Journal of Energy Technologies and Policy
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.6, No.10, 2016

Various Aspects and Analysis of Earthing/Grounding System for Protective and Functional Applications

Er. Parveen Kumar Goyal
B.E.(Electricals), M.Tech.(Power Systems), Gurgaon, India

Sapna Aggarwal
M.A.(Mathematics), M.Phil, Gurgaon, India

Abstract
Earthing or grounding means connection of neutral point or body / enclosure of a system with the ground mass to avoid any accident & smooth functioning of system whether it may be power system, fuel pipelines, telecomm, lightning protection or data processing centres. It will transfer the undesired charge directly to the ground because impedance of such path will be very low. Earthing/Grounding is low impedance return path to fault currents. Earthing should provide at generating station/ESS (Electrical Sub Stations) & consumer's premises as required. Presented paper is focussing on earthing essential, systems, design calculations, standard practices & applications.
Keywords: Types of Systems/Electrodes, Installation, Fault/size calculations, Testing, Applications.

1. Introduction

A well-designed Earthing system is essential for any electrical installation to avoid dangers associated with fault currents. Good Earthing protects both equipments and people against dangerous step & touch voltage. A low resistance Earth Termination System aims:
To provide security for people by limiting the step & touch voltage.
To protect installations and equipment by providing a low impedance path for fault currents.
To improve the quality of the signal by minimizing the electromagnetic noise.
To eliminate the explosions and fire hazards in fuel/gas pipelines & storage tanks.

2. Types of system earthing

TN, TT & IT system for earthing are accepted internationally. PEN conductor, combined for protective & functional requirement runs along the supply lines in TN system. Minimum acceptable cross section area for PEN conductor is 10 mm^2 for Copper (Cu) and 16 mm^2 for Aluminium (Al)/ Galvanized Iron (GI).

2.1 TN-S system

It is applicable for 415/660 volt power supply system. In this system, neutral point is earthed at source. Independent protective earth (PE) conductor connected to the source runs along with the distribution lines. All exposed parts are connected to this PE conductor. Independent earthing pit is also installed in the consumer's premise.

2.2 TN-C

In this system, neutral point is earthed at source. Neutral & PE are on common conductor in distribution lines. All exposed parts of installation as well as neutral line connected to this PE & N conductor. CNE cable is used for such installations. Additional earth electrode installed locally for 3 phase consumers.

2.3 TN-C-S

It is also called protective multiple earthing – PME system. In this system supply line is as per TN-C system and arrangement is as per TN-S system i.e. PE and neutral are combined in common conductor at supply line. This is earthed at source as well as frequent intervals in supply network also. An independent protective conductor runs in consumer premises. Local earth pit provided at consumer station which will link with PE and N conductor. All non-current carrying conductors and exposed parts are connected to PEN through protective conductor and main earth terminal link.

2.4 T-TN-S

This system not require any earth conductor with HV supply line which is terminated in delta connected transformer's primary winding. Neutral (star point) is earthed at secondary side of transformer. Independent earth electrodes and bus bars are provided for the body earth. Protective conductors are run throughout the LT distribution network.

2.5. TT

Neutral protective earthing provided only at source and no PE conductor run along with supply line. All exposed parts are connected to earth electrode at consumer premises which is independent of the source earth, electrically.

2.6. IT system

In this system source has either no earth or earthed through high impedance. All the exposed parts of installation connected to the local earth which is electrically independent to source earth.

3. Types of Earth Pit Installations

3.1. Strip/conductor

In such type of earthing, GI/Cu strips or conductors are buried horizontally with depth more than 0.5 metre below ground. Length of buried strip/conductor should be minimum 15 metre to obtain required earth resistance. It may be increase on the basis of soil resistivity and other factors. This type of earth is out of date and used very rarely.

3.2. Rod earth

It comprises solid rod of 12.5 mm dia. Cu or 16 mm dia. GI, which penetrate vertically by manual means or pneumatic hammer up to minimum depth of 1.5 metre. No digging or excavation required in this type of earth pits. This is used in sandy soils & temporary installations.

3.3. Pipe earth

It is installed with 40mm dia. GI medium class pipe, 3.45 to 4.5 metre long with no joints. GI pipe cut tapered at bottom & holes of 12 mm Ø, @ 75 mm spacing up to 2m length from bottom. Pipe buried vertically and keeps top of pipe 20 mm below ground level. If full length is not possible due to water table/rocks, reduce the length if achieved required value of earth resistance with or without additional electrodes. It may also be installed in horizontal formations. Spacing between it to pit should be more than 02 meters. Reducer (40/20 mm) used to fix the funnel with mesh and electrode is housed in a masonry chamber. Cast Iron or MS frame with MS/CI cover of 6 mm thickness with locking arrangement should be fixed on chamber. Wire type earth lead terminates using a through bolt, nut, washer & termination socket. GI tape terminated with double C-clamp with watering pipe.

3.4. Plate earth

Plate size will be 600x600x6 mm for GI and 600x600x3 mm for Cu. Cross section of strip should me minimum 100 mm^2 for GI and 40 mm^2 for Cu or 8 SWG Cu wire. Top of earthing plate shall be min 1.5 metre below ground level, with vertical faces. Gap between Pit to pit shall be minimum 3 metre and keep 2 metre away from building. 20mm Ø medium GI watering pipe attached to electrode for periodic maintenance. Keep Funnel with mesh on the top of pipe and chamber specifications is same as of pipe earth. Terminate earthing lead on plate with nut/bolt/check nuts and washers.

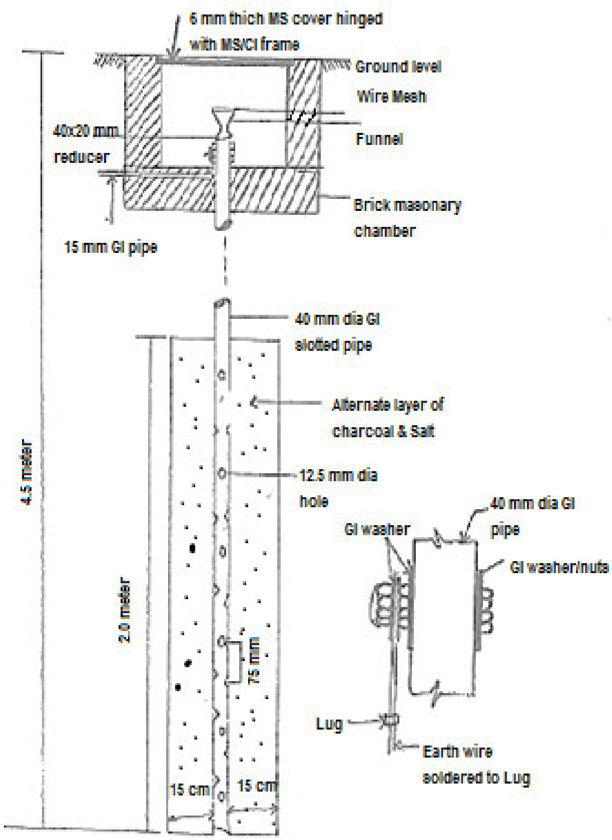

Fig.-A, Pipe Earth

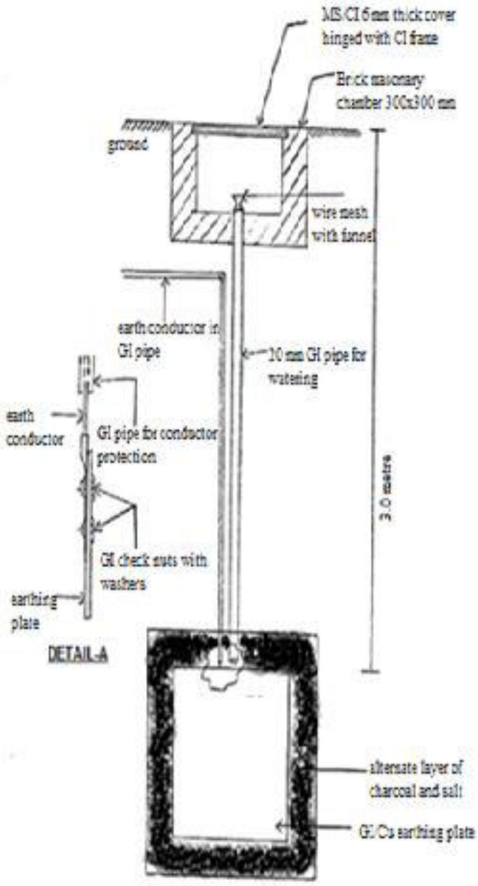

Fig.-B, Plate Earth

3.5 Earthing Mat

Before 1960, design criterion was low earth resistance. During 1960's, new criteria evolved especially for EHV AC & DC ≥ 220 KV. It includes low earth resistance, low touch potential & low step potential. STEP potential is difference between feet of a person standing on the floor of ESS with 0.5 meter spacing between both feet, during the earth fault current should flow through grounding system and should not affect the personnel.

TOUCH potential is difference between finger of raised hand touching the faulted structure and the feet of person standing on the ESS floor. Man should not get shocked if touch potential is in safe limit.

STEP/TOUCH potential value should be < 30 V rms (42V peak).

In modern systems earthing MAT /grid used for ESS. Earthing rods run along fencing and cover some meters more, out of fencing also. In earth Mat underground horizontal steel rods with 3-4 metre gap, under 0.5 metre depth are placed to form a earth mesh, known as MAT /grid. Several identical Earthing electrodes/spikes of 25/40 mm Ø MS bar 0f 2-3 metre length drive vertically in ground at various locations and welded to the earthing rods of mesh. Larger the spikes, results in lower resistance. Earthing risers are MS rods or 75X10 mm MS/GI flats, which are welded to mesh & brought up to equipment & foundations by bending in required shapes. Connections are of GI strips or electrolytic Cu flats/strips, stranded wire/cable with welded/clamped/bolted connections. All the joint welding must be covered by 2mm thick bitumen paint. Thumb rule for earth mat is 250A/spike if soil resistivity is ≥ 5000 ohm meter and 500A/spike if ≤ 500 ohm meter.

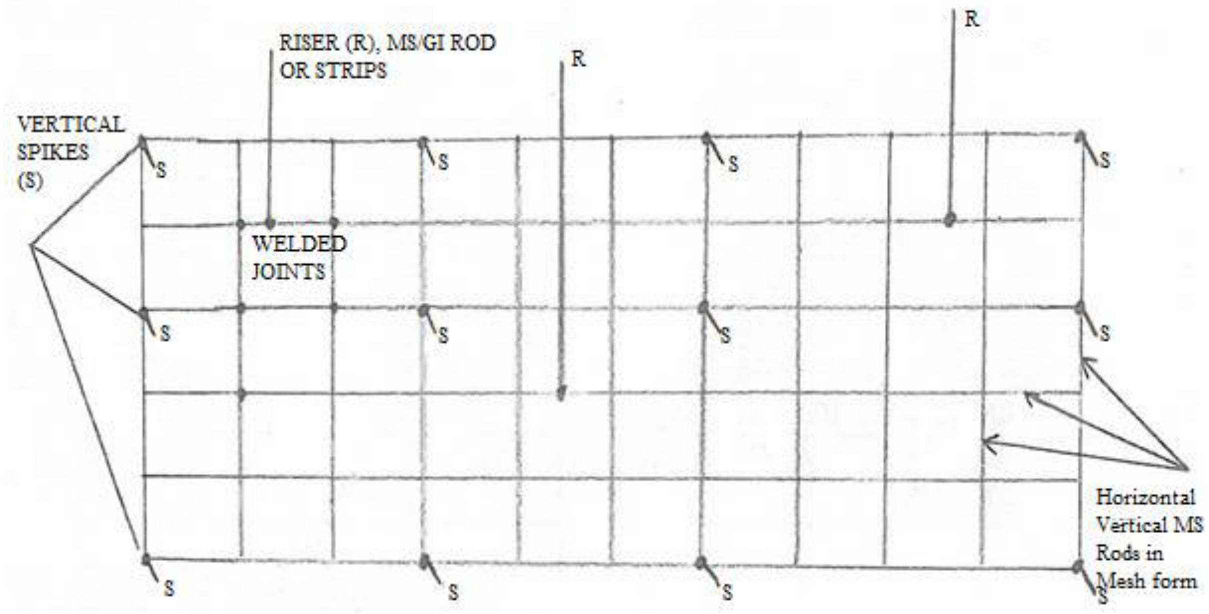

Fig.- C, Earth Mat Arrangement

If fault current is10 KA, no. of spike will be 10000/500=20 to 10000/250=40. IEEE Std 80 gives the simplified method as modified by Sverak to include the effect of earthing grid depth:

$$R_G = \rho\left[\frac{1}{L} + \frac{1}{\sqrt{20A}}\left(1 + \frac{1}{1+h\sqrt{20/A}}\right)\right] \qquad - \qquad (i)$$

Where R_G is the earthing grid resistance with respect to remote earth (Ω), ρ is the soil resistivity (Ω.m), L is the total length of buried conductors (m), A is the total area occupied by the earthing grid (m^2), h is the depth of the earthing grid (m). Consider a rectangular earthing grid with soil resistivity 300 ohm meter and the following parameters is proposed to understand clearly:

Length of 90 meter and a width of 50 meter with 6 parallel rows and 7 parallel columns. Grid conductors will be 120 mm^2 and buried at a depth of 600mm. 22 earthing rods will be installed on the corners and perimeter of the grid and each earthing rod will be 3 meter long. Using the simplified equation (i), the resistance of the earthing grid with respect to remote earth is:

$$R_G = 300\left[\frac{1}{956} + \frac{1}{\sqrt{20x4500}}\left(1 + \frac{1}{1+0.6\sqrt{20/4500}}\right)\right] = 2.2753\ \Omega \qquad - \qquad (ii)$$

3.5.1 Steps to be followed for earth mat installation-

a. Prepare detailed layout with trenches & foundations
b. Dig trenches at 1.0 meter depth
c. Dress & fill with soft soil, followed by ramming and levelling of trenches
d. Lay down earthing rods in mesh form
e. Insert spikes vertically in ground
f. Laid risers between earthing mesh & structures/foundations
g. Joints are welded after proper clamping, V-grooves & bitumen paint of 2 mm thick over joints
h. Fill the trench with earth and cover by crushed stone of 5 to 8 mm size
i. Measure & record resistance at each step of 01 meter

4. Selection/Applications of electrodes and earth conductor

GI pipe for Distribution Boards, Meter Boars, Feeder Pillars, OH line poles & street lighting with GI strip or wire.
GI plate for fire pumps, Water works, lightning conductors, Substation/DG protective earth with GI strip.
Cu plate for Neutral point of transformer and DG sets with Cu strip or wire.
Earth Mat for EHV AC and DC substations. It is used to discharge over voltages from OH ground wires, to provide path for surge arrestor & earthing switch

4.1. Specifications for Electrodes and earthing conductors-

GI pipe - 38/40mm Ø GI medium class pipe, 3.45 to 4.5 metre long with no joints. GI pipe cut tapered at bottom & holes of 12 mm Ø @ 75 mm spacing up to 2m length from bottom
GI plate – dimensionally correct and surface shall be bright, clean, smooth, free from scratches, porosity, black oxide layer and other visible defects. Other specifications, testing and acceptance criteria are given in

Galvanising details.
Cu plate – dimensionally correct and surface shall be clean, high conductivity, smooth, free from scratches, porosity, black oxide layer and other visible defects
For high HP motors- hard drawn bare cu wire or cu strip

4.2. Galvanization-
4.2.1 Process
Wet process, dry process and continuous galvanizing process*
Hot dip Galvanization is an old & well known process for protection against corrosion. Zinc coating firstly protects the bare metal by acting as an impervious shield between metal & atmosphere and secondary offers sacrificial protection of the base metal surface. Zinc solution used for coating should contain minimum 98.5 % (by mass) of pure zinc.
It consists of cleaning base steel surface by first oxidizing and subsequently reducing the surface oxides under controlled atmosphere. Mild Steel is heat treated in annealing/normalizing furnace followed by continuous feeding through molten zinc bath & passivation treatment by suitable agent like chromic acid. After galvanizing the excess molten zinc is wiped off by air or gas jets. There is no flux in this process. Advantages of this process on dry & wet process are high productivity, control of coating thickness, uniformity, better adherence, less drop formation, better surface appearance.
4.2.2. TESTING & INSPECTION---
a. Freedom from defects- shall be adherent, smooth, bright, continuous and free from imperfection like flux, dross inclusions, bare & black spots, pimple, lumpiness, rust, bulky white deposits & blisters.
b. Uniformity in thickness- Preece test for small specimens and for newly coated item only. For quick and approximate measurement of thickness, magnetic gauges may be used with suitable calibration.
c. Bending test- sample shall free from burrs of size 230 mm long, 75-100 mm wide. Sample shall withstand bending through 180 degree around a mandrel having dia. 3 times of sheet thickness, without peeling or flaking of zinc coating. Crack or fracture of base metal is not permitted. For GI tubes bend at 90 degree with a radius 8 times of dia.
d. Water immersion test- partially immerse the test piece in distilled water at room temp. Failure of coating is indicated by the appearance of iron rust spots in a few hours to 48 hours.
e. Adhersion test-
i. Pivoted hammer test- hammer should be made of 3-4% of carbon steel. Hammer blow shall be controlled by holding the pivoted base of the handle on horizontal surface of galvanized sample and allowing hammer head to swing freely through an arc from vertical position to strike the horizontal surface. Two or more standard blows forming parallel impression with 6mm spacing away from edges ≥ 12mm. Removal or lifting of coating in the area between impression shall prove failure of coating, an extruded ridge less than 2mm wide immediately adjacent to the impression shall be disregarded. Test at several places of specimen.
ii. Knife test-when try with pressure only small particles should be removed & shall not possible to peel of any portion.
iii. Supplementary test- Qualitative test- Apply a drop or several drops of dilute HCL (1:1) to the sample. The presence of zinc is indicated by immediate vigorous effervescence (evolution of hydrogen) , if no appreciable zinc is present the effervescence will be mild. By carefully removing the acid a confirmatory test for the zinc may be made as follows. Neutralize the acid with ammonium hydroxide, acidify with acetic acid and pass hydrogen sulphide into the solution. A white precipitate confirms the presence of zinc. By cleaning and dipping in copper sulphate solution if no red point arises, then sample is OK. Store always in ventilated space to avoid white rust & wet stains
4.2.3 Acceptance

TABLE-1

Defect Description	Action
Bare patches/black spot	Accept if patches are small & apply zinc rich paint spray
Roughness	Reject
Pimples	Reject, if pimples are heavy
Lumpiness	May be accepted
Flux inclusions	Accept
Ash inclusions	Accept, if in gross lumps
Dull grey coating	Reject
Rust stains	Reject
Bulky white deposits	Reject
Blisters	Accept, if generally spread

5. Design Parameters

5.1 Calculation of earth fault current by per unit values-

Consider a system of source impedance 4.8 ohm connected to a 5 MVA transformer (11/0.4 KV) at 6% impedance. We have to find the fault level at secondary side.

Base current is-

$$I_{base} = \frac{P_{base}}{V_{base}\sqrt{3}} = \frac{5}{11x\sqrt{3}} = 0.262kA \quad (1)$$

And base impedance is

$$Z_{base} = \frac{V_{base}}{I_{base}\sqrt{3}} = \frac{11}{0.262x\sqrt{3}} = 24.229\ \Omega \quad (2)$$

Per unit impedance at source is

$$Z_{pu.source} = \frac{Z_{actual}}{Z_{base}} = \frac{4.8}{24.229} = 0.198\ \Omega \quad (3)$$

$$per\ unit\ inpedence\ of\ transformer\ Z_{pu.transformer} = \frac{MVA_{base}}{MVA_{transformer}} X \frac{Z\%}{100} = \frac{5}{5} X \frac{6}{100} = 0.06\ \Omega \quad (4)$$

$$fault\ MVA\ is\ MVA_{fault} = \frac{MVA_{base}}{Z_{pu}(source+fault)} = \frac{5}{0.258} = 19.37\ \text{MVA} \quad (5)$$

The line – neutral voltage on the secondary side of transformer is 0.4/√3=0.230 KV, by putting the values of above equations, we will find out the earth fault current-

$$I_{fault} = \frac{MVA_{fault}}{3\ X\ U_{LN}} = \frac{19.37}{3x0.230} = 28.072\ kA \quad (6)$$

5.2 size of protective conductor

$S=\frac{\sqrt{I^2t}}{K}$ sqmm where I is fault current in Amp. K is constant value for different material & different conditions. t is duration of fault current. S is cross section area in sq.mm of earthing conductor. Value of K for cu & GI from can be taken from given table.

TABLE(2)

Area conditions	Time of fault currents	Copper	Steel/GI	initial / final temp (Cu ; Steel)
no risk of fire, no danger to surrounding	1 sec / 3 sec	205 / 118	80 / 46	40 / 395;500
bare earth conductor touching with insulated cables	1 sec / 3 sec	170 / 98	62 / 36	40 / 160 ; 250
explosive areas/ high risk of fire	1 sec / 3 sec	153 / 88	56 / 32	40 / 200 ; 200

Factors – condition of soil, temp, moisture contents in soil, type, size & spacing of electrode, depth, material, quality of coal dust/charcoal.

6. Installation standards

6.1 Selection of system

Select the earthing system as per your requirements and permissible by local authorities. In India, TN-S system is adopted for networks up to 0.4 KV and T-TN-S system for 11 KV and above.

6.2 Selection of electrode type

Select suitable earth electrodes for the different systems and applications, mentioned in **clause 4.1**. If metal sheath & armour has been used as earth continuity conductor, armour to be bond with metal sheath & connection between earth wire & electrode shall be made to metal sheath

6.3 Location and gaps

Keep minimum 2.0 metre away from building & avoid any damage to the foundations of building. Prefer moisturised soil for better results. Avoid entrance, pavements & roadways. Pit may be zig zag @ 45 degree, curved/ polygon if not possible straight. Keep gap between pipe to pipe electrode 2 meter and plate to plate electrode 3 meters. Main earth conductor to be laid in 15 mm medium GI for wire & appropriate sized GI pipe for strips up to building at depth 300-600 mm from ground level. It should not buried/crossed in direct earth soils. Inside building, it may recess in walls or floors. Earth conductor shall be of same material as of electrode GI/Cu/Al strip wire or cable. All fittings must be of GI for GI electrode & forged tinned brass for Cu. Maximum cross sectional area of strip is 150 mm^2 for GI & 100 mm^2 for Cu. Earth pit shall not installed to proximity of metal fence to avoid possibility of fence become live. Bare AL shall not be used underground.

6.4 Installation
Refer details in **clause 3** for various types of earth pits.

6.5 Size selection of earth continuity conductor
Refer details in **clause 5.2**

6.6 Testing
Measurement can be done by earth tester (Fig. –D), short C2 & P2 and connect to electrode under test. Connect C1 with auxiliary electrode (A1) & P1 with middle electrode (A2). It gives direct value of earth resistance. At the time of test, electrode should be isolate by the system. Auxiliary electrodes shall be of 12.5 mm^2 MS @ 1.0 metre depth and 30 metre away from the test electrode. Insert electrode A2 in between both.

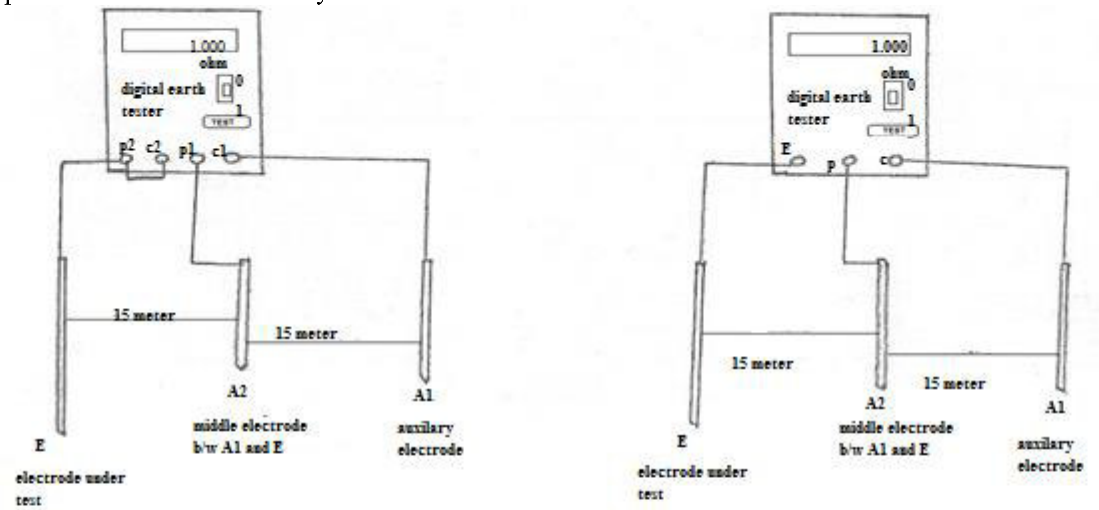

Fig. –D, 4 terminal earth tester (1) and 3 terminal earth tester (2)
Max permissible value for Large power station<= 0.5; Major ESS <=1.0; Small ESS<=2.0; Other cases<=5.0; Rocky soil<=8.0earth; and continuity from pit to any point in installation 01 ohm. If earth resistance exceed above mentioned values then process for artificial treatment of soil

6.7 Artificial treatment of soil
If required ohmic value is not achieved we shall proceed to artificial treatment of soil. Electrode shall be surround by charcoal/coke & salt. Excavation shall be increased in depth & surface area to lock moisture better. Treat by copper sulphate $CuSO_4$, calcium chloride $CaCl_2$, sodium carbonate Na_2CO_3 soft coke. In special cases pits should be irrigated during summer. Gel/chemical earthing may also be used if treatment is not possible.

6.8 Protection of earth pit
Refer details in **clause 3.3**

6.9 Marking
Earth points shall marked permanent **'E'** and main earthing terminal shall be marked **'safety earth- do not disconnect'**

6.10 Detailed layout
Detailed dimensional layout plan should be prepare showing all earth pits with adopted system/type and function. Layout shall contain nos. , locations, function, route, size and type of all earth continuity conductors & bonding points

6.11 Maintenance
All earth terminals/joints shall be visible for inspection & testing except in compound filled & encapsulated joints & drawing must prepare for layout & details with connections. Test link shall provide for periodic testing and to maintain moisture in soil. Visual inspection of electrode & all connections must carry out once in quarter Earthing may not give protection against faults which are not essentially earth faults. Electrode shall keep free from paint, enamel & grease.

7. Requirements and applications

7.1 Statuary

Neutral may be earthed through suitable impedance. All power system of today operates with grounded neutral because earth fault protection is based on the method of neutral earthing and system voltage during earth fault also based on the method of neutral earthing. Neutral earth provide at source end only, not at load end. OH shielded wire earthed at 30 Metre above ground with adequate clearance. Keep shielding angle 45 degree & steel wire should be 7/9 SWG.

7.2 Equipment earthing

Ensures that exposed parts do not become dangerous by attaining high touch potential during any fault. It will also carry earth fault currents, till clearance (by protective device) without creating fire hazards.

7.3 Domestic

01 no. earth conductor for single phase & 2 nos. of earth conductor by separate earth pits for 3 phase systems is essential. Looping allowed only in point wiring, not in socket outlets. Every switch board has to be bond with earth. Earth link shall provide in DB and earth pin of sockets. Avoid twisted earth connections

7.4 OH lines

Stay wire in OH lines, transmission towers, non current carrying metallic parts to be connect with earth.

7.5 ESS

Body earth the sheath of cable & other non conductor parts of ESS. Terminate neutral point of equipment and /or earth bus truck as required. Bonding is not required for separate units inside a cubicle. Types of neutral earthing given in table-

TABLE- (3)

Type	Voltage	Reason
Solid	Up to 660 Volt	low earth fault current, easy fault detection, higher safety
Low resistance /reactance	3.3 kv to 11 kv	to limit fault currents, to prevent m/c from damage
Solid	22 kv and above	Fault currents limited by fault resistance. No rotating m/c connected at this voltage in distribution systems

Common earth pit can be used for DG body earth & ESS equipments if in same building, but shall be separate for each lightning arrestors & neutral points. Neutral of generator may be connect to impedance to limit the fault currents to earth. Points to be earthed in ESS -

Surge arrestor - lower earth point
LA - each pole earth terminal
PT - LV neutral, LV winding phase lead
CT - secondary winding
Transformer tank - all detachable parts

7.6 Telecomm

It is essential to complete the circuit of telegraph/telephone which employing on earth path for signalling purpose. To earth power supply and to stabilize the potential of equipment w.r.t. earth. For Lightning protection apparatus and earth screening conductors for reduction of electrical interface with telecom circuits. Separate earth shall provide for protective, functional, power system & LA.

7.7 Data processing units

RF interface suppression filters fitted to data processing equipments may produce high earth leakage current. In such cases, failure of continuity in the protective earth connection may cause a dangerous touch voltage Data processing equipments are electrically operated m/c units that separately or assembled in system, accumulate process & store data. Acceptance or divulgence of data may or may not be electronic means. The requirement of this clause apply where equipment (having high leakage current >10mA) is connected to any power system. Earth electrode system in HV—it includes all metal work, fence, bonded to power system earth electrode & situated within 100 metre outside the fencing that surrounds the HV compound. It also includes 1st 03 supports of OH line leaving the station. Earth electrode area- any area within 5 meter of any part of earth electrode system .avoid earth electrode system area or provide separate earth pit for Data centre in that area.

7.8 Pipelines and storage tanks

When a liquid flows in a pipe, charge separation occurs between the liquid & inner surface of pipe, producing electrostatic charge on the both. In case of pure gas or mixture of pure gases, it will not occur but in practice, gases often contains solid & liquid particles, so charge may be generate when these particles impinge on the walls of pipe or on obstructions. The extent to which the charge are retained is depends on resistivity of pipe material & conductivity of liquid flowing. High resistivity pipe may have metallic components such as flanges or valves & these may retain charge if not earthed. It may also accumulate on the outer surface & insulated metal components in the line. Potential will be high enough to cause incendive discharges which can be generated by flow of both flammable & non flammable liquids & gases. Also if the liquid/gas is flammable, there may be an ignition risk if air enters the system and produce a flammable mixture within the pipe. Plastic pipes are restricted for flammable to avoid fire risks. Keep Earth value ≤ 10 ohm for such cases. If pipeline is completely buried in ground, no earth required

7.9 Mobile DG sets

Neutral to be connect with vehicle chassis. Earth terminal at each outlet on vehicle should connect to neutral separately. Electricity board earth terminal or exposed structural metal work can be used for body earth.

8. Earth bonding points

8.1 Essential

Stay wire in OH lines,
Transmission towers
Body/frame of non current carrying path,
Special provisions for operation theatres, data processing units, telecomm,
Lightning protection
Earth with fence body, tanks, supports, structures, towers, water pipes etc
In DC 3 wire system middle conductor at generating station only and reading should be taken continuously by recording ammeter. If exceeds 1/1000th part of maximum supply immediate take step for improvement.
Cradle guarding crossing over telecom shall earthed with value≤25 ohm with breaking strength of 635 kg for GI
Continuous earth wire for each pole in oh line, earth 3 points in every km at equidistance.

8.2 Avoidable

OH line insulators, wall brackets or other metal out of arm's reach
Inaccessible steel reinforcement in RCC poles
Fixing screws of non metallic part on line parts
Short length of conduits or similar items which are not accessible
Metal enclosure for mechanical protection of double insulated equipments

9. Protective Devices

9.1 Surge arrestor

It is a device to protect electrical equipment from over-voltage transients caused by external (lightning) or internal (switching) events. Also called a surge protection device (SPD) or transient voltage surge suppressor (TVSS)

9.2 Lightning Arrestor

It is a device used on high rise building structures, electrical power systems and telecommunications systems to protect from the damaging effects of lightning. The typical lightning arrester has a high-voltage terminal and a ground terminal

9.3 RCDs

RCD stands for Residual Current Device and this term can cover a multitude of devices with other acronyms such as ELCB, RCCB, RCBO and RCD. Earth Leakage Circuit Breaker (ELCB), Residual Current Circuit Breakers (RCCB) or Residual Current Breaker with Overload (RCBO), are frequently found in the mains switchboards or consumer units. They protect the consumer supplied sockets and lighting from a specific fault condition such as a leakage of current to earth. These units will trip when the device detects small amounts of stray current. The most common trigger value is 30mA as it is also stipulated in many wiring regulations for domestic applications. An ELCB required a third connection to an associated earth terminal. The earthed connection was used to detect any voltage difference between the earth and neutral indicating that there was a current flow into the earth being monitored. The RCCB detects a current difference between the live and neutral conductors. This current is known as a residual current. Correctly functioning circuits will always have a balanced live and neutral current and a residual current only occurs when there is a fault or potential shock hazard. RCBO is a combination of a residual current device and a miniature circuit breaker combined. In a single pole device you still need to feed through the Neutral conductors of the circuit but only the live conductor is actually switched. Technically, all the above are Residual Current Devices (RCD's) but generally the term RCD tends to refer to the power socket level implementation of RCD. These can either be built into a power socket or alternatively, they plug between the power socket and the plug of the appliance to be protected

9.4 Earthing switch

A switch which connects conductor to the earth, to discharge the charge on the conductor to the earth. Generally these are installed on the frame of isolators. Normally it is open, closed when line disconnected to discharge the trapped voltage on line. Used at each incomer & earth bus bar section

9.5 Earth truck

The earthing truck has the function of connecting the busbars in one half-switchboard to earth. Naturally, the earthing operation must be carried out when de-energised so as not to create a short-circuit. It is used in maintenance purpose. When we put any system for maintenance, earthing truck inserted in bus bar/cable section under shut down and it will earth the static current/charge remaining on the conductor to the ground mass & ensure safety to the working personnel.

9.6 Instrumentation/relays

Earth fault relays sense the fault current and proceed command to circuit breaker for tripping the line. There are various types of relays & other instrumentation which depends upon the type/location of fault and grounding arrangements.

Conclusion

Grounding of any system is most essential part to achieve required safety & smooth functioning of systems. We can minimize/eliminate fire hazards, electrocution to system/personnel, improve signal & efficiency of system by means of good practice and suitable system selection of earthing. Major points to be focussed for successful and effective earthing systems are selection of system, type/size of electrode and conductor, good installation practice, periodic testing and maintenance.

References

1. S. Rao, Electrical substation engineering and practice, Khanna Publishers, Delhi -06.
2. Bureau of Indian standards IS: 4736-1986 (reaffirmed 1998) Specifications for hot dipped zinc coating on mild steel tubes.
3. Bureau of Indian standards IS: 7689—1974 (reaffirmed 2005) Guide for control of undesired static electricity
4. Bureau of Indian standards, IS: 3043-1987 (2006) Code of practice for earthing
5. Bureau of Indian standards, IS: 2633-1966(reaffirmed 2006) Method for Testing Uniformity of Coating on Zinc Coated Articles
6. Bureau of Indian standards, IS: 2629-1985(reaffirmed 1994) Recommended Practice for Hot Dip Galvanization of Iron and steel
7. Bureau of Indian standards, IS: 277-2003 (amended 2007) Galvanized Steel Sheets - Specifications
8. CPWD general specifications for electrical works part 1, Internal
9. S. Rao, Testing, commissioning, operation and maintenance of electrical equipment, Khanna Publishers, Delhi-06.
10. J.B. Gupta, Electrical installation estimating and costing, S.K. Kataria and sons, New Delhi-02
11. Bureau of Indian standards, IS: SP 30-2011 (National electrical code)
12. Indian Electricity Rules: 1956 (amended up to 2012)
13. IEEE standard 80-2000, IEEE guide for safety in AC substation grounding
14. IEC code 60364, International Electrotechnical Commission's standard on Electrical installation on buildings
15. myelectrical.com, fault calculation-per unit system by Steven McFadyen