Earthing

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CHAPTER 1

GENERAL

1.1 INTRODUCTION

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 resistance offered to AC and DC also differs considerably. Theoretically, it is possible to calculate the resistance of any system of earthing electrodes. However as there are too many variables such as temperatures, season, moisture contents etc., it is usually measured in practice rather than calculated.

1.2 OBJECT OF EARTHING

The object of earthing system is to provide a surface under and around a station, 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.

1.3 ADVANTAGES OF EARTHING

For efficient/effective operation of any power system, it is very much essential to connect the neutral to suitable earth connection. The following are the few advantages:

- Reduced operation & Maintenance cost
- Reduction in magnitude of transient over voltages.
- Improved lightning protection.
- Simplification of ground fault location.
- Improved system and equipment fault protection.
- Improved service reliability
- Greater safety for personnel & equipment
- Prompt and consistent operation of protective devices during earth fault.
1.4 EARTHING TERMINOLOGY

The following terms are commonly used in earthing systems:

1.4.1 Earth

The conductive mass of the earth, whose electrical potential at any point is conventionally taken as zero.

1.4.2 Earth electrode

A Galvanized Iron (GI) pipe in intimate contact with and providing an electrical connections to earth.

1.4.3 Earthing grid

A system of a number of interconnected, horizontal bare conductors buried in the earth, providing a common ground for electrical devices and metallic structures, usually in one specific location.

1.4.4 Equipment Earthing

It comprises earthing of all metal work of electrical equipment other than parts which are normally live or current carrying. This is done to ensure effective operation of the protective gear in the event of leakage through such metal work, the potential of which with respect to neighboring objects may attain a value which would cause danger to life or risk of fire.

1.4.5 System Earthing

Earthing done to limit the potential of live conductors with respect to earth to values which the insulation of the system is designed to withstand and this to ensure the security of the system.

1.4.6 Touch Voltage (E touch)

The potential difference between a ground metallic structure and a point on the earth’s surface separated by a distance equal to the normal maximum horizontal reach of a person, approximately one meter.

1.4.7 Step Voltage (E step)

The potential difference between two points on the earth's surface separated by distance of one pace that will be assumed to be one meter in the direction of maximum potential gradient.

1.4.8 Mesh Voltage (E mesh)
The maximum touch voltage to be found within a mesh of an earthing grid.

### 1.4.9 Power Supply installation

The electrical equipment and associated structure provided at a Railway Traction transformer station on the 25 kV overhead equipment.

#### 1.5 GENERAL REQUIREMENT FOR EARTHING

- Earthing shall generally be carried out in accordance with the requirement of I.E. rules, 1956, as amended from time to time and the relevant regulation of the electricity supply. Codes /Standard given below may also be referred:
  
  i) IS:3043 - Code of practice for earthing (latest)
  ii) National Electricity Code - 1985 of BIS

- In cases where direct earthing may prove harmful rather than provide safety, relaxation may be obtained from the competent authority.

- Earth electrodes shall be provided at generating stations, substations and consumer premises in accordance with the requirements.

- As far as possible all earth connections shall be visible for inspection.

- All connections shall be carefully made. If they are not properly made or are inadequate for the purpose for which they are intended, loss of life or serious personnel injury may result.

- Each earth system shall be so devised that the testing of individual earth electrode is possible. It is recommended that the value of any earth system resistance shall not be more than 5 ohms unless otherwise specified.

- The minimum size of earthing lead used on any installations shall have a nominal cross-section at areas of not less than 3.0 mm² if of copper and 6.0 mm² if of galvanized iron or steel. The actual size will depend on the max. fault current which the earthing lead will be required to carry safely.

- It is recommended drawing showing the main earth connection and earth electrode be prepared for each installation.

- No addition to the existing load whether temporary or permanent shall be made, which may exceed the assessed earth fault or its duration until it is ascertained that the existing arrangement of earthing is capable of carrying the new value of earth fault current resulting due to such addition.

- All materials, fittings etc. used in earthing shall confirm to Indian Standard specification wherever these exist. In the case of material for which Indian standard specifications does not exists, the material shall be approved by the competent authority.
CHAPTER 2

EARTHING ARRANGEMENT

2.1 GENERAL

Earthing eliminates the possibility of any dangerous potential rise on the body of an electrical equipment. It drains away the charge on the equipment body through an earth connection. When the equipment is earthed, a fault in the equipment, say, winding insulation failure causes a heavy current to flow into the general mass of the earth. This also causes blowing out of fuse or operation/tripping of protective device if any.

The meaning of earthing or grounding is to connect earth point of equipment to the general mass of earth by wire of negligible resistance. This brings the body of electrical equipment to zero potential and thus will avoid the shock to the human being.

2.2 EARTH ELECTRODE

It is a metal pipe, rod or other conductor which makes an effective connection with the general mass of the earth.

When a fault is passing, the potential of the electrode is much above the general mass of the earth. The potential exists over an areas in the vicinity of the electrode. The potential gradient i.e. the voltage drop between two points on the earth surface is high close around the electrode. It decreases as moved away from the electrode. Each electrode has a resistance area within which the voltage gradient exists.

The resistance areas of two earth electrode should not overlap each other; otherwise the effectiveness of the electrode is reduced. The recommended distance between the two electrodes is minimum twice of its length.

Several types of earth electrodes are in use. They are as follows:

2.2.1 Plate Electrode

This may be made of copper, galvanized iron or steel. If made of copper the minimum size is 60 cm x 60 cm x 3.15 mm. If of galvanized iron or steel, the minimum size should be 60 cm x 60 cm x 6.3 mm

2.2.2 Pipe Electrode
If should be made of ‘B’ class G.I pipe. the internal diameter should not be smaller than 38 mm and it should be 100 mm for cast iron pipe. The length of the pipe electrode should not less than 2.5 mtrs. It should be embedded vertically. Where hard rock is encountered it can be inclined to vertical. The inclination being limited 30% to vertical.

2.2.3 Strip Electrodes

Where strip electrode is used for earthing, it should not be less than 25 mm x 1.60 mm, if made of copper and 25 mm x 4 mm if made of G.I. or steel. The length of the buried conductor should not be less than 15 mtrs. laid in a trench not less than 0.5 mtrs deep.

The location of the earth plate and its depth should be such as to ensure that the earth plate is surrounded by moist earth to possible extent.

2.3 EARTHING LEAD

It is the conductor by which the final connection to the earth is made. Its size should be of sufficient cross sectional area so that it will not fuse under worst fault condition.

The earthing lead should be terminated on a soldered lug and secured perfectly to the body at the point of connection to the earth plate. There should be a clean metal to metal surface contact which will remain intact permanently without deterioration or corrosion.

2.4 ‘IS’ SPECIFICATION REGARDING EARTHING

The various important specifications regarding earthing as recommended by BIS (Bureau of Indian Standard) are given below:

2.4.1 Distance of Earth From Building

An earthing electrode shall not be situated with in a distance of 1.5 meter from the building whose installation system is being earthed.

2.4.2 Size of Earth continuity Conductor

The conductor, by means of which the metal body of an equipment or appliance is connected to the earth, is known as earth continuity conductor (E C C). The earth continuity can be ensured either through metal conduit, metal sheathed cables or by a special earth continuity conductor. The cross section of earth continuity conductor should not be less than 2.9 mm$^2$ (14 SWG) or half of the installation conductor size.

2.4.3 Resistance of Earth

There is no hard and fast rule. The main principle regarding earth resistance is that the earth resistance should be low enough to cause flow of current sufficient to operate the protective relays.
blow fuses, in the event of an earth fault. The value of earth resistance does not remain constant but changes with the weather, as it depends upon the moisture content of the soil, and is maximum during dry season. As a general rule the lower the value of earth resistance better it is but even then the following values of earth resistance (maximum permissible values) will give satisfactory results.

<table>
<thead>
<tr>
<th>Type of Station</th>
<th>Maximum Permissible Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large power station</td>
<td>0.5 Ω</td>
</tr>
<tr>
<td>Major power station</td>
<td>1.0 Ω</td>
</tr>
<tr>
<td>Small substation</td>
<td>2.0 Ω</td>
</tr>
<tr>
<td>In all other cases</td>
<td>8.0 Ω</td>
</tr>
</tbody>
</table>

Earth continuity inside an installation i.e. from the earth plate to any point in the installation – 1.0 Ω

The sensitivity of the protective equipment, system voltage and the maximum fault current directly relate to permissible value of earth resistance. In case the earth exceeds the permissible value, then in the event of earth fault, the fault current may not reach a sufficient value to operate the protective equipment (such as fuses or relays) and dangerous condition may arise.

As per the code No. ETI/PSI/120 (20/91), the values of each resistance (max. permissible) of traction installation switching station should be as

i) T.S.S. - 0.5 Ohms
ii) Switching Station - 2.0 Ohms
iii) BT and AT station - 10 Ohms

2.4.4 The earth wire and earth electrode will be of same material.

2.4.5 The earth wire shall be taken through G.I. pipe of 13 mm diameter for at least 30 cm length above and below ground surface to the earth electrode to protect it against mechanical damage.

2.4.6 It is not necessary that earth wire connected to an earth electrode should be run along the whole wiring system. All the earth wires run along the various sub-circuits shall be terminated and looped firmly at the main board and from main board the main earth shall be taken to earth electrode. The loop earth wires used shall not be either less than 2.9 mm² (14 SWG) or half of the size of the sub circuit conductor.

2.4.7 The earthing electrode shall always be placed in vertical position inside the earth or pit so that it may not be in contact with all the different earth layers.

2.5 POINTS TO BE EARTHED

Earthing is required to be done in the following cases:

- The metallic frames of wiring heavy power equipment such as Electric Motors, Generators, Starters, Iron clad, Main Switches, Distribution board, Transformers and Structural Steel
work of substations etc., should be earthed by two independent earth conductor and electrodes.

- Fabricated steel transmission lines towers, Rail or Tubular posts which carry over head conductors. The individual posts may be earthed by connecting them suitably to over head earth wires. In addition, independent earth should be provided at least 3 per km for the structure and at every 8th posts of service mains and the steel structure of the earth wire connected to it solidly. This will ensure that the over all earth resistance is low since several earth will be in parallel.

- Stay wires provided for overhead lines should be earthed.

- The metal casing of portable apparatus should be earthed.

- The metal body of Iron clad switch, G.I. pipe or conduit pipes encasing the VIR or OVC cables, the Iron clad fuse boards, the down rod of ceiling fans and metallic reflectors of F,D. fittings.

- Earth pin of three pin plug and socket or four pin power plug socket.

It is the practice of Railway to run an overhead Earth conductor and earth all the metal parts of the supporting structures. All guarding is to be effectively earthed at intervals of not more than five spans.

2.6 FACTORS INFLUENCING EARTH RESISTANCE

The resistance of earth system depends upon the following factors:

- Condition of soil.
- Temperature of soil.
- Moisture content of soil.
- Size and spacing of earth electrodes
- Depth, at which the electrode is embedded.
- Material of conductor.
- Quality of coal, dust, charcoal and salt in the earth electrode pit.
- No. of electrodes connected in parallel.

2.7 METHODS OF REDUCING EARTH RESISTANCE
As discussed in above point, earth resistance depends upon the condition, temperature and moisture content of soil, areas of earth electrode and depth to which it is driven. The earth resistance can be considerably reduced by digging around the earth electrode to a depth of 1.5 or 1 meters, cleaning the surface of the earth plate or pipe of rust, filling with charcoal soaked in salt solution. In summer season the pouring of fresh salt water (copper sulphate solution in case of copper plate earthing) through pipe over all the coal bed will reduce the earth resistance.

The additional steps for reducing the earth resistance of the system are increasing of plate areas, increasing of pit depth and increasing of number of electrodes in parallel.

The methods of increasing of plate area and increasing of pit depth have got limitations and so can not prove more useful. Hence where the earth resistance can not be reduced to a desired value by the methods above number of electrodes interconnected in parallel may be used. This method is suitable only where greater surface area of free soil is available for earthing. The electrodes should be so spaced in parallel so as not to overlap the earthing region covered by the individual electrodes.

2.8 METHOD OF EARTHING

The various methods of earthing are:

2.8.1 Strip or Wire Earthing

In this system of earthing strip electrodes of cross section not less than 25 mm x 1.6 mm if of copper and 25 mm x 4 mm if galvanized iron or steel are buried in horizontal trenches of minimum of depth 0.5 meter. If round conductors are used, their cross-sectional area shall not be smaller than 3.0 mm² if of copper and 6 mm² if of galvanized iron or steel. The length of buried conductor shall be sufficient to give the required earth resistance. It shall, however, be not less than 15 meters. The electrodes shall be as widely distributed as possible, preferably in a single or circular trench or in a number of trenches radiating from a point, If conditions require use of more than one strip, they shall be laid either in parallel trenches or in radial trenches.

This type of earthing is used at places which have rocky earth bed because at such placed excavations work for plate earthing is difficult.

2.8.2 Rod Earthing

In this system of earthing 12.5 mm diameter solid rod of copper or 16 mm diameter solid rod of galvanized iron or steel; or hollow section 25 mm G I pipes of length not less than 2.5 meters are driven vertically into the earth either manually or by pneumatic hammer. In order to increase the embedded length of electrodes under the ground, which is sometimes necessary to reduce the earth resistance to desired value, more than one rod sections are hammered on above the other.

This system of earthing is suitable for areas which are sandy in character. This system of earthing is very cheap as no excavation work is involved.
2.8.3 **Pipe Earthing**

Pipe earthing is the best form of earthing and is very cheap in cost. In this method of earthing, a galvanized and perforated pipe of approved length and diameter is placed up right in a permanently wet soil.

The size of the pipe depends upon the current to be carried and the type of the soil. Usually the pipe used for this purpose is of diameter 38 mm and 2.5 meters in length for ordinary soil or of greater length in case of dry and rocky soil. The depth at which the pipe must be buried depends upon the moisture of the ground. The pipe is placed at a depth of 3.75 meters (minimum). The pipe is provided with a tapered casing at the lower end in order to facilitate the driving. The pipe at the bottom is surrounded by broken pieces of coke to increase the effective area of the earth and to decrease the earth resistance respectively. Another pipe of 19 mm diameter and minimum length 1.25 meter is connected at the top to GI pipe through reducing socket.

In our country in summer the moisture in the soil decrease which cause increase in earth resistance. So a cement concrete work, is done in order to keep the water arrangement accessible, and in summer to have an effective earth, 3 or 4 buckets of water are put through the funnel connected to 19 mm diameter pipe, which is further connected to GI pipe.

The earth wire (either GI wire or GI Strip of sufficient cross section to carry faulty current safely) is carried in a GI pipe of diameter 13 mm at a depth of about 60 mm from the ground).

Care should be taken that earth wire is well protected from mechanical injury, when it is carried over from one machine to another.

2.8.4 **Plate Earthing**

In plate earthing an earthing plate either of copper of dimensions 60 cm x 60 cm x 3 mm or of galvanized iron of dimensions 60 cm x 60 cm x 6 mm is buried into the ground with its face vertical at a depth of not less than 3 meters from ground level. The earth plate is embedded in alternate layers of coke and salt for a minimum thickness of 15 cm. The earth wire (GI wire for GI plate earthing and copper wire for copper plate earthing) is securely bolted to an earth plate with the help of a bolt, nut and washer made of material of that of earth plate (made of copper in case of copper plate earthing and of galvanized iron in case of GI plate earthing).

A small masonry brick wall enclosure with a cast iron cover on top or an RCC pipe round the earth plate is provided to facilitate its identification and for carrying out periodical inspection and tests.

For smaller installations GI pipe earthing is used and for larger stations and transmission lines, where the fault current, likely to be high, plate earthing is used.
2.9  EARTHING ARRANGEMENT AT TRACTION SUBSTATION

2.9.1  Earthing grid

2.9.1.1  An earthing grid is formed by means of bare GI rod of appropriate size as indicated in clause 2.9.1.2 buried at a depth of about 600 mm below the ground level and connected to earth electrodes. The connection between electrodes and the grid shall be means of two separate and distinct connections made with 75 mm x 8 mm GI flat. The connection between the GI flat and the GI rod shall be made by welding, while that between the earth electrode and the GI flats through GI links by bolted joints. The earth electrodes shall be provided at the outer periphery of the grid. As far as possible the earthing grid conductors shall not pass through the foundation block of the equipment. All crossings between longitudinal conductors and transverse conductors shall be jointed by welding. The longitudinal and transverse conductors of the earthing grid shall be suitably spaced so as to keep the step and touch voltage within the acceptable limit. However the overall length of the earthing grid conductors shall not be less than the calculated length.

2.9.1.2  The size of the earthing grid conductor shall be decided based on the incoming system voltage and fault level (refer annexure I). The fault level considered shall take into account the anticipated increase in fault current during the life span of the station. The size shall be given below:

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>System voltage (KV)</th>
<th>Fault level (MVA)</th>
<th>Diameter of grid conductor (GI rod) in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>66</td>
<td>upto 4000</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>above 4000</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>upto 5000</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>110</td>
<td>upto 6000</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>above 6000</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>upto 8000</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>132</td>
<td>upto 7000</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>above 7000</td>
<td>36</td>
</tr>
<tr>
<td>4</td>
<td>220</td>
<td>upto 12000</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>above 12000</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>upto 16000</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>above 16000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>upto 20000</td>
<td></td>
</tr>
</tbody>
</table>
2.9.2 **Buried rail**

2.9.2.1 A steel rail of section 52 kg/m (the one used for the railways track) and length about 13 m shall be buried near the track at the traction substation at a depth of about one meter to form part of the earthing system. Two separate and distinct connection shall be made by means of 75 mm x 8 mm GI flat between the earthing grid and the buried rail. The buried rail shall be connected by means of two separate and distinct connections made with 75 mm x 8 mm GI flat to the non-track circuited rail(s) in a single-rail track circulated section and to the neutral point(s) of the impedance bond(s) in a double rail track circulated section.

2.9.2.2 In case where the feeding post is located separately away from the traction substation, the buried rail shall be provided at the feeding post (where one terminal of the secondary winding of the traction transformer of the substation is grounded).

2.9.3 **System Earthing**

2.9.3.1 One terminal of the secondary winding (25 kV winding) of each traction power transformer shall be earthed directly by connecting it to the earthing grid by means of one 75 mm x 8 mm GI flat, and to the buried rail by means of another 75 mm x 8 mm GI flat.

2.9.3.2 One designated terminal of the secondary of each potential, current and auxiliary transformer shall be connected to the earthing grid by means of two separate and distinct earth connection made with 50 mm x 6 mm GI flat.

2.9.4 **Equipment Earthing**

The metallic frame work of all outdoor equipment such as transformers, circuit breakers, interrupters and isolators, as well as steel structure shall be connected to the earthing grid by means of two separate and distinct connections made with GI flat of size as indicated below: one connection shall be made with the nearest longitudinal conductor, while the other shall be made to the nearest transverse conductor of the grid:

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Equipment (KV)</th>
<th>System voltage and fault level</th>
<th>Ground conductor or size</th>
</tr>
</thead>
</table>
| 1      | Equipment on the primary side of traction power transformer | 66 KV, upto 3000 MVA  
110 KV, upto 5000 MVA  
132 KV, upto 6000 MVA  
220 KV, upto 10000 MVA  
66 KV, above 3000 upto 6000 MVA  
110 KV,above 5000 upto 10000 MVA  
132 KV,above 6000 upto 12000 MVA  
220 KV,above 10000 upto 20000 MVA | 50mm x 6 mm  
75 mm x 8 mm |
2.9.5  **Earthing inside control room**

An earthing ring shall be provided inside the control room by means of 50 mm x 6 mm GI flat which shall be run along the wall on teak wood blocks fixed to the wall at a height of about 300 mm from the floor level. The earthing ring shall be connected to the main earthing grid by means of two separate and distinct connections made with 50 mm x 6 mm GI flat. The earthing ring shall also be connected to independent earth electrode by means of two separate and distinct connections made with 50 mm x 6 mm GI flat. The metallic framework of control and relay panels, LT AC and DC distribution boards, battery chargers, remote control equipment cabinets and such other equipment shall be connected to the earthing ring by means of two separate and distinct connection made with 8 SWG galvanized Iron wire. The connections shall be taken along the wall and in the floor. All recesses shall be covered with cement plaster after finishing the work. Connection between the GI flats shall be made by welding.

2.9.6  **Earthing of Lightning arrester**

In addition to the earth electrodes provided for the main earthing grid, an independent earth electrode shall be provided for each lightning arrester. This earth electrode shall be connected to the ground terminal of the lightning arrester, as well as to the main earthing grid by means of two separate distinct connections made with 50 mm x 6 mm GI flat for the 25 KV side lightning arresters, and with 75 mm x 8 mm GI flat for the primary side lighting arresters. The earth electrode shall be provided as close as possible to the lighting arrester and the connection shall be as short and straight as possible avoiding unnecessary bends. For lightning arresters provided for the traction power transformers, there shall also be a connection as direct as possible from the ground terminal of the lighting arrester to the frame of the transformer of the being protected. This connections shall also be made by two separate and distinct connections made with 50 mm x 6 mm GI flat for the 25 KV side lightning arresters, and with 75 mm x 8 mm GI flat for the primary side lighting arresters.

2.9.7  **Earth Screen**

The area covered by outdoor substation shall be shielded against direct strokes of lightning by an overhead earth screen comprising 19/2.5 mm galvanized steel standard wire strung across the pinacles of the metallic structures. The earth screen wires shall be strung at a height as indicated in the approved traction substation layouts (not less than 2.5 m above the live conductor) and shall be solidly connected to the traction substation earthing grid at each termination by means of 50 m x 6 mm GI flat.

2.9.8  **Earthing of fencing uprights and panels**
Each metallic fencing upright shall be connected to the traction substation main earthing grid by means of two separate and distinct connections made with 50 mm x 6 mm GI flat. In addition, all the metallic fencing panels shall be connected to the uprights by means of two separate and distinct connections made with 6 SWG GI wire. All the metallic door panels shall also be connected to the supporting uprights by means of two distinct connections made with 6 SWG GI wire.

2.9.9 **Earthing at the point of 240 V ac 50 Hz supply for oil filtration plant**

The 240 V ac 50 Hz distribution board for power supply to oil filtration plant shall be connected to the main earthing grid by means of two distinct connections made with 50 mm x 6 mm GI flat.
2.10  **EARTHING ARRANGEMENT AT SWITCHING STATION**

2.10.1  A minimum number of three earth electrodes (excluding the one to be provided separately for the remote control cubicle earthing refer clause 8.4) shall be provided at each switching station, and they shall be interconnected by means of 50 mm x 6 mm GI flat forming a closed loop main earthing ring. This ring shall be connected by two separate and distinct connections made with 50 mm x 6 mm GI flat, to the non-track circuited rail in a single rail track circuited section and to the neutral point of the impedance bond in a double rail track circuited section of the nearest track, so as to limit the potential gradient developing in the vicinity of the switching station in the event of a fault.

2.10.2  **System earthing**

One designated terminal of the secondary of each potential current and auxiliary transformer shall be connected to the main earthing ring by means of two separate and distinct connections made with 50 mm x 6mm GI flat.
2.10.3 Equipment earthing

2.10.3.1 All masts, structures, fencing uprights and all outdoor equipment pedestals including auxiliary transformer tank shall be connected to the earthing ring by means of two separate and distinct connections made with 50mm x 6mm GI flat. All fencing panels shall be connected to the supporting uprights by means of two separate and distinct connections made with 6 SWG G.I. wire. All the metallic door panels shall be connected to the supporting uprights by means of two separate and distinct connections made with 6 SWG G.I. wire.

2.10.3.2 The metal casing of potential and current transformers shall be connected to the mast/structures by means of two separate and distinct connections made with 50mm x 6mm GI flat.

2.10.3.3 The ground terminal of lightning arrester shall be connected directly to the earth electrodes by means of two separate and distinct connections made with 50mm x 6mm GI flat. The earth electrode shall be so placed that the earthing leads from the lightning arrester may be brought to the earth electrodes by as short and straight a path as possible.
2.11 **EARTHING OF NEUTRAL OF LOCAL POWER SUPPLY SYSTEM**

At traction substations and switching stations where power supply at 415 V/240 V, ac, 50 Hz, is taken from the local supply authority and having neutral earth at some distance point in the premises of the supply authority, the neutral of such supply shall also be earthed by means of two separate and distinct connections made with 6 SWG G.I. wire by connecting to an independent earth electrode.

2.12 **EARTHING ARRANGEMENT AT BOOSTER TRANSFORMER STATION**

2.12.1 The minimum number of earth electrodes to be provided at each booster transformer station shall be two. They shall be interconnected by means of 50mm x 6mm GI flat to form an earthing ring. The ring shall be connected by means of two separate and distinct connections made with 50 mm x 6mm GI flat to the non-track circuited rail in single rail track circuited section or to the neutral point of the impedance bond in a double rail track circuited section.

2.12.2 Each mast of the supporting gantry shall be connected at the bottom to the earthing ring by means of two separate and distinct connections made with 50mm x 6mm GI flat. The booster transformer tank shall be connected to the gantry mast by means of two separate and distinct connections made with 50 mm x 6 mm GI flat.

2.13 **EARTHING ARRANGEMENT AT AUXILIARY TRANSFORMER STATION**

2.13.1 The combined earth resistance at an auxiliary transformer station shall normally be less than 2.0 ohms. In rocky terrain, however, the value shall not exceed 10.0 ohms. Normally, one earth electrode is sufficient at each auxiliary transformer station. The earth electrode shall be connected to the transformer mast by means of two separate and distinct connections made with 50 mm x 6 mm GI flat. In additions, both the mast and the earth electrode shall be connected to the non track circuited rail in a single rail track circuited section or, to the neutral point of the impedance bond in a double rail track circuited section by means of 50 mm x 6mm GI flat.

2.13.2 The earthing terminal on the transformer tank shall be connected to the mast on which the transformer is mounted by means of two separate and distinct connections made with 50mm x 6mm GI flat. One terminal shall be connected to the earthing terminal on the transformer tank and as well as to the mast by means of 50mm x 6mm GI flat. These connection shall be as short and straight as possible and avoiding unnecessary bends.
CHAPTER 3

INSPECTION, TESTING & MAINTENANCE

3.1 INSPECTION OF EARTHING ARRANGEMENTS

The earthing system should be checked before the installation is brought into use. Also it should be checked once a year on a dry day during dry season. During such tests, following checks should be exercised.

1. Earth resistance should be within the prescribed limits. If not, immediate remedial measures should be taken.

2. Earth conductor should have its cross sectional area as large as possible. (not less than minimum limit specified)

Earth wire should never be twisted together for making joints. Such joints are quite unreliable since they may become loose or slack during the course of time and increase the earth resistance. All the joints should be soldered together solidly after binding the wires or they should be provided into a copper sleeve and the wire ends should be soldered. If the earth connection is made for a steel structure, a tapped hole should be made and the cable shoe should be bolted solidly. A good metal to metal contact should be ensured. If possible, the metal surface should be tinned.

All the heavy power equipment should have two separate and distinct connections to the earth. They should follow different routes. If one of the earth conductors gets opened accidentally the other should continue to serve the purpose. This connection should be made to two entirely independent earth electrodes. They should never be in series since failure of one terminal (due to bad conductor etc.) fails the other simultaneously.

The earthing lead should be protected against any mechanical damage, corrosion etc., If the earthing lead and wires cannot be buried deep under the soil or embedded in a concrete or cement plaster etc., and theft cases are common, galvanized iron wire of sufficient cross section should be used.

3.2 TESTING OF EARTHING

Earth tester megger is invariably used for measuring the earth electrodes resistance. Earth testing megger consists of a hand driven magneto type D.C. Generator. A current reverser, rotary rectifier and ohm meter.

The current reverser and rotary rectifier are driven along with D.C. Generator by a driving system which incorporate a clutch mechanism for unidirectional rotation and a governor for speed control. The function of current reverser is to change the direction of flow of current in
the soil and that of rotary rectifier is to maintain unidirectional current in the potential coils of
the ohm meter.

The ohm meter consists of a current coil and a potential coil mounted on a common spindle and
placed in the magnetic field of a permanent magnet. The current coils is connected in series
with the earth electrodes and current electrodes. The potential coil is connected across the earth
electrode and the potential electrode through the rotary rectifier. While measuring the earth
resistance the terminals C1, P1 are connected to the main earth electrode P2 to the potential
electrode and C2 to the current electrode. The potential and current electrodes are temporary
electrodes placed in the ground 50 to 75 feet apart and 50 to 75 feet & from the earth electrode.

When the megger is operated an A/C current is produced in the coil. The voltage drop produced
in the earth electrode is applied across the potential coil. The current coil produces a Torque in
the clockwise direction, and the potential coil produces a Torque in anticlock wise direction.
The current applied to the current coil is inversely proportional to the earth resistance and the
voltage drop applied across the potential coil is directly proportional to the earth resistance the
Torque opposes each other and bring the moving system to rest when they are equal.

- The pointer indicates the earth resistance values on a calibrated scale. The potential
electrode is shifted 10’ close to the earth electrode and second reading is taken in a
similar manner third reading also taken after shifting the potential electrode 10’ closer to
the current electrode. All the three readings should be equal.

PRECAUTIONS

1. The electrode under test should be from the installation while measuring the resistance.
2. The resistance areas of the electrodes should not overlapped.
3. The length connecting lead between earth resistance megger and the earth electrode
should be as short as possible other wise 4 terminal megger should be used and the
terminal P1 should be connected to earth electrode directly.
3.3 MAINTENANCE OF EARTHING SYSTEMS

3.3.1 GENERAL

- It is recommended that periodical checks & tests of all earth electrodes should be carried out. Records should be maintained of such checks.

- Where earth leakage circuit breakers are employed, a check shall be kept on the associated earth electrode by periodically operating the testing device which is embodied in the earthed leakage circuit breaker.

- The neighboring soil to the earth electrode shall be kept moist, where necessary, by periodically pouring water through a pipe where fitted along with it or by pouring water in the immediate vicinity of the earth electrode.

- Substations and Generating Stations: Records shall be kept of the initial resistance of substation and generating station earth electrodes and of subsequent tests carried out.

- Normally annual measurement of earth resistance of substation shall be carried out but local circumstances in the light of experience may justify increase or decrease in this interval but it should not be less than once in two years.

- Periodical visual inspection of all earth electrode connection, wherever available, shall be carried out to ensure their rigidity and other signs of deterioration.

- In rural substations, particularly those connected to overhead high-voltage and low-voltage lines, greater reliance should be placed on the electrode system, and therefore facilities for testing the resistance of the electrode to general mass of earth, annually or as required by experience should be provided.

- Where installations are earthed to a cable sheath which is not continuous to the substation neutral (that is, there is an intervening section of overhead line without earth wire), a supplementary electrode system may be necessary. The adequacy of the electrode system shall be checked initially be an earth fault loop test.
### 3.3.2 MAINTENANCE SCHEDULE

#### A. HALF YEARLY SCHEDULE:

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Items to be inspected</th>
<th>Nature of inspection</th>
<th>Action required , if inspection shows unsatisfactory condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Earth strip, joints and connections to structure and rails (Visually)</td>
<td>Check for proper continuity</td>
<td>If found broken or loose, this should be immediately replaced /tightened</td>
</tr>
<tr>
<td>2.</td>
<td>Earth clamp bolts &amp; nuts in the earth pit (visually)</td>
<td>Check for proper contact of earth clamp, slackness of bolts &amp; nuts, rust and dirt.</td>
<td>Rust and dirt should be cleaned. Bolt and nuts of this clamps should be tightened.</td>
</tr>
<tr>
<td>3.</td>
<td>Sump</td>
<td>Check up general condition including dryness.</td>
<td>If the surrounding area is too dry one or two buckets of water should be poured into the sump every week to keep the soil surrounding earth pipes permanently moist.</td>
</tr>
</tbody>
</table>

#### B. YEARLY SCHEDULE:

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Items to be inspected</th>
<th>Nature of inspection</th>
<th>Action required , if inspection shows unsatisfactory condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Earth resistance</td>
<td>Measure the earth resistance &amp; see that the results obtained are not greater than those shown below : Main earth- 1 ohm Isolated earth - 8 ohms</td>
<td>If the earth resistance is higher than the figures shown, immediately steps should be taken to improve the figure to bring it within the permissible limits.</td>
</tr>
<tr>
<td>2.</td>
<td>Earth pits</td>
<td>Check up the electrode for proper earth</td>
<td>Remove the hardened top layer of the earth pit for a depth of 1</td>
</tr>
<tr>
<td>continuity.</td>
<td>meter, mix with coke and loamy soil (non-sandy) and ram the earth. Repair the earth. Repair sides and top cover of the earth pits. Avoid use of salt as far as possible to avoid rusting of earth pipe.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 4.

DO’S & DONT’S

4.1 DO’S :

1. Do ensure that the electrode shall, as far as practicable, be embedded below permanent moisture level.
2. Do inspect earth electrode regularly.
3. Do ensure that every earth wire shall be of copper, galvanized iron or steel.
4. Do ensure good and reliable electrical connection between earthing leads and earth electrodes.
5. Do ensure that path of earth wire should as far as possible, be out of reach of any person.
6. Do consider all parameters while designing earth system.
7. Do ensure the size of earthing wire are proper and according to IS 3043 (Code of practice for earthing and IE rules).
8. Do ensure that all materials, fittings etc. used in earthing system shall confirm to IS specification wherever they exists.
9. Do ensure safety earthing while working on electrical installations.
10. Do ensure that as far as possible all earth terminals should be visible.

4.2 DONT’S

1. Don’t connect single pole switch or fuse in a neutral circuit. Always connect it in the live or phase wire circuit.
2. Don’t renew a blown fuse until you are satisfied as to the cause of its blowing and also as to the removal of the cause.
3. Don’t use copper or aluminum wire as substitute for fuse wire.
4. Don’t touch or tamper with any electrical gear or conductor unless you have made sure that it is dead and earthed. High Voltage apparatus may give shock or flashover without touching.

5. Don’t disconnect earthing connections or render ineffective the safety gadgets installed on mains and apparatus till you are at work.

6. Don’t expose your eyes to an electric arc. Painful injury may result even with short exposure.

7. Don’t take unnecessary risk with electricity. Low voltage under certain circumstances can be dangerous.

8. Don’t use paint, enamel and grease on the electrodes.

9. Don’t use neutral conductor as earth wire.

10. Don’t use water pipe line for earthing.