TT Grounding / Earthing system)

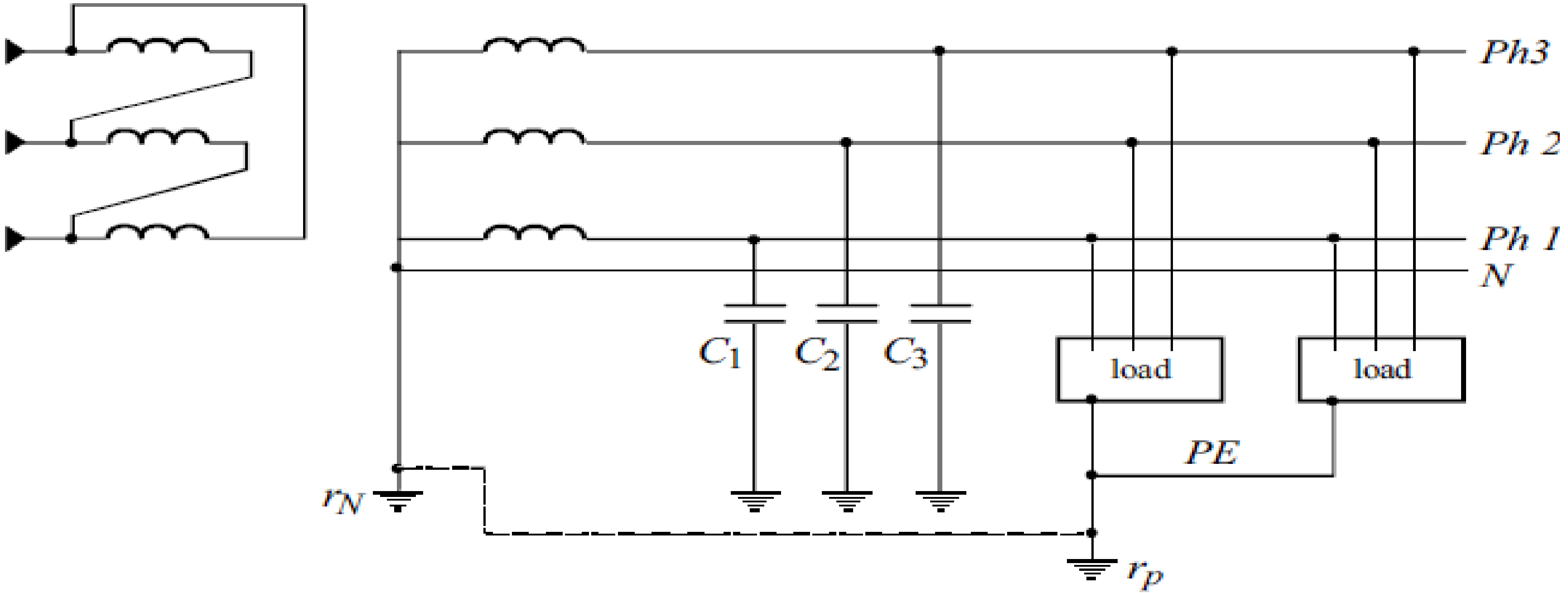
The **Source** neutral point is directly earthed (first letter *T*).

The exposed conductive parts of the **loads** are interconnected, either altogether, or in groups, or individually, and are earthed (second letter *T*).



WHY TT?

If Protection system is ensured by **residual current devices**. All the exposed conductive parts protected by the same protective device must be connected to the same earth electrode.



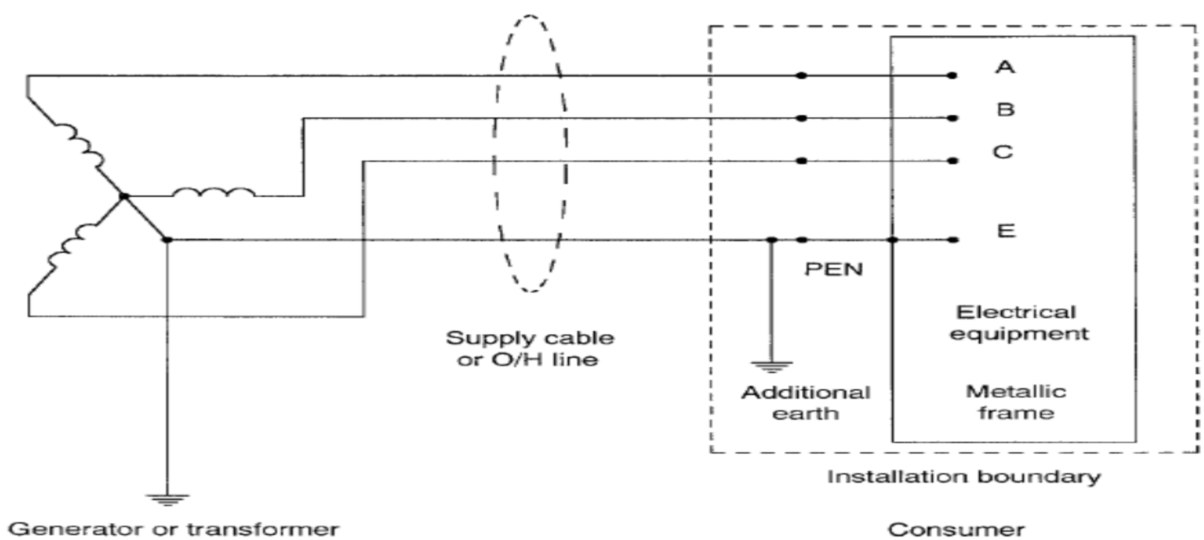
solidly earthed neutral (TT earthing system) in low voltage

3- Combined Neutral Grounding / Earthing (TNC Grounding / Earthing system)

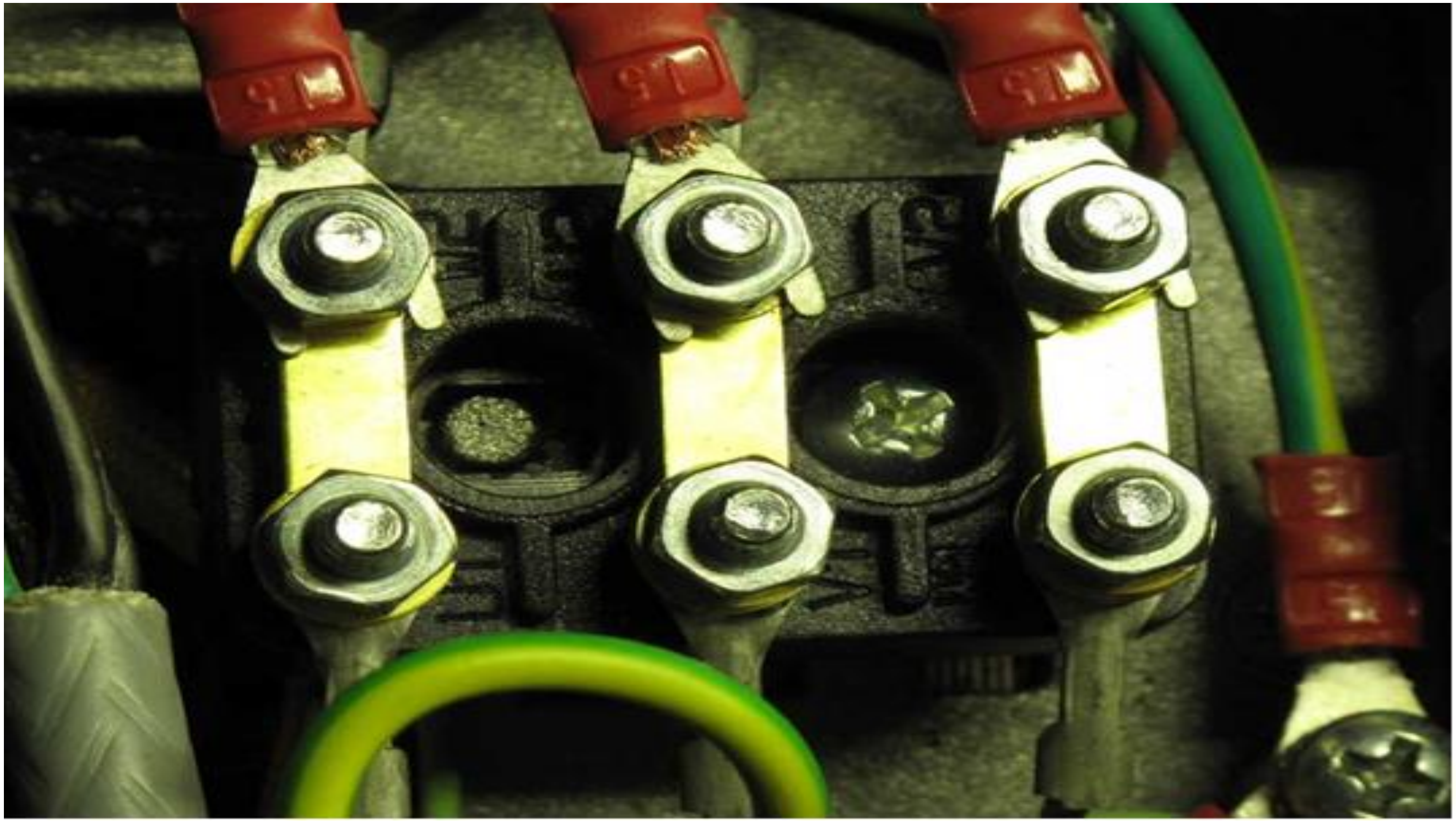
The **Source** neutral point is directly earthed (first letter *T*).

The exposed conductive parts of the **loads** are connected to the neutral conductor (second letter N).

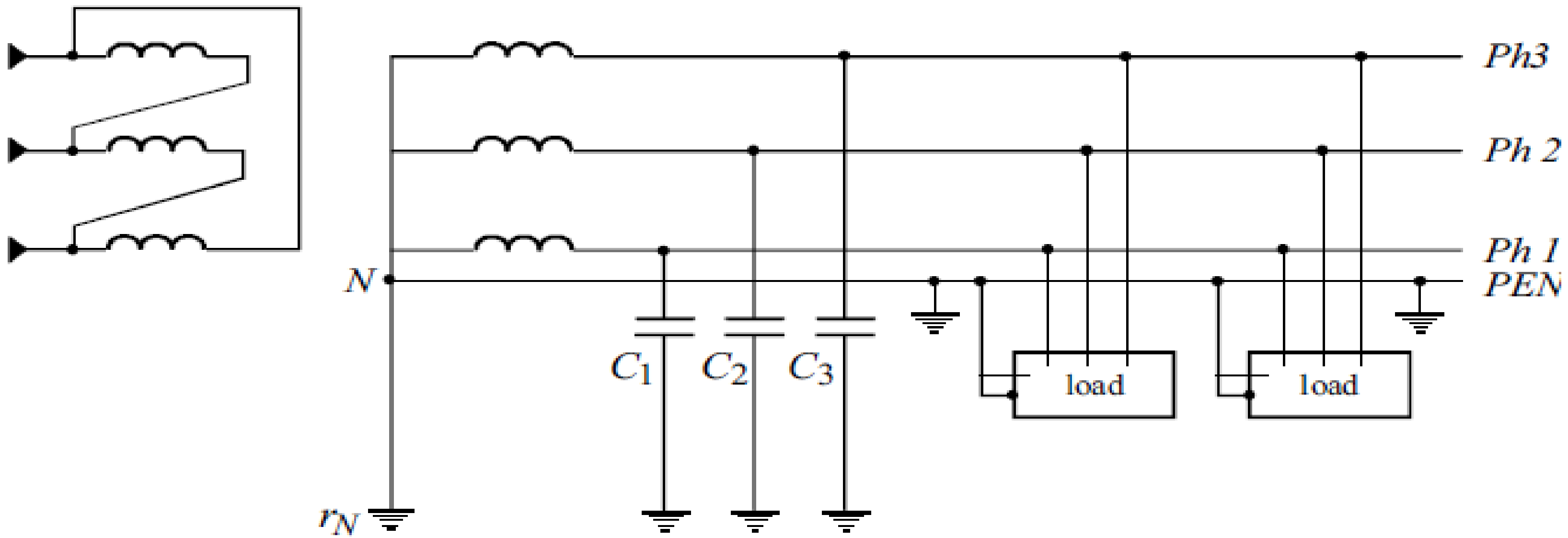
The **neutral** and **protective conductors** form a single conductor called the ***PEN*** . This system is identified by a (third letter C)and is called the ***TNC*** system



Motor junction box connected Combined Neutral earthing (TNC Grounding/ earthing system) Motor Delta Connection

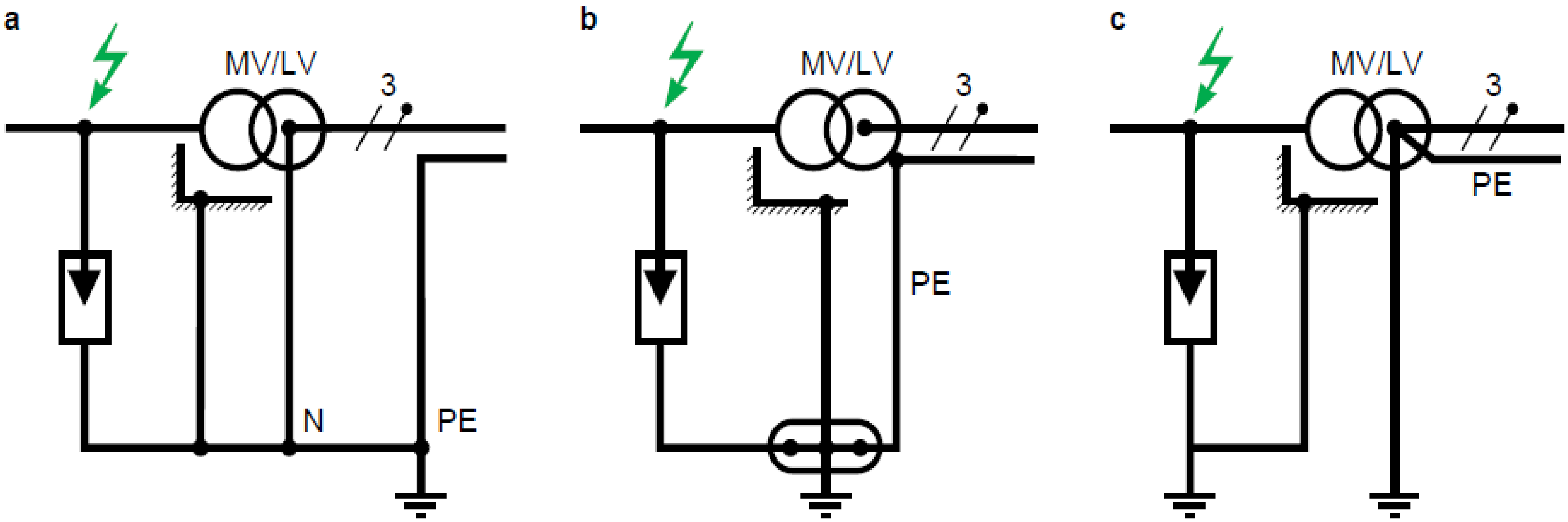


- It is advisable to regularly connect the ***Protective earthing conductor Netural PEN*** to earth
- This system must not to be used for cross-sectional areas below **10 mm² for copper or 16 mm² for aluminium**, as well as for mobile wiring systems.



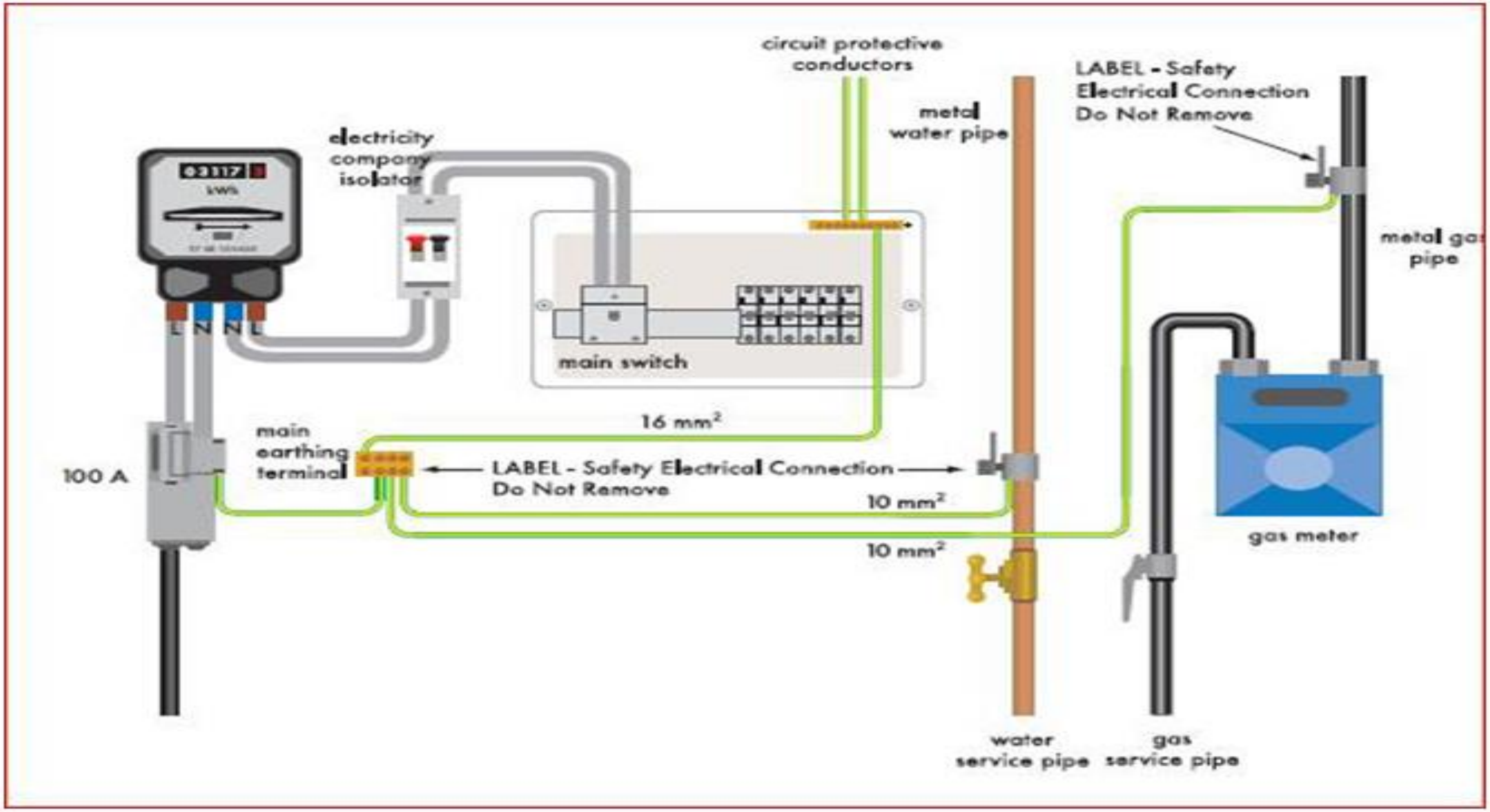
TNC earthing system

avoid common-impedance coupling when dealing with disturbance of MV origin.



The best way of creating two earth connections (**see c**). More usually an electrical conductor across which an abnormal (fault) current flows generates a potential difference between its ends which may cause disturbance, and this is common-impedance coupling.

TNC Application



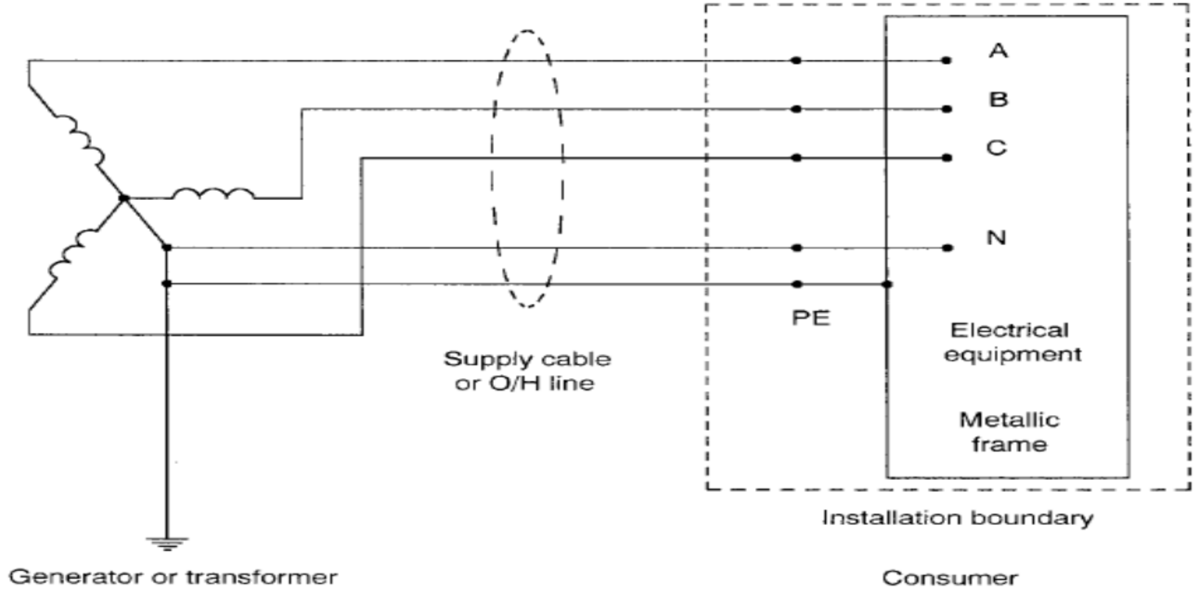

Neutral inductor

4- Separate Neutral Grounding/ Earthing (TNS Grounding / earthing system)

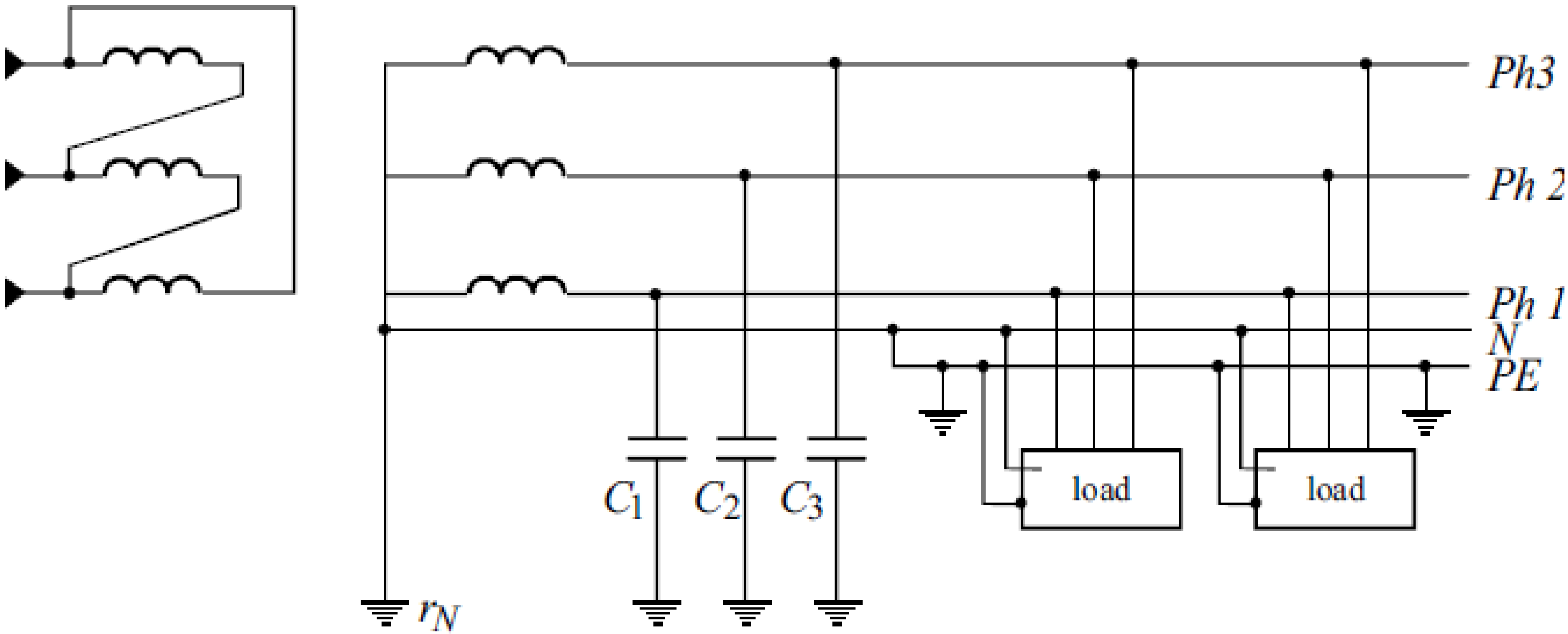
The **Source** neutral point is directly earthed (first letter *T*).

The exposed conductive parts of the **loads** are connected to the neutral conductor (second letter N).

The **neutral** conductor and **protective conductor** are separate. The system is then identified by a the (third letter S) and is referred to as the *TNS* system

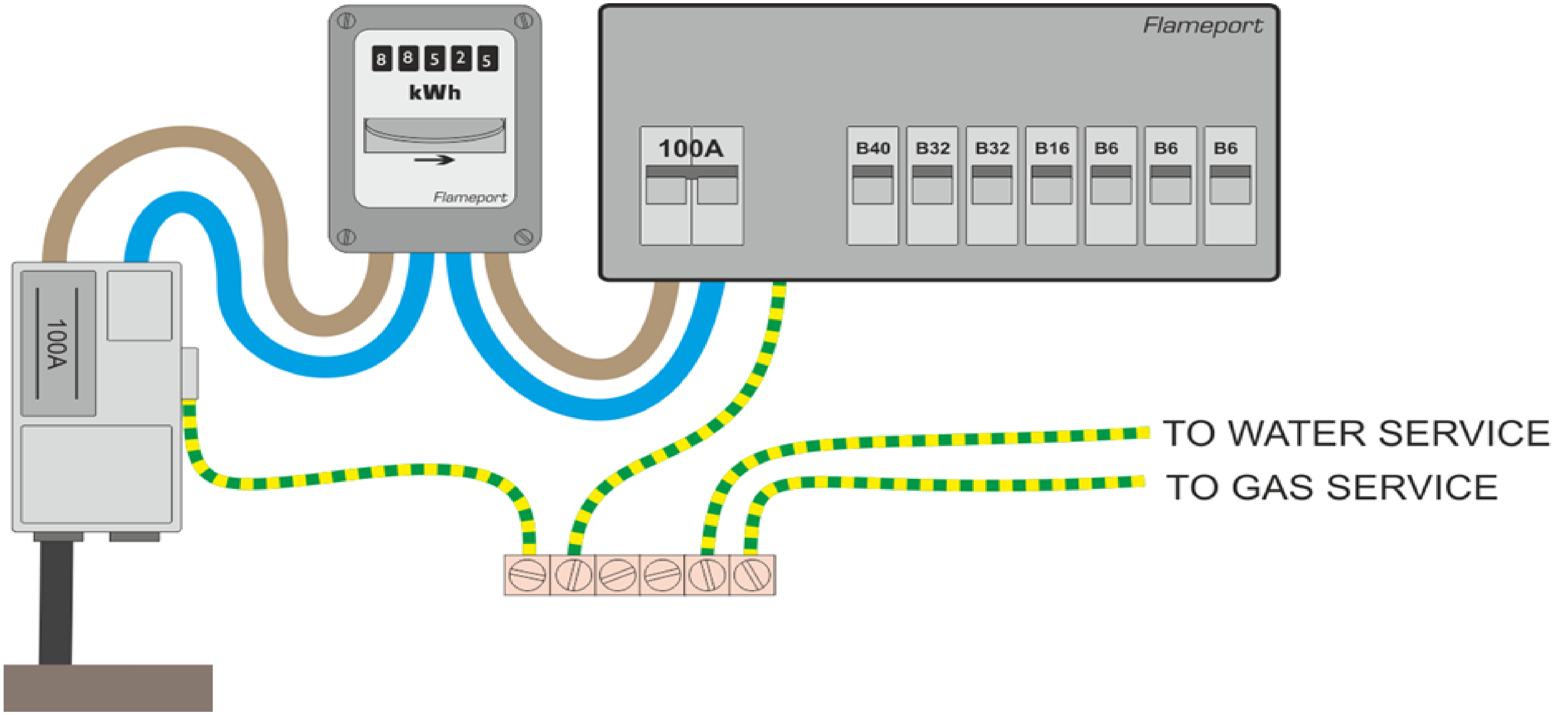


This Grounding / earthing system is for cross-sectional areas below **10 mm² for copper10 mm2 or 16 mm² for aluminium**, as well as for mobile wiring systems .



TNS earthing system

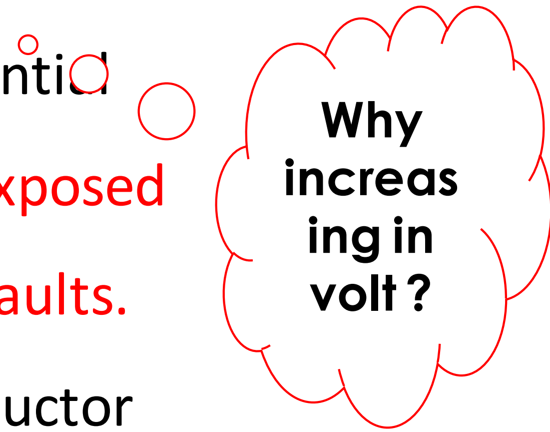
TNS Application

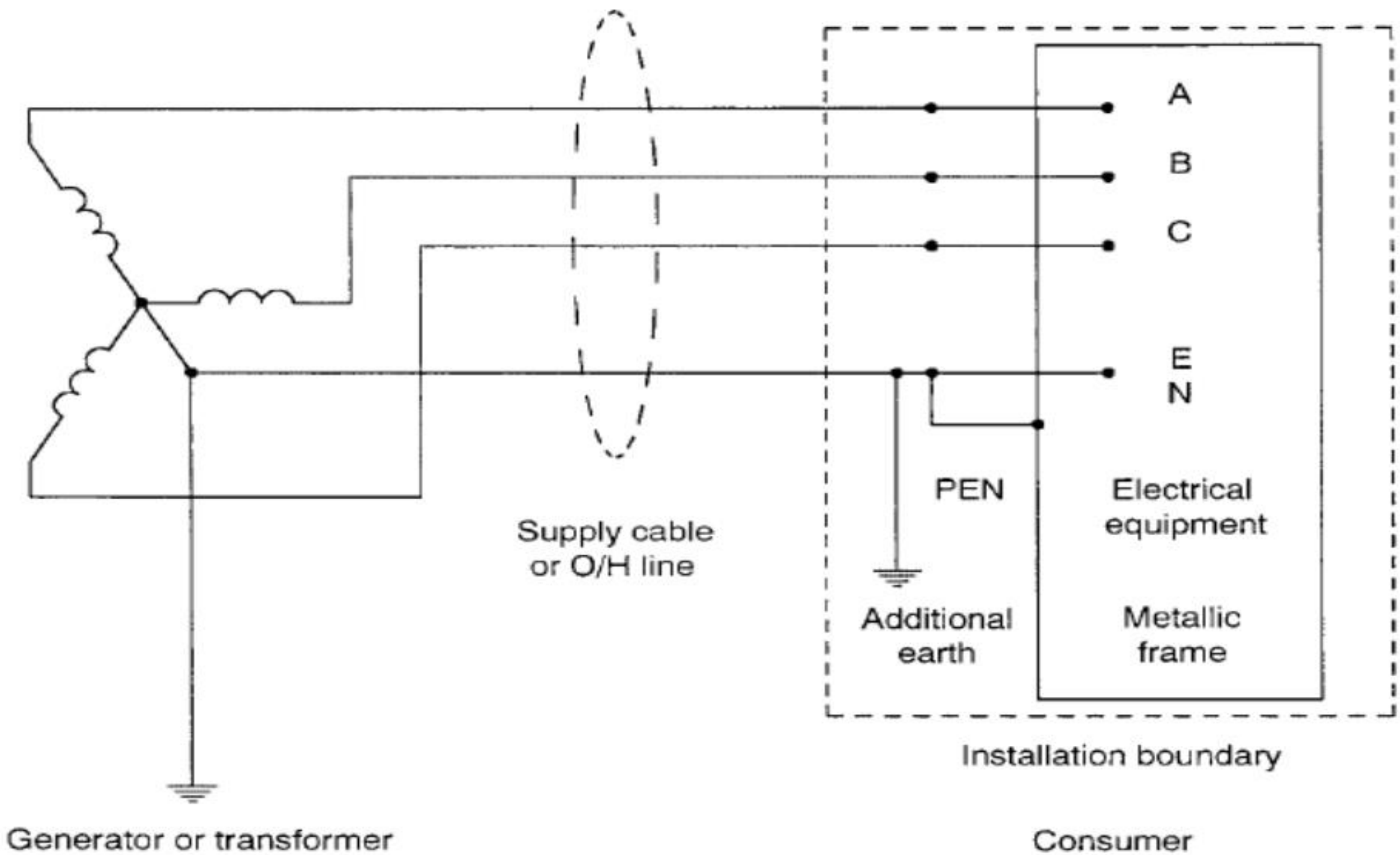


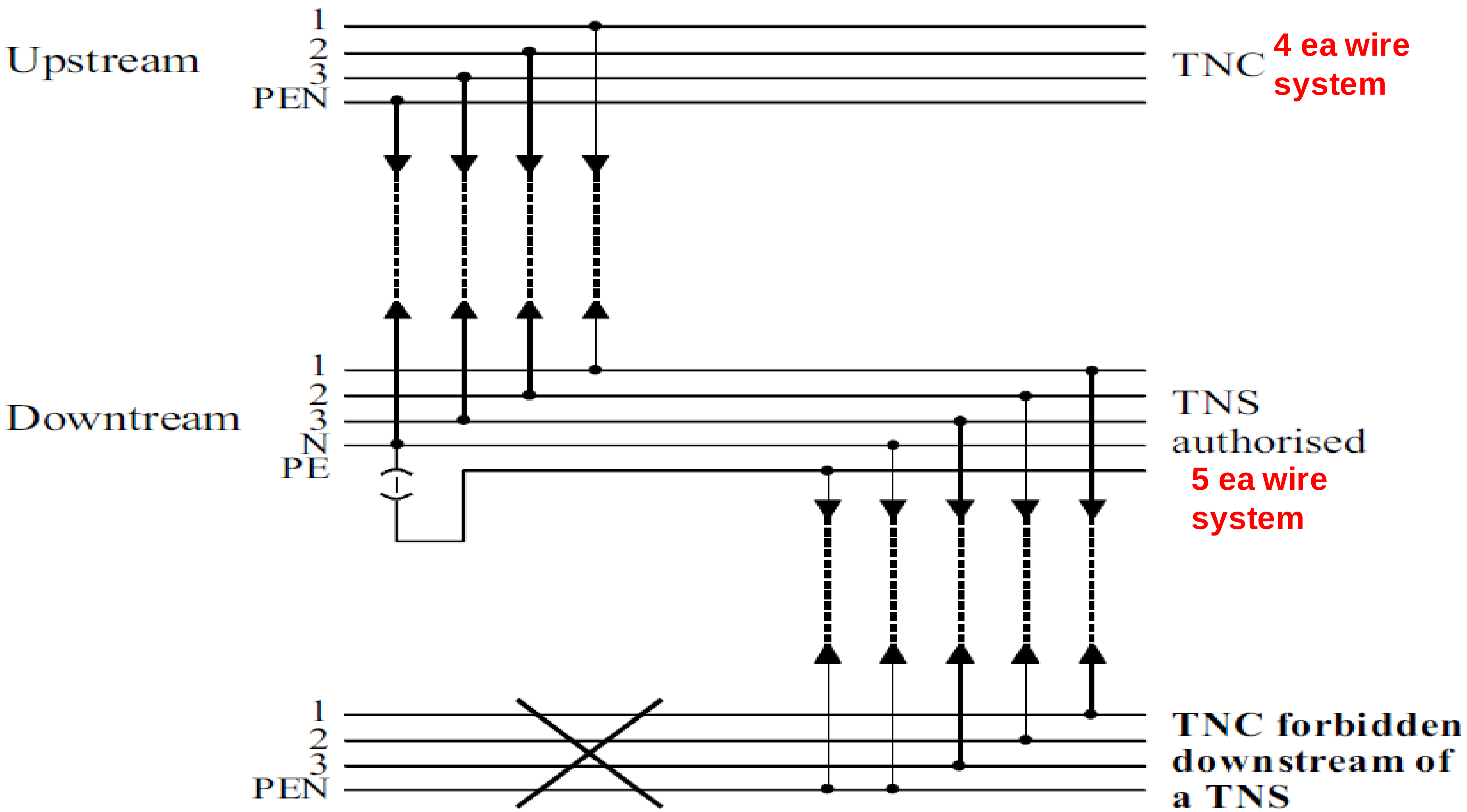
5- Separate & combined Neutral Earthing (TNC S Grounding Earthing system)

both TNC and TNS earthing systems can be used in the same installation. We then refer to a TN - C - S earthing system. But the TNC earthing system (4 wires) must never be downstream of the TNS earthing system (5 wires) .

Neutral earthing requires the creation of an equipotential bonding system to avoid the rise in potential of the exposed and up normal conductive parts during phase-earth faults. It is consequently necessary to connect the *PEN* conductor to numerous earth electrodes spread out over the installation.




A
B
C
E
N
PEN
Electrical equipment
Supply cable or O/H line
Additional earth
Metallic frame
Installation boundary
Generator or transformer
Consumer



combination of TNC and TNS earthing systems

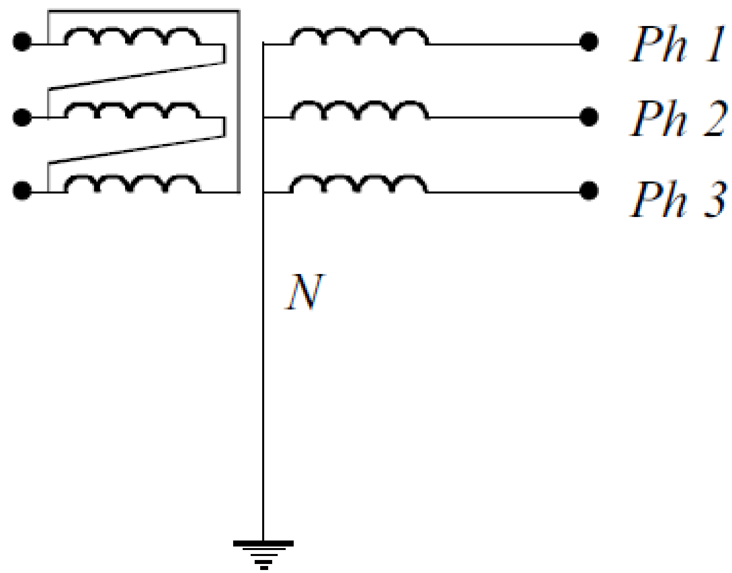
Types of Grounding/ Earthing Systems According to Type of Connection

There are different types of neutral point connection to earth are We can make a distinction between:

1. The solidly (or directly) grounding / earthing neutral
2. The unearthed neutral, or high impedance-earthed neutral
3. Resistance grounding / earthing
4. Reactance grounding / earthing

1- Solidly grounding / earthed neutral

An electrical connection is intentionally made between the neutral point and earth. **The single-phase earth fault current** in a solidly earthed system may exceed the three phase fault current. Th magnitude of the current depends on th fault location and the fault resistance.

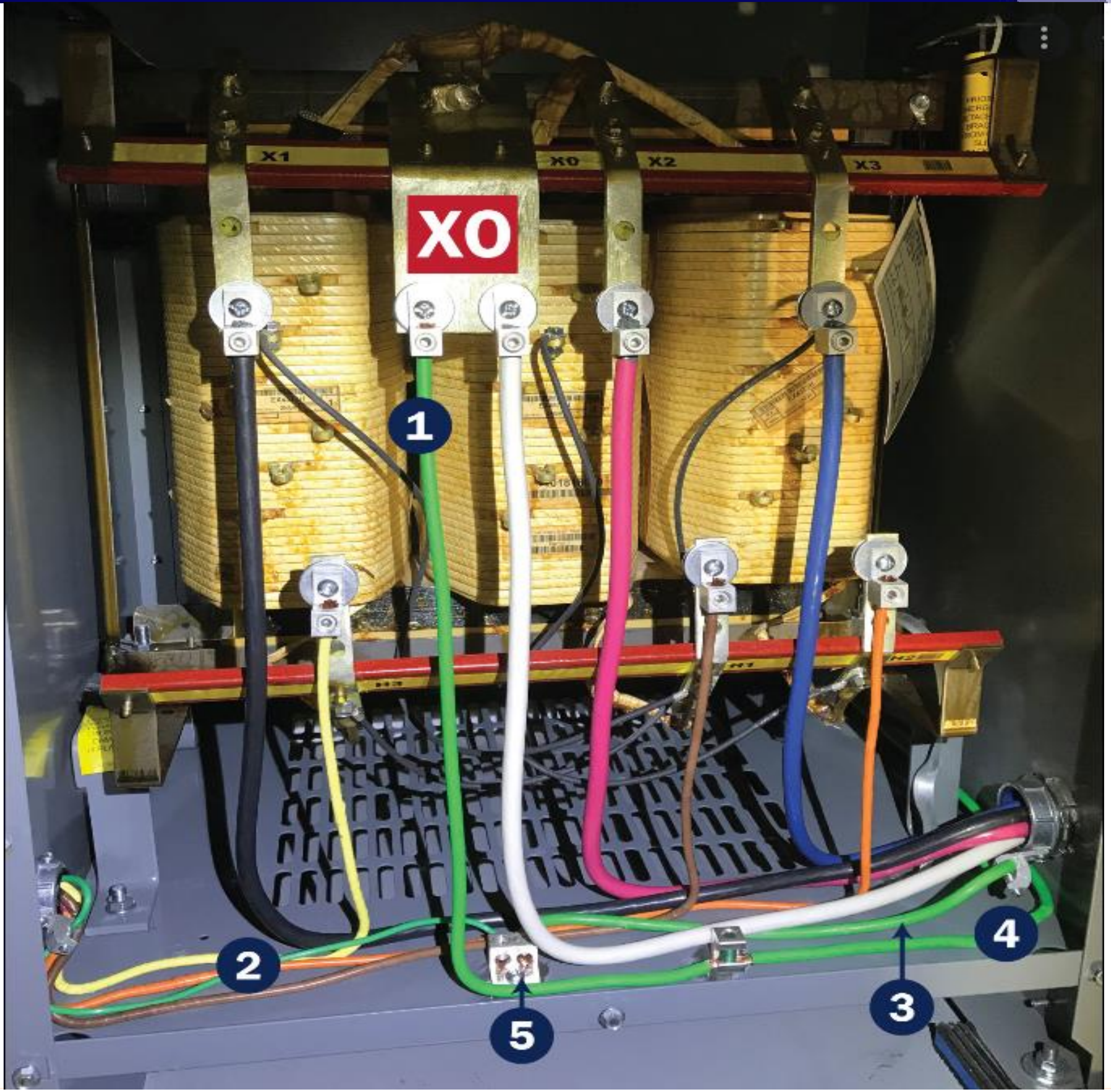


The main advantage of solidly earthed systems is low over voltages, which makes the earthing design common at high voltage levels (HV).

Solidly grounding/ earthed neutral Application

Neutral Solidly Earthed

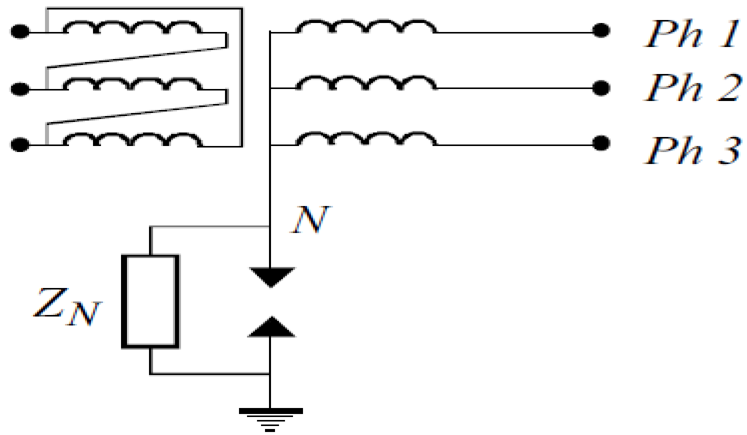

WARNING



X1
X0
X2
X3
XO
1
2
3
4
5

2- Unearthed neutral or (high impedance-grounding / earthed neutral) or (Isolated neutral systems)

There is no electrical connection between the neutral point and earth, **except for measuring and protective devices.**



High impedance earthing

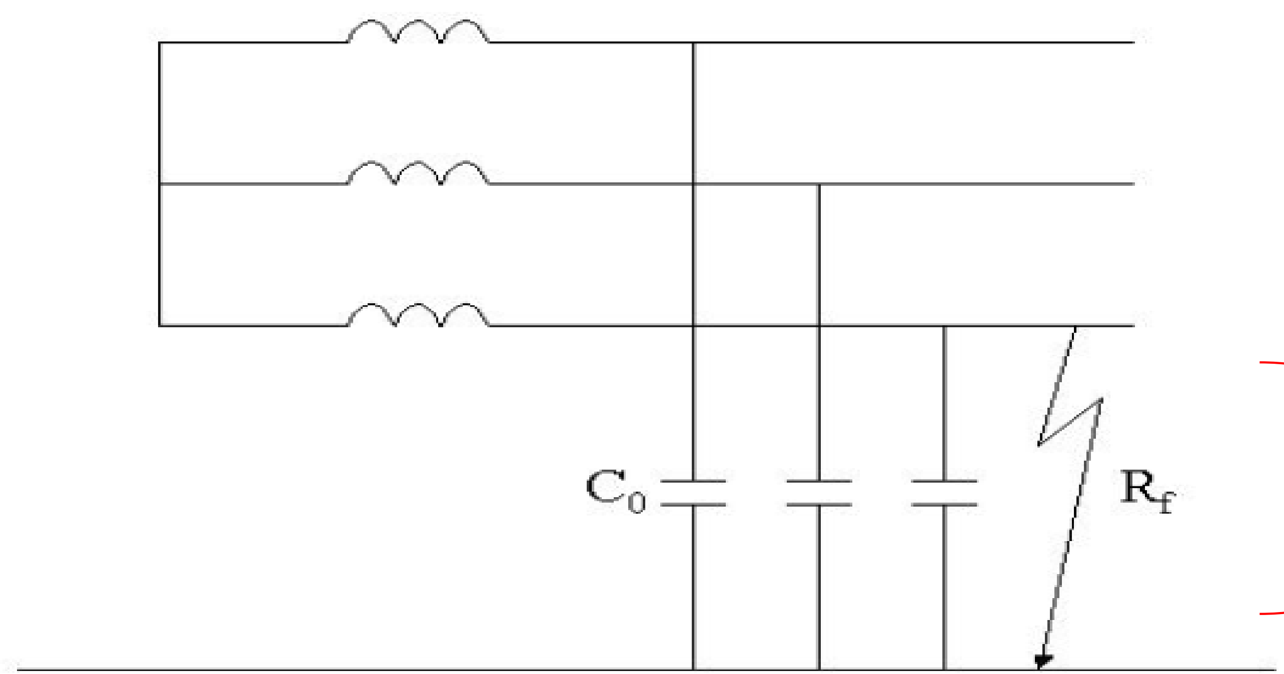
A high impedance is inserted between the neutral point and earth.

such as surge arresters or voltage transformers.

In a power system there are however always capacitive connections between the phases and earth.

The strength of the capacitive connection depends on **type** and **length of the power system circuit**.

When an earth fault occurs in the system, the capacitance to earth of the faulty phase is bypassed.



This faulty phase as if short between phase and ground and by passe other phases

Earth fault in a network with an unearthed neutral

High impedance grounding / earthing neutral Application

high impedance
earthed

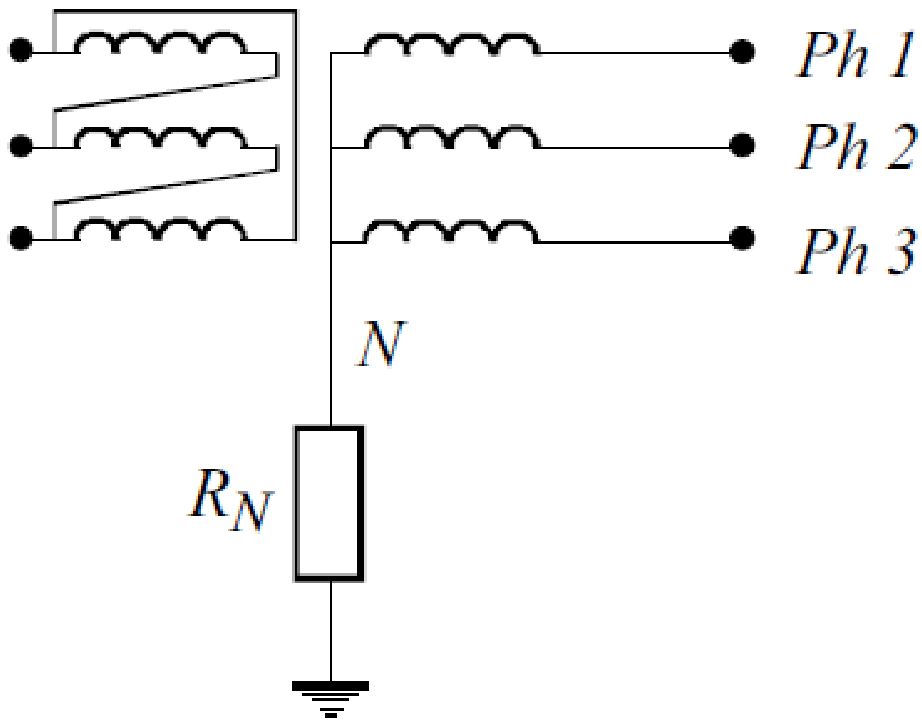
high impedance
earthed


SG13
E T
SUPERGRID T3
EARTHING
TRANSFORMER
high impedance
earthed

3- Resistance Grounding/ Earthing

A resistor is inserted between the neutral point and earth

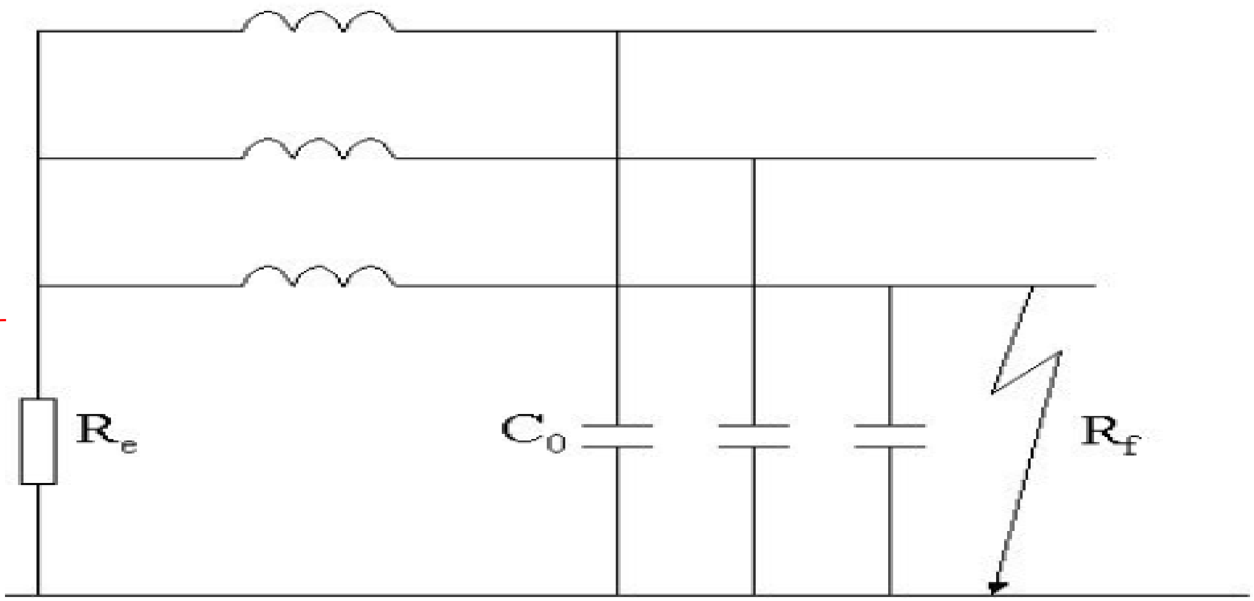
To improve the earth fault detection in a power system a resistance can be connected between a transformer neutral point and the station earthing system.



The purpose of the neutral point resistor is to **increase the resistive part of the earth fault current and hence improve the earth fault detection.**

The following figure shows an earth fault in a system with a resistance earthed neutral.

Protection devices detected active power connect in natural



Earth fault in a network with a resistance earthed neutral

Resistance grounding / earthing Application

Always this resistance of heat dissipation resistance type and can sense value of heat by using :

- Thermocouples
- RTD

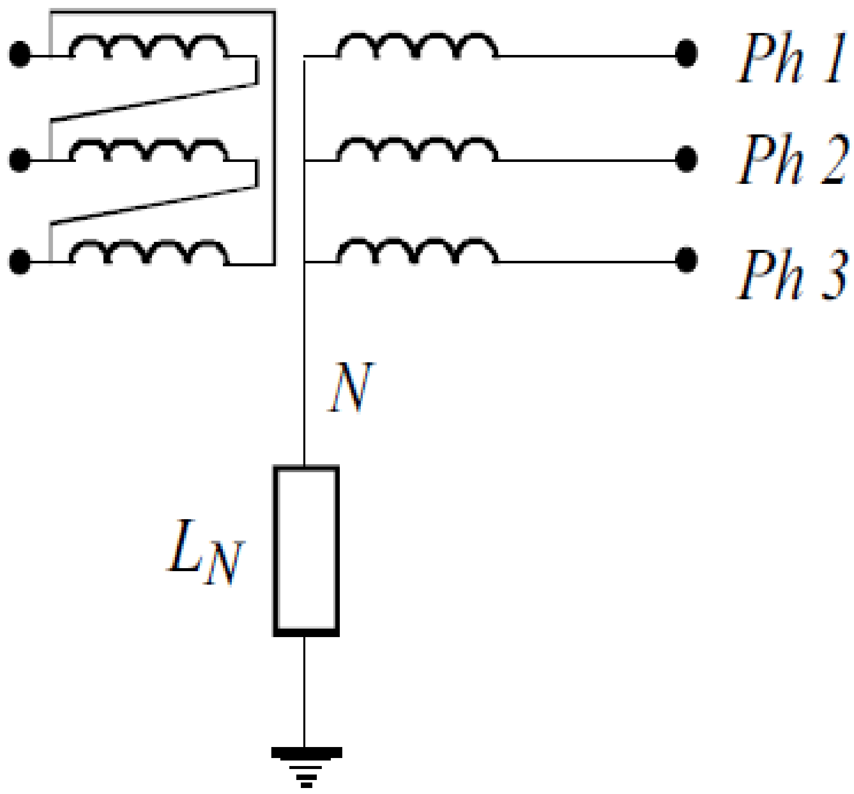
Connected with power system

Connected with electrode

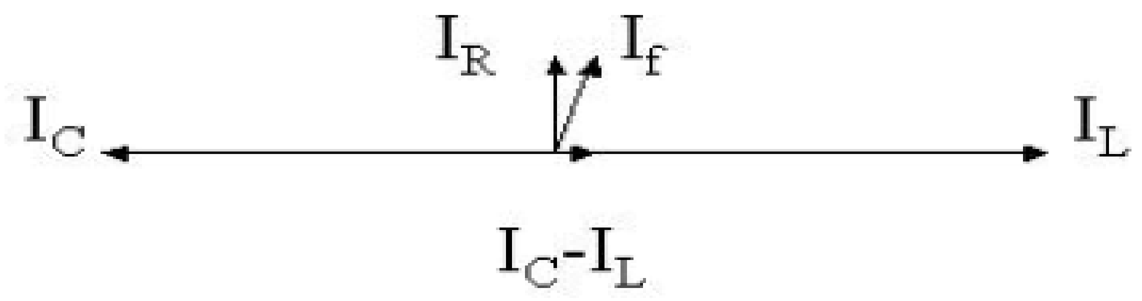
4- Reactance grounding / earthing

A reactor is inserted between the neutral point and earth.

To limit the reactive part of the earth fault current in a power system a neutral point reactor can be connected between the transformer (or any another power source) neutral and the station earthing system.

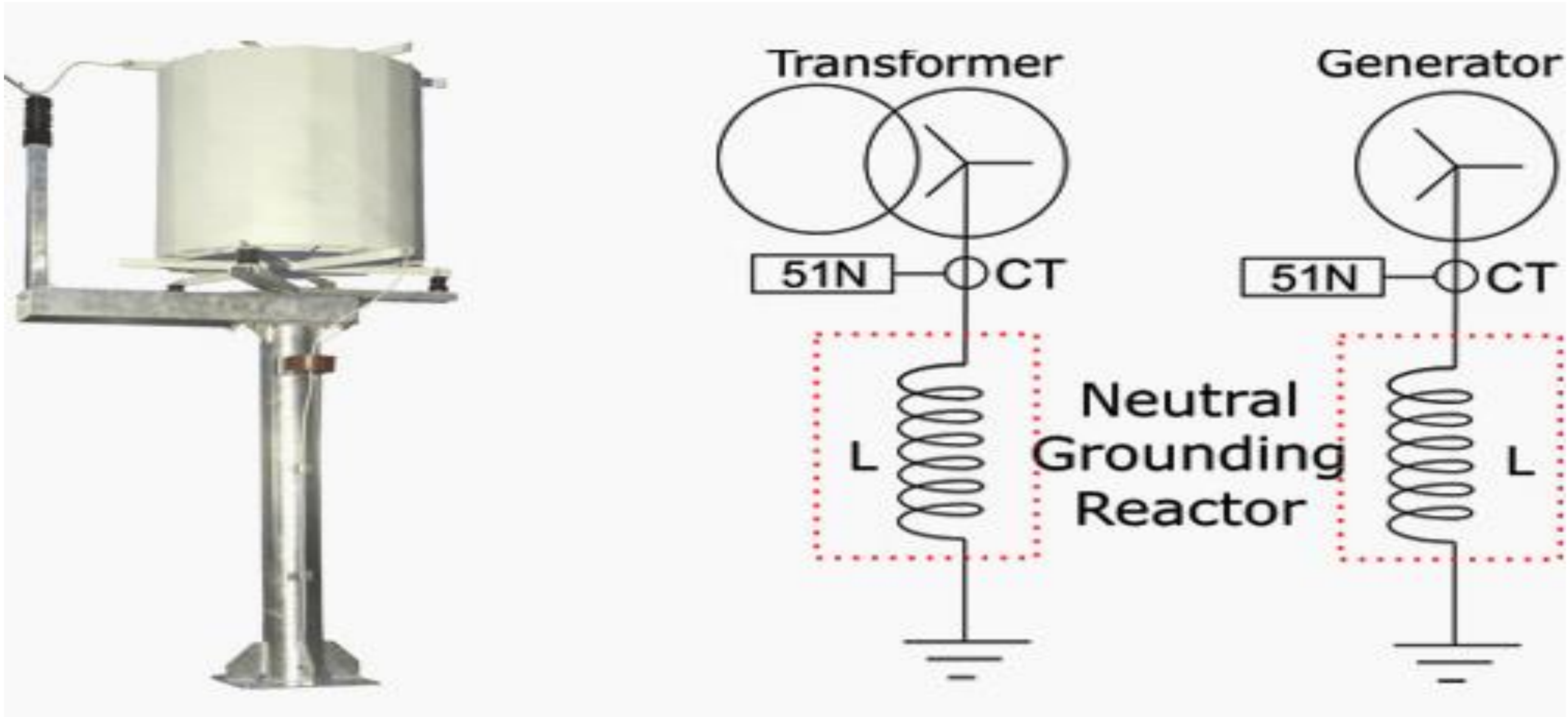


The system is hardly ever exactly tuned, i.e. the reactive current does not exactly equal the **capacitive earth fault current** of the system. A system in which the inductive current is slightly larger than the capacitive earth fault current is over compensated. A system in which the induced earth fault current is slightly smaller than the capacitive earth fault current is under compensated.



the earth fault current phasors of a slightly over compensated system.

Reactance grounding / earthing Application


Transformer
Generator
51N
CT
51N
CT
L
Neutral
Grounding
Reactor
L


GES

	Methods of System Grounding			
Characteristics	**Ungrounded**	**Solid Ground**	**Low Resistance Ground**	**High Resistances Ground**
Susceptible to Transient over voltages	WORST	GOOD	GOOD	BEST
Under fault conditions (line-to-ground) increase of voltage stress	POOR	BEST	GOOD	POOR
Arc Fault Damage	WORST	POOR	GOOD	BEST
Reliability	WORST	GOOD	BETTER	BEST
Economics' (Maintenance costs)	WORST	POOR	POOR	BEST
Plant continues to operates under single line-to-ground fault	FAIR	POOR	POOR	BEST
Ease of locating ground faults (time)	WORST	GOOD	BETTER	BEST
System coordination	NOT POSSIBLE	GOOD	BETTER	BEST
Upgrade of ground system	WORST	GOOD	BETTER	BEST
Reduction in number of faults	WORST	BETTER	GOOD	BEST
Potential flashover to ground	POOR	WORST	GOOD	BEST

Grounding / Earthing Systems Component & Accessories

Earthing / Grounding Systems Component

Earthing system in an installation is normally comprised of these components:

- **Earth wells and accessories**
- **Earthing grid conductors (Grounding conductor / Bonding conductor)**
- **Marshaling earth buses (earthing distribution buses)**
- **Earthing wires and cables.**

1. Earth (grounding) wells and accessories

Earth /Ground wells for an specific building are **actually** the location, where the **pure zero potential** is provided and **practically** act as drain pits for any rush current which accidentally appears in the earthing system grid in the event of an earth fault.

Earth / Ground Well Components

- Earth /Ground rod
- Earth /Ground Electrode Conductor
- Earth /Ground clamp
- Earth /Ground rod coupling
- Earth /Ground rod tip
- Earth /Ground rod driving head
- Carbon bedding mixed with salt
- Earth /Ground plate
- Concrete Earth /Ground pit
- Concrete slab cover

What will occur in case of touch earthing system In when Human body resistance :

- **more than grounding system**
- **Less than grounding system**

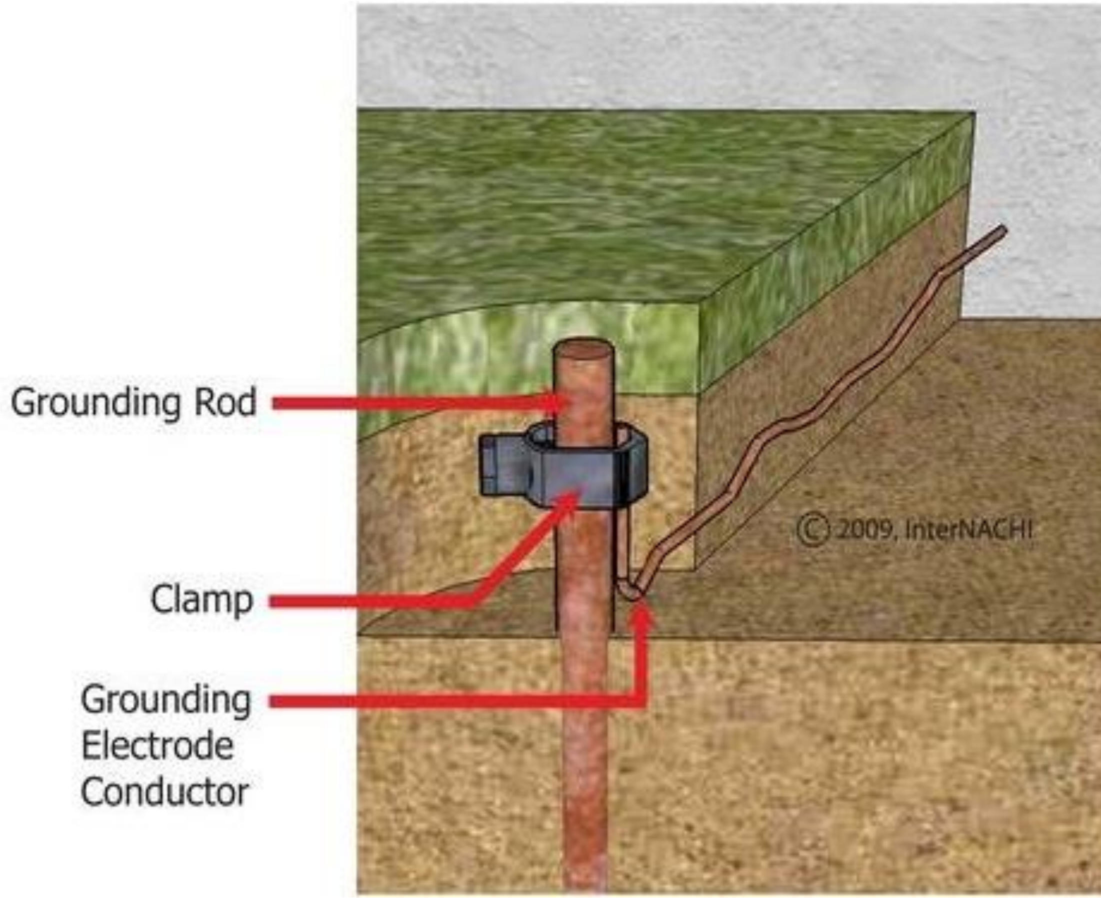
Earth /Ground rod

Earth /Ground rod is the main passe of current to ground.

In cases where two or more earth rods are to be driven, the individual rods are coupled to each other by means of "earth rod coupling".

During the driving of rod into the ground, and to protect the earth rod against impact of **hammering**, a "driving head" is screwed onto the top of the rod.

For easy and convenient driving of the earth rod into the ground an earth rod tip with sharp point is screwed to the first rod.

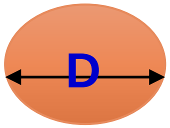


Grounding Rod
Clamp
Grounding Electrode Conductor
© 2009, InterNACHI

Earth / Ground Rod Dimensions

Depending on the **Design specification of the earthing / grounding system** and the corresponding earthing wells, various earth rods of different dimensions would be incorporated.

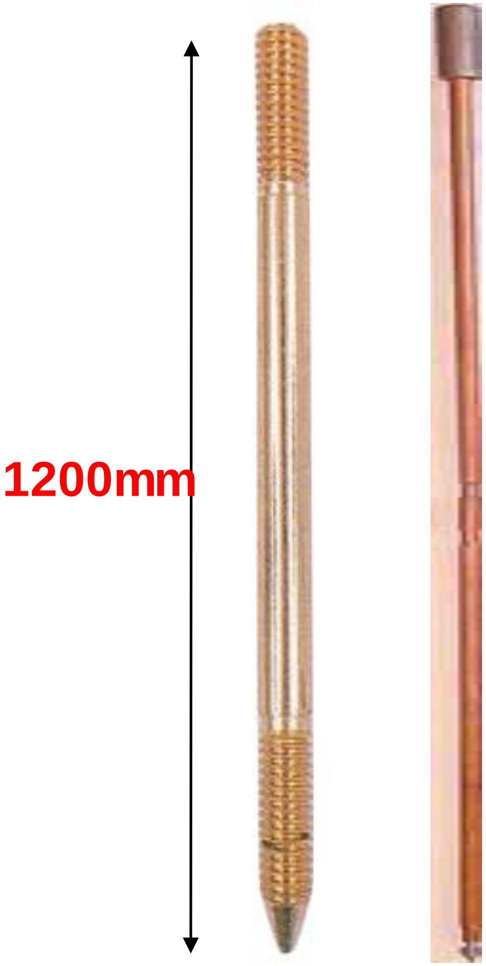
The range of **Diameter** for the earth rods vary from 13 mm to 25mm (13mm, 16mm, 20mm, 25mm)



Different **lengths** of earthing / ground rods are used in design and installation of earth wells:

The standard lengths are:

- 1200mm
- 2400 mm (2 × 1200 mm)
- 3600 mm (3 × 1200 mm)
- 4800 mm (4 × 1200 mm)



The **Coupling material** is essentially the **same as the material for the earth rod** with respect to the rigidity and the required conductivity.

Two or more earth rods are to be driven

Protect the earth rod against impact of hammering

For easy and convenient driving of the earth rod into the ground

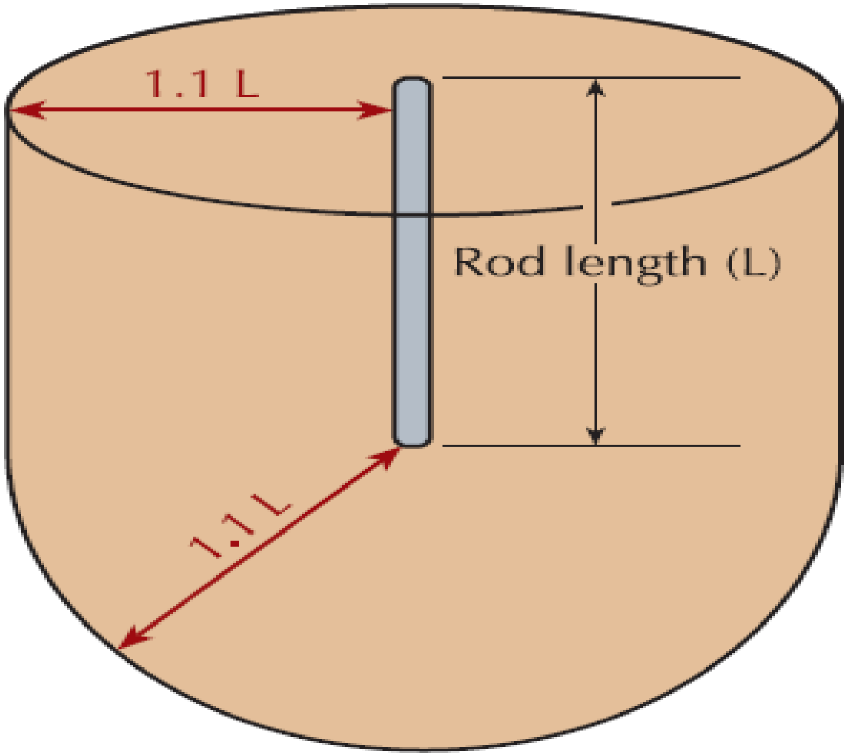
Diameter

(13mm, 16mm, 20mm, 25mm)

lengths

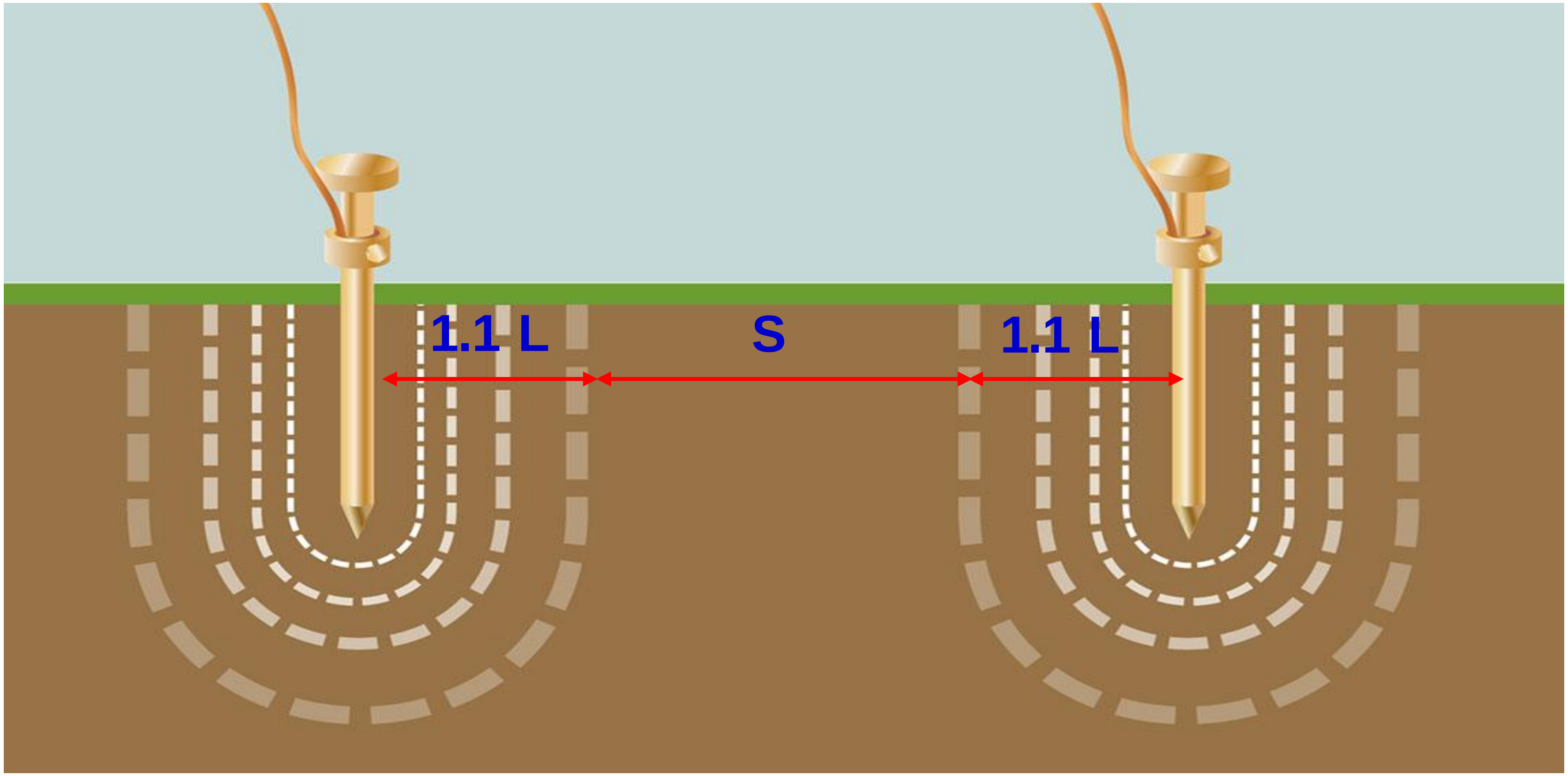
- 1200mm
- 2400 mm
- 3600 mm
- 4800 mm

Earth / Ground Rod Length Effect



The ground rod injects current into the surrounding volume of soil.

There must be proper spacing between ground electrodes and earth stakes to reduce or eliminate their spheres of influence



Earth / Ground Plate

Earthing / Grounding plates are normally used instead of **Earthing / Ground rods.** The earth plate is made of copper and shaped in the following forms:

Flat rectangular copper plate.

Perforated rectangular copper plate (a grate-like framework of copper plate) the standard dimension of the flat rectangular earth plate is normally **100 × 100 × 3** mm.

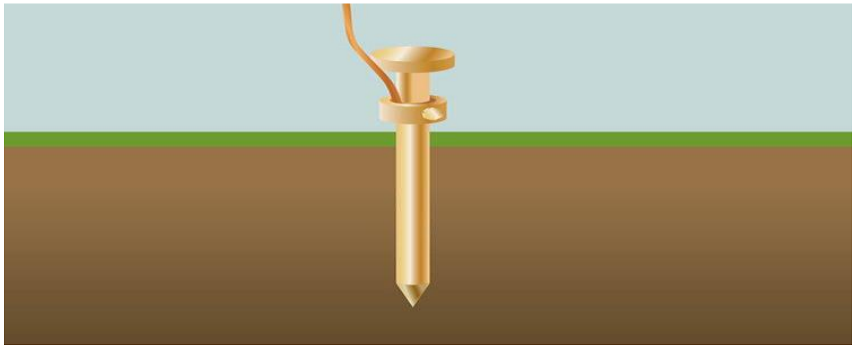
The standard cross section area for the copper rod or copper strips used in construction of the perforated rectangular earth plate is normally 75 sq-mm.

Flat rectangular copper plate

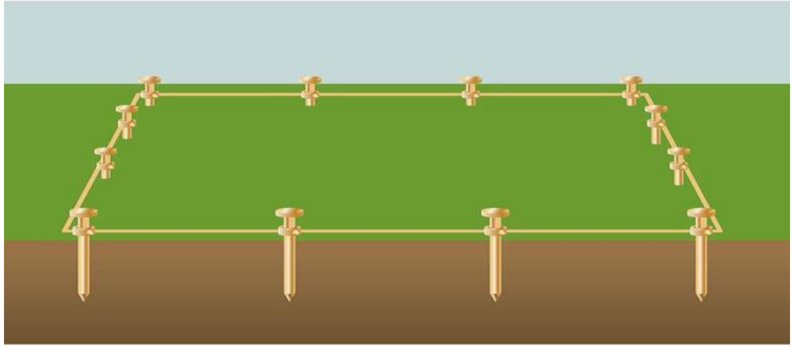
Perforated rectangular copper plate (Earth Mat)

Earth Plate

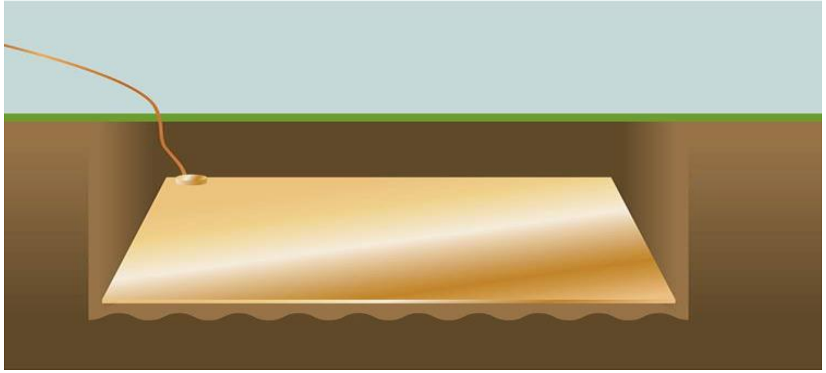
Types of Ground Systems



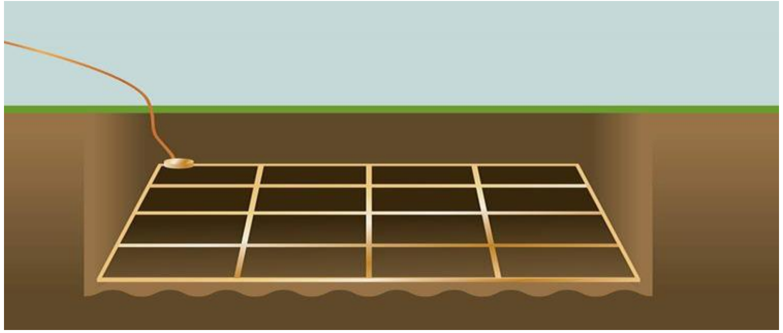
Single Ground Rod



Multiple Ground Electrodes



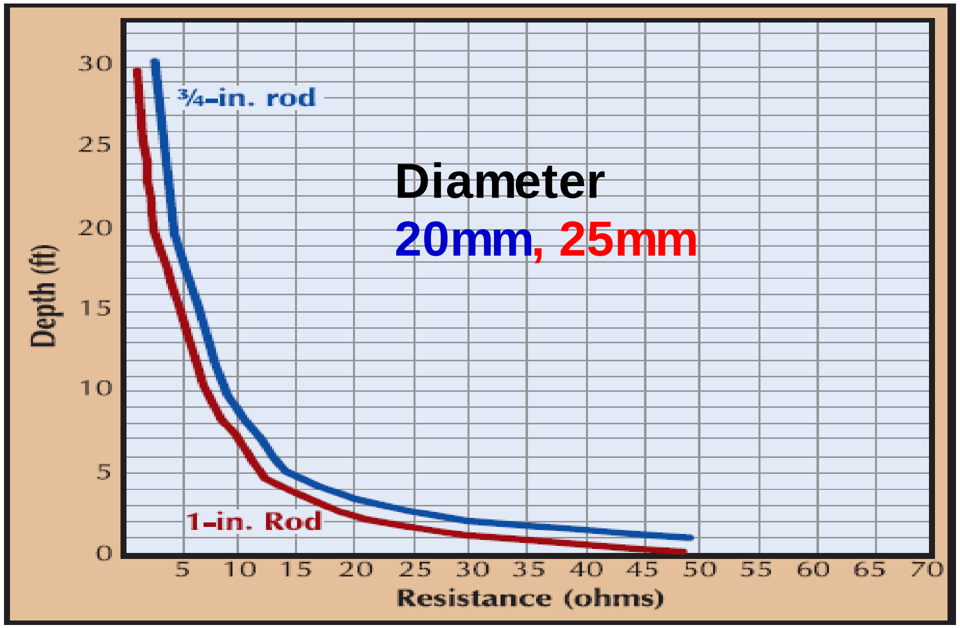
Ground Plate



Ground Mesh

Earthing / Grounding Electrode Material

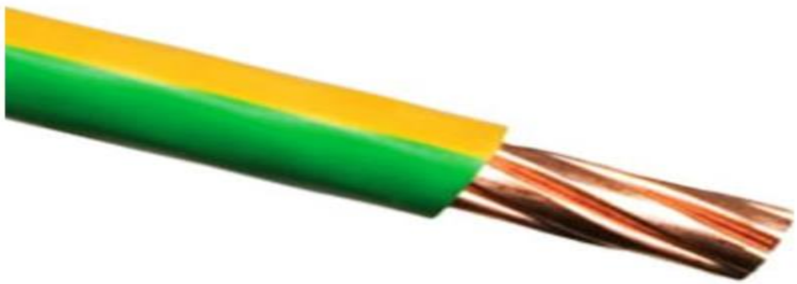
Earth / Ground electrode resistance is the number of ohms of resistance measured between the ground rod and a distant point on the earth called remote earth.



Ground rod resistance varies with depth and rod diameter.

Material	% Conductivity
Copper	100
Stainless steel	2.4
Zinc-coated steel	8.5
Copper-clad steel	40

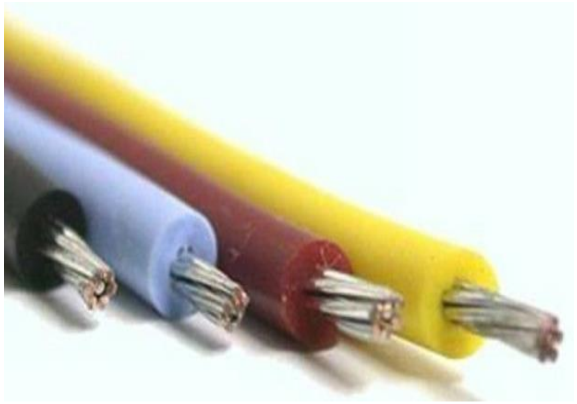
Earthing / Grounding Electrode Conductor



NEC permits

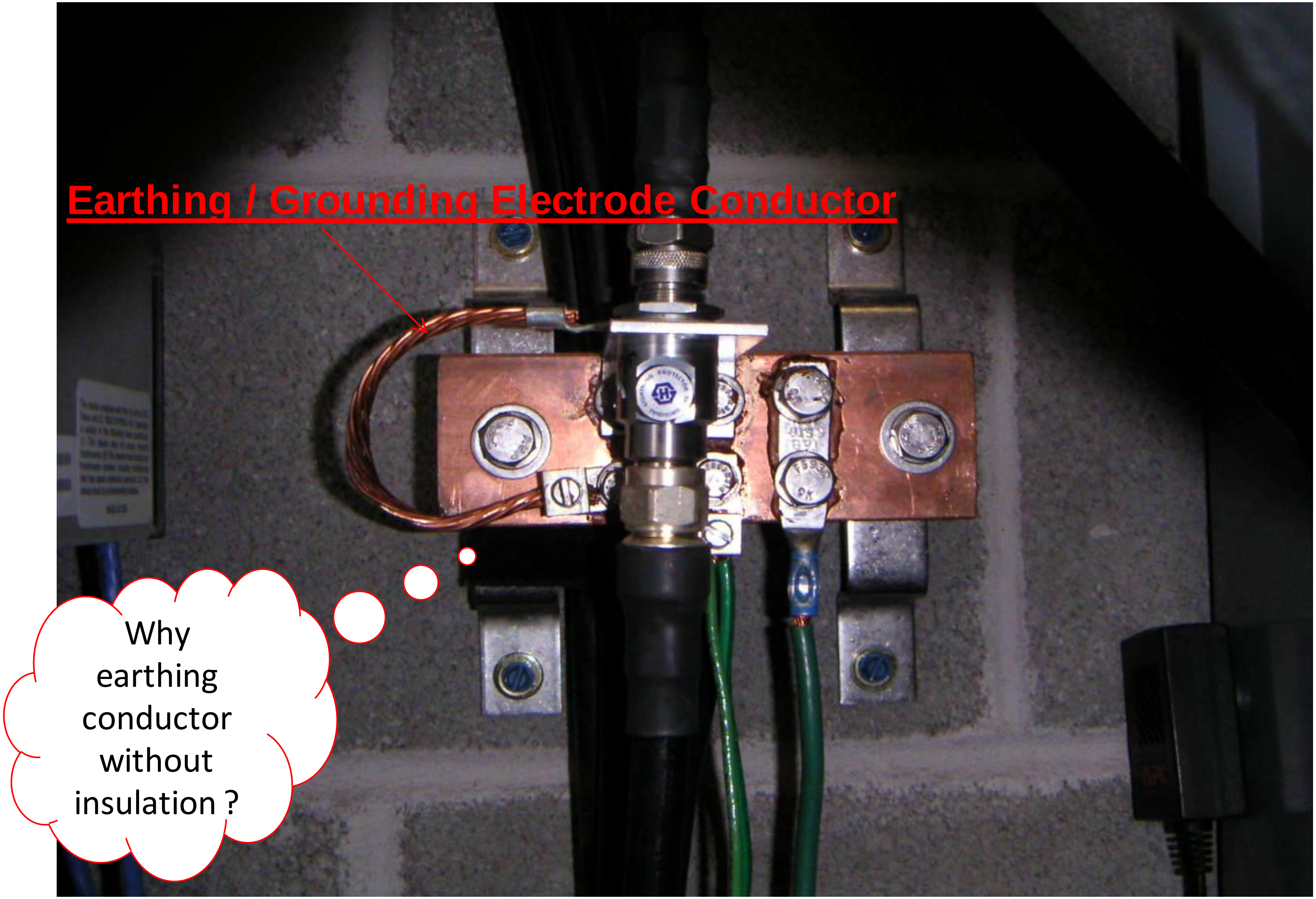
- Copper
- Aluminium
- Copper-clad (tinned copper)

AL and AL-CU may not be used in contact with masonry



Why :

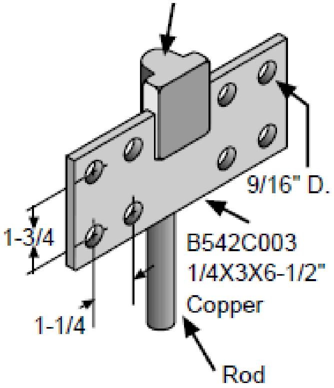
- Corrosive
- in direct contact with the earth (as occur in OHTL or housing sources).

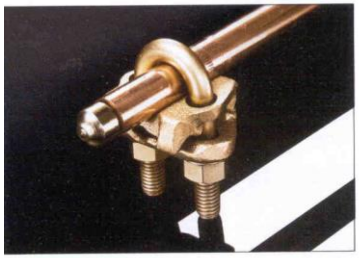

Earthing / Grounding Electrode Conductor
Why earthing conductor without insulation ?

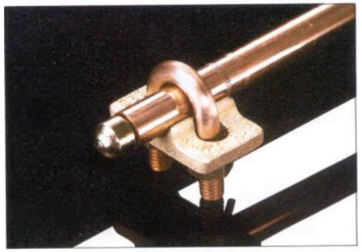
Earthing / grounding Clamp

Earthing / Grounding grid conductors are connected to the earth rods, already driven into the ground, by means of earthing clamps.

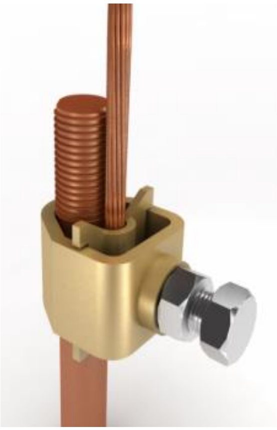
Connection is essentially made by **tightly clamping** of the grid conductor to the rod using the bolt and nut assembly of the earthing clamp.

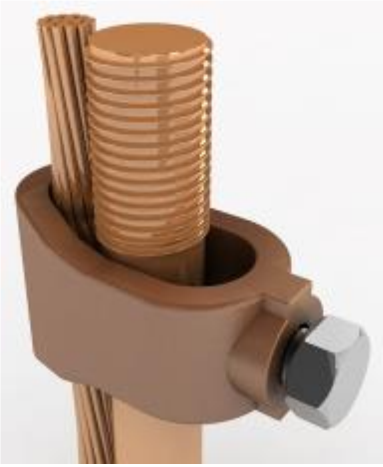


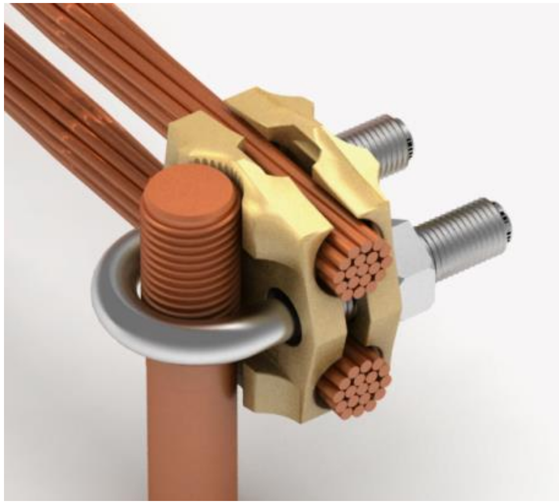
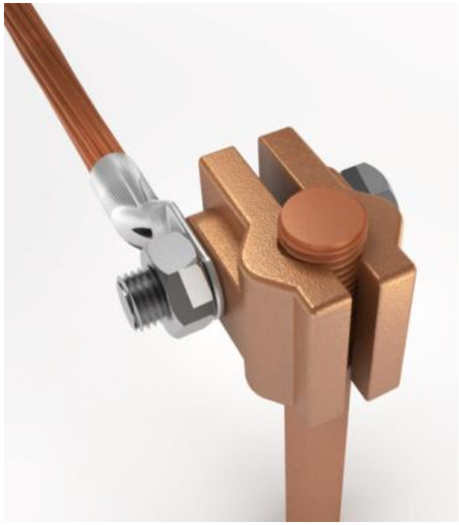


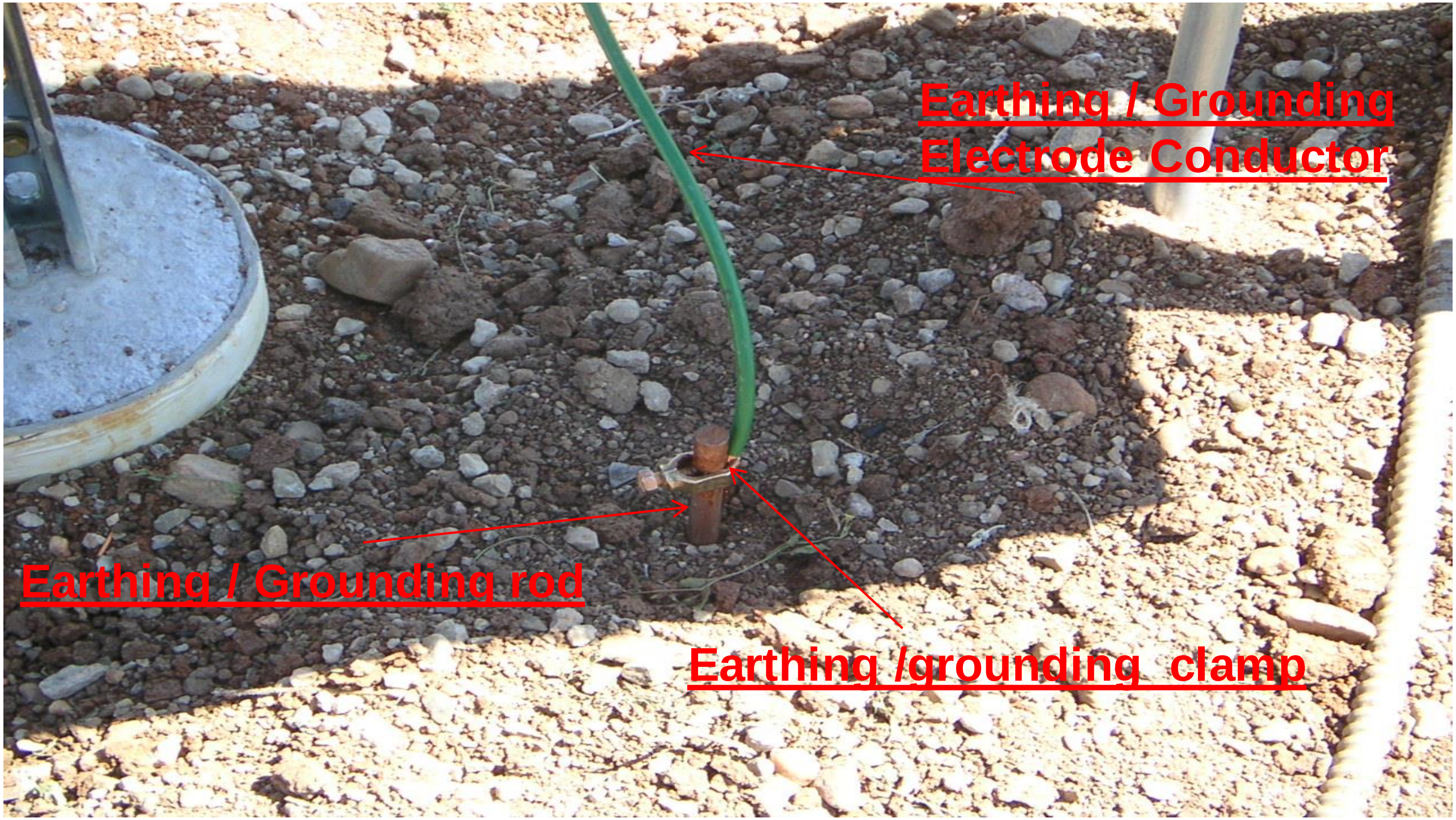


Earthing clamps and associated bolts nuts, washers, etc. are made of either **Aluminum or copper** but preferred copper .



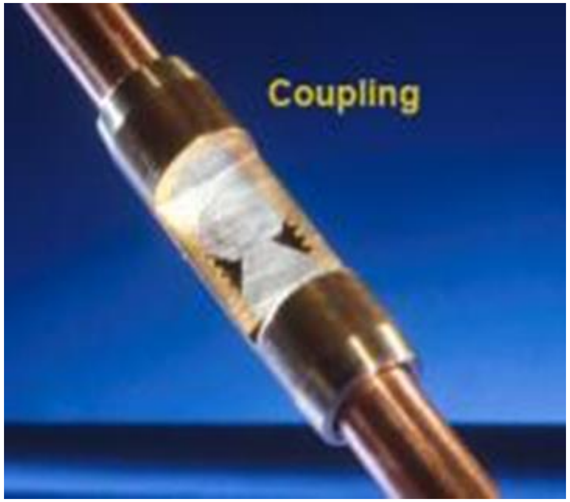




Earthing / Grounding
Electrode Conductor
Earthing / Grounding rod
Earthing /grounding clamp

Earthing / grounding rod coupling

Earthing rod coupling are made of both steel and copper.

A steel core, coated with pure copper to the appropriate thickness, provides the sufficient rigidity for the earthing rod to help driving it straightly into the ground without any harm and bending.



The copper coating of the earth rod provides the sufficient conductivity for the earthing system.

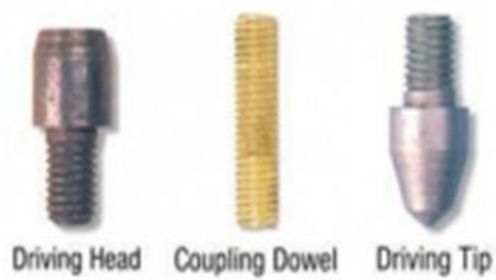
Earthing / Ground rod tip

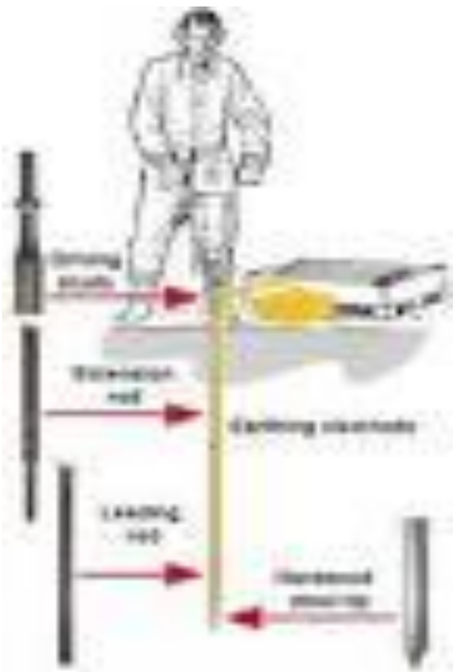
The earth rod tip material is not necessarily the same as the earth rod itself, as only a rigid quality is essentially required for the tip other than conductivity.

Therefore the earth rod tip is primarily **made of steel with slight coating of the copper for conductivity purpose** as well as protection against corrosion reasons.

Earthing / Grounding rod driving head

The **driving head material is not necessarily the same as the earth rod itself**, as only a rigid and robust quality is essentially required for the driving head to withstand the impact of hammerings. Driving head is practically discarded when the earth rods are all driven and installed in the ground.



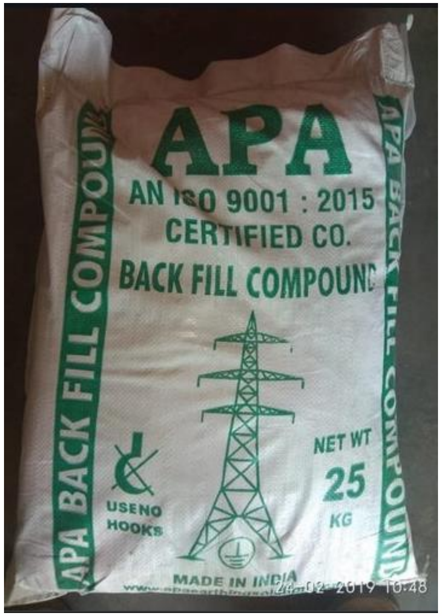


Carbon bedding mixed with salt

Depending on the **technical design specification of the earthing system** and primarily for **soil conductivity reasons** of the area where the earth wells are to be installed, the earth rods are embedded in **carbon mixed with salt bedding**.

To install the carbon bedded earth wells, pre-excavation of the ground, to sufficient size and dimension, would be carried out to provide **room** for the carbon bedding and the earthing components (rods, plates, etc.). To achieve the maximum conductivity for the earth well, an appropriate amount of salt is added to the carbon and mixed before charging into the earth well.


COMCO
PES
Permanent
Earthing
Solution
25kg


APA
AN ISO 9001 : 2015
CERTIFIED CO.
BACK FILL COMPOUND
APA BACK FILL COMPOUND
NET WT
25
KG
USE NO
HOOKS
MADE IN INDIA


SGI Product
Earth Enhancing Compound
Earth
Con
Regular
12.5Kg
FOR INDUSTRIAL USE ONLY
DO NOT USE HOOK


ELECTACT
EARTH COMPOUND
GOLD
MANUFACTURER:
JJ ENGINEERING-INDIA

Type of soil Resistivity

Type of Soil	Soil resistivity R_E	Earthing resistance (Ω)					
		Earthing rod m depth			Earthing strip m		
	Ω m	3	6	10	5	10	20
Moist humus soil, moor soil, swamp	30	10	5	3	12	6	3
Farming soil loamy and clay soils	100	33	17	10	40	20	10
Sandy clay soil	150	50	25	15	60	30	15
Moisty sandy soi	300	66	33	20	80	40	20
Dry sand soil	1000	330	165	100	400	200	100
Concrete 1: 5	400	-	-	-	160	80	40
Moist gravel	500	160	80	48	200	100	50
Dry gravel	1000	330	165	100	400	200	100
Stoney soil	30,000	1000	500	300	1200	600	300
Rock	10^7	-	-	-	-	-	-

Concrete earth / ground pit

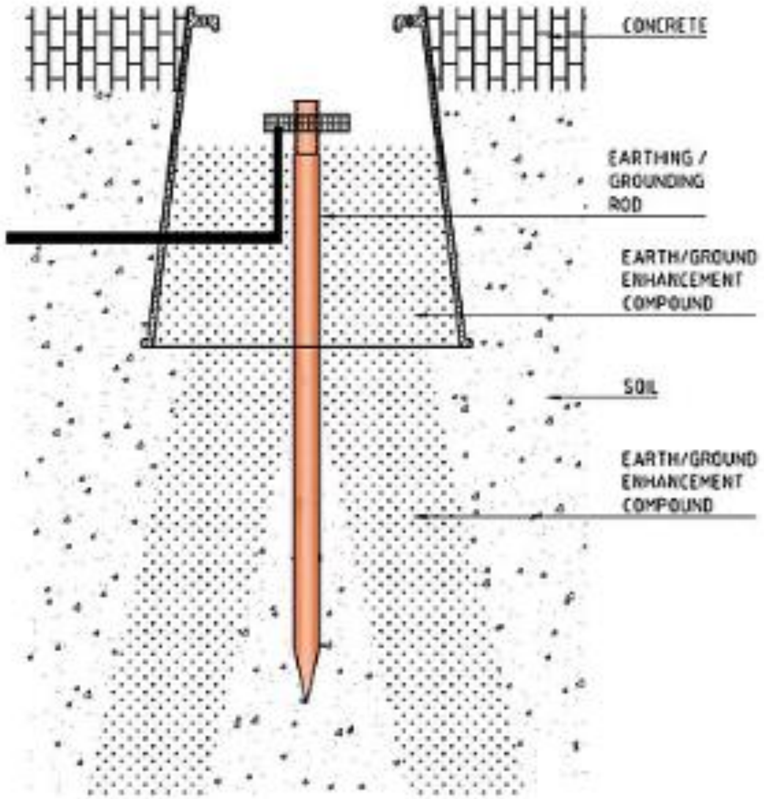
To provide access to the earth rod and its corresponding connection to the earthing grid at the top section of the rod, a small pit-like space is fabricated over the earth well, which is referred to as “**earth pit**” or “**Ground Pit “** .

Earth pit’s side walls are constructed of concrete material to appropriately isolate the earth rod’s top connection from the surrounding soil and protect it for future reference test and maintenance practices.

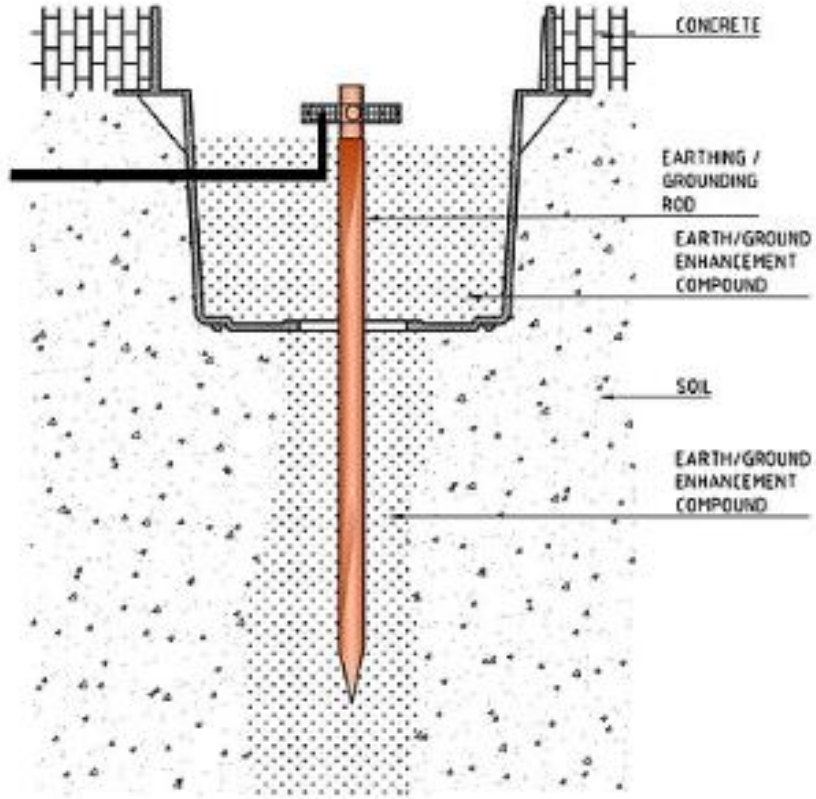
How can effect in total Earthing/ Grounding system resistance ?

what do different earth pit or ground inspection housing shapes deliver as far # recharge of Earth Enhancement Compound

"A" SHAPE EARTH PIT



"V" SHAPE EARTH PIT

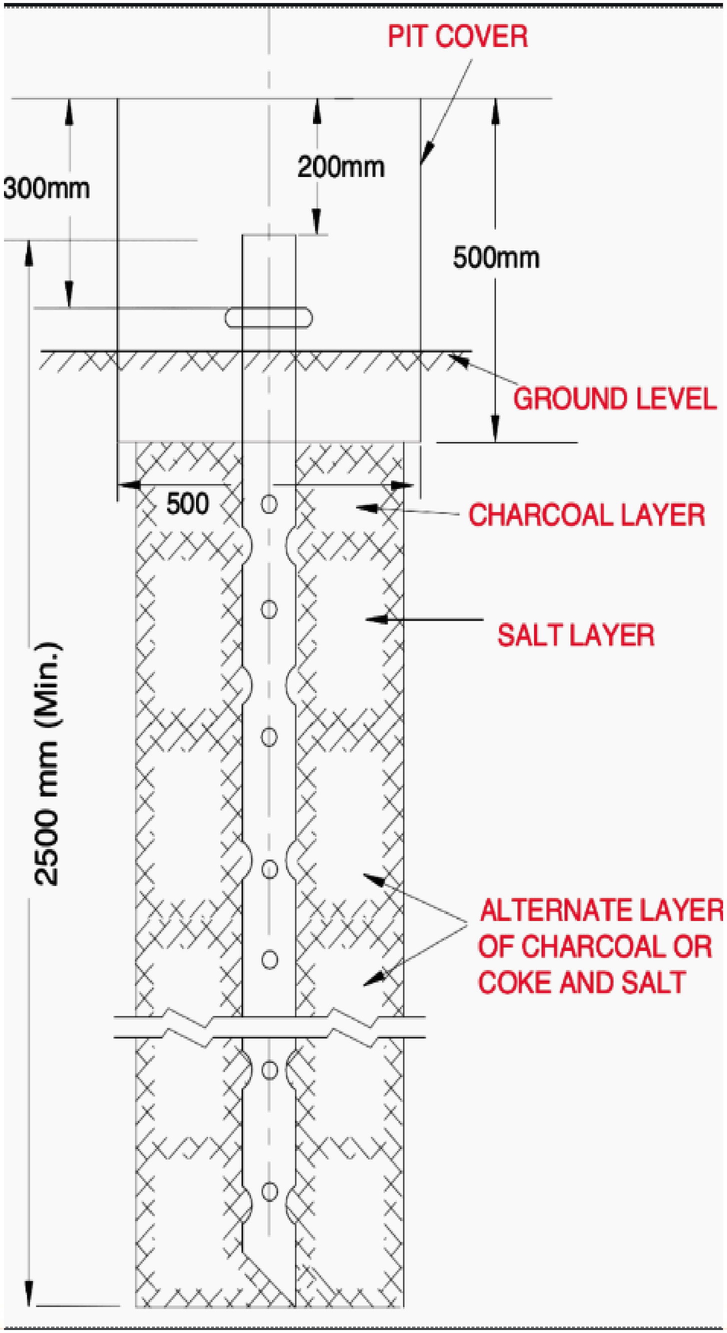


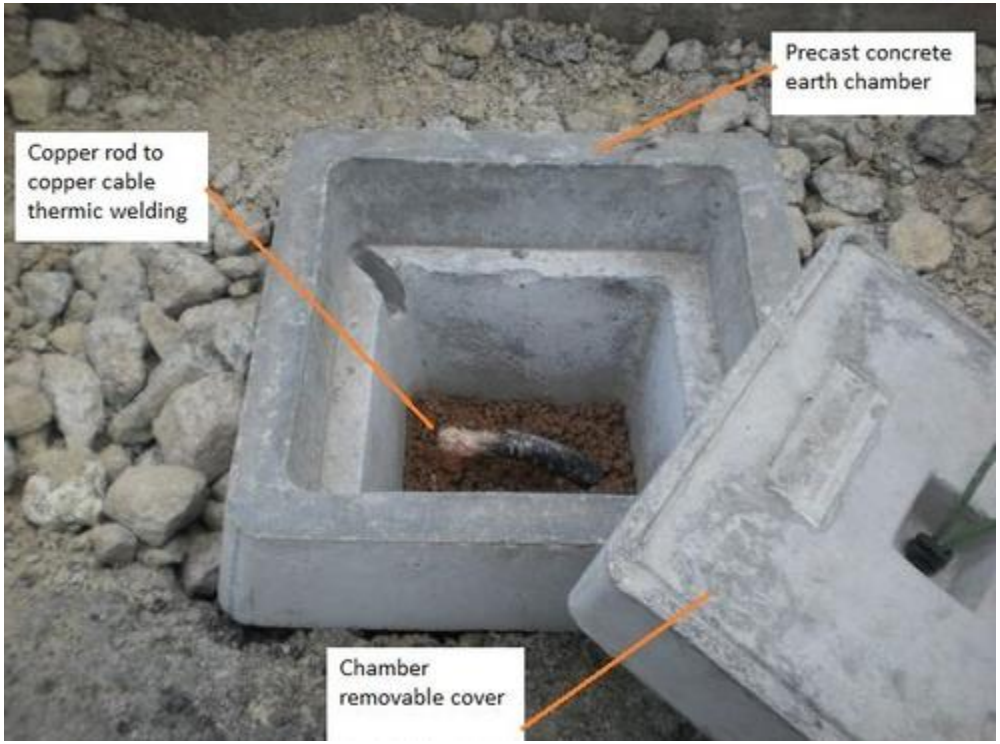
"A" SHAPE

Disburses the Earth / Ground enhancement compound away from the rod. Dees this also effect charge the ground connect - every

"V" SHAPE

Con contrates the Earth / Ground enhancement compound around the Rod.


PIT COVER
300mm
200mm
500mm
GROUND LEVEL
500
CHARCOAL LAYER
SALT LAYER
2500 mm (Min.)
ALTERNATE LAYER OF CHARCOAL OR COKE AND SALT

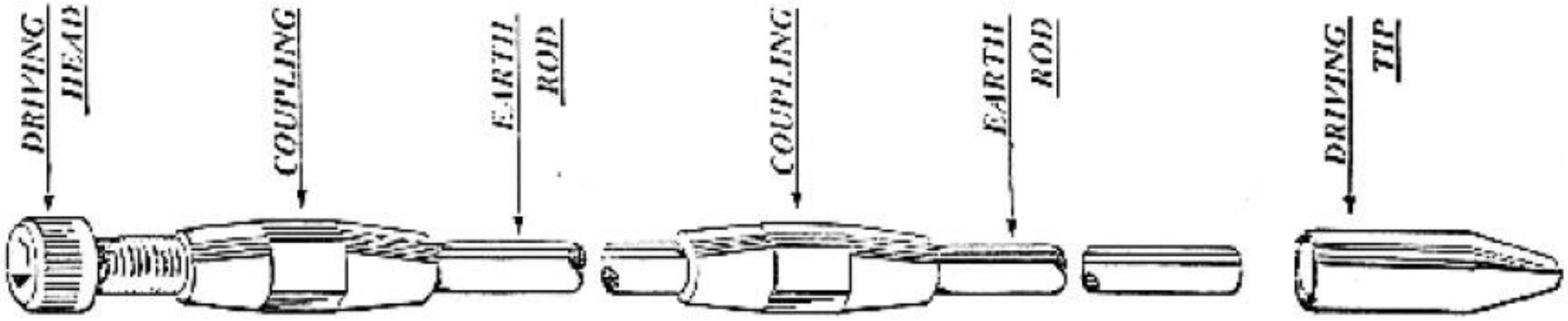

Precast concrete earth chamber
Copper rod to copper cable thermic welding
Chamber removable cover

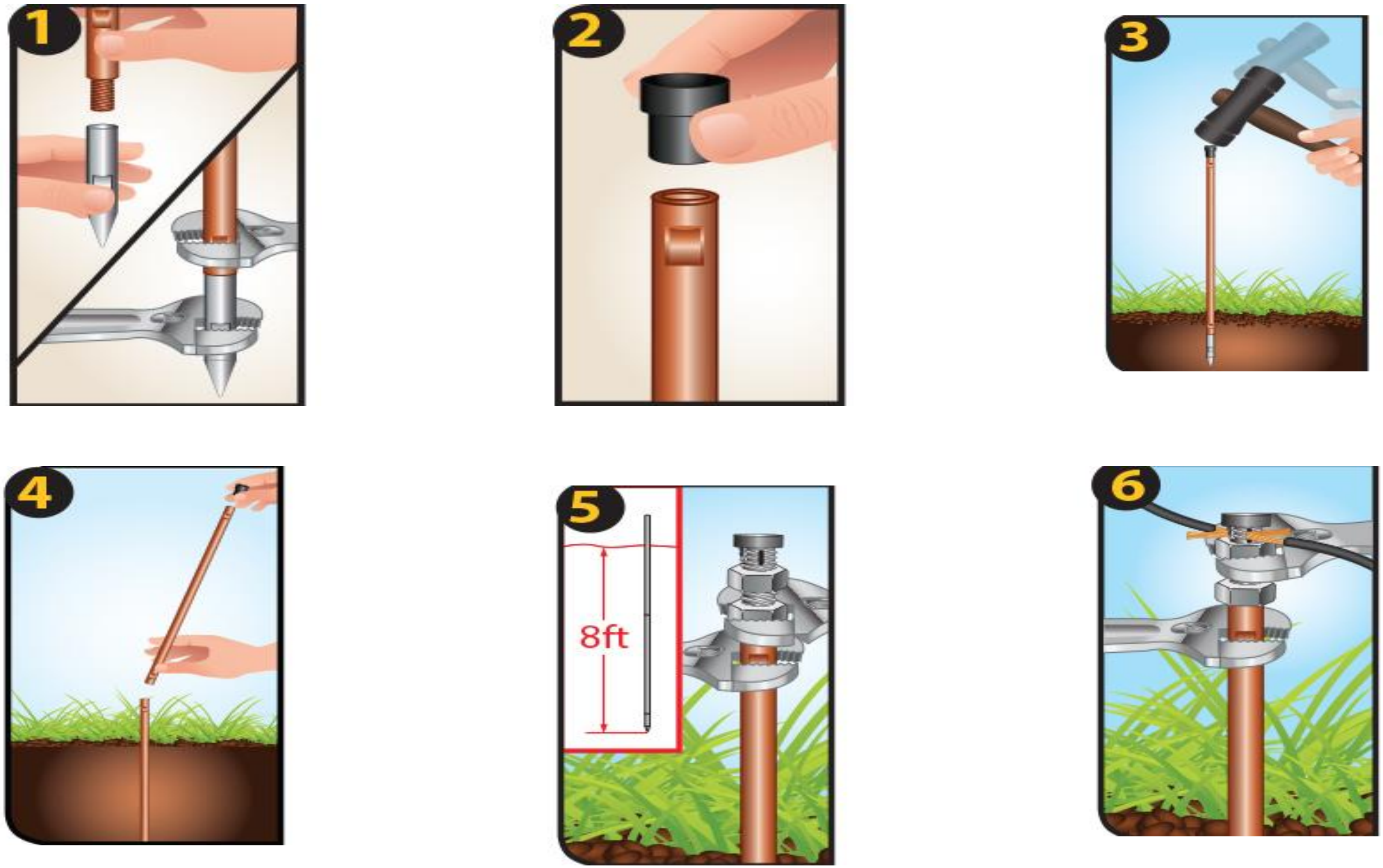
Concrete slab cover

To protect the earth pits against ingression of foreign material, an appropriate concrete cover is provided to be placed atop the earth pit.

The slab-like concrete cover is equipped with a rigid handle for convenient removing and replacement practices.

Complete Earth rod Parts




1
2
3
4
5
8ft
6

2. Earth grid conductors Grounding conductor / Bonding conductor

All electrical earth wells in a specific residential, commercial and industrial installation should essentially be interconnected to plant earthing systems form the main earthing grid.

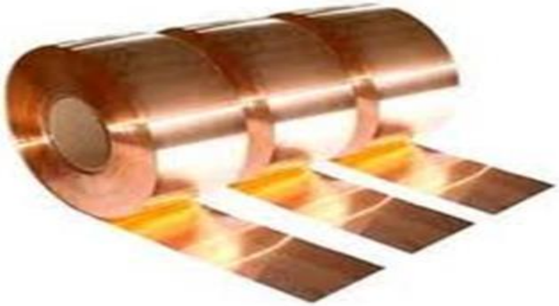
Different Types of Grid Conductors

Interconnecting conductor used for the grid are in the following forms:

According to type of earthing

1. Bare copper strip conductor
2. Single core bare stranded copper cable
3. Single core stranded copper cable with PVC sheath
4. Copper strip conductor with PVC covering

Bare copper strip conductor



Single core bare stranded copper cable

Single core stranded copper cable with PVC sheath

Copper strip conductor with PVC covering

450 /750 V
0.6/1 KV

Applications

- **Bare copper strip conductor**

For direct buried grid in dry and non-corrosive grounds (soils)

- **PVC-Covered copper strip conductor**

For direct buried grid in wet or corrosive ground.

- **Single core stranded copper conductor**

For direct buried grid in dry, and noncorrosive grounds.

- **Single core stranded copper conductor with PVC sheath**

For direct buried grid in wet or corrosive grounds.

Earthing / Grounding Grid Conductors Dimension

Depending on the design specification of the earthing system, the size of the grid conductors, would be different as followings:

- **Bare or PVC-covered cables (stranded)**

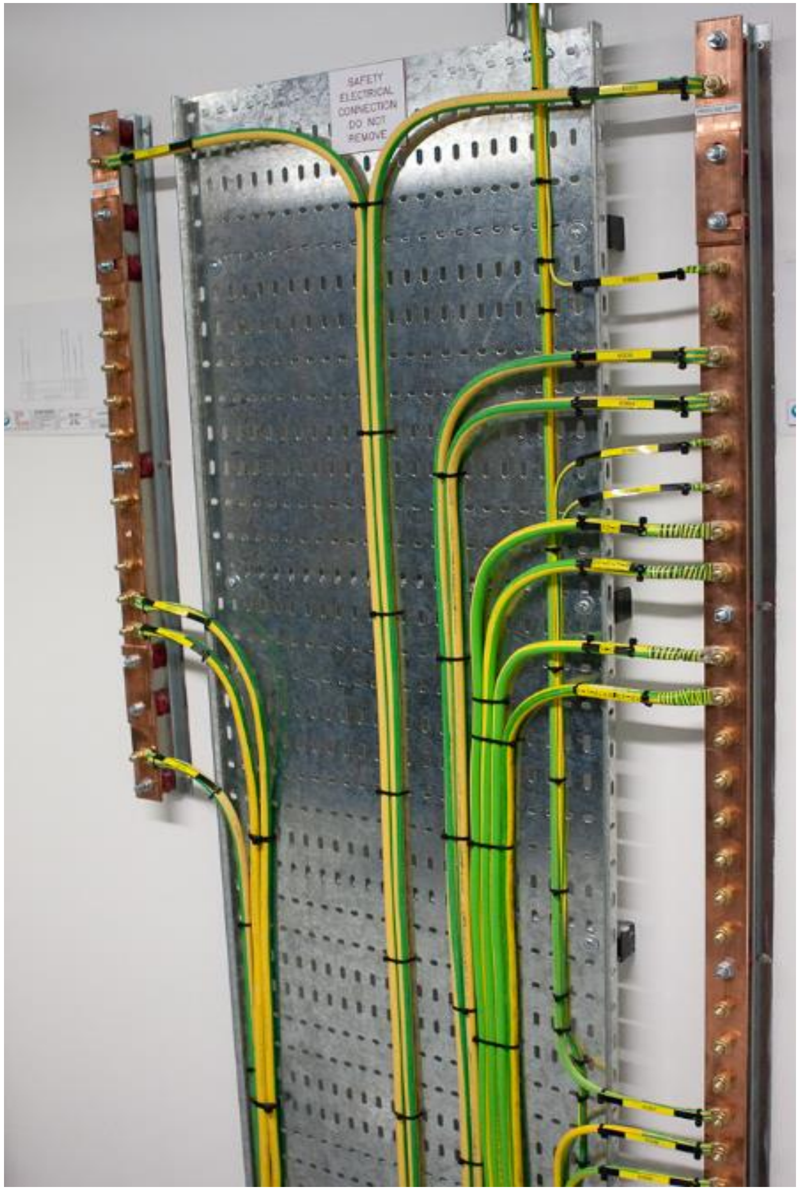
The cross section area of the cable could be either 35mm2, or 70mm2, or 95mm2 depending on the design specification.

- **Bare or PVC-covered copper strips**

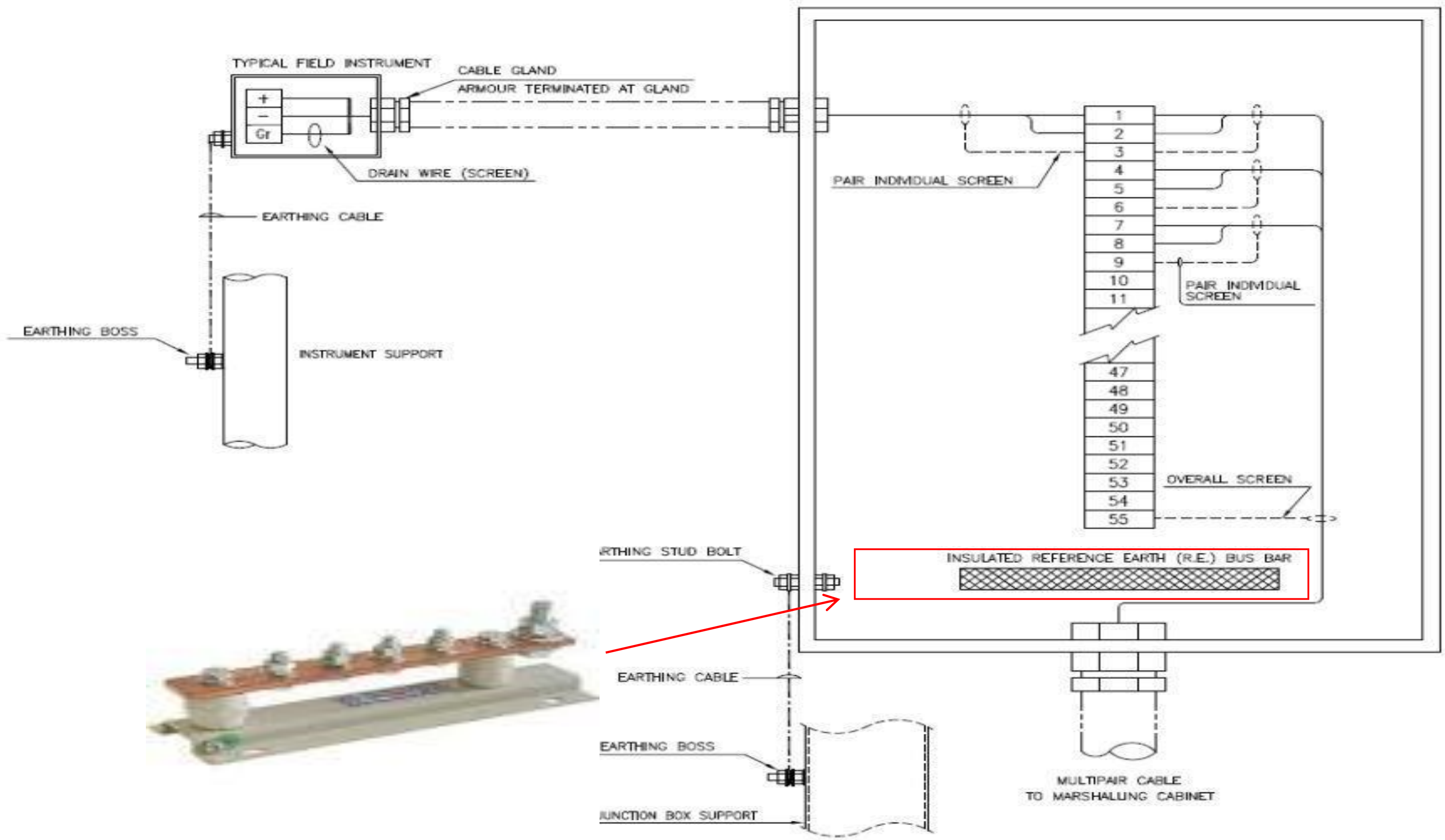
The cross section dimension of the strip is normally 25 × 3mm.

3. Marshaling EARTH / Grounding BUS

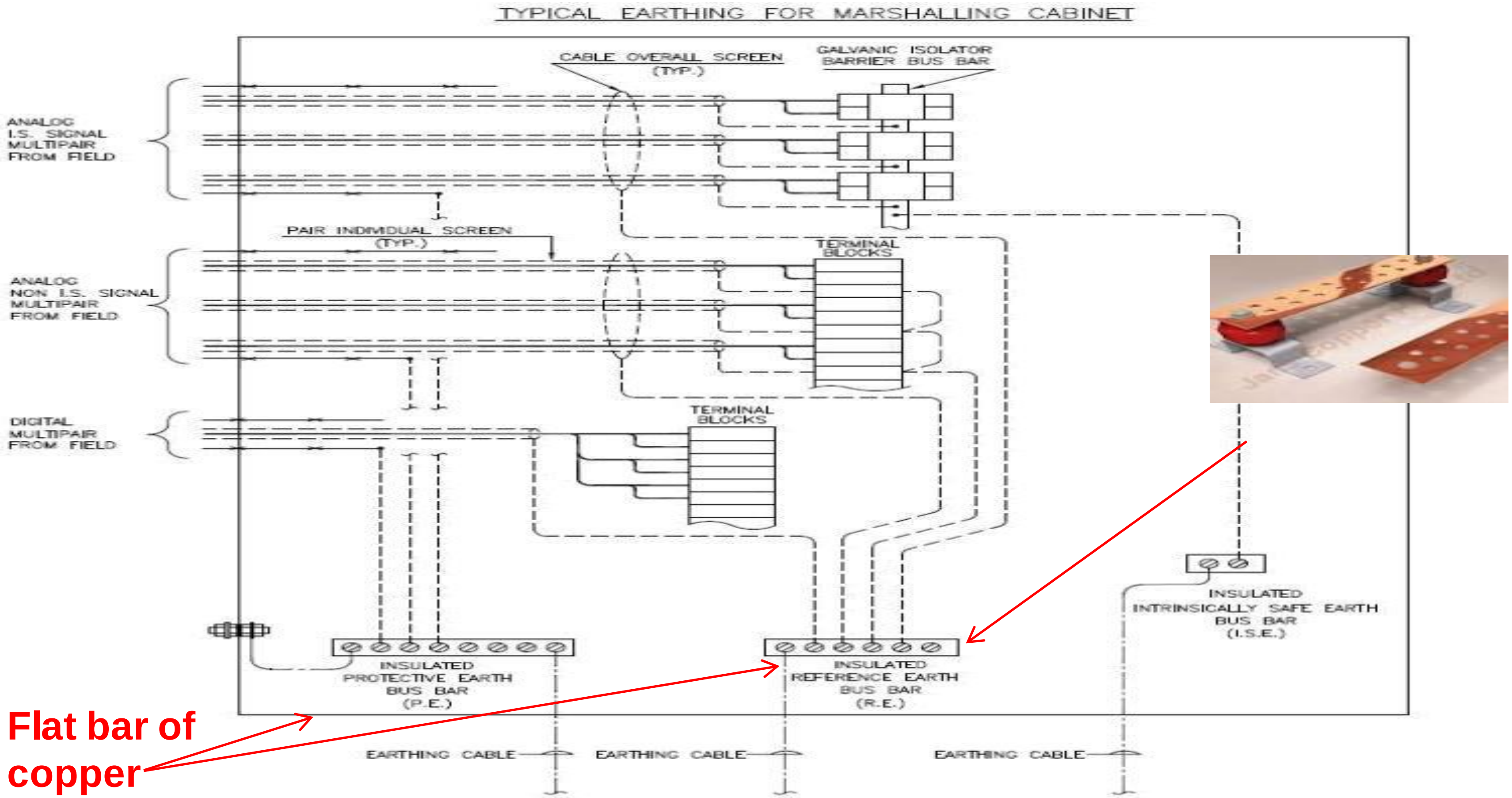
To provide easy access to the earthing grid, particularly to make proper and convenient connections of the equipment to the grid, several common connection points in the form of a **flat bar of copper material are established** and erected through out the grid and referred to as “earthing marshalling points” or “earthing marshalling bus”, or simply as “earth bus”.



TYPICAL EARTHING FOR ANALOG SIGNAL JUNCTION BOX

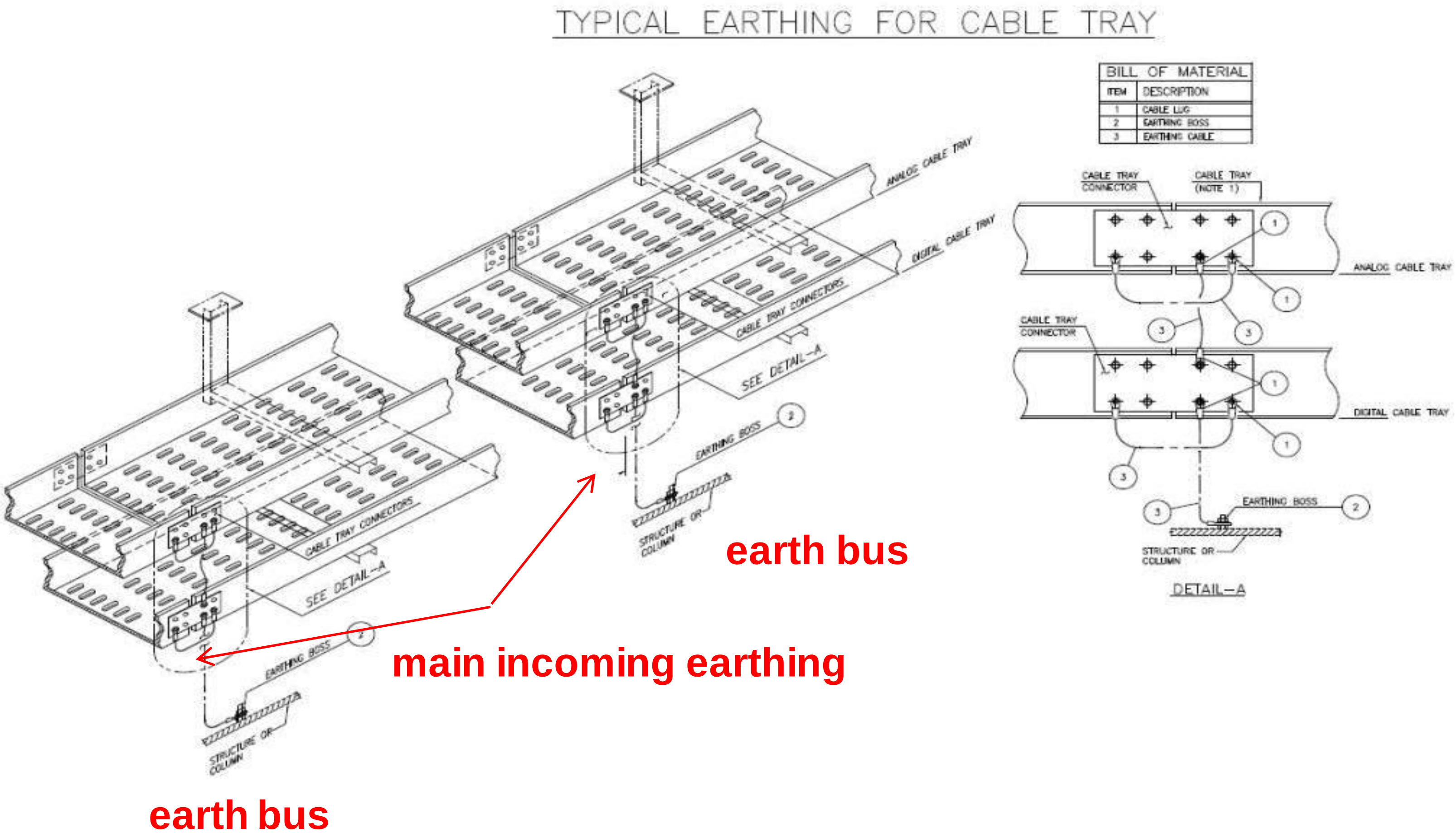


Earthing /Grounding Marshalling points



Flat bar of copper material

- The main incoming earthing cable connected to the earth bus is branched off from the main earthing grid.
- The outgoing earthing cables, connected to the earth bus in one end, shall be connected to the corresponding equipment on the other end.
- **All the connections** of the main incoming and outgoing earth cables shall be made to the earth bus by means of appropriate cable lugs the **compression** type and zink coating, using bolts, nuts, flat washers and spring washers for well-tight connections.



TYPICAL EARTHING FOR CABLE TRAY
BILL OF MATERIAL
ITEM
DESCRIPTION
1 CABLE LUG
2 EARTHING BOSS
3 EARTHING CABLE
CABLE TRAY CONNECTOR
CABLE TRAY (NOTE 1)
ANALOG CABLE TRAY
DIGITAL CABLE TRAY
EARTHING BOSS
STRUCTURE OR COLUMN
DETAIL-A
CABLE TRAY CONNECTORS
SEE DETAIL-A
earth bus
main incoming earthing
earth bus

4. Earthing / Grounding Wires (Cables)

Connections between the marshalling earth buses and the equipment's are carried out by means of single wires or cables of appropriate size, which are referred to as "**earthing wire**", or "**earthing link**".

The connection between the earthing buses and the earthing grid is also made by means of earthing cables.

Earthing wires and cables are used either **bare or PVC-covered** (preferably bare) and are normally single core of the different cross section area.

The common range of the cable size used is 16mm2, 25mm2, 35mm2,50mm2 and 70mm2 or **4 AWG & 6 AWG stranded Copper** conductor.

Earthing wires (cables) of smaller and higher size could be used depend on the design specification and requirements.

Connections of earthing wires (cables) on both ends is made by appropriate **compression-type** cable lugs, fitted with bolts, nuts, flat washer and spring washers for tight connections.

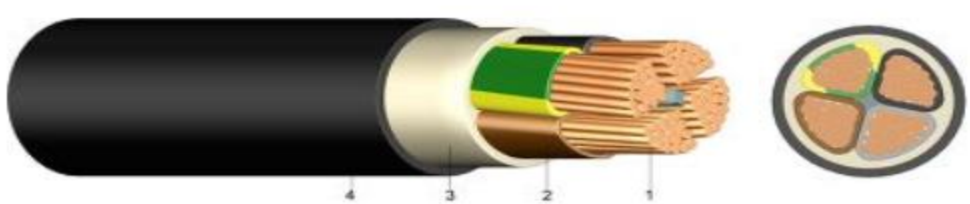
Earthing / Grounding Wires Sizing And Selection

The cross-section of the protection conductors (PE, PEN) destined to be connected to external conductors in Electrical panel must be determined using one of the following methods:

IEC 60479

1. The cross-section of the protection conductor must not be less than the one specified in the table(neutral currents do not exceed **30%** of the phase currents).

Cross-section of the phase conductor S (mm²)					Minimum cross-section of the corresponding protection conductor S (mm²)
		S	≤	16	S
16	$<$	S	≤	35	16
35	$<$	S	≤	400	S/2
400	$<$	S	≤	800	200
		S	≤	800	S/4



2. The cross-section of the protection conductor (PE, PEN) can be calculated with the help of the following Short Circuit formula:

$$S_P = \frac{\sqrt{I^2\, t}}{k}$$

Sp is the area of the cross-section expressed in mm2.

I is the r.m.s. value of the fault current passes through the protection device.

T is the trip time of the breaking device, in seconds.

k is a factor whose value depends on the material of the protection conductor.

		PVC	XLPE EPR Bare conductors	Butyl rubber
Final temperature		*160 °C*	*250 °C*	*220 °C*
K for conductor	copper	143	176	166
	aluminium	95	116	110
	steel	52	64	60

3. The cross-section of the protection conductor by Using Normal current

Cross-section of the service conductor I_n (A)					Minimum cross-section of the equipotential protection conductor (mm²)
		I_n	≤	20	S
20	<	I_n	≤	25	2,5
25	<	I_n	≤	32	4
32	<	I_n	≤	63	6
63	<	I_n			10

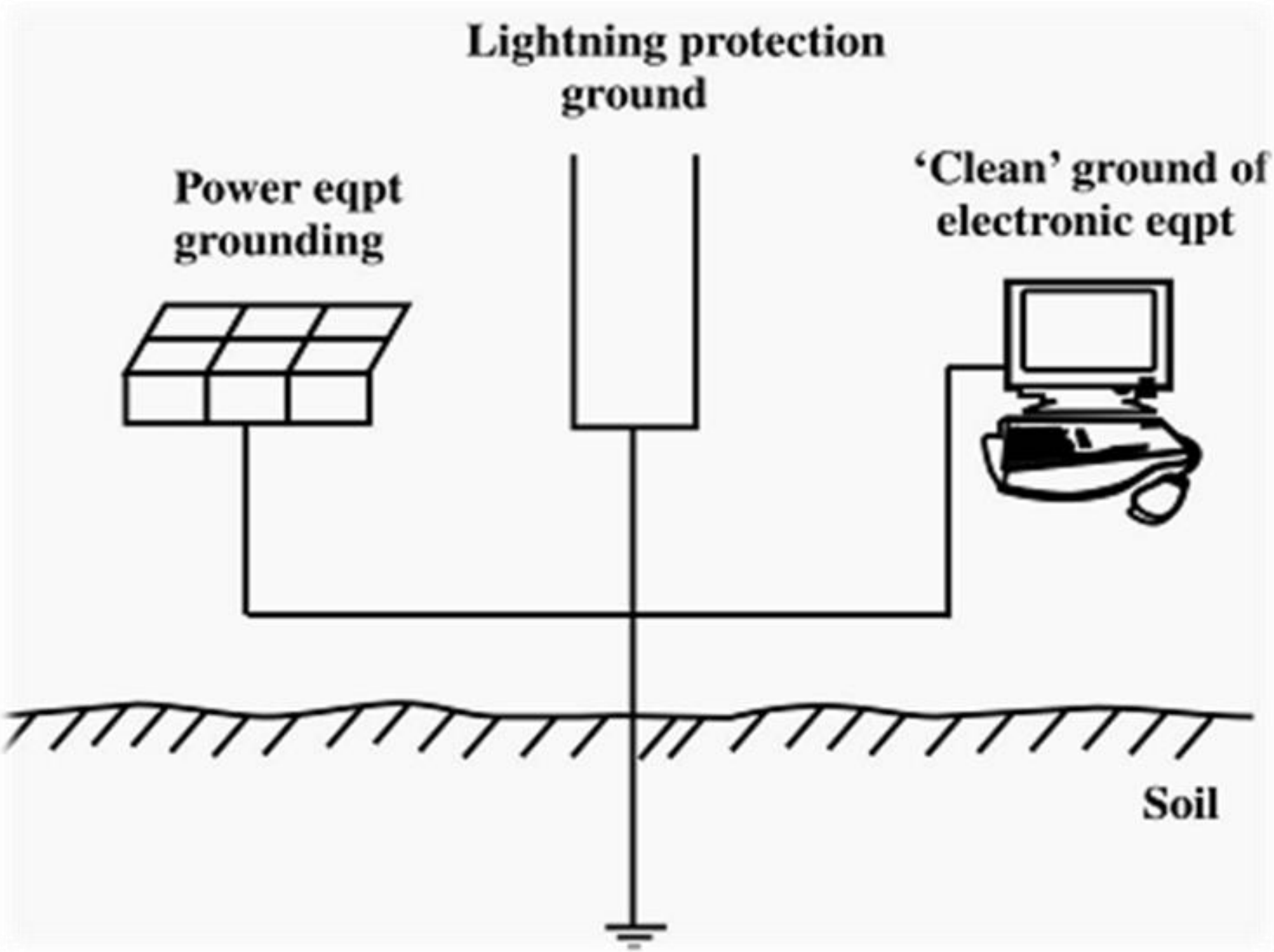
Design / Calculation of Grounding (Earthing) system

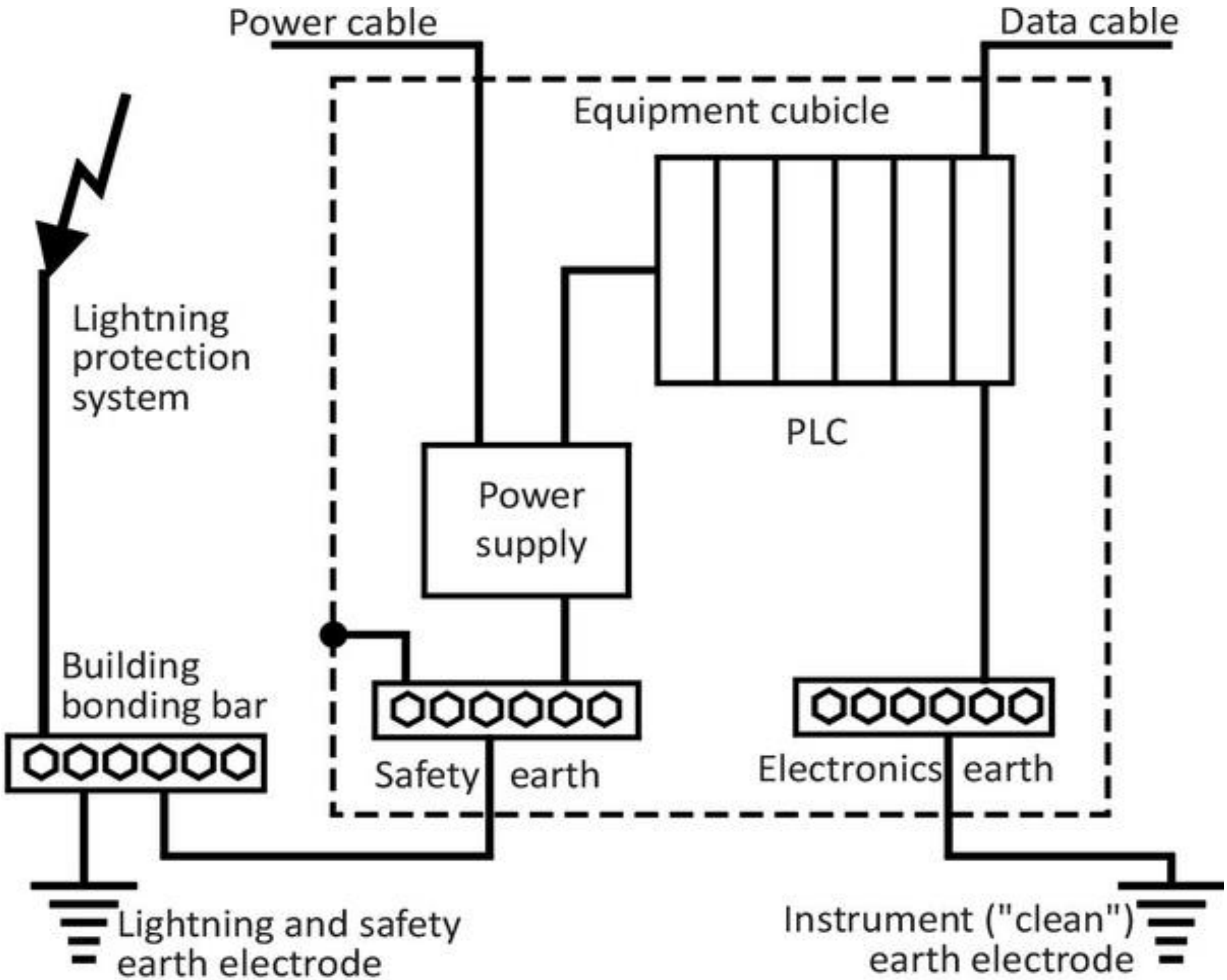
Earthing System Resistance Measurement

- Earthing resistance for the lightning protection system shall not exceed 5 OHM.
- Earthing resistance for the power system earthing in power station and power plants shall not exceed 5 OHM.
- Earthing resistance for the electrical Distribution system (equipment earthing) shall not exceed 4 OHM.
- Earthing resistance for the electronic devices and **instrumentations** shall not exceed 1 OHM.

Power station

As Magnetic pickup
in Generator


Lightning protection ground
Power eqpt grounding
'Clean' ground of electronic eqpt
Soil


Power cable
Data cable
Equipment cubicle
Lightning
protection
system
PLC
Power
supply
Building
bonding bar
Safety earth
Electronics earth
Lightning and safety
earth electrode
Instrument ("clean")
earth electrode

Design of Earthing System by Rods

Using IEEE std.142 formula

For s < L

$$R_n = \left(\frac{\rho}{2 n \pi L}\right) \cdot \left[\left(\ln \frac{8L}{d}\right) - 1\right] + \left(\frac{\rho}{2 n \pi s}\right) \cdot \left[1 - \left(\frac{L^2}{3 s^8}\right) + \left(\frac{2 L^4}{5 s^4}\right)\right]$$

For s > L

$$R_n = \left(\frac{\rho}{2 n \pi L}\right) \cdot \left[\left(\ln \frac{8L}{d}\right) + \left(\ln \frac{4L}{s}\right) - 2 + \left(\frac{s}{2L}\right) - \left(\frac{s^2}{16 L^2}\right) + \left(\frac{s^4}{512 L^4}\right)\right]$$

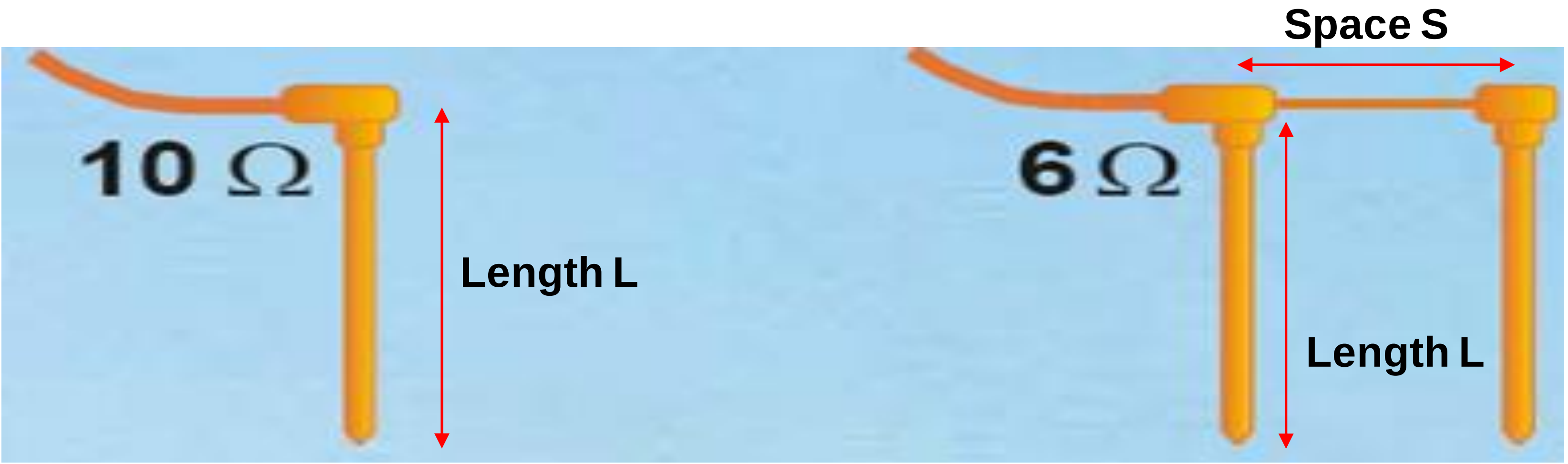
n : is the number of rods.

ρ : is the soil resistivity in (Ω-m).

d : is the diameter of driven rod in (m).

s : is the distance between two adjacent rods in (m).

Electrodes Configuration



Empirical Calculation of Earthing / Grounding resistance for one electrode driven at the earth

Equation used to calculate earthing resistance is

$$R = (\rho / 2\pi l)[\ln(8l/d) - 1]$$

Where

ρ = earth resistivity in ohm.m

l = length of the electrode (m)

d = diameter of the electrod in (m)

Example 1 : calculate the earthing resistance of an earthing electrode of length 3m and its diameter is 2 cm driven in an earth of 60 Ω.m resistivity.

Solution:

$$R_I = (\rho / 2\pi\ l)[\ln(8l/d) - 1] = (60 / 2\pi x3)[\ln(8x3/0.02) - 1] = 19.4\ \Omega$$

This is very large value. To reduce this resistance we can put another rode (electrode) at distance D in parallel with the first rode. Hence the total earthing resistance R_{II} will be:

$$R_{II} = ((1+\alpha)/2)\, R_I$$

$$\alpha = (\rho / 2\pi D R_I)$$

Example 2: For example 1 above calculate the erthing resistancse when two similar electrod are put in parallel.

Solution:

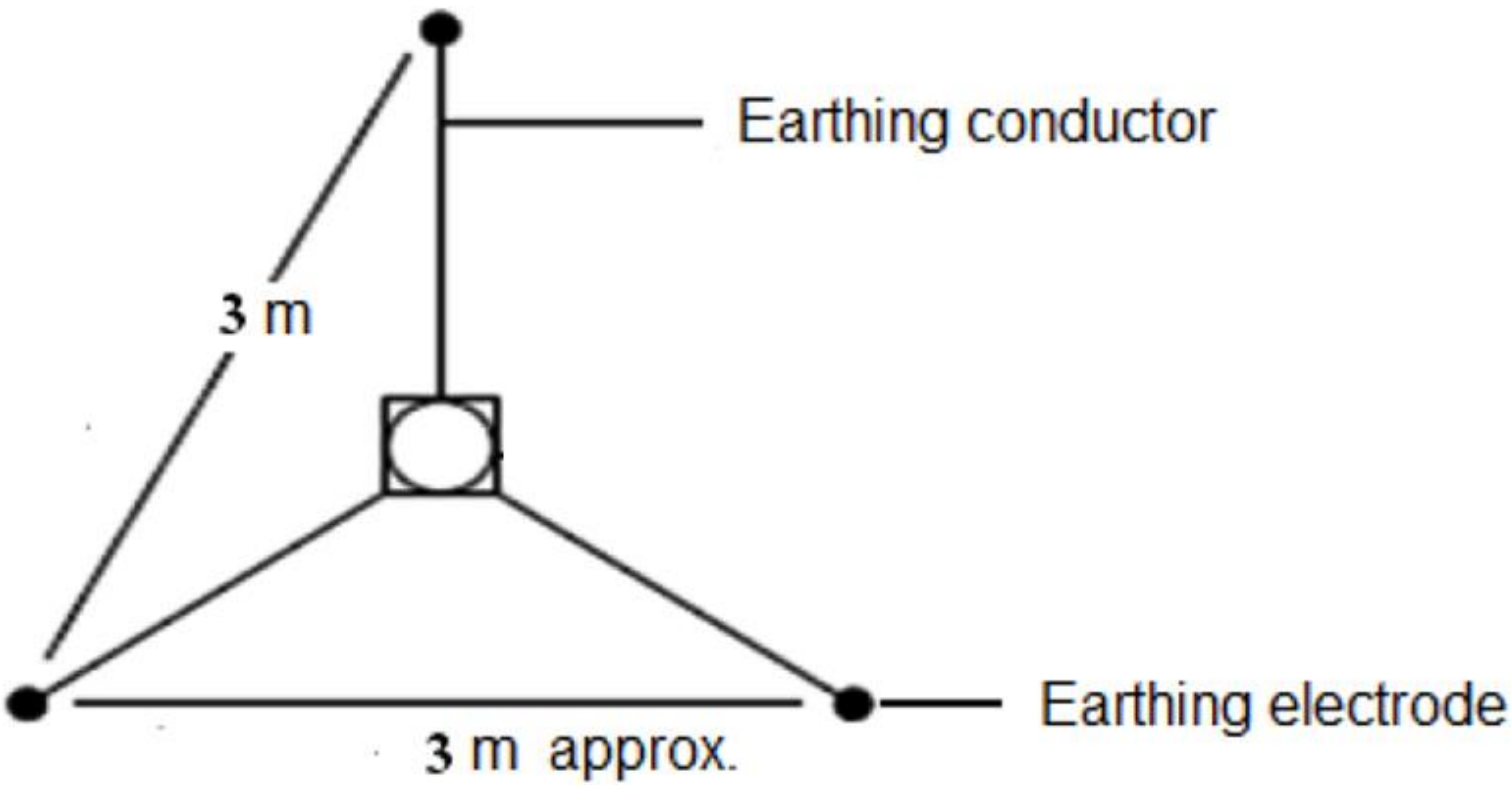
From **example 1**

$$R_I = 19.4\ \Omega$$

$$\alpha = (\rho / 2\pi D R_I) = (60/ 2x3.14x3x19.4) = 0.16$$

$$R_{II} = \{(1 + 0.16) /2\} (19.4) = 11.25\ \Omega$$

For standard building, it is found that the best earthing system is to use thee rodes connected in triangular form as shown, in this case the earthing resistance will be reduce to **RIII= RI/3.**



For any number of rods in parallel, we can calculate the earhing resistance from the following equation and table

$$\boxed{R_{eq} = [\ RI\ /\ \text{No. of rods.}]\ x\ F}$$

Where **F** is a multiplying factor that can be taken from the following

F	No.of rods
1.16	2
1.29	3
1.36	4
1.68	8
1.8	12
1.92	16
2.0	20

Earthing System Resistance

Under fault condition on an specific point in the overall earthing grid and earthing network, a high amount of **rush current** flows into the earthing system to find its way to the earth wells.

The closer an earth well to the fault point, the greater amount of the fault current is absorbed and drained by that well, and the remaining fault current is absorbed by the other nearby earth wells.

Based on the **specification and location** of the fault point, the fault current value can be calculated and therefore predicted.

Factors Influential With Respect To The Fault Current Value

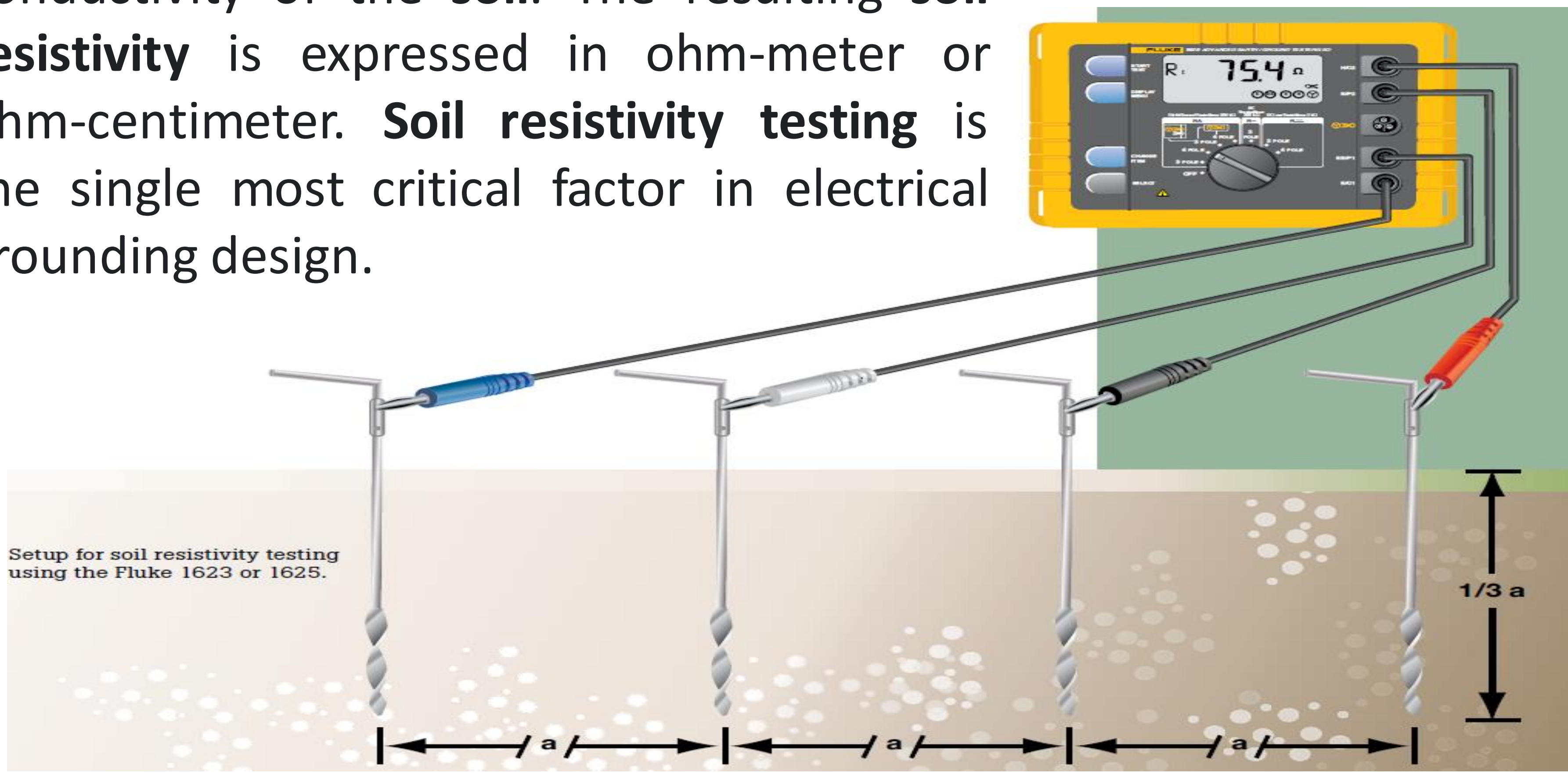
- The **value of voltage** applied to the fault point.
- The **pure ohmic resistance of the fault point** with respect to the ground, which includes the ohmic resistance of each individual well, as well as the earthing grid conductors and earthing wires and earthing cables.
- The number of **rotating machineries** (motors and generators) and their rated power at the time of fault.
- The **distance between the fault point and the rotating machineries.**

What are the effect of motor during Short circuit

Soil Resistivity Testing

To test soil resistivity connect the ground tester as indicated.

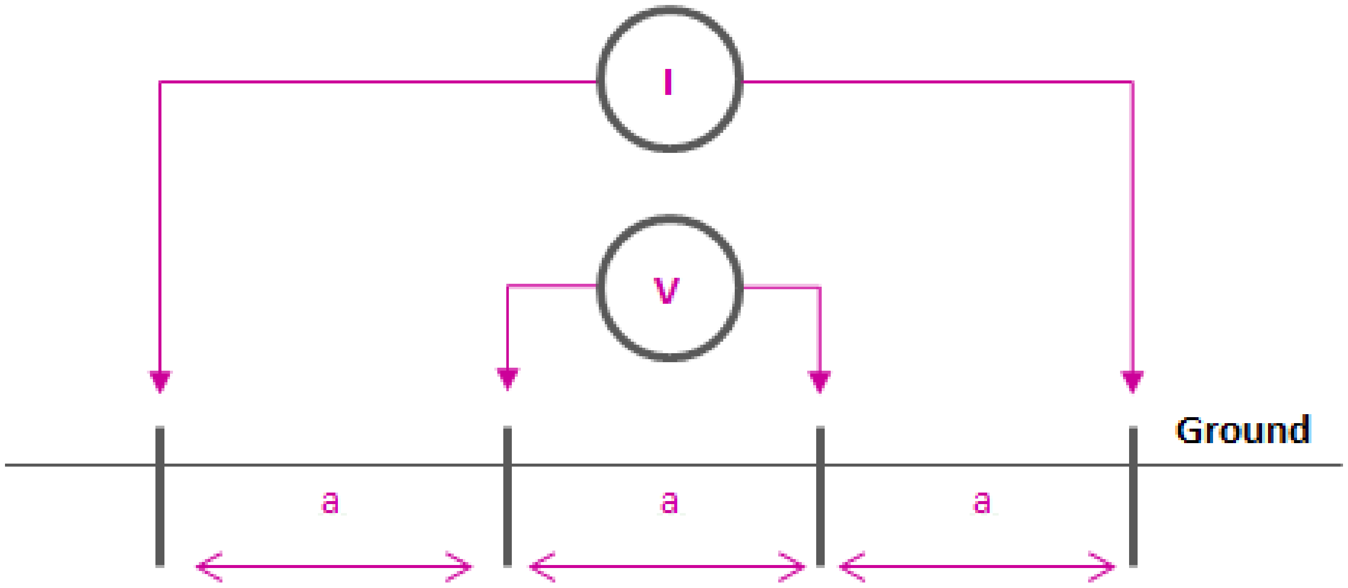
Soil resistivity testing is the process of **measuring** a volume of **soil** to determine the conductivity of the **soil**. The resulting **soil resistivity** is expressed in ohm-meter or ohm-centimeter. **Soil resistivity testing** is the single most critical factor in electrical grounding design.



Setup for soil resistivity testing using the Fluke 1623 or 1625.

Why do we need soil resistivity testing?

Soil resistivity influences the plan of an earthing system absolutely and is the major factor that decides the resistance to earth of a grounding system. Thus before designing and installing a new grounding system, the determined location should be tested to find out the

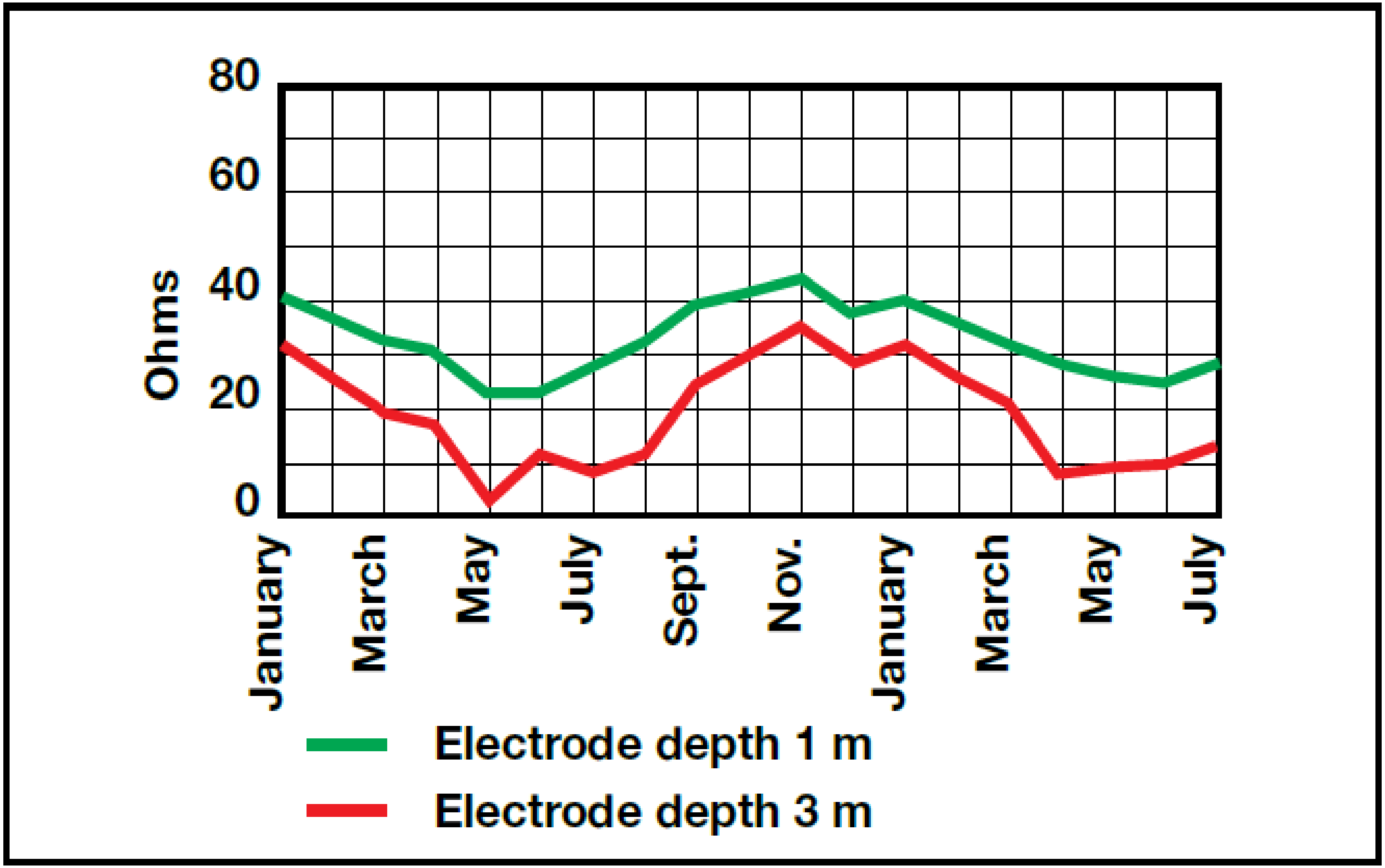


Type of soil Resistivity

Soil	Resistivity (approx.), Ω-cm Min.	Average	Max.
Ashes, cinders, brine, waste	590	2370	7000
Clay, shale, gumbo, loam	340	4060	16,300
Same, with varying proportions of sand and gravel	1020	15,800	135,000
Gravel, sand, stones with little clay or loam	59,000	94,000	458,000

Seasonal variation of earth resistance

(Earthing: electrode in clay soil)



Calculate Soil Resistivity

The formula is as follows:

$\rho = 2 \pi A R$

(ρ = the average soil resistivity to depth A in ohm—cm)

$\pi = 3.1416$

A = the distance between the electrodes in cm

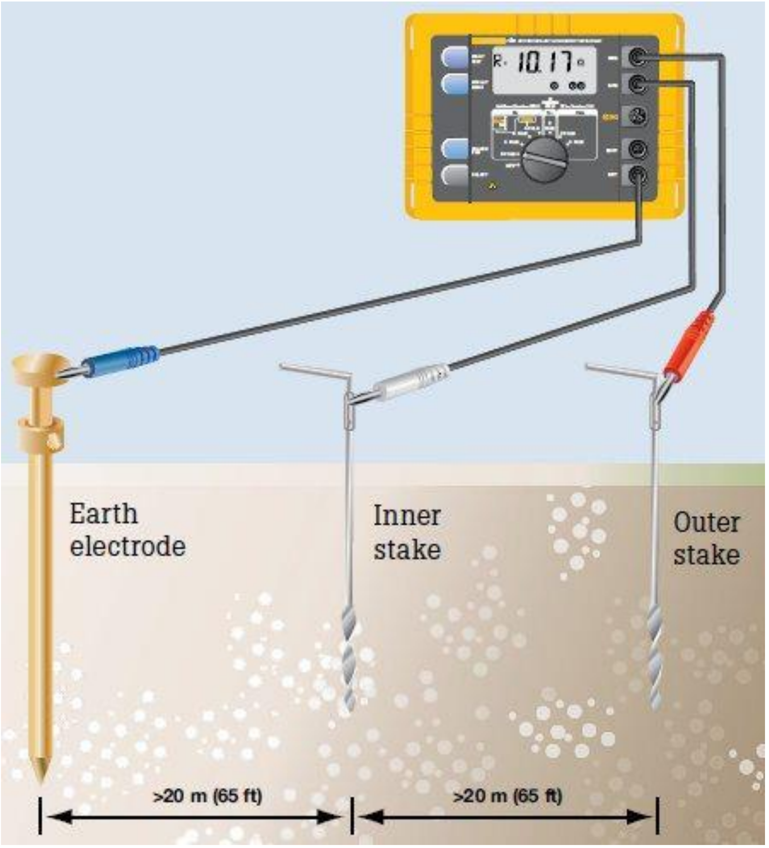
R = the measured resistance value in ohms from the test instrument

Typical Devices Used For Earthing System Resistance Measuring

Digital Earth Resistance Tester

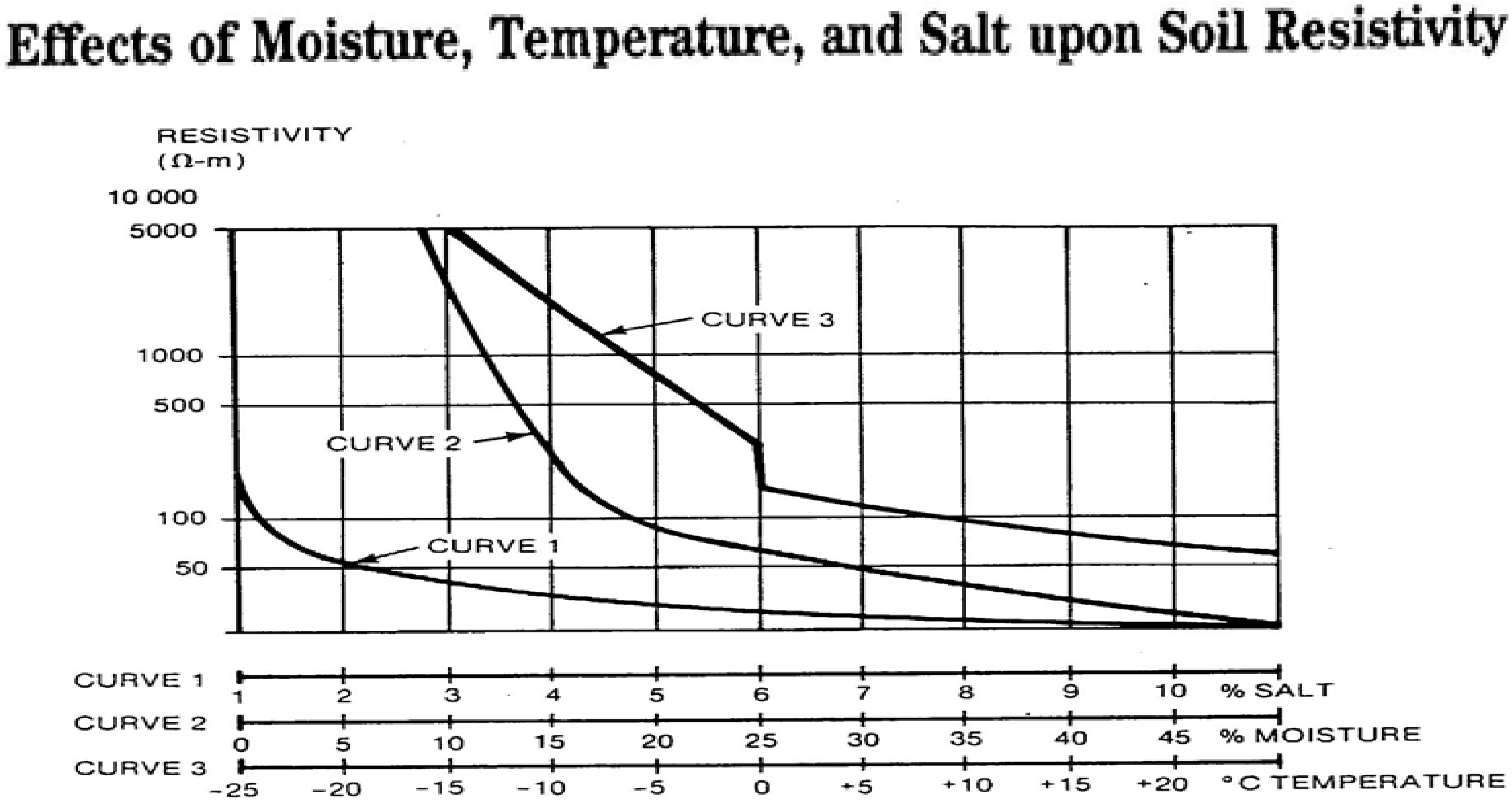
Clamp-On Type Earth Resistance Tester

Rod Earth Resistance Tester



Phenomena Effect Ground Resistance

- Soil Moisture
- Soil Mineral Content
- Temperature



Lightning & Surge Arrestor

What is lightning?

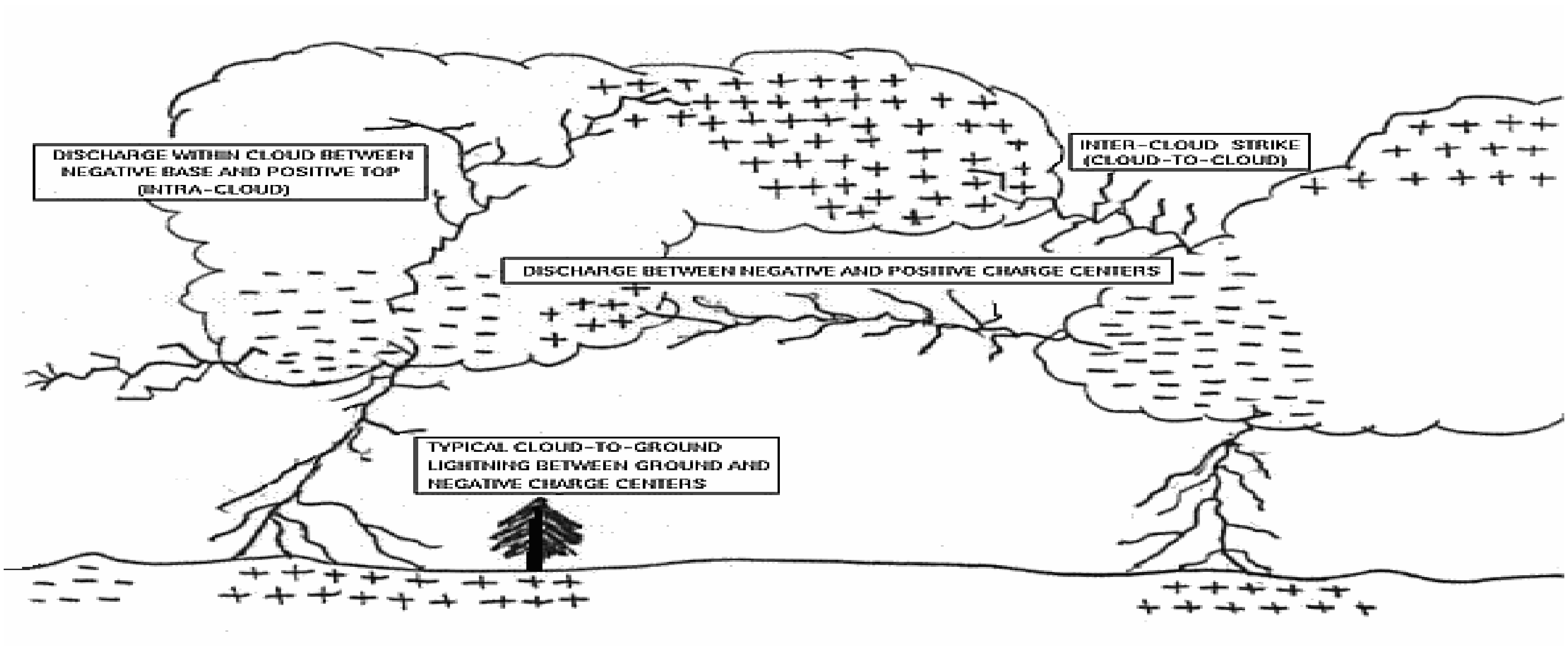
Lightning is Produced due to a charge & discharge of static electricity caused by the atmosphere (The conditions for lightning are normally hot and humid). and usually occurs during rain storms and comes with thunder.

An electric discharge, or spark, that occurs in thunderstorms (usually)

- 80% occurs within clouds
- 20% occurs between cloud and ground

Lightning is ubiquitous , with more than 6,000 ground strikes per minute from 40,000 thunderstorms per day worldwide

An electric discharge



Types of lightning

- **Ball lightning**
- **Fork lightning.**

Ball lightning

Ball lightning characteristics

- Floating ball of **electric charge**
- Do not have a usual speed the speed at which they float depends on the conditions they are in.
- They make crackling or hissing noises and have been known to enter houses and disappear with a bang
- They are **very rare**.

Fork Lightning

Fork lightning characteristics

- This is lightning that bolts straight to the ground in two prongs شوكة often.
- It bolts down like this because it is a sudden release of electrical energy rather than a collection of energy mixed with ball lightning is.
- Fork lightning is the most common type of lightning it has very many.

Effects of lightning

Lightning has very many effects on the environment it can be very destructive here are some ways in which it can do damage.

It can **hit tall objects** like trees making them fall or setting them alight.

Lightning has melted the wing of this plane.

This hole was ripped in someone's ceiling after their house was hit by lightning.

Lightning has very many effects on the **Human** it can be very destructive here are some ways in which it can do damage.

Over **1000 people** get struck by lightning in America every year and only 100 of those people are likely to die.

The main cause of death if hit by lightning is cardiac arrest توقف قلبى(when your circulatory system stops working).

If you do survive your **nervous system** and your brain may suffer damage. People who have been hit by lightning often have memory difficulties…………

Facts about lightning

- Each second there are 50 to 100 Cloud-to-Ground Lightning Strikes to the Earth world-wide.
- An average lightning strike is between 2-3 miles long and carry a voltage of **100,000,000 volts**. (**10,000 amps**)
- The **typical temperature of a lightning** is hotter than the surface of the sun.
- Lightning strikes, like stars, are almost impossible to see during the day but at night it can be seen for 100 miles.

Lightning Arrestor

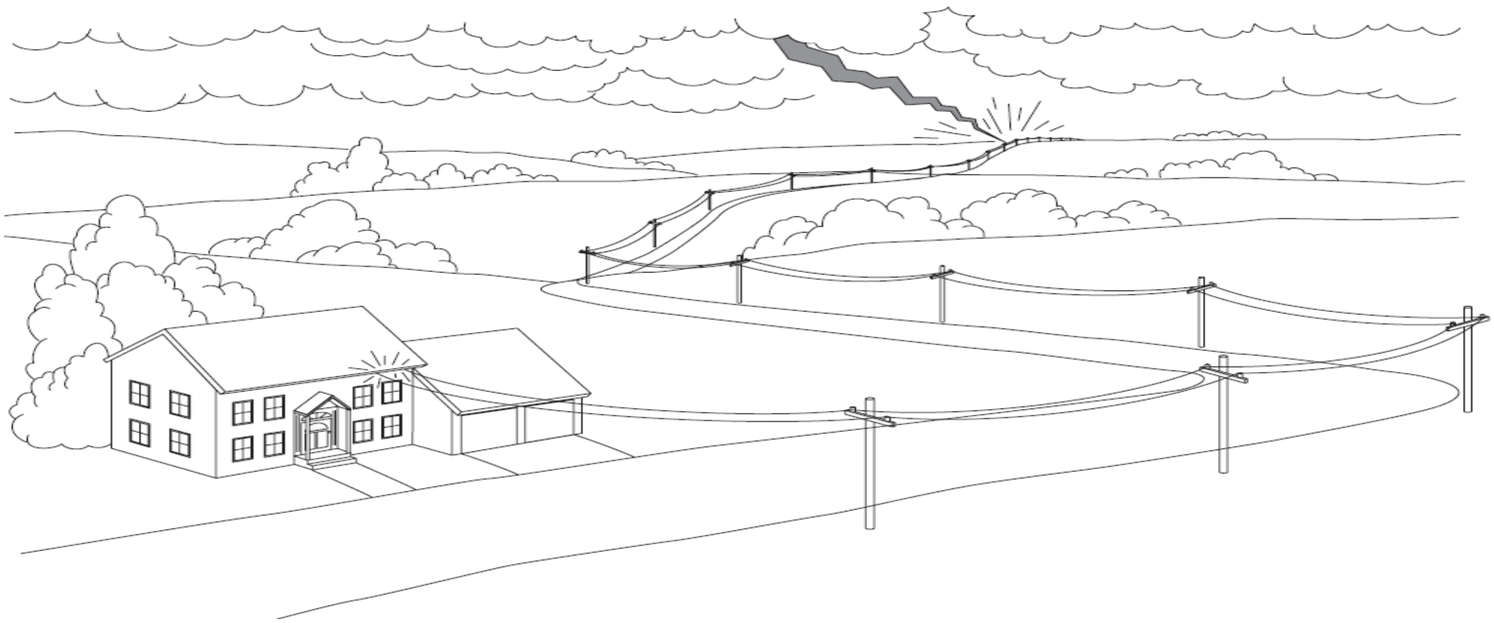
To protect the equipment , devices , tress and all installation against the damages which could happen in the event of a lightning strike, special equipment of different installation set-up are used.

The prime element of these electrical safety equipment is the **lightning arresters** which are installed **on the highest point of an installation** which are most liable to be struck by the lightning.

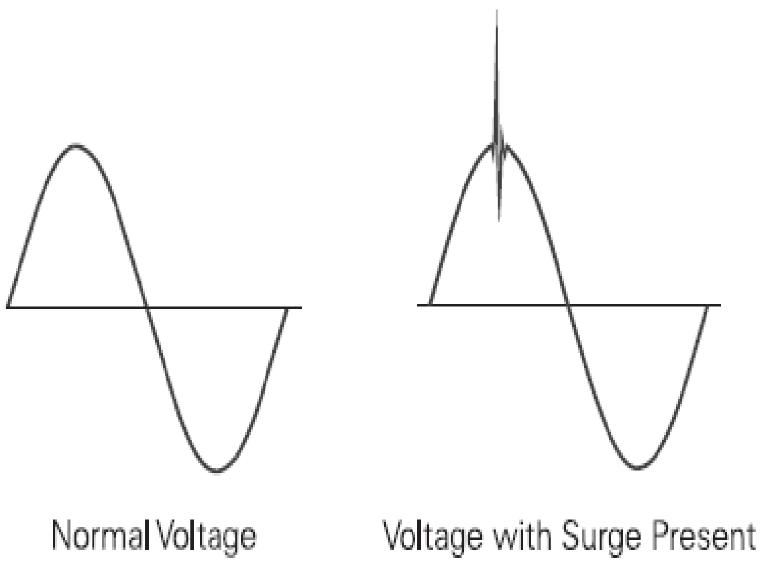
Lightning arresters are actually part of the earthing system of an installation and are, therefore, appropriately connected to the earthing grid by means of separate purpose made earth wells.

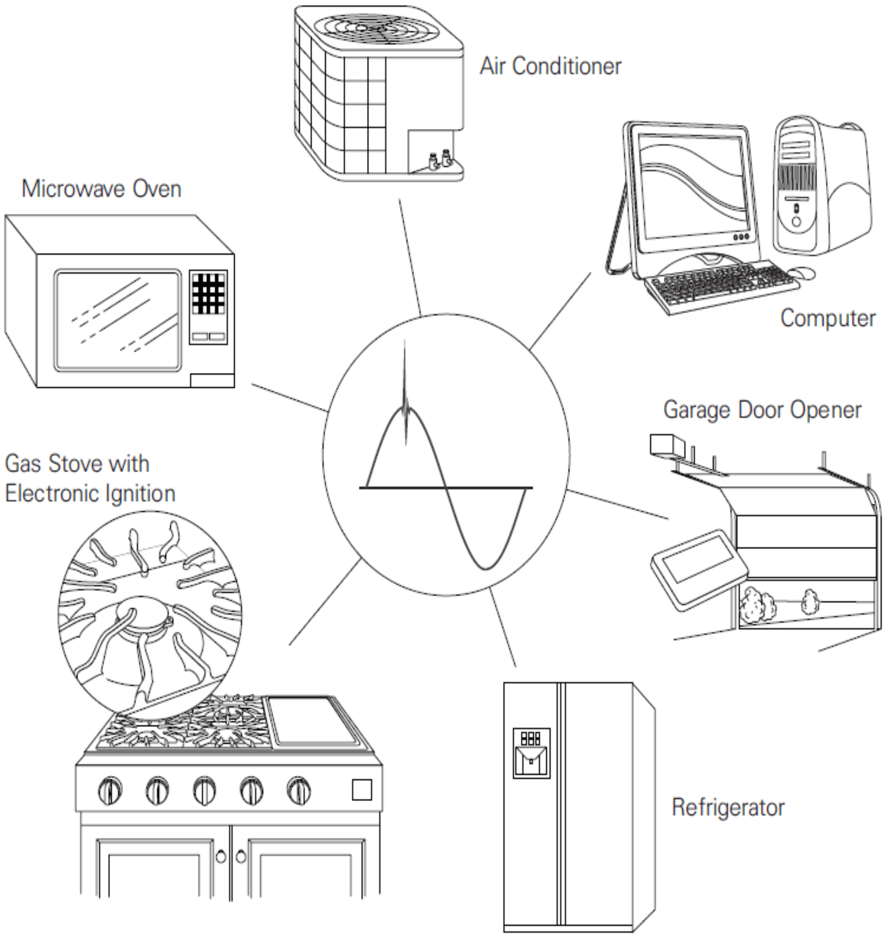
Lightning / Surge Arrestor Idea Of Operation

In case of lightning an up normal value of voltage can applied in devices , equipment , installation ….. , **The main idea of lightning arrestor is to absorb this high value of voltage produced from lightning and passé it to earthing grid through earthing cables**

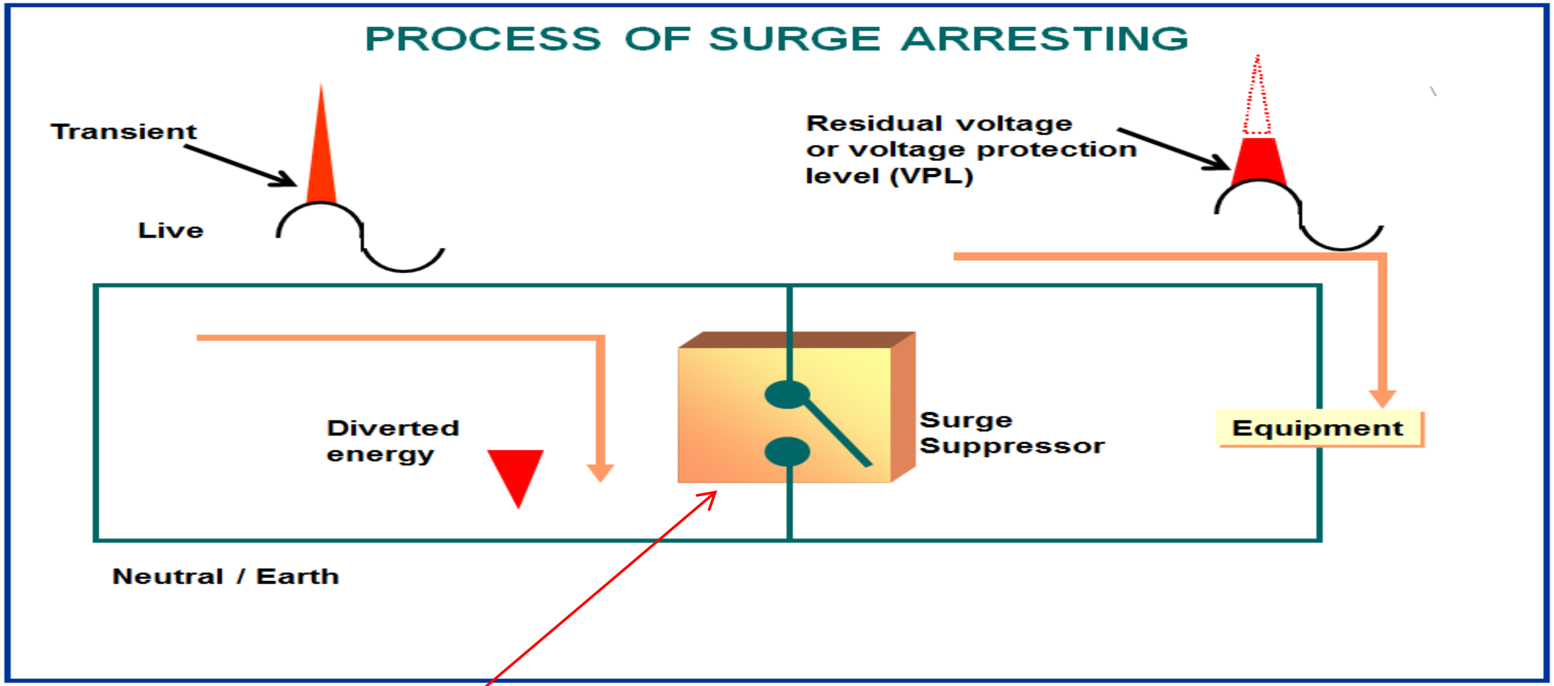


Applied voltage wave form in all home , factories , sites ,…. Devices in normal condition





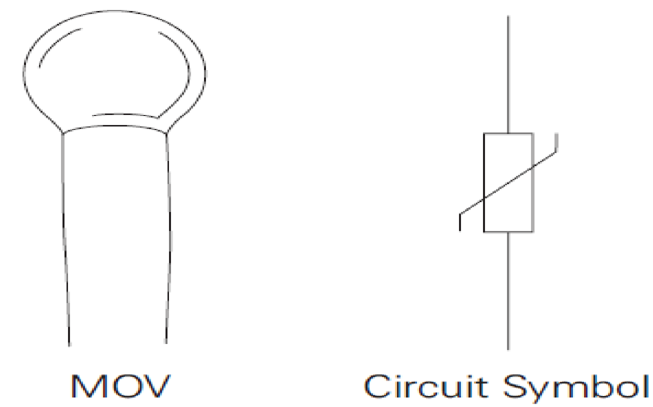
Applied voltage wave form in all home , factories , sites ,…. Devices in Lightening condition

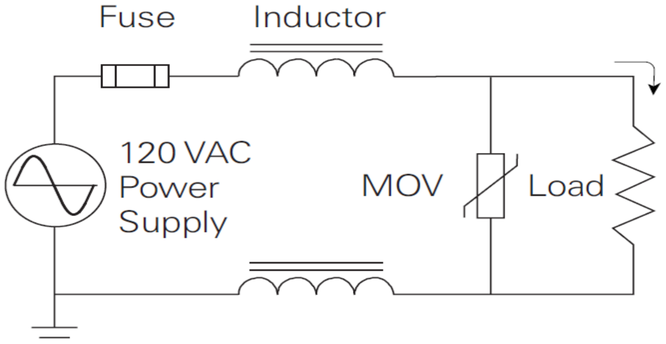


In normal condition this switch open and at case of up normal condition this switch is closed

The Switch

Is A **metal oxide varistor** (MOV) is a device commonly used in **surge protectors**. There are two characteristics of MOVs that make them desirable for surge protection. First, the resistance of an MOV decreases with an increase in voltage. In addition, MOVs are fast acting and can respond to a surge in just a few nanoseconds. This results in suppressing a surge before it has a chance to damage electronic equipment.



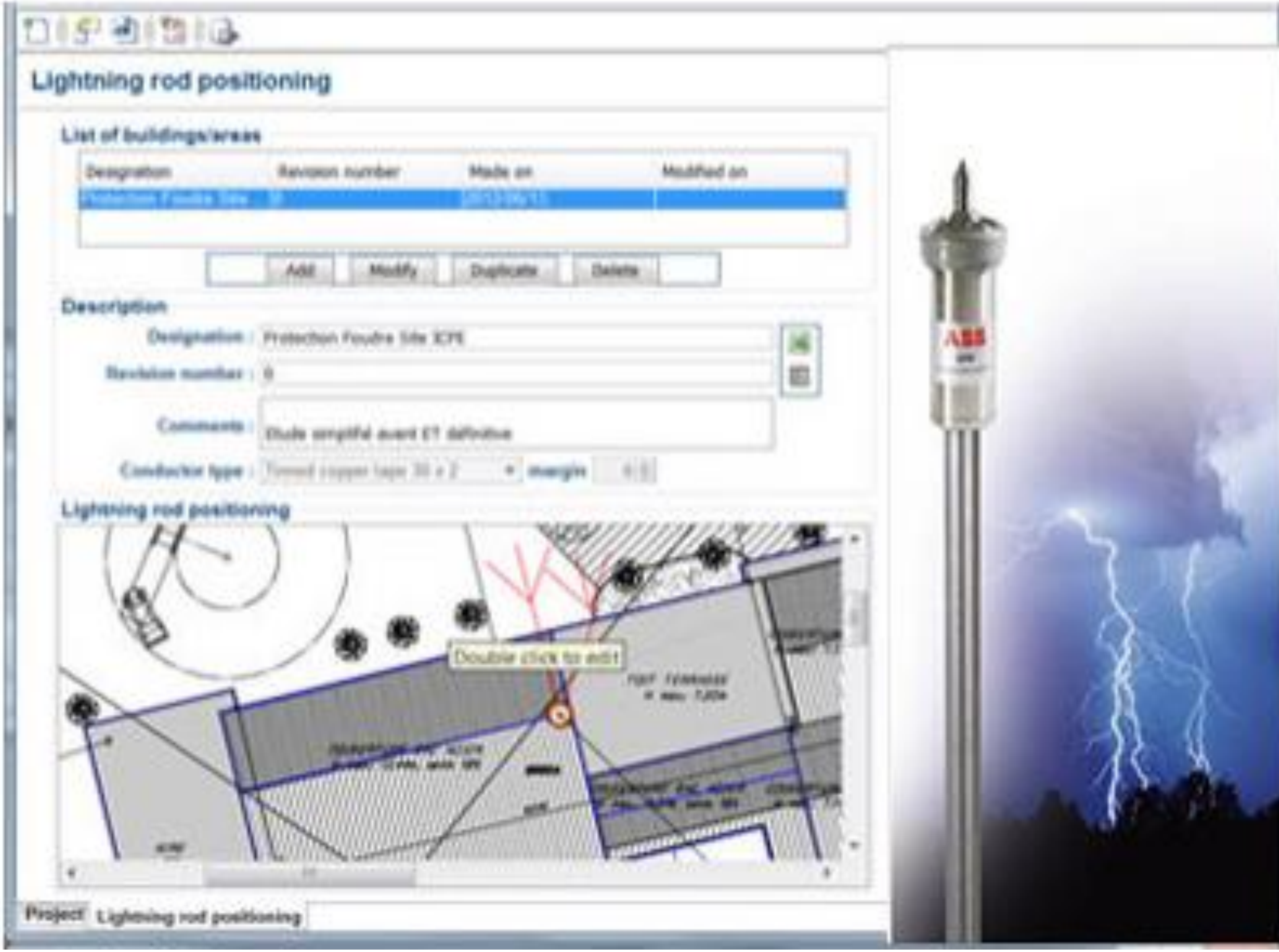


Normal Voltage

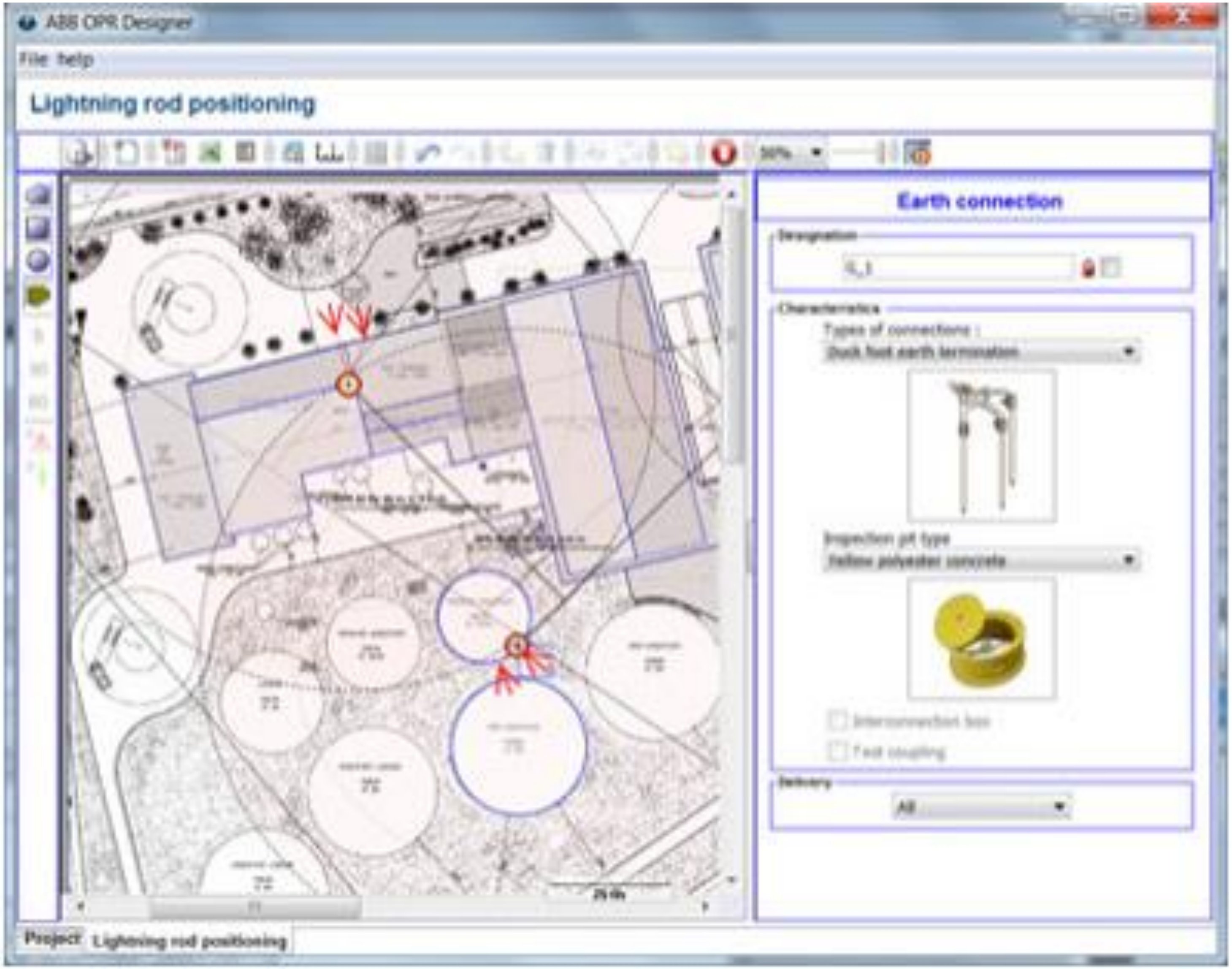
Typical Lightening Arrestor

CDRisk software

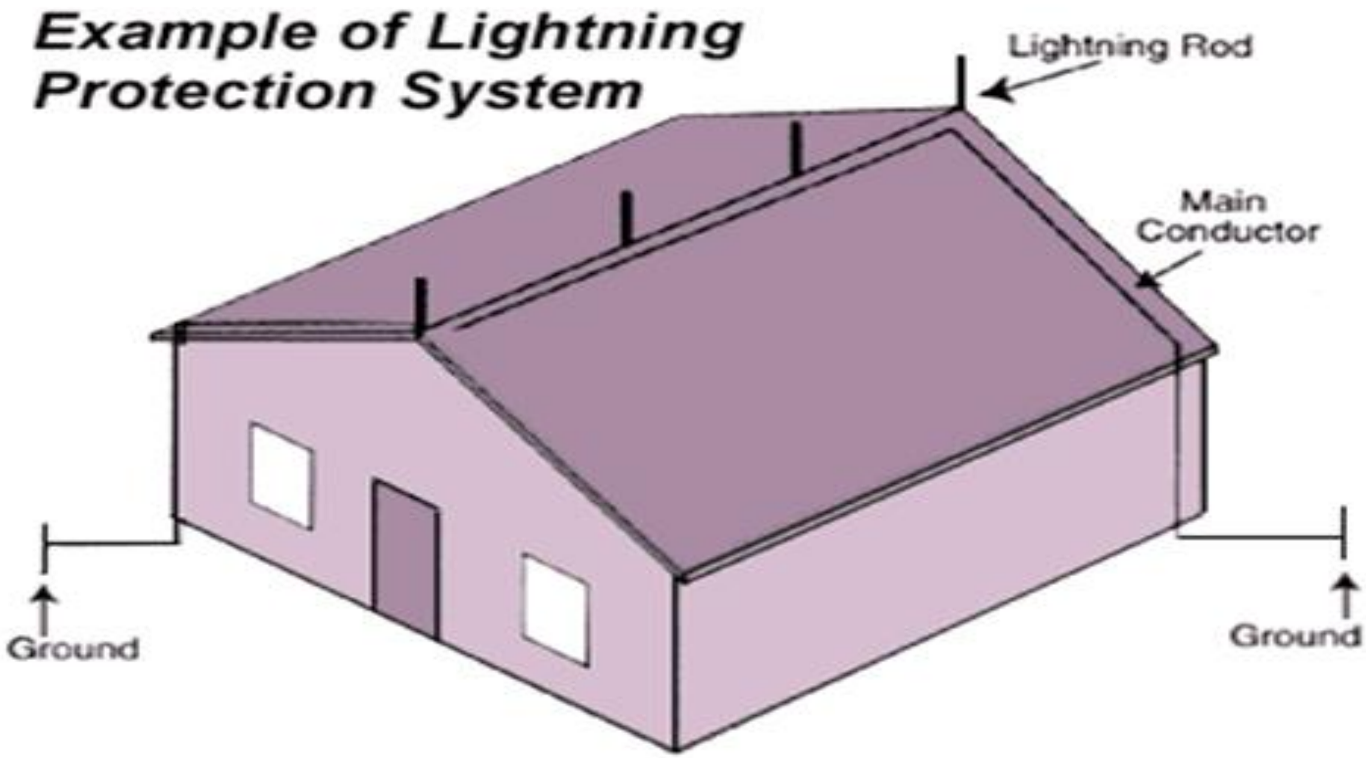
OPR Designer software



OPR Designer software



Home Lightning arrestor



Let's look at example involving the installation of a lightning conductor.

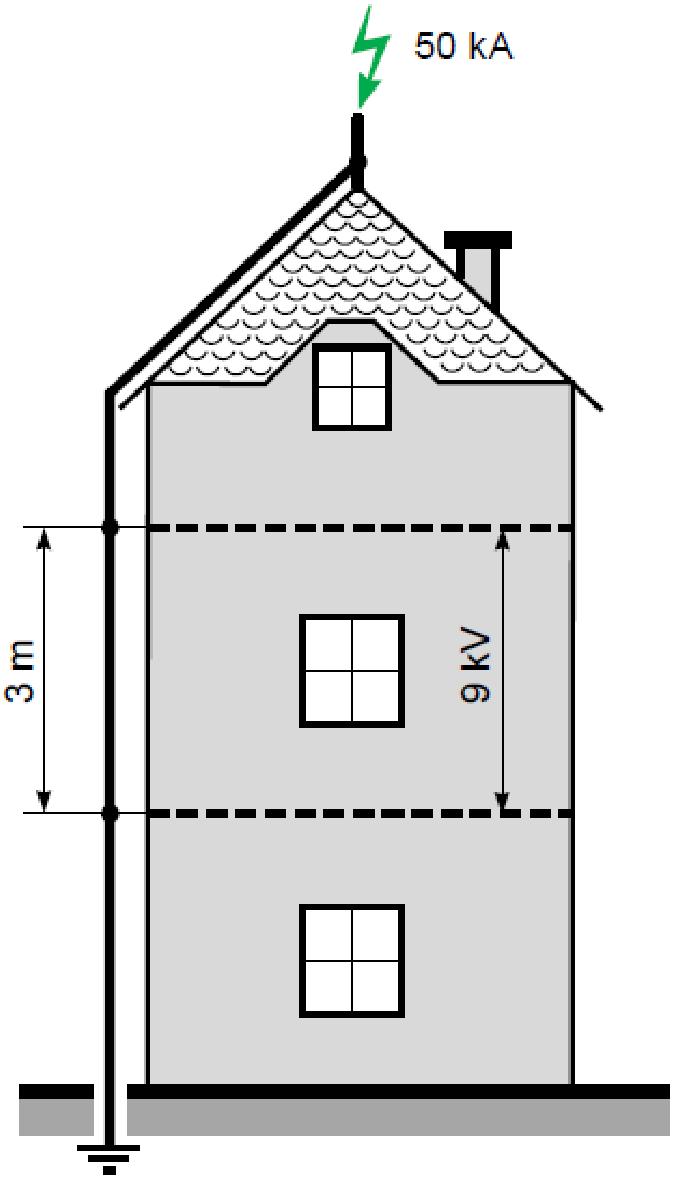
We will assume that the partly metal floors are linked to the lightning rod down comer where:

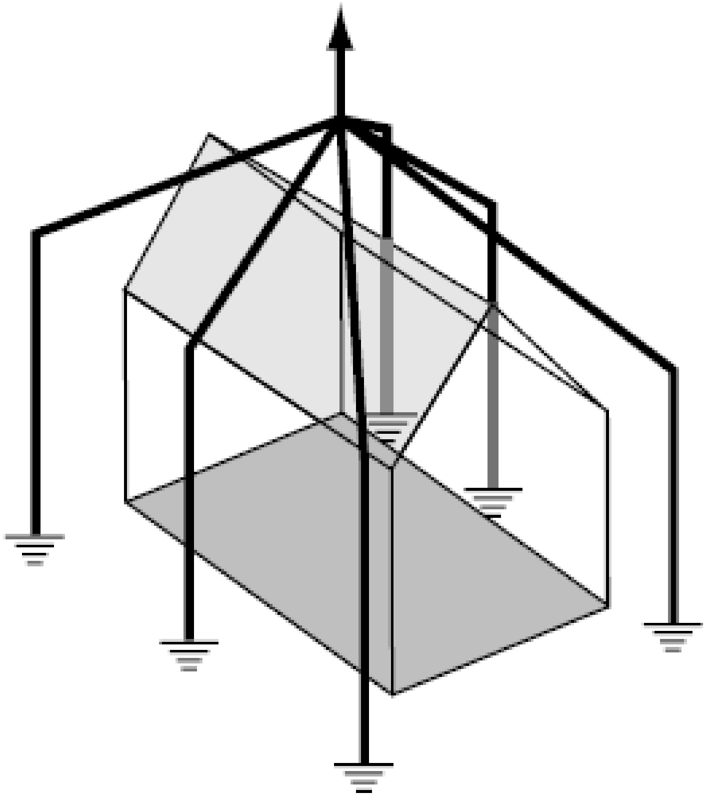
L = 0.5 mH/m (flat conductor)
length of the conductor = 3 m
$\hat{I}$ = 50 kA
the ΔV between floors will be:

$$\Delta V = L\frac{di}{dt} = 1.5 \times 10^{-6} x \frac{50 \times 10^{3}}{8 \times 10^{-6}} = 9.4\ k\hat{v}$$

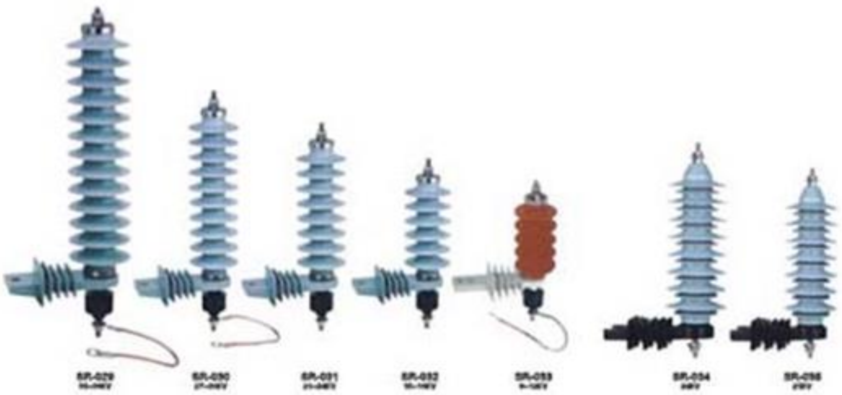
The equipotentiality in the building may be jeopardized!

One solution is to use multiple lightning conductors and keep them away from all electrical circuits, but a better solution is to use a "bell-shaped" Faraday cage


50 kA
3 m
9 kV



Typical Surge Arrestor


SR-029
SR-030
SR-031
SR-032
SR-034


SR-044
110KV
SR-045
SR-046
SR-047
110KV


SR-036
SR-037
SR-038
SR-039


SR-048
10KV
SR-049
SR-050
10KV
SR-051
SR-052
10KV

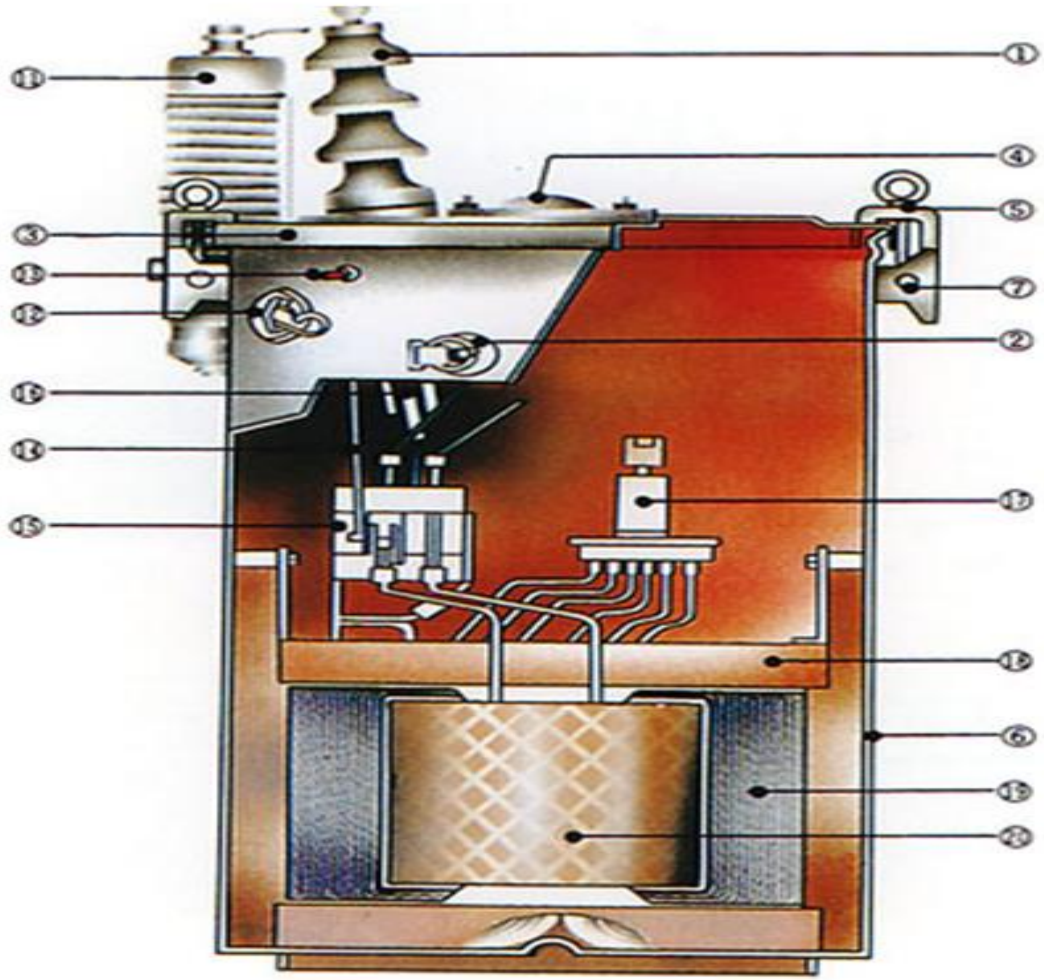

SR-040
SR-041
SR-042
SR-043


SR-053
SR-054
SR-055
SR-056
SR-057
SR-058

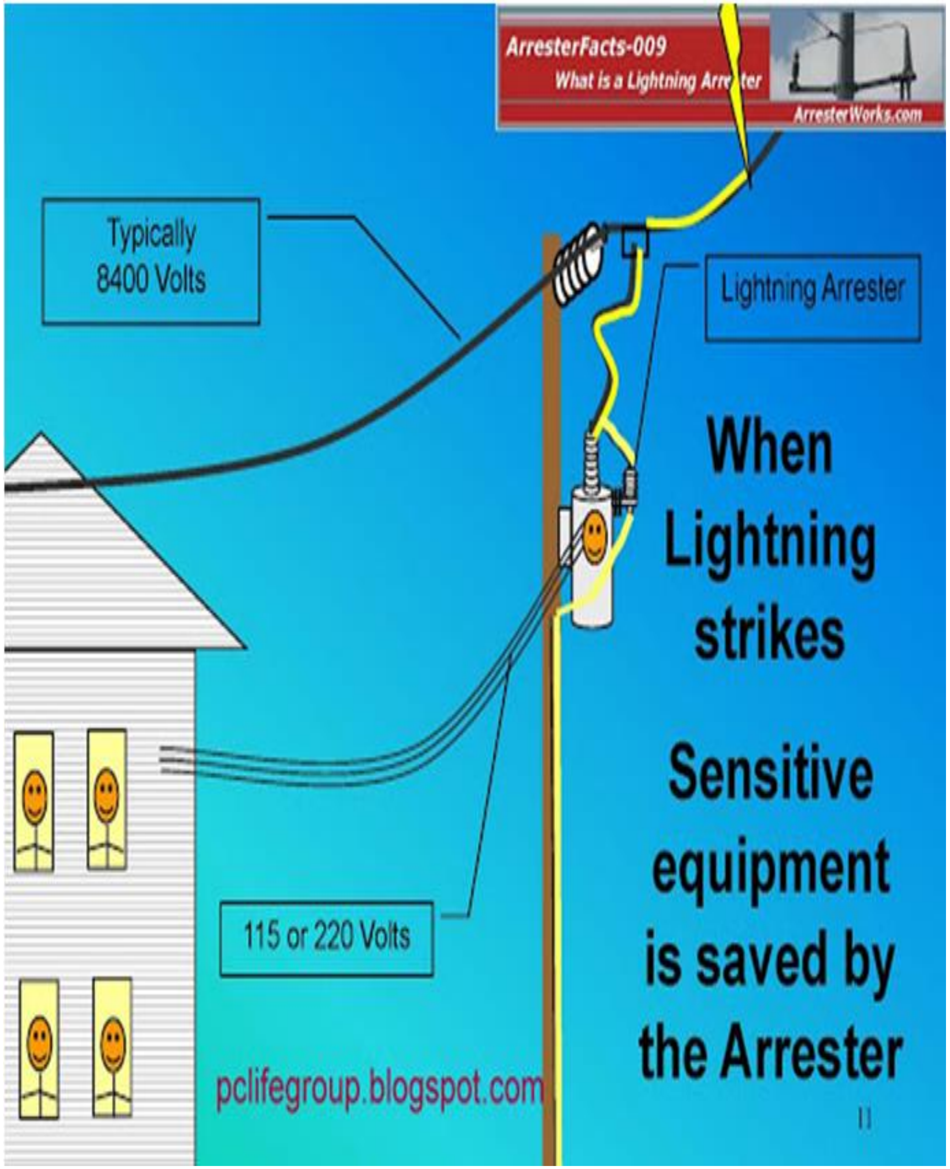
Transformer Surge arrestor

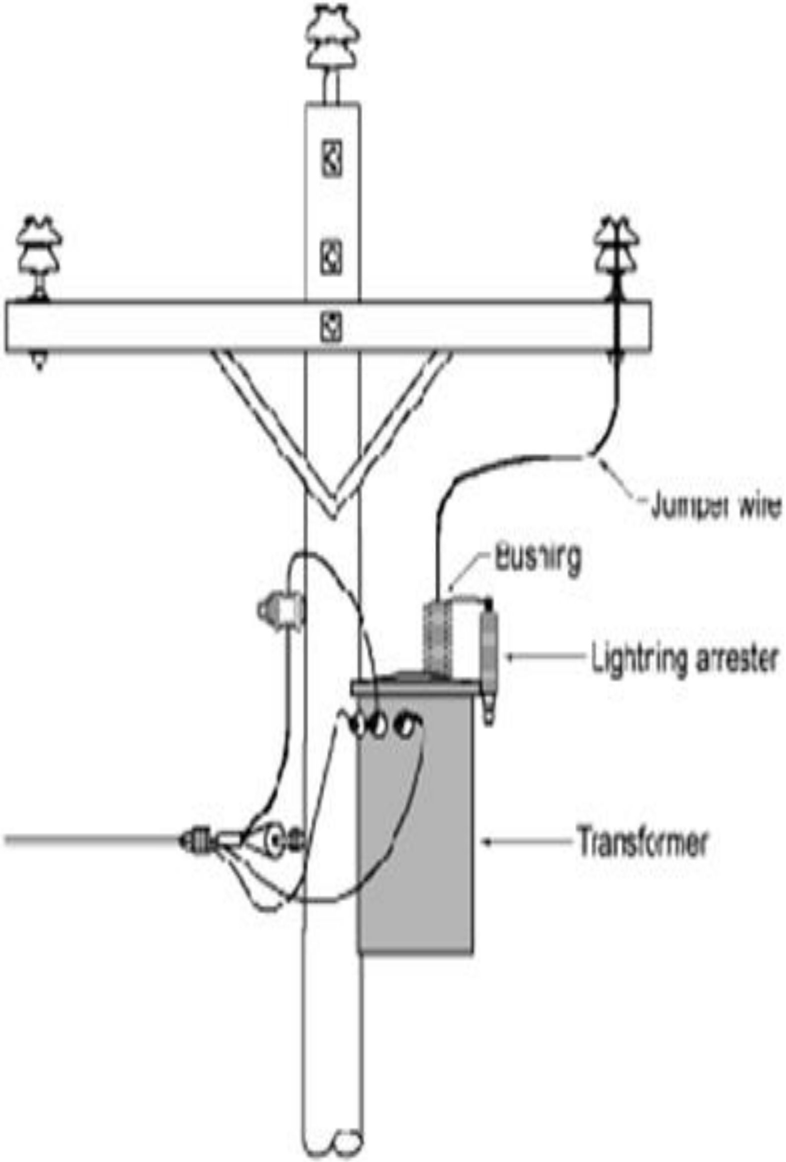
Transformer Lightning arrestor

① HV Bushing
② LV Bushing
③ Cover
④ Hand Hole
⑤ Cover Clamp
⑥ Tank
⑦ Lifting Lug
⑧ Hanger Lug (not shown)
⑨ Grounding Pad (not shown)
⑩ Name Plate (not shown)
⑪ HV Surge Arrester
⑫ Circuit Breaker Operating Handle with Emergency Overload Reset Lever
⑬ Signal Lamp
⑭ Breaker Operating Rod
⑮ LV Circuit Breaker
⑯ Protective Link
⑰ Tap Changer
⑱ Core Clamp
⑲ Core
⑳ Coil



Electrical Tower Lightning Arrestor





Person - Lightning Safety Position (LSP)

Crouch with feet as close together as possible.

Have heels touch.

Place hands over ears.

REMEMBER DO NOT LIE FLAT ON THE GROUND