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Feasibility Study of Adequacy of Existing Earthing Grid to the Extended Gas Insulated Substation

Vijay Shinol[1], S. M. Takalkar[2]
[1]Assistant Professor, Electrical Engineering Department, Itm Universe, Vadodara, India. [2]managing DIrector, Takalkar Engineers & Consultants Pvt. Ltd., Vadodara, India.

Abstract:- *The paper presents the situation of the 220 kV gas insulated substation at Aarey Boriwali, Mumbai as a part of extension to air insulated substation and gives detail of earthing grid design. The design of earthing grid for air insulated and using same grid for earthing of gas insulated substation is described. The connection of GIS enclosure to earthing grid is also described. The earthing grid design is performed according to IEEE std. 80 – 2000 and CBIP publication 223.*
Keywords:- *Grounding system design, GIS enclosure grounding, touch voltage, step voltage, safety criteria.*

I. INTRODUCTION

A metal enclosed, SF6 gas insulated substation (GIS) has been constructed and put in operation at the area of Aarey, to provide the power of 125 MVA in addition with 400 MVA power of existing air insulated substation (AIS). The Air insulated substation with two main and transfer busbar switching scheme and ten 220 kV bays in total is first in operation at Aarey. Due to increase in power demand and non availability of space, GIS extension provides the solution. A simplified layout of substation is presented in Fig. 1. As the AIS is already exist at Aarey, The ground grid of AIS is already exist. Due to increase in power demand, GIS is constructed. The safety criteria of grounding system for GIS are different from conventional AIS. This paper proposes the adequacy of existing earthing grid of AIS to the GIS. Special consideration of earthing in GIS to meet safety criteria will be described. The design was carried out according to the IEEE std. 80 "Guide for safety in AC substation grounding" and CBIP publication 223 "Design of earthing mat for high voltage substation".

II. SUBSTATION GROUNDING SYSTEM DESIGN CONCEPT

The two major design goals of any substation grounding system under normal and fault conditions are as follows [1]:

- To provide means to dissipate electric currents into the earth without exceeding any operating and equipment limits.
- To assure that persons in the vicinity of grounded facilities are not exposed to the danger of critical electric shock.

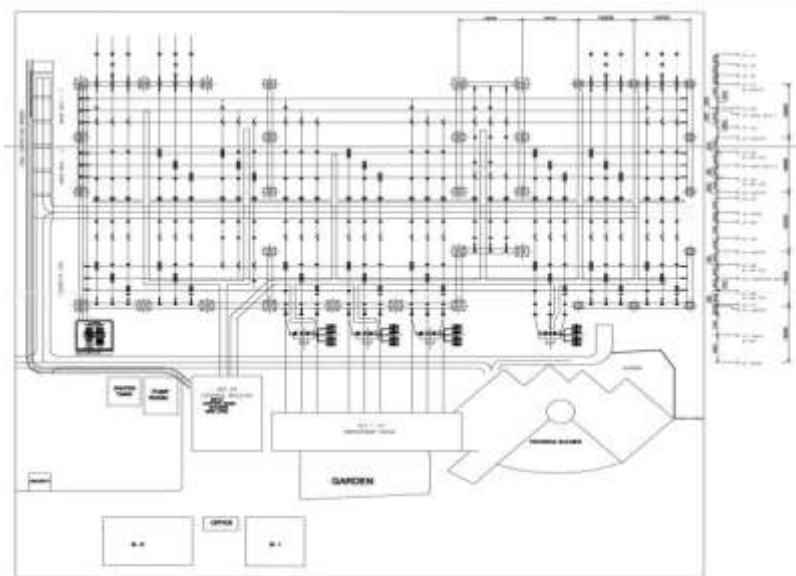

Fig. 1. Layout of substation

III. DESIGN OF EARTHING GRID

The main ground grid is laid under substation building with the depth of 0.3-0.6 meter [1] from ground level and ground rod at suitable point. Under the normal conditions, the ground rods contribute little towards [redacted]he ground resistance. However, these are helpful in lowering mesh potentials and maintaining low values of resistance under all weather conditions.

A. Primary design parameters

The following major parameters which influence design of earthing grid are [1]:

- Magnitude of fault current (I_G). Fault current at substation is determined from system study. However, in general practice 40 KA for 400/220 kV system and 31.5 KA for 132 kV systems are adopted for design purpose.
- Duration of fault current (t_f) and duration of shock (t_s). Duration of fault current is required to size ground conductor and duration of shock is required to determine allowable body current. Typical values for t_f and t_s range from 0.25 s to 1 s.
- Soil resistivity (ρ). The grid resistance directly depends on soil resistivity. Sufficient measurement must be taken in the substation yard to determine soil resistivity. The wenner method is most widely used. Measured value of soil resistivity of existing AIS is 60 Ω-m.
- Surface layer resistivity (ρ_s). A layer of surface material helps to limit the body current by increasing contact resistance between soil and feet of the person. The soil in substation is covered with gravel layer. Typical resistivity of gravel ranges from 1000 Ω-m to 10000 Ω-m. The GIS bay will be installed on the surface layer of concrete. Typical resistivity of concrete in dry condition ranges from 10^6 Ω-m to 10^9 Ω-m.
- Grid geometry. Generally, the limitation on the physical parameters of ground grid is based on economics and the physical limitations of the installation of the grid. The spacing between conductors is 7 m (range: 3 to 15 m [1]) and the depth of grid is 0.6 m (range: 0.5 to 1.5 m [1]).
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B. Special criteria for GIS

Currents are induced in metallic enclosure of GIS and specially during internal earth fault, the inductive voltage drop occurring with GIS assembly must be taken into account for design to touch voltage in GIS substation [2], which is given by

$$\sqrt{E_m^{\,2} + E_G^{\,2}} < E_T$$

E_m = calculated touch voltage
E_G = metal to metal touch voltage
E_T = tolerable touch voltage

C. Calculation procedure

The major equations used to calculate the design parameters are given below [1], [2]:

$$A_{mm^2} = \frac{I}{\sqrt{\left(\frac{TCPA*10^{-4}}{t_c*\alpha_r*\rho_r}\right)\ln\left(\frac{K_o+T_m}{K_o+T_a}\right)}} \qquad (1)$$

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

$$E_{touch50} = (1000 + 1.5*C_s*\rho_s)*\frac{0.116}{\sqrt{t_s}} \qquad (3)$$

$$E_{step50} = (1000 + 6*C_s * \rho_s) * \frac{0.116}{\sqrt{t_s}} \quad (4)$$

$$R_g = \rho\left[\frac{1}{L} + \frac{1}{\sqrt{20A}}\left(1+\frac{1}{1+h\sqrt{20/A}}\right)\right] \quad (5)$$

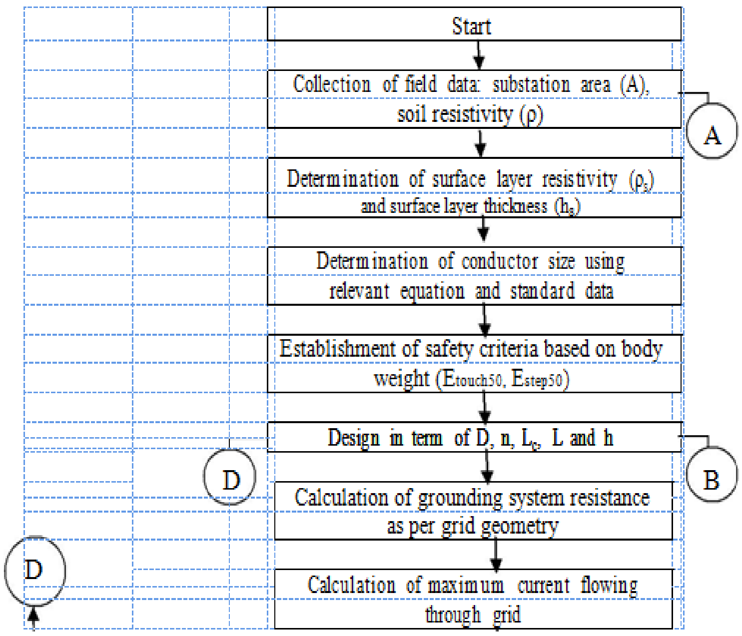
$$I_G = D_f * S_f * I_g \quad (6)$$

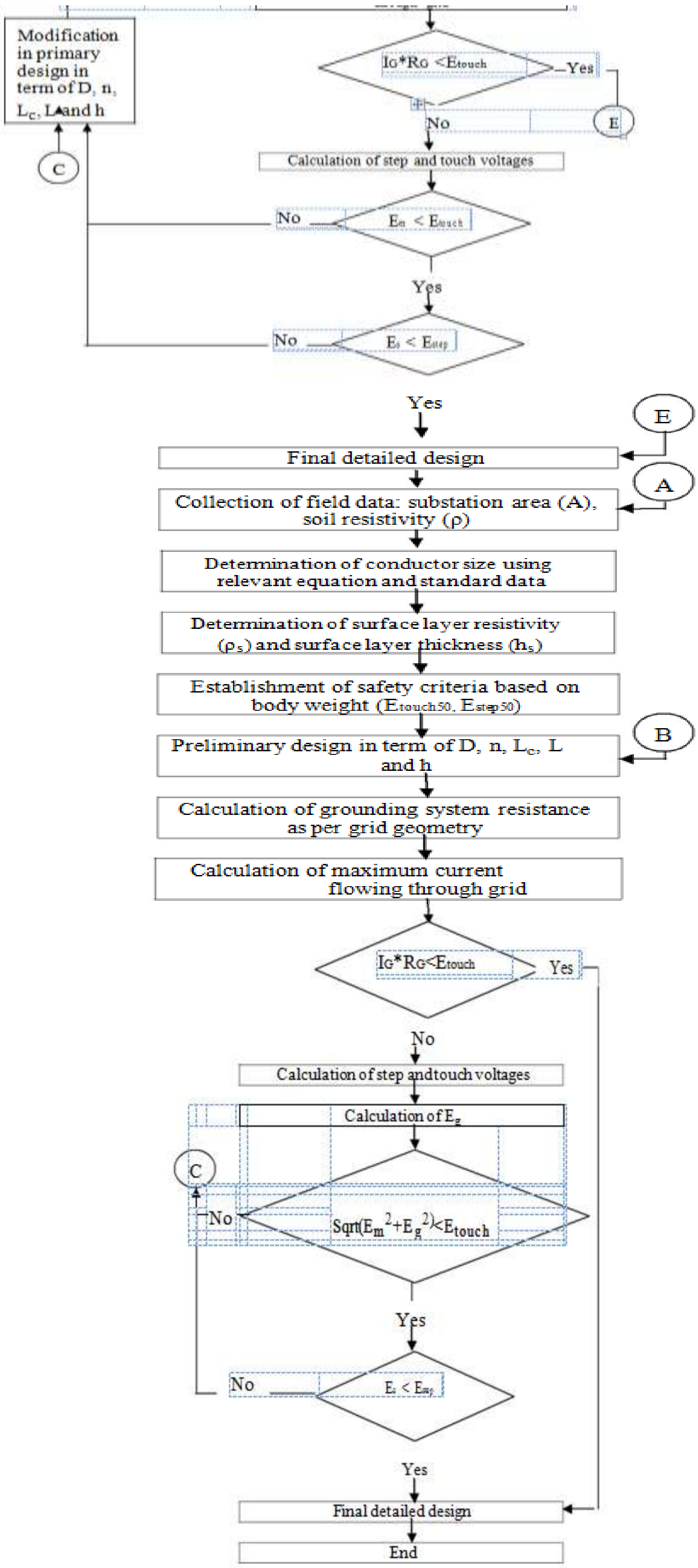
$$E_m = \frac{\rho * K_m * K_i * I_G}{L_m} \quad (7)$$

[redacted]

D. Design procedure

In order to check the capability of existing earthing grid of AIS to provide protection with GIS bay, first the earthing design of AIS is shown. Then using the same grid parameters of AIS, the earthing design of GIS with the surface layer resistivity of concrete is verified. The flowchart for carrying out feasibility study of existing earthing grid of AIS to the extended GIS is shown in figure 2 [1].




Modification in primary design in term of D, n, Lc, L and h
C
IG*RG <Etouch
Yes
No
E
Calculation of step and touch voltages
No
Em < Etouch
Yes
No
Es < Estep
Yes
E
Final detailed design
A
Collection of field data: substation area (A), soil resistivity (ρ)
Determination of conductor size using relevant equation and standard data
Determination of surface layer resistivity (ρs) and surface layer thickness (hs)
Establishment of safety criteria based on body weight (Etouch50, Estep50)
B
Preliminary design in term of D, n, Lc, L and h
Calculation of grounding system resistance as per grid geometry
Calculation of maximum current flowing through grid
IG*RG<Etouch
Yes
No
Calculation of step and touch voltages
Calculation of Eg
C
No
Sqrt(Em2+Eg2)<Etouch
Yes
No
Es < Estep
Yes
Final detailed design
End

E. CASE STUDY: FEASIBILITY STUDY OF EXISTING GRID TO THE EXTENDED GIS

The GIS will be placed in the area of AIS. The detailed layout and plan for GIS bay has been already prepared. Total area covered by GIS will be 10 x 10 m. Entire GIS with two main bus system is shown in fig 3.

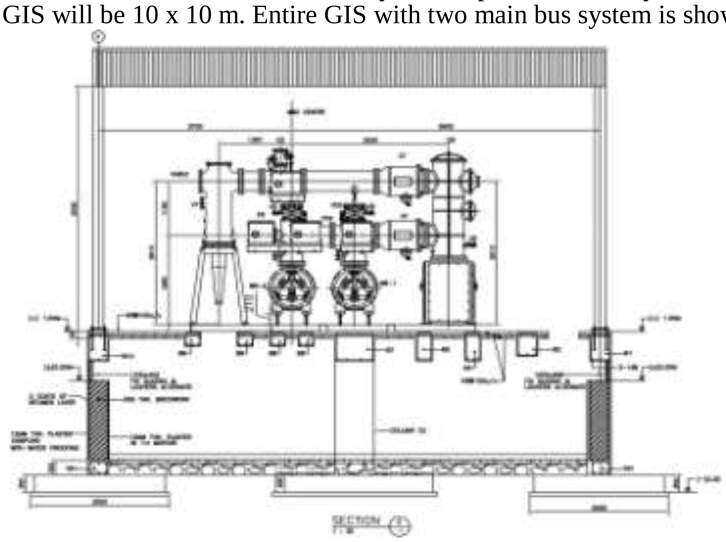


Fig. 3: 220kV two main bus GIS

A. Design data

Design input data required for earthing grid design are as follow: Maximum ground fault current: 40kA
Duration of fault current tc: 1 sec.
Soil resistivity ρ: 60 Ω-m
Surface layer resistivity (for AIS) ρs: 3000 Ω-m
Surface layer resistivity (for GIS) ρs: 106 Ω-m
Surface layer thickness hs: 0.15 m
Diameter of earthing conductor d: 0.04 m
Depth of earthing grid conductor h: 0.6 m
Length of grid conductor in X direction LX: 203 m
Length of grid conductor in Y direction LY: 112 m
Spacing between parallel conductors D: 7 m
Length of rod at each location Lr: 3 m
Number of rod placed in area Nr: 45 nos.
Decrement factor Df: 1
Material used for grid conductor: Zinc coated steel material

B. Design results

Design results are shown in table 1. For given design input data the safety criteria is satisfied for AIS. Now, using the same input data the safety criteria for GIS are verified. The design result shows that, as the concrete is used as the surface layer for GIS, the maximum permissible touch and step voltages are increased at high value, very small variation in touch voltage due to special criteria and no change in step voltage as compared to AIS. The mesh and step voltages are lower than maximum allowable touch and step voltages. So that, safety criteria for GIS is also satisfied.

Parameters	AIS	GIS
Required area	688.79	688.79
Provided area	900	900
Maximum allowable touch voltage	735	189755
Maximum allowable step voltage	2449	757326
Grid resistance	0.19	0.19
Ground potential rise	4444	4444
Mesh voltage	501.600	501.600
Step voltage	380.857	380.857
Metal to metal touch voltage	-	1.922

Special criteria for GIS for touch	-	501.6039
voltage		
Table 1. Design result		

IV. CONCLUSION

As the safety criteria for the GIS satisfied, it is feasible to use the main earthing grid of AIS for earthing with GIS bay. So that, risers of equipment can be directly connected to the main earthing grid.

REFERENCES

[1]. IEEE std 80-2000, "IEEE giude for safety in AC substation grounding".
[2]. CBIP publication no. 223-1992, " Design of Earthing Mat For High Voltage Substation