TECHNICAL SPECIFICATION FOR MAINTENANCE FREE EARTH FOR ELECTRICAL INSTALLATION

1. SCOPE

This specification covers supply, installation, connecting, testing & commissioning of Maintenance Free Earthing suitable for Package Substations, distribution transformers, RMU & Feeder Pillars etc.

Earthing is essential in any electrical installation to provide safety. The conventional GI pipe earthing system employing charcoal & salts are provided for various applications as per IS:3043. Corrosion of metallic parts is comparatively fast besides maintenance by way of watering of earth pits and chiseling of corrosion prone parts & their replacement requires monitoring which may not always be feasible in certain crowded and inaccessible areas.

This specification covers components, enhancing material & jointing used and procedure for constructing the earth pit for maintenance free earthing system to ensure that the resistance to earth is near zero consistent throughout the year.

2. SERVICE CONDITIONS

Equipment to be supplied against this specification shall be suitable for satisfactory continuous operation under the following tropical conditions.

a) Maximum ambient temperature of air: 50˚C
b) Maximum temperature of air in shade: 4˚C
c) Maximum daily average ambient temperature: 40˚C
d) Maximum yearly average ambient temperature: 30˚C
e) Relative Humidity: up to 95%
f) Average number of thunder storm days per annum: 15
g) Maximum annual Rainfall: 150cm
h) Maximum Altitude above mean sea level: 1000Meter
i) Maximum Wind Pressure: 150 Kg/cm2 (As per IS 802 latest code)
j) Maximum soil temperature at cable depth: 30˚C
k) Maximum soil thermal resistively: 150˚C cm/watt

3. APPLICABLE CODES & STANDARDS

a) IEEE 80 :IEEE guide for safety in AC sub-station grounding
b) IS : 3043 :Indian standard code of practice for earthing
c) IEEE 837 :Standard for qualifying permanent connections used in substation grounding

4. APPLICATION

Earthing systems covered in this document shall be for providing effective grounds for

I. Sub-Stations
II. supply control posts
III. RMU, Transformer and Generator neutral earths
IV. Lightning arrester earths
V. Equipment earths including panels
VI. In applications for PRS, UTS, FOIS, COIS, ATMs and data processing centre etc.

5. GENERAL TECHNICAL REQUIREMENTS

(I) SELECTION OF EARTHING SYSTEM

Sl. No	Installations/ Current Capacity	IR Value Required	Soil Type/ Resistivity	Earth System
1	House hold earthing/ 3kA	8 ohm	Normal Soil/ upto 50 ohm-mtr	Single Electrode
			Sandy Soil/ between 50 to 2000 ohm-mtr	Single Electrode
			Rocky Soil/ More than 2000 ohm-mtr	Multiple Electrodes
2	Commercial premises Office buildings/ 5kA	2 ohm	Normal Soil/ upto 50 ohm-mtr	Single Electrode
			Sandy Soil/ between 50 to 2000 ohm-mtr	Single Electrode
			Rocky Soil/ More than 2000 ohm-mtr	Multiple Electrodes
3	Transformers, substation earthing, LT line equipment/ 15kA	1 - 2 ohm	Normal Soil/ upto 50 ohm-mtr	Single Electrode
			Sandy Soil/ between 50 to 2000 ohm-mtr	Single Electrode
			Rocky Soil/ More than 2000 ohm-mtr	Multiple Electrodes
4	Transformers, substation earthing, HT line equipment/ 40kA	less than 1 ohm	Normal Soil/ upto 50 ohm-mtr	Single Electrode
			Sandy Soil/ between 50 to 2000 ohm-mtr	Single Electrode
			Rocky Soil/ More than 2000 ohm-mtr	Multiple Electrodes
5	Lightning arresters, extra high current applications etc./ 50kA	less than 1 ohm	Normal Soil/ upto 50 ohm-mtr	Single Electrode
			Sandy Soil/ between 50 to 2000 ohm-mtr	Single Electrode
			Rocky Soil/ More than 2000 ohm-mtr	Multiple Electrodes
	PRS, UTS, RTUs, FOIS,		Normal Soil/ upto 50 ohm-mtr	Single Electrode

6	COIS, ATMs and data processing centre etc./5KA	less than 0.5 ohm	Sandy Soil/ between 50 to 2000 ohm-mtr	Single Electrode

			Rocky Soil/ More than 2000 ohm-mtr	Multiple Electrodes

(II) TYPE OF SOILS

Soil can be classified in to various types, though based on the size of the particles it contains:

Normal soil

Black cotton soil, vegetable soil, garden soil, loamy garden, soil shallow black, soil medium black soil, deep black soil and marshy soil etc. having low soil resistivity value (up to 50 ohm-meter)

Sandy soil

This type has the big particles and the size of the particles does determine the degree of aeration and drainage that the soil allows. It is granular and consists of rock and mineral particles that are very small. Therefore, the texture is gritty and sandy soil is formed by the disintegration and weathering of rocks such as limestone, granite, quartz and shale, thus resulting in over-drainage. It warms very fast in the spring season. Coastal area, silt soil, red sandy soil, sandy clay and coastal alluvium etc having soil resistivity up to 2000 ohm-meter are considered as sandy soil.

Rocky soil

The area containing rocks, pebbles, uneven hard surface laterite soil, lime stone, sand stone, gravel, granite and chalk etc having soil resistivity more than 2000 ohm-meter is considered as rocky soil. This type of soil does not absorb moisture and are extremely poor conductor.

(III) LOCATION OF EARTH ELECTRODE

Where there is option, site should be chosen in one of the following types of soil in the order of preference given: -

a. Wet marshy ground;
b. Clay, loamy soil, arable land.
c. Clay and loam mixed with varying proportions of sand, gravel and stones;
d. Damp and wet sand, peat.

Dry sand, gravel chalk, limestone, granite, very stony ground and all locations where virgin rock is very close to the surface should be avoided,

(IV) MEASUREMENT OF EARTH ELECTRODE RESISTANCE

The earth resistance shall be measured using fall of potential method as per para 37 of IS:3043.

(V) EARTHING SYSTEM

The earthing system includes earth electrode, installation of earth electrode in suitable pit size, construction of earth pit with cover for the installation, connection of earth electrode with equipotential earth bus and connection of equipment to equipotential earth bus.

Earth electrode

The earth electrode is the main component of the earthing system which is in direct contact with the ground and thus provides a means of releasing or collecting any earth leakage currents. The material should have good electrical conductivity and should not corrode in a wide range of soil conditions. For an effective earthing system, two types of earth electrodes can be used as described here:

Rod earth electrode

- High tensile-low carbon steel rod having diameter not less than 17mm complying with requirements of BS 4360 Grade 43A or EN10025:2-004 S275JR, molecularly bonded by 99.99% pure high conductivity copper on outer surface with copper coating thickness 250 micron or more, Length 3000 mm (minimum). Length of the electrode may be increased in multiple of 1 meter to reduce earth resistance if required. To increase the length, pieces of similar rod shall be either exothermally welded to basic 3-meter electrode or connected using socket of suitable size. These sockets shall also be molecularly bonded by 99.99% pure high conductivity copper on inner & outer surface with copper coating thickness 250 micron or more.
- Copper bus bar of size 250 mm x 50mm x 6 mm having electrical conductivity of 101% IACS, minimum 99.9% copper content shall be exothermically welded to rod with 4 holes of 12 mm dia. (2 on each side) for connecting earthing conductor.
- Current carrying capacity: The design of the electrode should be such as to have more than 15kA current carrying capacity for 1 second.

Concentric pipe earth electrode:

- Primary conductor
  MS pipe with 25 - 50 mm diameter, class B, ISI mark as per IS-1239, Length 2000 or 3000 mm as per table below current carrying capacity.
- Secondary conductor
  MS pipe with 40-100 mm diameter, class B, ISI mark as per IS-1239, Length 2000 or 3000 mm as per table below current carrying capacity.
- Conductive mixture
  For hermetically filling inside the cavity i.e. between secondary conductor & primary conductor, crystalline compound is to be injected in the electrode assembly. It is a combination of high conductivity metal alloys, copper & aluminum powder, conductive carbon/cement and bonding material etc. mixed in different proportion. The mixture is forced (pressurized) filled inside the earth electrode in the paste form and after solidification of the same, the end caps are welded. The metal alloys shall help in conducting the current and conductive carbon gives anti corrosive property. Bonding material should provide strength to the mixture. Resistivity of the mixture shall be less than 0.2 ohm-meter. Resistivity shall be tested by making a 20cm cube of the material and checking resistance across the opposite face of the cube.

- Complete electrode shall be molecularly bonded by 99.99% pure, high conductivity copper on outer surface with copper coating thickness 300 micron or more.
- Its surface shall be clean and free from any visible oxide layer or foreign material.
- Copper bus bar of size 250 mm x 50mm x 6 mm having electrical conductivity of 101% IACS, minimum 99.9% copper content shall preferably be exothermically welded to earth electrode or connected with the help of two number stainless steel nut bolts of appropriate size having 4 holes of 12 mm dia. (2 on each side) for connecting earthing conductor.

- Current carrying capacity:
  The design of the electrode should be such as to have more than following current carrying capacity in kA (for 1 second):

Sl. No	Current Capacity	Primary Conductor diameter	Electrode dimensions (dia. x length)
1	3 kA	25 mm	40 mm x 2000 mm
2	5kA	25 mm	40 mm x 3000 mm
3	15kA	25 mm	50 mm x 3000 mm
4	40kA	40 mm	80 mm x 3000 mm
5	50kA	50 mm	100 mm x 3000 mm

Note: - For more than 50KA applications, multiple electrodes of 50KA capacity shall be installed and connected.

Earth enhancement material:

Earth enhancement material is a superior conductive material that improves earthing effectiveness, especially in areas of poor conductivity (rocky ground, areas of moisture variation, sandy soils etc.). It may contain conductive cement, graphite, hydrous aluminium silicate, sodium montmorillonite etc and shall not contain bentonite. It improves conductivity of the earth electrode and ground contact area. It shall have following characteristics

i. It should have low resistivity preferably bellow 0.2 Ohm-meters. Resistivity shall be tested by making a 20cm. cube of the material and checking resistance across the opposite face of the cube.
ii. It shall not depend on the continuous presence of water to maintain its conductivity.
iii. It should be a little alkaline in nature with pH value >7 but test certificate from NABL approved laboratory to be provided for the composition so designed.
iv. It should have better hygroscopic properties to absorb moisture. It should absorb and release the moisture in dry weather condition and help in maintaining the moisture around the earth electrode.
v. It should have capacity to retain >10% moisture at 105ºC. Test certificate from NABL approved lab to be submitted for the composition so designed.
vi. It should have water solubility < 5%. Test certificate from NABL approved lab be submitted for the composition so designed.
vii. It should be granular with granule size 0.1 mm to 3 mm.

viii. It should be nontoxic, non-reactive, non-explosive & non-corrosive.
ix. It shall be thermally stable between -10 degrees centigrade to +60-degree centigrade ambient temperature.
x. It shall not decompose or leach out with time.
xi. It shall not pollute the soil or local water table and meets environmental friendly requirement for landfill.
xii. It should expand & swell considerably and removes entrapped air to create strong connection between earth electrode and soil.
xiii. It should be diffusing into soil pores and creates conductive roots enlarging conductive zone of earth pit.
xiv. It shall be permanent & maintenance free and in its "set form", maintains constant earth resistance with time.
xv. It shall not require periodic charging treatment or replacement.
xvi. It shall be suitable for any kind of electrode and all kinds of soils of different resistivity.
xvii. It shall not cause burns, irritation to eye, skin etc.
xviii. Minimum quantity of earth enhancement material to be supplied: For 5' x5'x 10' earth pit – Min. 75 kgs per pit for 300mm bore type earth pit – Min 50 kgs per pit
xix. The Earth enhancement material shall be supplied in sealed, moisture proof bags. These bags shall be marked with Manufacturer's name or trade name, quantity, batch no & date of manufacture.

Backfill material

Normally the excavated soil shall be used if it is free from sand, gravel and stones. In case the excavated soil contains sand, gravel and stones these shall be removed by appropriate methods such as hand picking, sieving etc. Small proportion of sand in the soil may be permissible. Material like sand, salt, coke breeze, cinders and ash shall not be used because of its acidic and corrosive nature. If the excavated soil contains sand, gravel and stone in large proportion and it is not feasible to remove these economically, good quality soil from other place may be used for backfilling. While backfilling the soil shall be thoroughly compacted with at least 5 kg compactor. In case the soil is dry, small quantity of water may be sprinkled only to make it moist enough suitable for compacting. Large quantity of water may make the soil muddy which is not suitable for compacting and after drying the soil may contain voids which may permanently increase earth resistance.

Equipotential bus & Earthing Conductor

- A copper bus bar of size 300mm x 25mm x 6mm to be installed in the equipment room as equipotential bus and must be connected with preferably copper strip of 25mm x 3mm (suitable length) from instrument to the bus bar. The connecting terminal of the earth electrode to the bus bar must be connected by copper strip of 25mm x 3mm (suitable length) buried inside a trench of 300mm width x 600mm depth (from the earth pit to the nearest wall). It shall be duplicated. However, it shall be ensured that only minimum required length is used and any extra length is cut away to keep the earth impedance minimum.

- It shall be high conductivity copper having electrical conductivity of 101% IACS i.e. minimum 99.9% copper content The maximum specific resistance of the copper strip earthing conductor shall be 17.241 x 10-7-ohm cm at 20ºC.
- At a temperature of 20ºC, its density shall be 8.89 gm/cm3
- Its surface shall be clean and free from any visible oxide layer or foreign materials.
- It shall preferably be connected to earth electrode and earth bus bar with the help of exothermic welding or at least two number stainless steel nut bolts of appropriate size.
- Normally a single length of copper strip shall be used for each duplicate copper strip earthing conductor and no joint should be used. However, in situation requiring greater length one joint in each copper strip shall be permitted. The joints shall be made by exothermic welding of at least 10mm overlapping portion of the strips.

Construction of ring earth by providing multiple earth pits

- Wherever it is not possible to achieve required earth resistance with one earth electrode/pit due to difficult/rocky soil conditions, provision of ring earth consisting of more than one earth pit shall be done. The number of pits required shall be decided based on the resistance achieved for the earth pits already installed. The procedure mentioned above for one earth pit shall be repeated for other earth pits.
- The distance between two successive earth electrodes shall be min. 3mtrs / length of electrode whichever is higher. and max. up to twice the length of the earth electrode.
- These earth pits shall then be inter linked using 25X3 mm copper strip to form a loop preferably using exothermic welding or with the help of at least two number of stainless steel nut bolts of appropriate size.
- The interconnecting strip shall be buried no less than 600mm (0.6m) below the ground level. This interconnecting strip shall also be covered with earth enhancing compound.

(VI) MARKING:

The marking shall be clear, distinct and visible to the naked eye from a distance of about 1 meter; the size of marking shall be of minimum 25 mm. Following information shall be legibly and indelibly marked on the packed sets:

a. Specification no.
b. Name of the manufacturer
c. Batch no. & Date of manufacturer
d. Current carrying capacity

6. TESTING & COMMISSIONING

Following tests shall be done on one sample-

- Testing of copper coating shall be done as described below: -

i. The copper coating mentioned in clause 14.5.5.1 shall not be less than the prescribed thickness at any point and shall comply with the adherence requirement in para (ii) & (iii) below.

ii. Length of the electrode with one end cut to a 45-degree point shall be driven between two steel clamping plates or the jaws of a vise set 0.04 in (1.02 mm) less than the diameter of the electrode, so as to shear off sufficient metal to expose the bond between the copper coating and electrode. Peeling of the coating by the steel plates or the jaws of the vise is acceptable, but there shall be no other evidence of separation of the coating from the metal core.

iii. At room temperature, a length of the electrode is rigidly held in a clamp or vise and the free end is bent by applying a force normal to the electrode at a distance from the clamping device equal to 40 times the diameter. The magnitude of the force and the direction of application of force shall be such that the electrode is permanently bent through a 30-degree angle. While bending of the electrode there shall be no evidence of cracking of the copper coating.

- Material composition of rod shall be tested as per standards mentioned in clause no. 14.5.5.1 (Rod Earth Electrode)
- MS pipes shall be tested as per IS:1239.
- Copper bus bars of shall be tested for percentage of copper as per IS:14644.
- Current carrying capacity test on rod electrode shall be done as per clause above.
- Corrosion Test: As per IS:2119, salt spray test for analysis of effect of corrosion for the specific electrode shall be done through NABL approved testing lab, preferably for 500 hrs. or more.
- Exothermic weld material shall be tested as per provisions of IEEE 837.
- Electrical properties test on conductive mixture as per clause above.
- Physical, chemical & electrical properties test on earth enhancement material as per clause no. 14.5.5.2.
- Toxic content tests for cadmium, lead, mercury, hexavalent chromium, polybrominated biphenyls (PBBs) & polybrominated diphenyl ethers (PBDEs) on conductive mixture & earth enhancement material.

  Certificates from NABL approved laboratories shall be submitted with test results of above tests. Test certificates shall not be more than three years old.

  For dimension, weight and specific resistance average of 3 readings shall be taken. Average value shall be within specified limits and individual values shall not go beyond double of tolerances.

ACCEPTANCE TESTS

Following shall constitute acceptance tests and shall be done on 100% sample basis for all the tests mentioned below except where otherwise indicated–

a. Physical check for earth electrode as per clause above for rod type electrode and as per clause above for concentric pipe type electrode.
b. Physical check for copper bus bar as per clause above for rod type electrode and as per clause above for concentric pipe type electrode.
c. Dimensional and construction feature tests of inspection chamber
d. Earth enhancement material as per clause no. 14.5.5.2
e. Earth resistance measurements as per clause no. 14.5.4.

Rejection:

In case the any component tested and inspected in accordance with this specification, fail to pass the tests or comply with the requirement of the specification, another two components from the same lot shall be inspected in accordance with the specification and if one of them also fail to pass the test, the whole lot of that component shall be rejected subject to the discretion of the purchaser or his nominee.

INSPECTION:

All the gauges/ test & measuring instruments shall be under calibration control at the time of inspection and proof to this office shall be produced. Inspection and testing shall be carried out by the inspecting authority nominated by the purchaser to ensure that all the requirements of this specification are complied with for the acceptance of the materials offered by the supplier for inspection. The purchaser or his nominee shall have right of free access to the works of the manufacturer and to be present at all reasonable times and shall be given facilities by the manufacturer to inspect the manufacturing process at any stage of manufacture. He shall have the right to reject whole or part of any work or material that does not conform to the terms of this specification or any other specification or requirement applicable and may order the same to be removed / replaced or altered at the expense of the manufacturer. All reasonable/complete facilities considered necessary by the inspecting authorities for the inspection shall be supplied by the manufacturer free of cost. The manufacturer shall at his own cost prepare and furnish the necessary test pieces and appliances for such testing as may be carried out at his own premises in accordance with the specification. Failing the existence of facilities at his own premises for the prescribed tests, the manufacturer shall bear the cost of carrying out the tests in an approved laboratory, workshop or test house.

COMPLETION REPORT & CERTIFICATION:

The last documents for the completion of the procedure will be submission of the work completion report to the engineer in charge. After testing the earth values of the pits and proper recording in presence of engineer in charge, certified grounding self-adhesive certificate shall be provided for all installations and the same will be displayed / pasted at the place of installation.
The complete layout with dimensions of the earthing & bonding system shall be submitted by the supplier in appropriate size (in three copies) after commissioning showing commissioning date, earth resistance, specification no. and manufacturer's name.

7. GTP

Sl. No.	Parameter Name	Details
1	Name of Manufacturer	
2	Type of earth electrode	
3	Whether Inner & Outer pipes of the earth electrodes are marked with ISI mark as per IS:1239	
4	Dimensions of the Outer Pipe (Dia x Length x Thickness in mm)	-------
5	Dimensions of the inner Pipe (Dia x Length x Thickness in mm)	------

6	Whether M. S. Pipes are hot dip galvanized as per this specification & the level of hot dip galvanizing in microns	250-300 microns
7	Whether the conductive material in the pipe electrodes is machine pressed to have homogenious solid mixture	
8	Contents of the Conductive materials (in Percentage) filled in between the two pipes & in the inner side pipe	70% Carbon powder & 30% metal powder preferably pure copper or aluminum material along with the required quantity of bonding materials
9	Whether the material is tested for resistivity as per this specification.	<0.2 ohm-meter
10	Size of bus bar connecting M. S. Plate (Hot dip Galvanized) welded to the electrode for earth connection.	350mmx50mmx6mm
11	Hardness of the Conductive material after setting	
12	Earth Resistivity of the earth electrode assembly after setting	
13	Total weight of the earth electrode assembly	
14	Brand name of the earth enhancement material (if any)	
15	Contents of the earth enhancement material (Percentage of various components in the mixture & their Chemical Composition etc.)	
16	Resistivity of the earth enhancement material	Below 0.2 Ohm-meter
17	pH value of the earth enhancement material	>7 & <9
18	Moisture retaining capacity at 105ºC	>10%
19	Granular size of the material	0.1mm to 3mm
20	Water solubility (in Percentage)	51%
21	Thermal stability of the material (Temperature Range)	-10ºC to 60ºC
22	Weight of material per bag	
23	Whether the Material is nontoxic, nonreactive, nonexplosive & noncorrosive as per the specification	
24	Whether the material is packed in proper bags & bags marked with details such as Brand name, Batch no., Year & month of manufacture & tender reference etc.	
25	Whether type tests as applicable for the materials offered are submitted if so Give details	