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DESIGN OF EARTH GRID FOR A 132/33 KV SUBSTATION: A CASE STUDY

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ABSTRACT

This paper presents the design of Earthing system for 132/33 KV substation and calculation of its necessary parameters. Successful operation of whole power system depends on an efficient and satisfactory performance of substations. Hence substations are considered as heart of power system. In any substation, a well-designed grounding system plays an important role. Since absence of safe and effective grounding system can result in mal-operation of control and protective devices, grounding system design deserves considerable attention for all the substations. Grounding system has to be safe as it is directly related with safety of persons working in the substation. Main purpose of this work is designing safe and cost effective grounding systems for EHV substations situated at such locations where soil of the substation site is not uniform. To get desired parameters such as touch and step voltage criteria for safety, grid resistance, earth resistance, maximum grid current, electrode size, minimum conductor size, maximum fault current level and resistivity of soil, standard equations are used in a design of earthing system by selecting the proper vertical electrode size, horizontal conductor size and soil resistivity the best choice of the project for safety purpose can be performed.[1] This paper mentions the calculation of the desired parameters of earthing for 132/33 kV substation. A case study is done at 132/33 kV substation Degaon at Solapur in Maharashtra state Transmission Co. Ltd.

1. INTRODUCTION:

Substations form an integral part of electrical power distribution systems. An efficient earthing system ensures safe, reliable and stable operation of substations. It ensures the safety of personnel in the immediate vicinity of the station. Substation earthing system is essential to provide the protection of people working in the vicinity of earthed facilities and equipment's against danger of electric shock to maintain proper function of electrical system. [4]

Reliability and security are to be taken in considerations as well as adherence to statutory obligation path for electric current to the earth without exceeding the operating limits of equipment. It ensures that in the case of a fault, the current is easily dissipated into the earth without damaging the equipment's or exposing personnel on site to dangerous touch and step voltages. Since the various factors to be considered while designing an earthing system such as soil electrical resistivity, system fault level, fault clearing time, area of substation plot, etc. varies from substation to substation; therefore it is not possible to have a common design. An earthing system for substation mainly consists of a buried grid consist of interconnected horizontal conductors and vertical earth rods forming an earth mat. All the power equipment's and metallic parts on site are earthed by connecting them to this buried earth mat. Various factors such as the soil type, depth, presence of moisture, temperature etc. could vary as per season.

2. BASIC EARTH GRID DESIGN

While designing an earthing system for any substation, the prime focus should be on the fact that the actual touch and step voltages should not exceed the tolerable values. Ground potential rise is the maximum voltage that the earthing system may achieve relative to a remote point assumed to be at the potential of earth. Touch voltage is the voltage between energised object and the feet of person in contact with the object. It is equal to the difference in voltage in between the object and the point some distance away. Step voltage is the surface potential difference experienced between the feet of a person standing on the surface .The primary data required to design an effective earthing system are grid area, soil resistivity, maximum grid current and grid fault clearing time. In general the design process of an effective earthing system involves related with a larger grid area, a lower grid resistance and hence lower GPR can be expected.

- **IMPORTANCE OF EARTHING & PRACTICES**

1. The earthing is provided for
a. Safety of Personnel in the substation
b. Prevent or minimize damage to equipment as a result of flow of heavy fault currents.
c. Improve reliability and stability of Power supply
2. The earthing is broadly divided as
a. System earthing means connection between part of plant in an operating system like LV neutral of a Power Transformer winding and earth.
b. Equipment earthing (Safety grounding)
The system earthing and safety earthing are interconnected each other and therefore fault current flowing through system ground raises the potential of the safety ground and also causes steep potential gradient in and around the substation plot. But separating of two earthing systems have disadvantages like low current flow through the relays ,higher short circuit current and long distance to be covered to separate the two earths.

EARTHING CONNECTION

Galvanized Steel Strips or Electrolytic Copper Strips/Stranded Wires are used for final connection between the earthing riser and the points to be earthed. For Transformer Neutral/High Current Discharge paths copper strips are preferred. Galvanized Iron Strips/stranded wires are more common for all other earthing connections. The earthing strips are finally welded or bolted to the Earthed Point.[6]

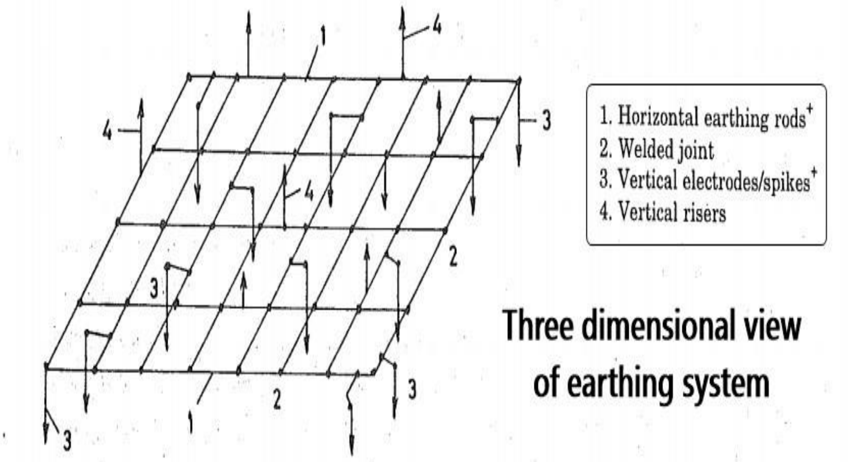

Fig (2). 3-Dimensional view of earthing system

3 .CALCULATION METHODOLOGY

This calculation is based as per IEEE STD 80 (2000), "Guide for safety in AC substation grounding".[3] There are two main parts in this calculation:

1. Earthing grid conductor sizing 2. Touch and step potential calculations

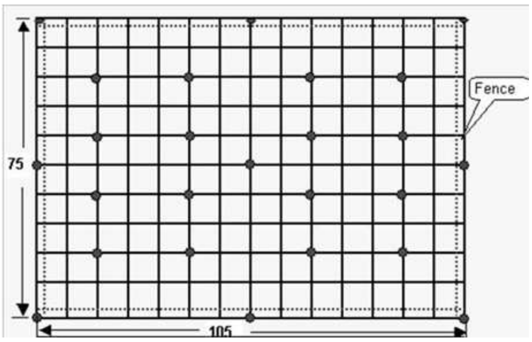

Figure : General configuration of earth mat

1. Earthing Grid Conductor Sizing:

$$A = \sqrt{ i^2 t \frac{\frac{\alpha_T \rho_T 10^4}{TCAP}}{In[\,1+(\frac{T_m - T_a}{K_0 + T_a})]} }$$

Where,

A= Minimum cross sectional area of earthing grid conductor mm^2

i^2t = Energy of maximum earth fault (A^2s)

T_m = Maximum allowable temperature (^0C)

T_a = Ambient Temperature (^0C)

AT = Thermal coefficient of resistivity ($^oC^{-1}$)

ρ_T = Resistivity of Earthing conductor

K_0 = Constant

TCAP = Thermal capacity of Conductor per unit value (Jam $^{-30}C^{-1}$

2. Touch and Step potential calculations

Touch voltages is defined as dangerous potential difference between earth and metallic object that a person is touching

Step voltages is defined as dangerous voltage gradient between the feet of person standing on the earth

Step 1: Soil Resistivity

There are few standard methods to measure soil resistivity (E.g. Wenner 4pin method). IEEE std. 80 table 8 gives some guidance on range of soil resistivity's based on general characteristics of soil i.e., wet organic soil = 10Ωm, moist soil = 100Ωm, Dry soil 1000Ωm

Step 2: Surface layer materials

$$C_s = 1 - \frac{0.09\,(1-\frac{\rho}{\rho_s})}{2h_s + 0.09}$$

Where,

1. C_s = the surface layer derating factor
2. ρ = the soil resistivity (Ω.m)
3. ρ_s = the resistivity of the surface layer material (Ω.m)
4. h_s = the thickness of the surface layer (m)

Step 3: Earthing grid resistance

A good earthing grid design has low resistance with respect to remote earth to minimize ground potential rise i.e. GPR and to avoid dangerous touch and step voltages..

$$R_g = \rho \left[\frac{1}{L_T} + \frac{1}{\sqrt{20A}} \left(1 + \frac{1}{1 + h\sqrt{20/A}} \right) \right]$$

Where,

R_g = the earthing grid resistance with respect to remote earth (Ω) ρ is the soil resistivity (Ω.m)

L_T = the total length of buried conductors (m)

A = the total area occupied by the earthing grid (m^2)

h = the depth of the earthing grid (m)

Step 4: Touch and Step Potential Criteria

In the case of calculation of touch and step potentials we need to prescribe maximum tolerable limits for touch and step voltages that do not lead to lethal shocks.

- 70 kg person: Etouch,70 = $(1000 + 1.5\, C_s\, \rho_s) \frac{0.157}{\sqrt{t_s}}$
- 70 kg person: Estep,70 = $(1000 + 6\, C_s\, \rho_s) \frac{0.157}{\sqrt{t_s}}$

Where,

E_{touch} = the touch voltage limit (V)

E_{step} = the step voltage limit (V)

C_s = the surface layer derating factor

ρ_s = the soil resistivity (Ω.m)

t_s = the maximum fault clearing time (s)

Step 5: Ground Potential Rise (GPR)

The maximum potential difference between the site and remote earth is known as the ground potential rise i.e. (GPR). The potential relative to a distant point on the earth is highest at the point where current enters the ground and declines with distance from the source. GPR is a concern in the design of electrical substations because the high potential may be a hazard to people or equipment at the point of fault.

GPR = I_G Rg

Where,

GPR = the maximum ground potential rise

I_G =the maximum grid current

R_g = the earthing grid resistance

Step 6: Earthing Grid Design Verification

Now we just need to verify that the earthing grid design system is safe for touch and step potential. If the maximum GPR calculated above does not exceed either of the touch and step voltage limits then the grid design is safe

Mesh voltage calculation:

$$E_m = \frac{\rho_s K_m K_i I_G}{L_M}$$

Where, ρ_s =soil resistivity (Ωm)

I_g =the maximum grid current (kA)

K_m = the geometric spacing factor

K_i = the irregularity factor

L_m = the effective buried length of the grid (m)

Step voltage calculation:

$$Es = \frac{\rho_s K_s K_i I_G}{L_s}$$

Where,

ρ_s = the soil resistivity (Ω.m)
I_g = the maximum grid
K_m =he geometric spacing factor
K_i = the irregularity factor
L_s =the effective buried length of the grid

Now that the mesh and step voltages are calculated above, compare them to the maximum tolerable touch and step voltages respectively, if

1. Em < Etouch and
2. Es < Estep

Then earthing design is safe

4. output results for grid construction design:

Specifications	Symbols	Values
System voltage	V	33 kV
Total power	P	100 MW
Total area	A	2100 m^2
Normal rated current	I	1.74954 kA
Maximum fault current	I_f	17.4954 kA
Grid conductor size	A_c	75 x 10 mm
Number of earthing rods	N_r	32
Total length of earthing Conductor	L_T	1100 m
Substation earthing Resistance	R_g	0.7337 Ω
Maximum grid current	I_g	20 KA
Grid potential rise	GPR	5869.6 V
Mesh voltage	E_m	273.55V
Step voltage	E_s	340.50V

5. CONCLUSION

This paper has a focus on designing of a 132/33 kV EHV AC substation earthing system. The paper aims to show the design and analysis of 132kV substation earthing grid. The results for earthing system are obtained by computational method. For earthing conductor and vertical earth electrode mild steel is used in a grid. The step by step approach for designing a substation earthing system is presented above. Construction of earthing grid is expressed in here. As step and touch voltages are dangerous for human body, human body may get electric shocks from step and touch voltages. When high voltage substations are to be designed, step and touch voltages should be calculated and values must be maintained as per specified standard[5]. Importance to be given to the transfer of Ground Potential rise (GPR) under fault conditions to avoid dangerous situations to the custmor, public and utility staff. The values of step and mesh voltages obtained for 132 kV substation are respectively 389.6783 Volt and 374.1747 Volt which are within the permissible limits.

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