International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 5 Issue 5, July-August 2021 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Design of Earthing in Underground Substation using ETAP with Constraints

Daud Ahmad, Dr. Javed Ashraf

Department of Electrical and Electronics Engineering, Al-Falah University, Dhauj, Faridabad, Haryana, India

ABSTRACT

This paper describes the earthing design of a distribution substation 33kV/415V, 50Hz system. in this type of substation equipment's are 33kV HV panel, transformer, battery, battery charger and Low voltage panels. The earth mat is below substation which is almost 15-18-Meter-deep from ground level. The main considerable factors for earth mat design are soil resistivity which is higher due to basalt rock and system fault current. Fault current level of the system considered as 70kA derived from calculations. Earthing is essential for proper functioning of substation equipment's and in the absence of proper designing affects in many ways like electric shock to personnel's and malfunctions and damage to the equipment's. The basic purpose of earthing is to ensure personnel safety, safe and reliable operation of equipment's, prevent stray current, protection against interferences and keeps steps and touch potential within safe limit. This paper also discussed constraint in design due to below ground level. Result of manual calculation compared with design simulated through ETAP software version 19. The data used in design considered from a substation in Mumbai, Maharashtra.

KEYWORDS: *33kV/415V underground substation, soil resistivity, Fault current, Earth mat, Step and touch potential*

How to cite this paper: Daud Ahmad | Dr. Javed Ashraf "Design of Earthing in Underground Substation using ETAP with Constraints" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-5 | Issue-5, August 2021, pp.195-200, URL: www.ijtsrd.com/papers/ijtsrd43787.pdf

IJTSRD43787

I. INTRODUCTION

In present paper discussion is focused on underground distribution substations which is used for public transport. In such installation equipment's used are essential and very essential and safe and reliable earthing is necessary for equipment's, service personnel and public. As large numbers of people use nowadays public transport, earthing system essential for the people assembled as well working personal and for the reliable functioning of the equipment's and plants[2, 3, 8]. Functionally earthing system provides low impedance path and incase of faults in the system shall clear without any disturbance to plants, equipment's and limits step and touch voltages allowable range for personnel safety[4, 5].Several types of faults may happen in the system and its problematic to know type of faultand its location resulting higher current flows from earth grid to nearby earth.

Design inputs are soil resistivity of the area, fault current, fault clearing time, ambient temperature, material of the conductors etc.[4, 5, 8].

In general, this type of premises constructed for a longer life compared to substation equipment's whose operational life is not more than 25-30 years. Since earth mat installed below concrete base slab and modification and enhancement of earthing system is not possible. Due care shall be taken during design for life and corrosion factor in conductor. Earth mat conductors used in such applications are copper due to the facts that in addition to high conductivity its less corrosive in buried condition as copper is cathodic with respect to the other metals buried nearby[1].

Earth mat installed exactly below the substation area which forms through horizontal and vertical copper conductors jointing together by means of brazing, exothermic welding, and deep-down rods for grounding fault currents[5]. Risers connected to down rods for the purpose of easy connectivity through riser cables to various plants, equipment's, and metallic items. Sizing of earth conductors to be done by simulation and considering necessary data as defined in IEEE-80 standard. In present solution result achieved by increasing number of down rods and increasing the length of vertical down rods. For basalt rock present in this case conductivity is poor hence 12 meters deep copper rods used to reach at moisture level.

Other factors which may contribute faults currents and affect earth mat design considered like motor contribution to short circuit currents. In present case is less than 5% which can be neglected. Relay malfunction can also result in faults in addition to fault clearing time however fault clearing time considered is suitable [1].

Earthing calculation can be performed through excel sheet by using formulae given in IEEE-80 standards. For areas having higher soil resistivity, limited space and other complexity software calculation can be simulated for quick and satisfactorily solution. In present case simulation performed through Electrical Transient Analyzer Program (ETAP) software version 19.

II. IMPORTANCE

Proper earthing design is essential for the safe and reliable operation of life safety equipment's, plants, working personnel and large numbers of the people in such premises. Earthing provides sufficiently low impedance to ensure satisfactorily operation of protective devices under fault conditions[2,7]. System voltages remains within allowable limits under fault conditions and similarly insulation breakdown voltages are not exceeded. Earthing also important for the personal working to prevent electric shock, stray currents and to provides an alternate path for induced current to reduce noise. In underground substation, large number of low voltage cables are used for connection to sub panels, equipment's and necessary to calculate earth impedance contribution from cables [9]. Earth fault loop impedance is path followed by fault current when fault occurs between phase conductor and earth. cable sheath or separate cable may used for earth fault loop impedance.

III. CONSTRAINTS

Nowadays due to shrinking space in urban area and high cost of land its challenging to use available space for distribution substation and earth mat below. Secondly, less space availability due to the column footing which are deep down structure which affects continuity of earth mat construction in this type of installation.

IV. DESIGN METHODOLOGY

The earth mat and conductor sizes depend on certain parameters which needs to collect before actual design. Soil resistivity is critical parameter for design as it varies and have larger impact on sizing of earth mat. Other parameters are fault currents and its duration, thickness of dry concrete and resistivity of ballast surface[2-4, 8] (earth mat below concrete level of substation), available space including columns and footing space.

1. Soil Resistivity Measurement at site

Soil resistivity measured at substation location is in the category of high. The level of underground substation from ground level is almost 18 Meter below. Due to the basalt rock presence excavation is quite difficult. Conductivity in basalt rock is very low, from available geotechnical report, moisture present almost 10 meters from the earth mat level hence down rods length designed for 12 meters deep. Substation located on concrete base slab of 1.05-meter-thickand from base slab earth mat is 0.4 meter below. Soil resistivity measurement at site performed through four pin Werner method[2].

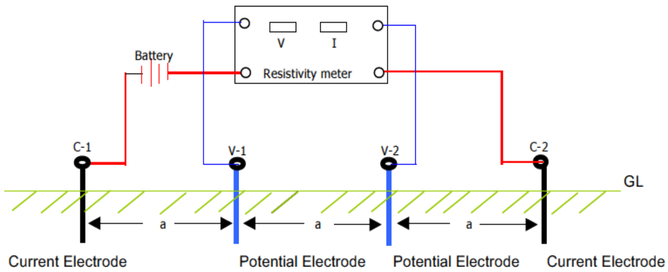

Figure 1: Typical Werner Electrode Arrangement for soil testing

Table 1: Soil Resistivity Measurement data collected from site

S. No.	Spacing of test electrode (Meter)	Resistivity values (ohmmeter)
1.	2	69
2.	4	74
3.	6	69
4.	8	57

The average value of soil resistivity on drawing of polar curve is 64 ohmmeters.

2. Fault Current and duration

Earth mat is common for high voltage (33kV) incomer panel, Distribution Transformer 33kV/415V and low voltage panels (415V). Maximum fault current which can be ground through earth mat calculated 70kA.Presently modern switchgears can clear the fault in microseconds, for design of earth system fault current duration considered 1 second[4].

3. Material for earth grid conductor

For this application earth mat is installed below the substation and entire building constructed for a life span of 100 year. From various research is established that corrosion rate in copper material in buried condition is lesser compared to other material in addition to a good conductor. For earth mat design hard drawn copper rods are used and diameter of each rod is 24mm for this application. Proper bonding for all metallic structure, ensure fault current clearance and safe working of personnel [1].

4. Depth of earth mat from substation level

Depth from substation level to earth mat is 0.4meter (desired for this project) excluding thickness of base slab. Combined earth resistance value achieved less than one ohm (prerequisite for this work).

5. Earth mat size

Size of earth mat for this high soil resistivity area is 69 meter and 15 meters with a spacing of 3 meters horizontal and equal vertical spacing, 20 numbers vertical rods of 12 meter deep each. Due to constraint like column footing, basalt rock and to achieve desired value of combined resistance number of rods and depth are more.

6. Earth mat conductor size

The adequate size of earth conductor can be evaluated by equation as per standard, IEEE 80, equation 37 at page 42 given below[1].

$$I = A_{mm^2}\sqrt{\frac{(TCAP \times 10^{-4})}{t_c \alpha_r \rho_r} In\left\{\frac{K_0 + Tm}{k_0 + Ta}\right\}}$$

Where: **I** = rms current in kA; **A$_{mm2}$**= cross section of conductor in mm^2

K$_0$ = $1/\alpha_o$or $(1/\alpha_r)$ – Tr in ^{o}C; **Tm** = allowable maximumtemperature in ^{o}C

Ta = Ambient temperature in ^{o}C; **Tr** = reference temperature in ^{o}C

α_o= thermal coefficient of resistivity at 0^{o}C

α_r= thermal coefficient of resistivity at reference temperature Tr

ρ_r= resistivity of ground temperature at reference temperature Tr

tc = duration of current in second

TCAP = thermal capacity per unit volume (from Table1 IEEE 80, page 46)

From above formulas, **area of conductor is A$_{mm2}$ is 453 mm^2**

7. Substation surface level

High resistivity surface is available at substation level above earth mat. This surface level provides comparatively high resistance between ground and person. Reference for resistivity value of dry concrete, 10000 Ω-meter taken from Table 3.1, IEEE 80 Standard [1].

8. Step and Touch Voltage

The values of step and touch voltage kept within tolerable limits of human body as described in IEEE 80 standards[1]. The tolerable values calculated for a 50 kg person for touch potential is 1785 Volts and step potential is 6792 Volts for low voltage system.

$$E_{touch} = (1000 + 1.5\, C_s \times \rho_s)\, 0.116\sqrt{ts}$$

Where: **Cs** = surface layer derating factor; **ρ_s**= resistivity of surface material in Ω-meter

ts= duration of shock current in second

Where: **Cs** = surface layer derating factor; **ρ_s**= resistivity of surface material in Ω-meter

Cs given as

$$Cs = 1 - \frac{0.09\left(1 - \frac{\rho}{\rho s}\right)}{2hs + 0.09}$$

Where: **ρ** = soil resistivity in Ω-meter; **ρ_s**= resistivity of surface material in Ω-m

h= depth of surface layer in meter

By using above formula's, we get

E$_{touch}$ =1785 Volts; **Estep** = 6781.8 Volts

V. CALCULATION PERFORMED

After collecting the data described in design methodology for earth mat design of different parameters can be taken place. Following steps followed for computation[1-4]

- Input soil resistivity data for computation
- Input for fault level and its duration
- Input for depth of burial of earth mat and ground rod depth
- calculate conductor size and type of material
- Evaluate with tolerable touch and step voltage as per persons weight (70 kg or 50kg)
- Calculate combined resistance of earth mat
- Find grid current I_G
- Analysis of Ground Potential Rise (GPR) with respect to tolerable touch voltage
- Calculation of Mesh voltage (Em) and Step voltage (Es)
- Evaluate and compare mesh voltage Em is lesser than tolerable touch voltage. Same process followed for step voltage. Design process is complete.

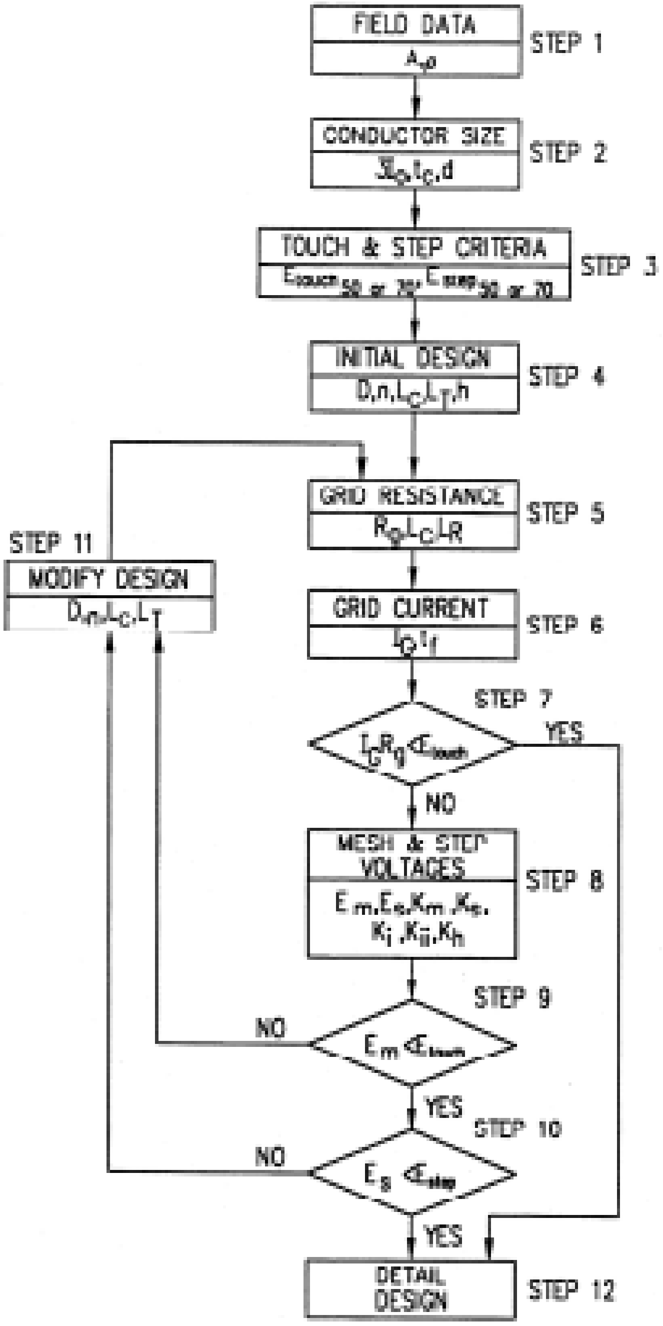

Figure 2: Block diagram for design procedure of earth mat [1]

VI. RESULTS

The parameters desired in results are satisfactorily in performed analysis. The value of combined resistance is less than one ohm. 3D view of earth mat, area input, output for step & touch voltage, combined resistance is shown in figures below[4].

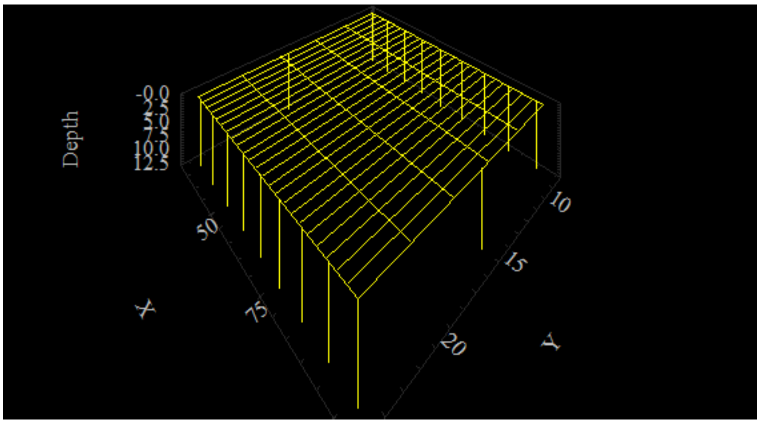

Figure 3: 3D View of Earth Mat in ETAP

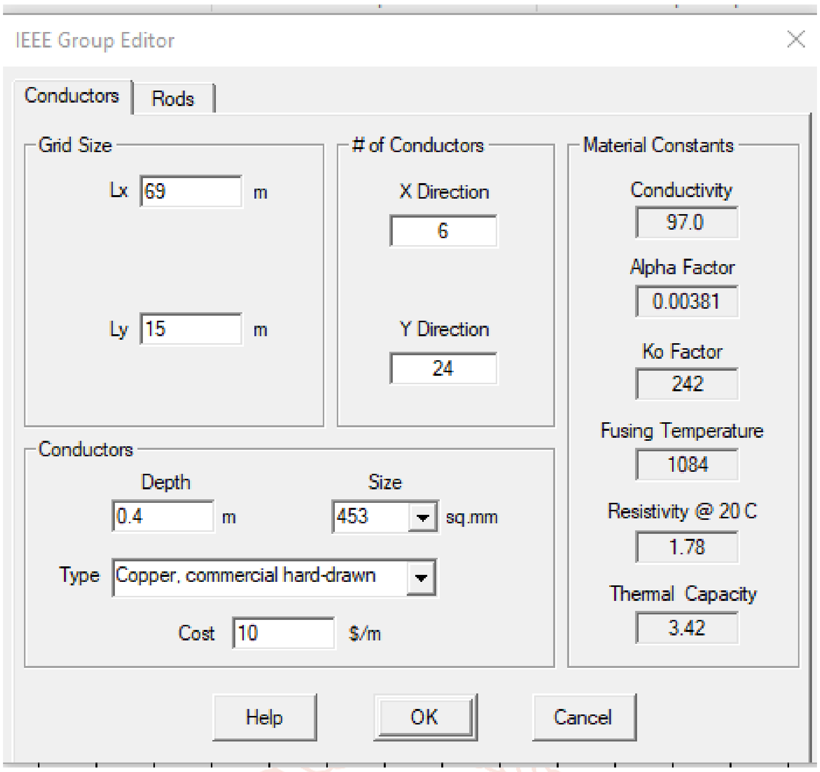

Figure 4: Area Input Parameters for Simulation in ETAP

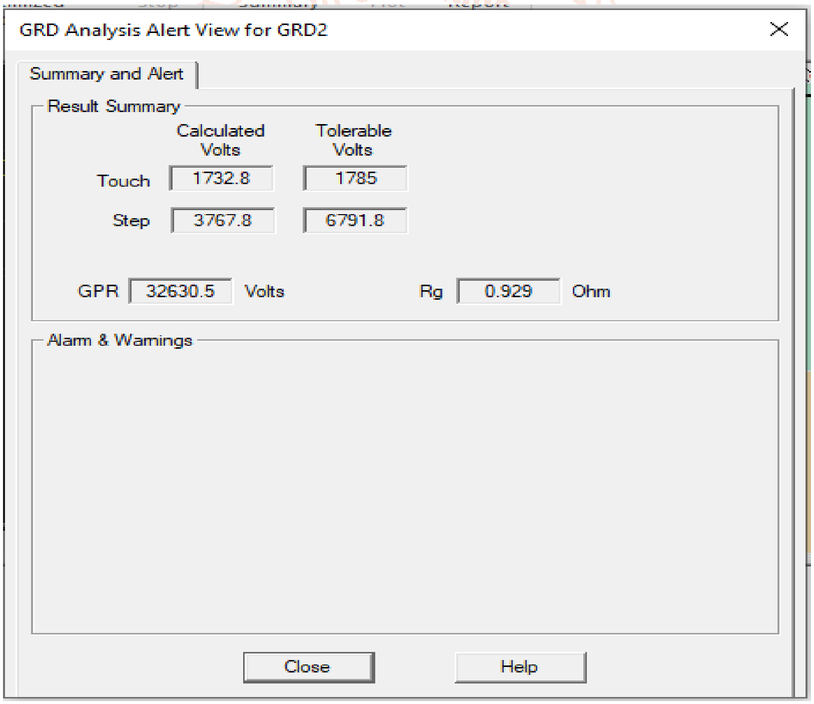

Figure 5: Step and Touch Simulation Result in ETAP

VII. CONCLUSION

This paper focused on the earthing system in a distribution substation of 33kV/415V. Results can be achieved from manual calculation but it's always lengthy procedure and sometime for different shape like L-shape earth mat and elimination of column footing from earth mat are time consuming. For earth mat design nowadays, specific software's are available to achieve desired solution for complex problems. In this problem result obtained from manual calculation and verified through ETAP calculation.

VIII. FUTURE SCOPE

For construction point of view after receiving soil resistivity data, design process of earth mat finalizes quickly so that other construction activity for entire premises do not hamper. Although measures to reduce soil resistivity is in use and defined in IEEE-80 standards but more option can be findingout for soil treatment for longer duration and same time cost effective. For such type of installation having higher soil resistivity one solution discussed in this paper however it may further evaluate for reducing earth mat area and other cost-effective solutions.

REFERENCES:

[1] IEEE Std 80-2013, IEEE Guide for Safety in AC Substation Grounding.

[2] Bhasme, N.R. & Shah S.G. (2014). Design of Earthing System for 400 kV AC Substation: A Case Study. International Journal of Electrical Engineering, 227-239

[3] Khan & Saleem (2020), Scope of Improvement for 400 kV AC Substation through Design, Analysis and Load Flow aspects. International Journal on Emerging Technologies, 780-784

[4] Jigyesh Sharma (2016), Optimal Design of Earth mat for 110 kV Substation using ETAP 12.6. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, ISSN (online): 2278-8875.

[5] Nevil Jose (2014), Design of Earth Grid for a 33/11 kV GIS Substation at a High Soil Resistivity Site using CYMGRD Software, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 3 Issue-10, October 2014.

[6] Mohammad Ali Adelian, Improvement of Substation Earthing, International Journal of Engineering Research & Technology (IJERT) ISSN: 2249-8958, Volume 3 Issue-4, April 2014.

[7] Akshay Patil, Substation Earthing Design, IOSR Journal of Electrical & Electronics Engineering (IOSR-JEEE), e-ISSN:2278-1676, p-ISSN: 2320-3331, Volume 12, Issue 1 Ver. II (Jan. – Feb. 2017), PP 12-17.

[8] Prudhvi Raj Bonda & Mahesh K. Mishra, Optimized Design of Earthing System for Substations with High Soil Resistivity and Limited Plot Area, proceeding of the National System Conference (NPSC) – 2018, December 14-16, NIT, Tiruchirappalli, India, 978-1-5386-6159-8/18/$31.00©2018 IEEE.

[9] Mark Davies, Robert Weller, Stephen Tucker, Estimation of substation earth impedance in a global earthing system, The Institution of Engineering and Technology (IET) Journals, ISSN 2515-0855, doi:10.1049/oap-cired.2017.0299.

[10] Hachimenum Nyebuchi Amadi, Design of Grounding System for AC Substations with Critical consideration of the Mesh, Touch and step Potentials, European Journal of Engineering and Technology, Vol. 5 No. 4, 2017, ISSN 2056-5860.

[11] A. Phayomhom, S. Sirisumrannukul and T. Kasirawat, Safety Design of Ground Grid in Distribution Substation: Case Study of Metropolitan Electricity Authority's System, GMSARN International Journal 4 (2010) 67-74.

[12] BS 7430: 2011+A1: 2015, Code of Practice for Earthing.