

# Industry Based Earthing System – A Case Study

**Aarti P. Malge, Nikita H. Mankar, Roshan R. Bangare, Rohit K. Hadap,  
Satyam L. Tikhade, Shubham B. Meshram**

*Students, Dept. of Electrical Engineering,  
Priyadarshini College of Engineering, Nagpur, India, 440016*

**Abstract** – Earthing (or grounding) is an essential part of any electrical installation. Within industrial plants with potentially explosive atmospheres earthing plays an essential role in maintaining the electrical systems in safe condition. The earthing system, although a single physical system, it carries out many different functions including automatic detection and clearance of electrical faults, prevention of dangerous potential differences which could cause injury, prevention and dissipation of static charges and save or increase the life of equipment which comes under grounding. Thus, the aim of this paper is to study earthing system of the industries and save life of their valuable costly equipments.

**Keywords-** Step potential, touch potential, ELCB, CI pipe earthing, plate earthing, earthing system for various equipment, drawbacks of failure of earthing system.

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## INTRODUCTION

Electrical installation in industries become important and it is necessary to use modern electrical installation methods. Earthing is very important, particularly since a large majority of faults involve ground or are caused by thunderstorm/lightning strikes. The terms earthing and grounding have the same meaning and it is a mean of making a connection between the equipment and the earth. Earth behaves as an Electrical conductor but its characteristics is that its conductivity is variable and unpredictable. The resistance of an earth connection varies with earth's composition, chemical contents, moisture, temperature, season of the year, depth and diameter of rod and other reasons. The principal purpose of earthing is to minimize potential transient overvoltage, in compliance with standards for personnel safety requirements and to assist in the rapid detection and isolation of the fault areas. Grounding connection is accomplished by driving ground electrode into several places of the earth. The installation of an earth electrode is an important factor in achieving a satisfactory earthing system.

The objective of earthing system is to provide a surface under and around a station, industry which shall be at a uniform potential (nearly zero or absolute earth potential). This Earth surface should be as nearly as possible to the system. This is in order to ensure that, all parts of apparatus other than live parts and attending personnel shall be at earth potential at all times. Due to this there exists no potential difference, which could cause shock or injury to a person, when short circuit or any other type of abnormalities takes place.

## LITERATURE

**NECESSITY OF EARTHING**

1. To provide the grounding of all conductive enclosures that may be touched by personnel, thereby eliminating shock hazards.
2. To reduce static electricity that may be generated within facilities.
3. To provide protection from large electrical disturbances (such as lightning) by creating a low resistive path to earth.

**FACTORS ON WHICH EARTH RESISTANCE DEPENDS**

1. Type of soil
2. Temperature of soil
3. Wetness of soil
4. Minerals in earth
5. Shape of earth electrode
6. Size of earth electrode
7. Depth of electrode in earth
8. Diameter of earth electrode
9. Number of ground electrodes
10. Distance between two electrode

**SYSTEM OR NEUTRAL EARTHING**

- This is primarily concerned with the protection of electrical equipment by stabilizing the voltage with respect to ground (Connection between part of plant in an operating system like LV neutral of a power Transformer winding and earth.)
- Neutral is a circuit conductor that may carry current in normal operation, and is connected to ground (earth) at the main electrical panel.
- In a poly-phase or three-Wire (three phase) AC system, the neutral conductor is intended to have similar voltages to each of the other circuit conductors.

**METHODOLOGY**

**1. EQUIPMENT EARTHING**

This is primarily concerned with the protection of personnel from electric shock by maintaining the potential of noncurrent carrying equipment at or near ground potential. Connecting frames of equipment (like motor body, Transformer tank etc. to earth.

**STEP POTENTIAL**

It is the potential difference available between the legs while standing on the ground. It is the difference in the voltage between low points, which are one meter apart along the earth when ground current is flowing.

**TOUCH POTENTIAL**

It is the potential difference between the leg and hand touches to the equipment.

**ELCB- EARTH LEAKAGE CIRCUIT BREAKER**

An Earth-leakage circuit breaker (ELCB) is a safety device used in electrical installations with high earth impedance to prevent shock. It detects small stray voltages on the metal enclosures of electrical equipment, and interrupts the circuit if a dangerous voltage is detected. Once widely used, more recent installations instead use residual current circuit breaker which instead detect leakage current directly.

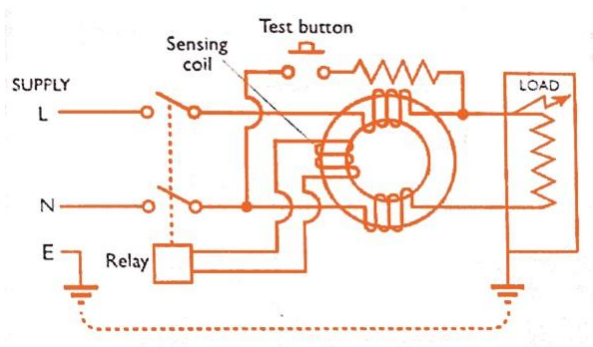


FIG.1: CONSTRUCTION OF ELCB

Basically, there are two types of ELCB: voltage operated and current operated ELCB.

**CONSTRUCTION OF ELCB**

Voltage operated ELCB operates at a detected potential of around 50 V to open a main breaker and isolate the supply from the protected zones. But since it operates at 50 V, it is not been used in newer domestic wiring as the 50 V is still considered as safe voltage for alternating current.

For newer domestic wiring, current operated ELCB is more preferable to be installed in premises due to reliability. Current-operated ELCB is generally known as residual current device (RCD). The function is similar, which protects against earth leakage, though the details and method of operation are different. [1]

2. CI PIPE EARTHING

- Pipe earthing is the best form of earthing and is very cheap in cost
- In this method of earthing, a cast iron pipe of approved length and diameter is placed up right in the ground.
- The size of the pipe depends upon the current to be carried and the type of the soil.
- Usually it is of diameter upto 110 mm and 1.5 to 3 meters deep in length for ordinary soil or of greater length in case of dry and rocky soil. [2]

LT EARTHING ELECTRODES							
NB mm	OD mm	THICKNESS (mm)	LENGTH OF ELECTRODE (m)				
50	57	3.5	1.5	1.8	-	-	-
75	82	3.5	1.5	1.8	2.5	2.75	2.9
100	108	4.0					
150	160	5.0					

HT EARTHING ELECTRODES							
NB (mm)	OD (mm)	THICKNESS (mm)	LENGTH OF ELECTRODE (m)				
100	114	7.0	2.5	2.75	3.0		
100	120	10.0					
100	126	13.0					
150	170	10.0					
150	176	13.0					

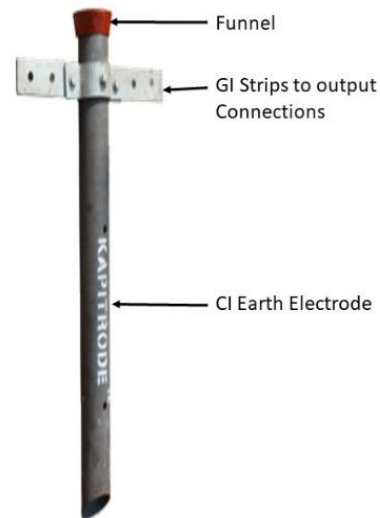


FIG.2: EARTH ELECTRODE

3. PLATE EARTHING

The earthing plate is placed deep into a pit (usually dug up to 1.5 to 3 meters), along with back filling component eg. Bentonite. The plate is connected via Copper conductor, or GI Conductor or concealed copper cable to the respective electrical set-up. A funnel is attached to add water at regular intervals. The plate electrode is buried vertically. The whole earthing system must be copper or GI, and bolts should be used of Brass. Copper earthing is the best in plate type earthing system because of very low resistance than GI. [2]

**Earthing Plate Size:**

Copper plate

For LT – 600 mm x 600 mm x 3.18 mm

For HT – 900 mm x 900 mm x 6 mm

GI plate

For LT – 600 mm x 600 mm x 6.35 mm

For HT – 900 mm x 900 mm x 6 mm

4. METHOD OF INSTALLATION

1. Piling

Installation process start with piling. Pile diameter should be twice of earthing electrode diameter. Similarly earth pit holes can be made by manual as well as boring process depending upon number of earth pits to be done so that it should be cost effective.

## 2. Back Filling

Variety of back filling procedure is adopted by customers depending upon soil conditions. Commonly used practice is to form alternate layers of back fill compound and soil treated with water for moisture.

Generally recommend 20 kg bag for LT earthing and 40 kg bag for HT earthing depending upon soil conditions.

## 3. Inserting Electrodes

Earthing electrode is inserted in soil. Specification of electrodes depends upon load, type of soil, and other related parameters.

## 4. Earth Pit

After successful installation of earthing electrode, earth pit chamber is made below or above ground level as per requirement which can be covered by cast iron cover available in different sizes.

Earth Pit Design Detail

Earthing Pit Size: 1000 X 1000 X 1800 mm Depth  
M.S. / C.I. Plate Size: 500 X 500 X 8 mm Thick

## ANALYSYS

### EARTHING SYSTEM FOR VARIOUS EQUIPMENT

#### 1. EARTHING OF RESIDENTIAL UNIT

The following is the method of implementation of earthing:

1. Low earth resistance is required to give effective earthing protection to electrical fittings.
2. Dry earth has more resistance whereas moist earth has less resistance.
3. The location of earthing point should be minimum 3 feet away from residential unit.
4. The location of earth pit should be such where the soil has reasonable chances of having moisture. If possible earth plates or pipes should be located near water tap, water drain or rain water pipe.

5. Electric earthing may be either pipe or plate earthing.
6. Normally GI pipe (2.5 inch diameter) or plate (600 mm X 600 mm X 3.18 mm) is used but if the soil is corrosive then copper pipe or plate should be used.
7. Use Double GI Strip size 25 mm X 2.5 mm to connect GI Plate to System Earthing.
8. 8 SWG GI wire should be used for internal connection.
9. Use back filling component like bentonite for low soil resistance.
10. The position of the earth plate or pipe when fixed should be clear from all building foundations.
11. Inside building in addition to all electrical appliances, all switch boxes, meter boxes etc. should be earthed also.

#### 2. EARTHING OF COMMERCIAL UNIT-HOSPITAL

Equipments used in the hospital is very costly and sensitive, it ensures an immediate discharge of electrical energy without any danger. It is the most essential part of electric work which must be provided to protect from any mishap. It saves human life from sudden electric shock. When proper earthing is done in building, it saves building of thunder effects i.e. from fall of natural cloud lighting. In case of a short circuit due to leakages arising from weak insulation or damage there is more chances of damage of equipments, if provided earthing is not proper.

The electrical safety in medical institutions covers complex questions, solved at the electrical supply of the separate consumers, according to the acting normative system in this field. It is known that the sick person has lower body resistance towards electric current where an additional safety requirement is needed. Medical institutions with sensitive and critical loads require reliability of the electrical supply, accuracy working of the contemporary complicated electronic medical devices, and high degree of personnel safety from direct injury with electric current.

Max commercial units consists of various equipments like transformer, solar panels, DG set, etc. so here the earthing system provided should be in separate manner i.e. each equipment should be separately earthed.

Type of Earthing To Be Used – CI Pipe Type  
 Size of Electrode – Ø120 mm, 3000 mm length  
 Size of GI Strip – 25mm x 2.5 mm  
 Number of Earthing Pipes required = Total Fault Current / Maximum current dissipated by one earthing pipe/electrode

### 3. EARTHING OF SUBSTATION EQUIPMENT

#### (33KV SUBSTATION)

Provision of adequate grounding in a substation and switching stations are very important for the safety of operating personnel as well as electrical devices do not rise above tolerable thresholds and that the earth connection is rugged to dissipate the fault to the earth. The importance of an effective, durable and a dependable earth for ensuring safety from electrical hazards does not require to be elaborated upon more. By earthing, connecting the electrical equipment to the general mass of the earth, this has a very low resistance.

#### Values of earth resistance in substation should be less than

1. Generating station	0.5 Ω
2. Large substation	1.0 Ω
3. Small substation	2.0 Ω
4. From earth electrode to internal assembly	2.0 Ω
5. Neutral bushing	2.0 Ω
6. Service connection	4.0 Ω
7. LT lightning arrester	4.0 Ω
8. LT pole	5.0 Ω
9. HT lightning arrester	8.0 Ω
10. HT pole	10.0 Ω
11. Tower	25.0 Ω

#### ISOLATORS AND SWITCHES

A flexible earth conductor is provided between the handle and earthing conductor attached to the mounting bracket and the handle of switches is connected to

earthing mat by means of two separate distinct connections made with MS flat. One connection is made with the nearest longitudinal conductor, while the other is made to the nearest transverse conductor of the mat.

#### LIGHTNING ARRESTERS

Conductors as short and straight as practicable to ensure minimum impedance shall directly connect the bases of the lightning arresters to the earth grid. In addition, there shall be as direct a connection as practicable from the earth side of lightning arresters to the frame of the equipment being protected.

In the case of lightning arresters mounted near transformers, earthing conductor shall be located clear off the tank and coolers in order to avoid possible oil leakage caused by arcing.

The resistance of earthing should be as low as possible, so that the current in lightning arrester, which is caused by excessive electrical pressures on the line, due to lightning stroke, should go into the uncontrolled soil and avoid potential damage.

#### CIRCUIT BREAKERS

For every breaker there will be five earth connections to the earth mat with: MS flat

- ( i ) Breaker body
- ( ii ) Relay panel
- ( iii ) CTs of the breaker
- ( iv ) Two side of the breaker structure.

#### TRANSFORMER

It is essential to earth transformer for better performance and safety of transformer. Mainly transformer consists of four earthings which two are connected to neutral to the star point of LV side of the transformer and two for the body i.e. transformer tank to pass the leakage current and ground it for better safety.

#### Purpose of transformer neutral bushing

1. Leakage or unbalanced current is dissolved by the earthing.
2. Possible to install high sensing protection equipment.

3. Help to reduce extra high voltage on line due to lightning or switching surge.
4. Helps to control fault current by connecting resistance in neutral earth.
5. Always helps to keep neutral voltage zero.

The tank of each transformer shall be directly connected to the main grid. In addition there shall be as direct connection as practicable from the tank to the earth side of projecting lightning arresters. The earthing of neutral bushing shall be by two separate strips to the earth grid and shall likewise be run clear to rank cell and coolers.

#### CURRENT TRANSFORMERS AND POTENTIAL TRANSFORMERS

The supporting structures of Current Transformer and Potential Transformer unit of bases, all bolted cover plates to which the bushings are attached connected to the earthing mat by means of two separate distinct connections made with MS flat. One connection is made with the nearest longitudinal conductor, while the other is made to the nearest transverse conductor of the mat.

#### OTHER EQUIPMENT

All equipment's, structures, and metallic frames of switches and isolators shall be earthed separately

#### FENCES

The Sub-station fence should be generally too far outside the substation equipment and grounded separately from the station ground. The station and the fence ground should not be linked.

If the distance between the fence and station structures, cannot be increased at least five feet and if the fence is too near the substation equipment structure etc., the station fence should be connected to the fence ground.

#### GROUND WIRE

All ground wires over a station must be connected to the station earth grid. In order that the station earth potentials during fault conditions are not applied to

transmission line ground wires and towers, all ground wires coming to the station must be broken at and insulated on the station side of the first tower or pole external to the station by means of 10" disc insulator.

#### CABLES AND SUPPORTS

Metal sheathed cables within the station earth grid area must be connected to that grid. Multi-core cables must be connected to the grid at least at one point. Single core cables normally should be connected to the grid at one point only.

#### PANELS AND CUBICLES

Each panel or cubicle should be provided near the base with a frame earth bar of copper to which shall be connected the metal bases and covers of switches and contactor unit.

#### INSTRUCTIONS ABOUT EARTHING IN SUBSTATION

1. On pole of HT line, fittings of all metal parts i.e. cross arm, top fittings, pins of insulator, clamps, etc. should be fixed by using GI wire of 8 SWG.
2. On pole of LT line, fittings of all metal parts and stay should be connected to neutral and then this neutral is to be solidly earthed with multiple earthing.
3. The earth wire of lightning arrester should not connect to any pole, it directly pass from the alkathene pipe and tightly connected to earth electrode.

Type of Earthing To Be Used – CI Pipe Type

Size of Electrode – Ø 120 mm, 3000 mm length

Size of GI Strip – 25mm x 2.5 mm

Number of Earthing Pipes Used = Total Fault Current / Maximum current dissipated by one earthing pipe/electrode

#### 4. EARTHING OF WEIGHBRIDGE

A basic weighbridge system consist of weighbridge platform with load cells, a junction box, a weight indicator, a personal computer and printer.

Load cell of weighbridge are always connect in pair (ex. Pair of 2, 3, 4,). Number of load cell use in weighbridge is depends on the maximum Weight to be measured. Normally weighbridge platform with four load cell is used as shown in below fig 3.

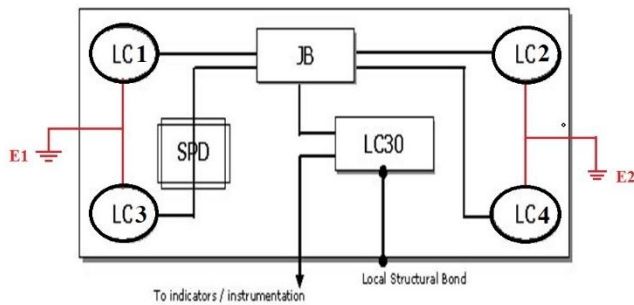


FIG.3: BRIDGE HAVING FOUR LOAD CELL

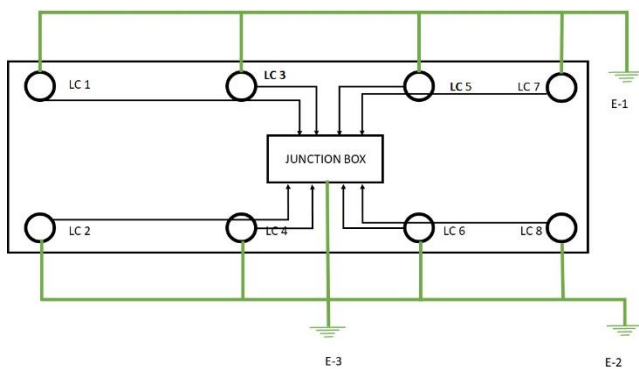


FIG.4: WEIGHBRIDGE HAVING EIGHT LOAD CELL

- In eight load cell weighbridge, load cells 1, 3, 5, 7 are connected in parallel with each other and similarly load cell 2, 4, 6, 8 are connected in parallel electrically with each other.
- Each load cell having five terminals having 2 for incoming and two for outgoing and other one remaining terminal is connected to earth. Load cells 1, 3, 5, 7 and 2, 4, 6, 8 are earthed separately in two earth connection as shown in fig 4.
- If load cells are mounted between the hylum sheets then the earthing of load cell is to be eliminated.
- The voltage between earth connection and neutral point of supply is generally varying in between 1V to 2V, but not exceeds more than 3V. And the minimum resistance of earth electrode will be less than 7 Ω.
- If this voltage more than 3V, it is considered that earth system of weighbridge fails to work. Then the following action takes place:

- Pour water in earth electrode, if not comes under the reasonable value then the total earthing system can be reinstalled.
- E1 is an earth connection for load cells 1, 3, 5, 7 and bridge and similarly E2 is for load cell 2, 4, 6, 8 and bridge.

Most weighing systems with multiple load cells use field junction boxes (JBs) to combine signals and also as a convenient point for line balancing or corner correction

Correct earthing is essential for successful protection. The goal of any protection device for electronic equipment is to maintain a minimal potential difference between the circuit and the local earth.

Load cells are connected between bridge and civil foundation. Load cell are not connected to any metal or structure it is separated by Hylum shit. If load cells are not separated by hylum shit then it means it is grounded by itself. Earthing is provided to junction box as well for the protection of electronic devices which are connected in it.

Earlier the earthing connection of weighbridge is given to load cell but now a days earthing is provided to body nearer to the load cell.

Correct earthing is essential for successful protection. The essence of protection for electronic/electrical equipment is a minimal potential difference between the circuit and local earth. Any device which operates by diverting large currents to earth must have a low impedance connection to that earth. Thus, the bonding connection(s) must be of low resistance and capable of carrying large currents without damage. These requirements are satisfied by making the connection as physically short and direct as possible and using a large diameter wire. Correct bonding at the load cell is shown in figure. By bonding the SPD and load cell together, they both rise to the same potential and the load cell is not subjected to additional common mode voltage. No additional ground rods or mats need be installed.

EFFECT OF FAILURE OF EARTHING IN WEIGHBRIDGE

1. Variation in weight measured values
2. Possibilities of failure of load cell
3. Failure in junction box

Type of Earthing To Be Used – GI Pipe Type  
Size of Electrode– Ø42 mm, 1500 mm length

Size of GI Strip – 25mm x 2.5 mm

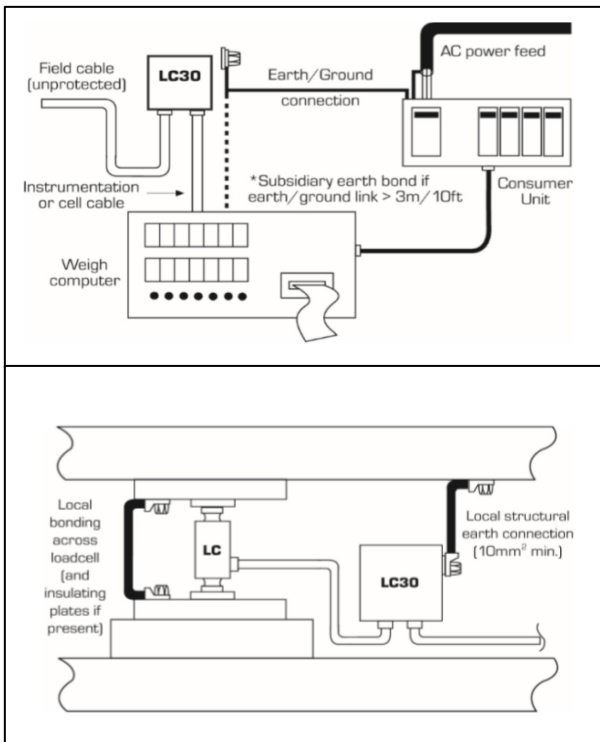


FIG 5: ARRANGEMENT OF LOAD CELLS AND EARTH CONNECTIONS

### 5. EARTHING OF HIGH MAST

A copper earth bar of high conductivity copper shall be provided along the full section of this conductor shall be such that it is capable of handling the anticipated fault current for the system but should in any case not be less than 300 mm<sup>2</sup>.

- Earthing shall be provided to minimize danger arising from faults between live conductors and non-current carrying metal work.
- The earthing system shall be such that a sufficiently high fault current will flow to cause protective devices to operate within prescribed times.
- All non-current carrying metal work associated with the electrical equipment shall be bonded together and this should include enclosures at switchboards and distribution boards, conduits, trunkings, cable armouring, etc. Which shall then be connected to appropriate earth continuity conductors.
- . The earthing terminal of every socket outlet shall be connected to the earth continuity terminal of the final sub-circuit.

- At every lighting point, an earthing terminal shall be provided and connected to the earth continuity conductor of the final sub-circuit.
- An earthing terminal, connected to the earth continuity conductor of the final sub-circuit, shall be provided at every lighting switch position.

Generally high mast should be of two earthings, one for the protection of switchboard and panel and other for the pole which is about 30 m to 50m in sky. The first earthing is provided for the safety from short circuit and leakage current and the second for the protection from lightning.

Type of Earthing To Be Used – GI Pipe Type

Size of Electrode– Ø25 mm, 1200 mm length

– Ø42 mm, 2000 mm length

Size of GI Strip – 25mm x 2.5 mm

## 6. EARTHING OF SOLAR PLANT

### 1. LIGHTNING PROTECTION

Lightning plate, metallic plate (usually copper) that protects a structure from lightning damage by intercepting flashes and guiding their currents into the ground. Because lightning tends to strike the highest object in the vicinity, plates are typically placed at the apex of a structure and along its ridges; they are connected to the ground by low-impedance cables. In the case of a building, the soil is used as the ground; on a ship, the water is used.



FIG 6: LIGHTNING PROTECTOR COPPER ROD

A lightning plate and its associated grounding conductors provide protection because they divert the current from non-conducting parts of the structure,



allowing it to follow the path of least resistance and pass harmlessly through the plate and its cables. It is the high resistance of the non-conducting materials that causes them to be heated by the passage of electric current, leading to fire and other damage. On structures less than 30 meters (about 100 feet) in height, a lightning plate provides a cone of protection whose ground radius approximately equals its height above the ground. On taller structures, the area of protection extends only about 30 meters from the base of the structure. (Left top) Vertical plates or masts up to 15 meters in height create lightning protection zones that extend in a 45° cone from the plate's tip. (Left bottom) Connecting two plates with a wire extends the zone of protection. (Right) Towers taller than 30 meters provide protection for an area 30 meters high and 60 meters wide. The protected zone is in the shape of an inverted funnel with inward-curving sides. Towers between 15 and 30 meters high create protected zones of similar shape but with height and width equal to tower height.

the AC and DC side of the inverter, it will fail. The average designed withstand voltage of solar inverters is 1750 volts between AC and ground and 500 volts between DC and ground.



FIG 7: FABRICATION GROUNDING

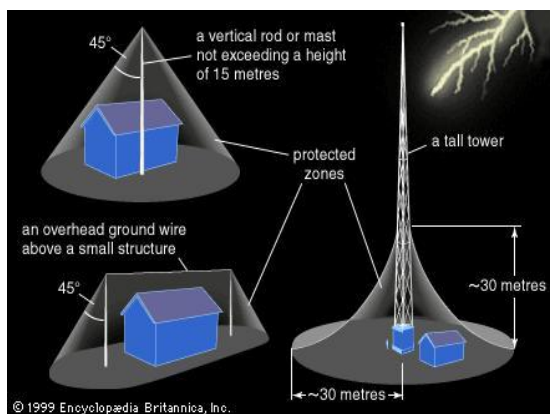


FIG 7: LIGHTNING PROTECTION

First step to grounding your inverter is to ensure that all electrical components are grounded at the same location.

This will ensure that there is no voltage potential between the rounds in the system, and no current flow through the system. In addition, keeping all equipment involved in the system physically located closely to one another reduces the potential of an over voltage taking place. This is referred to as single point grounding. If single point grounding is not achievable due to your site requirements, consult either the manufacturer of the inverter, a mater electrician, or the installation guide for your individual inverter. Oftentimes, inverter manufacturers will provide best practices to their systems.

## 2. INVERTER AND FABRICATION GROUNDING

Although many inverters come with integrated grounding and arc fault protection, proper care to ensure complete grounding is necessary to ensure that your inverter will not be overcharged from a power outage and other outside forces. To find out more about grounding, looking up the authority to full grounding techniques for your electrical system and specific environment, the NEC. If an electoral system has components that are grounded at different points, large voltage differences will be present between these points during a lightning strike. If the voltage appears between

## 3. SOLAR PLATE AND METALLIC ARRANGEMENT GROUNDING

Minimal grounding is provided by a copper- plated ground, usually 8 ft. long, driven into the earth. This is a minimum procedure in an area where the ground is moist (electrically conductive). Where the ground may be dry, especially sandy, or where lightning may be particularly severe, more plates should be installed, at least 10 feet apart. Connect or "bond" all ground plates together via bare copper wire (6 or larger,) and bury the wire. Use only approved clamps to connect wire to plates. If your

photovoltaic array is some distance from the house, drive ground plate(s) near it, and bury bare wire in the trench with the power lines. Metal water pipes that are buried in the ground are also good to ground to. Purchase connectors approved for the purpose, and connect ONLY to cold water pipes, NEVER to hot water or gas pipes. Beware of plastic fittings - bypass them with copper wire. Iron well casings are super ground plates. Drill and tap a hole in the casing to get a good bolted connection. If you connect to more than one grounded object (the more the better) it is essential to electrically bond (wire) them to each other. Connections made in or near the ground are prone to corrosion, so use proper bronze or copper connectors. Your ground system is only as good as its weakest electrical connections.

If your site is rocky and you cannot drive ground plates deeply, bury (as much as feasible) at least 150 feet of bare copper wire. Several pieces radiating outward is best. Try to bury them in areas that tend to be moist. If you are in a lightning-prone area, bury several hundred feet if you can. The idea is to make as much electrical contact with the earth as you can, over the broadest area feasible, preferably contacting moist soil.

Type of Earthing To Be Used – Copper Plate Type

Size of Plate – 600 mm x 600 mm x 3.18 mm

Size of Copper Wire – 4 sq. mm

#### EFFECT OF FAILURE OF EARTHING SYSTEM IN SOLAR PLANTS

1. Due to high lightning surges solar panel and other components may have permanent damage.
2. Because of poor fabrication earthing charges to be grounded does not get earthed and gives fluctuation in output voltage.
3. Mounting structure earthing fails, the leakage current does not get earthed.

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