GUJARAT ENERGY TRANSMISSION CORPORATION LTD.

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STANDARD GUIDELINES

FOR EARTHING SYSTEM

FOR EHV SUB-STATION

GETCO/E/STD/P-009/R3, Dt.25.05.17

STANDARD GUIDELINES FOR EARTHING SYSTEM FOR EHV SUB-STATION

1.0 General

Earthing system in the Sub-Station plays very vital role in power system performance and due to that it requires special attention. Here, general philosophy for earthing system for GETCO is framed based on various standards and references.

- IS 3043-1987 gives overall guidelines for earthing of equipments.
- IE Rules-1956, rule 67 gives the guidelines for the earthing in the sub-station.
- IEEE Standard 80-2000 gives detailed guidelines for providing Earthing Mat in Sub-Station.
- IEEE Standard 81-2012 gives detailed guidelines for Measuring earth Resistivity, Ground Impedance and Earth Surface Potentials of a Grounding System
- CBIP Manual for earthing system (# 302) – gives various papers on earthing practices and case studies.

2.0 Methodology

The earthing design of complete earthing system of EHV substations should be carried out based on above mentioned standards.

2.1 Earth mat is designed as per IEEE STD 80-2000 and equipment earthing are provided as per IS 3043-1987. The drawings for equipment earthing are compiled in Drg No GETCO/E/STD/P-012 sheet 1 to 24.

2.2 The complete design of earthing system depends on the data input. Soil Resistivity is the key input and hence its measurement plays major role in correct and optimum design. Soil Resistivity should be measured with reliable and accurate instrument. The process for measurement of soil resistivity is described here for standard 66/11kv substation.

- Typical Switchyard Area: 70 Mtrs x 58 Mtrs
  Lx = 70 Mtrs
  Ly = 58 Mtrs
  Diagonal Dm = 90 Mtrs
- 14 numbers of locations shall be selected at a distance of 10 - 12 Mtrs along the diagonal point for measurement of resistance (Refer Drg no GETCO/E/STD/P-012/R0, Sheet 24).

- Measurement of resistance shall be carried out with reliable (preferably electronic earth tester) meggar using Wenner's method. (Refer Drg no GETCO/E/STD/P-012/R0, Sheet 23).

- First select Location no.1. The spacing between the spikes should be varied from 1.0 Mtr to 10.0 Mtr (i.e. at distance 1, 2, 5 and 10 Mtr) and take the readings of resistance (R) keeping distance between two spikes as 1, 2, 5 & 10 Mtr. Similarly take the set of readings for all 14 locations.
- Calculate Soil Resistivity (rho) = 2 Π S R
  (Where, S = Distance between two spikes in Mtrs
  R = Earth Resistance in Ohms)
- Record the data as per following table.

RESISTANCE MEASURED					RESISTIVITY CALCULATED			
Loc. No.	With S=1 Mtr	With S=2 Mtr	With S=5 Mtr	With S=10 Mtr	With S=1 Mtr	With S=2 Mtr	With S=5 Mtr	With S=10 Mtr
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
				Average				

- Resistivity (rho) is calculated for each spike spacing at all the 14 locations. Average of resistivity shall be derived is calculated for each spike spacing. This will give the average resistivity of the switchyard. If variation between max. and minimum values is < =30 % then uniform Soil Resistivity Model can be considered other wise two/multi layer model should be selected and design in this case becomes complicated and requires special care.
- Resistivity measured with distance between two spike S will actually represents the resistivity at the depth of S mtr. So one should take the readings for more distance between two spike (as the availability of land permits) to get the real model of soil resistivity.

2.3 The entire switch yard is laid with one or more Earth Mat (also called MESH) as per design. The typical drawing of mesh is given in Drg No GETCO/E/STD/P-010/R1 dtd 25.05.17. Mesh is made up of conductors (either MS round bar or MS Flat or GI strip). Conductors are laid along X and Y direction of yard with separation of D mtr. (as per design) at a depth of min.0.6 mtr.and joined together with the help of welding joints at all junctions.

2.4 Mesh should also be extended one/two meter beyond the fencing of switch yard. The poles of fencing should be connected to the mesh. The switch yard area should be such defined that fencing and 1-2 mtr beyond fencing area may fall in the area purchased by GETCO.When it is not possible to lay the mesh outside the fencing area, chainlink fencing should be replaced by compound wall of two-meter height with poles (1.5mtr ht) of chain link fencing and these poles should be connected to main mesh.

2.5 Vertical ground rods (MS round bars of 3.0 mtr length) shall be laid below the mesh level along the periphery and at the junction points of mesh. These rods help fault current to spread over the vicinity of land and thus discharge it in an earth rapidly.

2.6 Crushed metal (or gravel) of 20mm size with a layer of 0.10 mtr or 0.15 mtr as per design should be spread above the soil. Normally surface resistivity of metal /gravel, we use, is considered as 3000 Ω-Mtr. 0.1 mtr layer may contain 0.05 mtr layer of crushed fine powder of metal or sand and 0.05 mtr layer of 20 mm dia metal/gravel.

3.0 Maintenance free treated Earth Electrodes

3.1 The typical drawings for maintenance free treated earth electrode is given in Drg No. GETCO/E/STD/P-021/R2 dtd 04.06.2015(Sheet 1 of 2 for Normal soil & sheet 2 of 2 for Rocky Soil).

3.2 At following locations in a substation, maintenance free earth electrodes should be provided for the equipments earthing. All the maintenance free earth electrodes shall be connected with the main earth mat.

- 2 Nos. for each Neutral of power transformers. Both the electrodes should be connected in parallel.
- 1 No. for each Lightning Arrestor
- 1 No. for each Coupling Capacitor/CVT/PT
- 1 No. for each neutral of distribution transformer.
- 1 No. for each class of C&R panels combined together
- 1 No. for all PLCC panels combined together
- 1 No. for all the auxiliaries like Battery Chargers, LTPB and Lighting in control room combined together
- 1 No. for all VHF set & computer sets combined together
- 1 No. for each Yard kiosk
- 2 Nos. for each LSTC

3.0 Recommendations (Important Aspects to keep in mind.)

i. Spacing between the conductors may be reduced as far as possible near the periphery of the grid.
ii. Check pits in reasonable no of quantities (2 Nos for 66kV,2/3 numbers for 132 kV, 4-6 nos. for 220 kV and 6-8 for 400 kV Sub-station) should be provided as per drawing attached. (GETCO/E/STD/P-011, Sheet 01)
iii. Electrode for LA should be as near as possible so as to shorten the length of earth connection and preferably it should be of copper.
iv. Each Street light pole outside the switch yard should be provided with an earthing as per our standard practice (charcoal + Salt +earth with round wire coil) and circumference of the pole at the foundation should be provided with a surface layer (metal gravel) for approximate one Mtr. dia. area.
v. If pipe line is passing through both the Zones of within switchyard and outside the switchyard, then it should be buried below earth and connected to mesh with a riser via clamp. If such pipe is required to be kept over the ground it should be painted with green color and one danger board should be provided stating caution of risk of high potential during fault.
vi. No control cable should be drawn from live switch yard to out side switchyard.
vii. Power cable if required to be run from inside to outside switchyard, separate earthing at the end outside the yard should be provided.
viii. All the reinforcement bars of RCC foundations should be firmly connected to the grid. It will increase the safety.
ix. Main Gate of the switchyard should be provided with a flexible bond (usually of copper) at least at two places of each door frame and should be connected with main mesh through suitable risers.
x. Tower with peak shall be provided with 1 No. of 40mm diameter, 3Mtr (or more length required as per design) MS rod and shall be connected with main mesh.
xi. No any maintenance free earth electrode or vertical rod electrode should be kept Isolated. In many cases maintenance free earth electrode of neutral of transformer and LA are not connected with the grid. It is very dangerous in case of fault; high resistance is offered by earth and detection of fault by relay setting may not be done in time causing failure of equipment, fire or other accidents.
xii. For the entire switchyard there should be common earthmat.
xiii. Single core cable with sheath should be earthed at one end only and not at the both ends as sheath will face circulating current for which is not designed and will get heated.

xiv. Gate opening should be inside the switchyard instead of outside to safeguard against the dangerous voltage during opening the gate.

xv. DG set doesn't require to be grounded as its operation is temporary and fault does not leave such bad effect on the system. Still for the sake of safety considering DG set as equipment it should be provided with body earthing at two places.

4.0 Standard Design and calculations

- Earth Mat sizes and Earthing material requirement for various conditions are given in Annexure-1.

Annexure-1

Sr. No.	Soil Resistivity	Fault Current	Substation Area	Size of Mesh		Grid spacing	Total Length of conductor	Nos. of 40mm 3m long vertical rod	Ground Resistance
	Ohm- Mtr.	If (kA)	Mtr. x Mtr.	Lx (Mtr.)	Ly (Mtr.)	Mtr.	Mtr.	Nos.	Ohm
1	20	10	70 x 70	70	58	10	954	30	0.18
2	50	10	70 x 70	70	58	10	954	30	0.44
3	100	10	70 x 70	70	58	6	1524	48	0.81
4	150	10	70 x 70	70	58	4	2222	70	1.15
5	200	10	70 x 70	70	58	3	2920	92	1.5
6	250	10	70 x 70	70	58	3	2920	92	1.87
7	20	25	70 x 70	70	58	10	954	30	0.18
8	50	25	70 x 70	70	58	4	2222	70	0.38
9	100	25	70 x 70	70	58	3	2920	92	0.75

- Nos. of Maintenance free electrodes required for 66/11kV Sub-station(R10) considering scope of 2 Nos. of Line bays, 2 Nos. of Transformer Bays and 2 Nos. of PT bays are given in Annexure-2.

Annexure-2

Equipment	Maintenance free Electrode/ Equip (1)	Qty. for 2 Nos. of Line Bays (2)	Qty. for 2 Nos. of Transformer Bays (3)	Qty. for 2 Nos. of PT Bays (4)	Other Requirement (5)	Total Nos. of Maintenance free Electrodes (2+3+4+5)
Lightning Arrestor	1	6	6	0	0	12
PT	1	0	0	6	0	6
Neutral of Distribution transformer	1	0	0	0	1	1
Neutral of Power transformer	2	0	4	0	0	4
Each class of CR panels combined together	1	0	0	0	2	2
Auxiliaries like Battery Chargers, LTPB and Lighting in control room	1	0	0	0	1	1
VHF set & computer sets together	1	0	0	0	1	1
					Total	**27**

Notes:
1) Quantity of LAs, PTs and Transformers may vary as per actual nos. of bays considered for Sub-station.
2) Quantity of specified in column of Other requirements shall remain same for all 66/11kV SS.

Assumption/Consideration made during designing earthing mat are as follows.

1. Resistivity of surface layer (20 mm gravel) is 3000 ohm-Mtr.
2. Unless otherwise specified, height of surface layer (hs) is considered as 0.1 mtr. above ground level.
3. Depth of mesh is 0.6 mtr.
4. 3 mtr. length of vertical ground rod to be driven into ground below mesh at junction points along periphery, towers with peak and LM.
5. Duration of fault current is considered as 0.5 sec for design purpose.
6. Earth Resistance value for distribution substation is supposed to be below 5 ohms as per IEEE-80. For GETCO substation it is recommended to have earth resistance value of less than 1 ohm for 400 kV, 220 kV & 132 kV and less than 2 ohms for 66 kV class substation.
7. Conductor to be used for substation should be 40 mm diameter MS rods.
8. 3 to 5 % extra quantity for conductor may be taken considering site contingencies.
9. Quantity of earthing material for LSTC is not considered as it may vary for each sub-station. However, earthing of LSTC shall be carried out as per approved drawing no. GETCO/E/STD/LST/R1 dtd 06.05.16

Note: Kindly refer to Engineering department for design and execution of earthmat if values of soil resistivity are higher than 250 ohms-mtr. for 10 kA and 100 ohms-mtr. for 25 kA fault current.