Optimal Design of Earth Mat For 110kv Substation

CHETAN KUDALE[1], DR. SUPANNA SHIRGUPPE[2]
[1]*Assistant Professor, Department of Electrical and Electronics Engineering, SGBIT, Belagavi*
[2] *Professor, Department of Electrical and Electronics Engineering, SGBIT, Belagavi*

Abstract—Earthing is essential for electric supply system to ensure safety and proper operation. An effective earthing system depends on various factors like resistivity of surface layer of soil, duration and magnitude of fault current, maximum safe current that a human body can tolerate and the permissible earth potential rise that may take place due to fault current. This paper presents the design of Earthing system for 110 KV substation and calculation of its parameters and effect of ground rods. It plays an important role when adding to the grounding grid to improve the performance of it by reducing not only the grid resistance but also the touch and step voltages to values that safe for human. The paper investigates the effect of vertical rods location on the values of grid resistance, step and touch voltages

Indexed Terms—Grounding grids, Grid resistance, Ground rods, Step voltage, Touch voltage,

I. INTRODUCTION

Main objectives of the grounding system are to guarantee the integrity of the equipments and continuity of the service under the fault conditions (providing means to carry and dissipate electrical currents into ground), and to safeguard those people that working or walking in the surroundings of the grounded installations are not exposed to dangerous electrical shocks. To attain these targets, the equivalent electrical resistance (R_g) of the system must be low enough to assure that fault currents dissipate mainly through the grounding grid into the earth, while maximum potential difference between close points into the earth's surface must be kept under certain tolerances (step, touch, and mesh voltages).The basic design quantities of the grounding grid are the resistance (R_g) (or ground potential rise (GPR), which is the product of the resistance by the grid current, touch (V_t) and step (V_s) voltages. In a uniform soil, the resistance can be calculated with an acceptable accuracy using several simplifying assumptions. Touch and step voltages are difficult to calculate by simplified method but it determined by analytical expressions. Vertical ground rods are considered the most suitable method for earth termination of electrical and lightning protection systems. The addition of the vertical ground rods to the grounding grid achieve a convenient design for grounding system by decreasing the grid resistance, the step and touch voltage to a safe values for human and public.

The earthing system in a plant / facility is very important for a few reasons, all of which are related to either the protection of people and equipment and/or the optimal operation of the electrical system.These include:

Equipotential bondings of conductive objects (e.g. metallic equipment, buildings, piping etc) to the earthing system prevent the presence of dangerous voltages between objects (and earth).

The earthing system provides a low resistance return path for earth faults within the plant, which protects both personnel and equipment.

For earth faults with return paths to offsite generation sources, a low resistance earthing grid relative to remote earth prevents dangerous ground potential rises (touch and step potentials)

The earthing system provides a low resistance path (relative to remote earth) for voltage transients such as lightning and surges / overvoltages

Equipotential bonding helps prevent electrostatic buildup and discharge, which can cause sparks with enough energy to ignite flammable atmospheres

The earthing system provides a reference potential for electronic circuits and helps reduce electrical noise for electronic, instrumentation and communication systems [5]

This calculation is based primarily on the guidelines provided by IEEE Std 80 (2000), "Guide for safety in AC substation grounding

MOST AFFECTED PARAMETERS FOR DESIGN OF EARTHING SYSTEM ARE

a. Magnitude and duration of fault current.
b. Soil and surface resistivity at the industrial plant site (soil structure and soil Model)
c. Property and cross-section of material used
d. Earthing mat geometry (Area covered by Earth mat).
e. Permissible touch and step potentials.

II. EARTHING MAT DESIGN METHADOLOGY

Step 1: The property map and general location plan of the substation should provide good estimates of the area to be grounded. A soil resistivity test, will determine the soil resistivity profile and the soil model needed (that is, uniform or two-layer model).

Step 2: The conductor size is need to be determined. The fault current $3I_0$ should be the maximum expected future fault current that will be conducted by any conductor in the grounding system, and the time, t_c , should reflect the maximum possible clearing time (including backup).

Step 3: The tolerable touch and step voltages are to be determined.. The choice of time, t_s , is based on the judgment of the design engineer

Step 4: The preliminary design should include a conductor loop surrounding the entire grounded area, plus adequate cross conductors to provide convenient access for equipment grounds, etc. The initial estimates of conductor spacing and ground rod locations should be based on the current I_G and the area being grounded.

Step 5: Estimates of the preliminary resistance of the grounding system in uniform soil can be determined. For the final design, more accurate estimates of the resistance may be desired. Computer analysis based on modeling the components of the grounding system in detail can compute the resistance with a high degree of accuracy, assuming the soil model is chosen correctly.

Step 6: The current I_G is need to be determined. To prevent overdesign of the grounding system, only that portion of the total fault current, $3I_0$, that flows through the grid to remote earth should be used in designing the grid. The current I_G should, however, reflect the worst fault type and location, the decrement factor, and any future system expansion.

Step 7: If the GPR of the preliminary design is below the tolerable touch voltage, no further analysis is necessary. Only additional conductor required to provide access to equipment grounds is necessary.

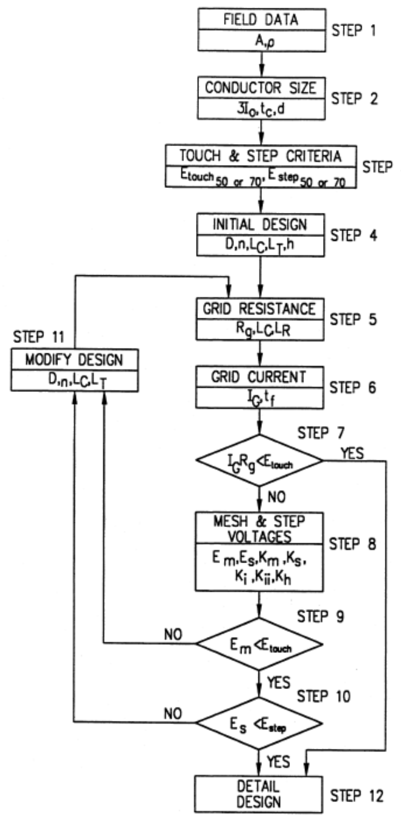

Fig.1 Design Procedure Block Diagram

Step 8: The calculation of the mesh and step voltages for the grid as designed can be done by the computer analysis techniques.

Step 9: If the computed mesh voltage is below the tolerable touch voltage, the design may be complete (see Step 10). If the computed mesh voltage is greater than the tolerable touch voltage, the preliminary design should be revised (see Step 11).

Step 10: If both the computed touch and step voltages are below the tolerable voltages, the design needs only the refinements required to provide access to equipment grounds. If not, the preliminary design must be revised (see Step 11).

Step 11: If either the step or touch tolerable limits are exceeded, revision of the grid design is required. These revisions may include smaller conductor spacings, additional ground rods, etc.

Step 12: After satisfying the step and touch voltage requirements, additional grid and ground rods may be required. The additional grid conductors may be required if the grid design does not include conductors near equipment to be grounded. Additional ground rods may be required at the base of surge arresters, transformer neutrals, etc. The final design should also be reviewed to eliminate hazards due to transferred potential and hazards associated with special areas of concern. [2]

III. DESIGN CALCULATION OF 110/11KV SUBSATTION

Table I: Field data of substation

Area Covered by Earth mat:	8160m^2
Depth of burial earth mat:	0.9m
Spacing Between mat conductor (M.S FLAT)	2m
Size of earth mat conductor (M.S FLAT)	50x6mm
MS Round Rods	25mm dia,1.5m
No of Horizontal Conductors	43
No of vertical Conductors	49
After Earthling work, respreading of jelly to a Height of 100mm over entire earth mat area.	816m^3
Present fault level for year 2016-17 3phase to Ground fault level Single phase to Ground fault level	829.5 MVA /4 .35kA 858.2MVA / 4.5kA
Soil Resistivity ρ	400Ω-m
Surface layer Resistivity ρ_s	2500Ω-m

Step1:
Ground area=96x85=8160sq.m
Step 2:
Soil resistivity ρ = 400Ω-m
Surface soil resistivity =ρ_s =2500Ω-m

Reflection factor=K= $\frac{\rho-\rho_s}{\rho+\rho_s}$ = - 0.724
Step 3:
Burial depth= h =0.9m

Reduction factor=C_s=1 $-\frac{0.09\left(1-\frac{\rho}{\rho_s}\right)}{2h_s+0.09}$ = 0.742
The resistivity of crushed rock is to be derated by a reduction factor C_s= 0.74

Step 4:
Reduction factor=C_s= 0.74
Fault clearing time=t_s=0.5
Surface soil resistivity =ρ_s =2500Ω-m
Step voltage
$E_{step\ 50}$ = [1000+(6 x C_s ρ_s)]$\frac{0.157}{\sqrt{t_s}}$ =2686.6V

Step 5:
Reduction factor=C_s=-0.74
Fault clearing time=t_s=0.5
Surface soil resistivity =ρ_s =2500Ω-m
Touch voltage
$E_{touch\ 50}$ =[1000+(1.5x$C_s\rho_s$)]$\frac{0.157}{\sqrt{t_s}}$ =838.2V

Step 6:
Decrement factor D_f =1
Symmetrical ground fault current I_f = 4.35KA
S_f = I_g / I_f = 0.6
Grid current=I_G= D_f I_g = D_f S_f I_f = 2610A
Step 7:
Effective length of grounding system conductor =L_T = 96x43+ 49x85 =8293
Total area=8160 Sqm
Soil resistivity=ρ =400Ω-m

Grid resistance = $R_g=\rho\left[\frac{1}{L_T}+\frac{1}{\sqrt{20A}}\left(1+\frac{1}{1+h\sqrt{\frac{20}{A}}}\right)\right]$ = 1.986Ω
Step 8:
Maximum Grid current=I_G= 2610A
Grid resistance = R_g = 1.986Ω
Ground potential rise =GPR=(I_G x R_g)=5183.46V

Step 9:
Soil resistivity=ρ =400Ω-m
Grid current=I_G= 2610A
Geometrical spacing factor to determine mesh voltage=K_m= 0.38V

Geometrical correction factor=K_i=7.425V
Effective buried length, L_M=8293m
Mesh voltage =$E_m = \frac{\rho.K_m.K_i.I_G}{L_M}$ =355.19V

Step 10:
Soil resistivity=ρ =400Ω-m
Geometrical correction factor=K_i=7.425V
Geometrical spacing factor to determine step voltage in volts=K_s =0.4457V
Effective length of =L_s = 8293m
Tolerable step voltage = $E_s = \frac{\rho.K_s.K_i.I_G}{L_s}$ =416.60V

Improved Design With Grounding Grids:

Step 11:

Total vertical rods at the perimeter of the grid =348

Effective length of grounding system conductor, including grid and grounding rods=

L_T=1.5 x 348+8293=8815m

Grid resistance=R_g=1.983
Ground potential rise.GPR=1.983 x 2610=5175.88V

IV. ANANLYSIS OF DATA USING CYMGRID

As can be seen from above, touch and step potential calculations can be quite a tedious and laborious task, and one that could conceivably be done much quicker by a computer. Even IEEE Std 80 recommends the use of computer software to calculate grid resistances, and mesh and step voltages, and also to create potential gradient visualisations of the site. Computer software packages can be used to assist in earthing grid design by modeling and simulation of different earthing grid configuration. The CYMGRD software is a substation grounding grid design and analysis program used to optimize the design of new grids of any shape.

Table 2: Results for grounding without rods

Grid resistance R_g	1.986Ω
Ground potential rise GPR	5183.46V
Touch Potential	838.2V
Step Potential	2686.6V

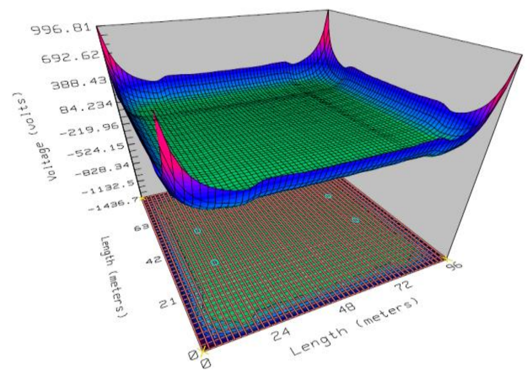

Fig.2 Touch Potential contour plot

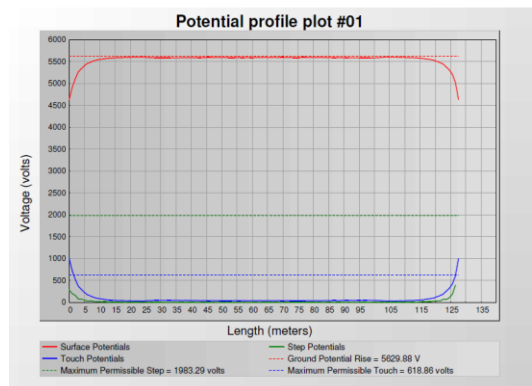

Fig .3 Potential distribution without ground rods

Table 3: Results for grounding with rods (vertical rods at the perimeter of the grid)

Grid resistance R_g	1.983Ω
Ground potential rise GPR	5175.88V
Touch Potential	838.2V
Step Potential	2686.6V

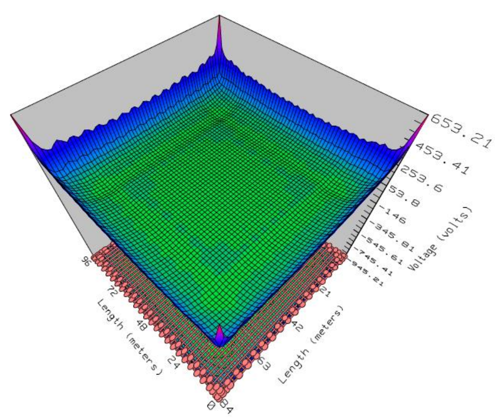

Fig.4 Touch Potential contour plot

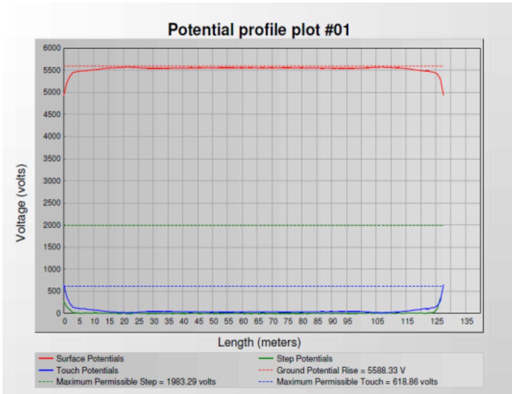

Fig.5 Potential distribution with ground rods

V. DISCUSSION AND CONCLUSION

Em= 355.19V E_{touch}= 838.2 V Em < E_{touch}

The computed mesh voltage is below the tolerable touch voltage, the design is complete

Es= 416.60V E_{step}= 2686.6 V Es < E_{step}

The computed touch and step voltages are below the tolerable voltages, the design needs only the refinements required to provide access to equipment grounds.

The vertical rods play an important role for reducing the grid resistance, the step and touch voltages. The number of meshes is an effective parameter for reducing the pervious values but it needs more copper then increases the cost. The study explains a small effect in the earth surface potential when changing the vertical rods locations at the same number of meshes

REFERENCES

[1] Sherif Ghoneim, Holger Hirsch, Ahdab Elmorshedy, Rabah Amer, "Improved Design of Square Grounding Grids," International Conference on Power System Technology, 2006

[2] "IEEE 80-2000 IEEE Guide for Safety in AC Substation Grounding.".

[3] C.S. Esobinenwu, B.O.H. Akinwole, C.O. Omeje, "Earth Mat Design for 132/33Kv Substation in Rivers State Using ETAP", International Journal of Engineering Trends and Technology (IJETT) – Volume 15 Number 8 – Sep 2014

[4] Lim, S.C.; Gomes, C.; Nourirad, G.; Kadir, M.Z.A.A."Significance of localized soil resistivity in designing a grounding system", 2014 IEEE 8th International Power Engineering and Optimization Conference (PEOCO), on page(s): 324 – 329

[5] N.M. Tabatabaei, S.R. Mortezaeei,"Design of Grounding System in Substation by ETAP Intelligent Software", IJTPE Journal, March 2010, pp.45-49