International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 5, July-August 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Grounding System Analysis

Mohd Kamran Khan, Mr. Ameen Uddin Ahmad

Department of Electrical, Electronics & Communication Engineering, Al Falah University, Faridabad, Haryana, India

ABSTRACT

Apropos of the above topic, in this thesis we will deal with the problem while designing the grounding for the substation at the generation, transmission, and distribution end for all main and auxiliary equipment in the substation. In the working manual calculations based on IEEE and CBIP manual are done for better understanding. Soil resistivity, short circuit current, etc are required to initiate the calculation. An additional computer program used for comparing attainable and tolerable in both step and touch voltages, results between these two voltages conclude the safety of the grounding of the switch yard. In a very common word, we can say that the earth mat or grid is the CPU of the grounding system.

KEYWORDS: *AC Substation grounding, step and touch voltages, grounding resistance, earth mat grid*

How to cite this paper: Mohd Kamran Khan | Mr. Ameen Uddin Ahmad "Grounding System Analysis" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-5, August 2022, pp.42-47, URL: www.ijtsrd.com/papers/ijtsrd50406.pdf

IJTSRD50406

INTRODUCTION

It is very important to protect the man working while construction or maintenance of the substation, there are two main functions of substation earth grid- operational and safety[1].To avail a path to scatter electric current inside the earth via ground grid without any tremendously operational and maximum voltage equipment limit. To make sure that person during maintenance or operation of a substation is not bare to instinctive voltage during the occurrence of earth fault current in the substation. Apart from safety and operation earth grid provides a path for emit of lightning and switching surges to the earth and to provide proper earth during maintenance of high voltage equipment inside the substation area. While earth fault occurs, the pass of surplus current to earth via. Earth grid or mat produces voltage gradients within or nearby the substation, voltage gradients can also damage or cause problems outside the substation premises[2].

When an earth fault occurs the maximum voltage gradients over the surface inside the switchyard may danger a person, and a hazardous voltage may develop between equipment support structure or main bus bar structure which is connected to the earth or surface on which a person is standing.

The major cause of hazardous voltage gradients

- Excessive value of earth fault current.
- Maximum soil resistivity
- Scattering of earth fault currents in such a way that ground current can return.
- A man is standing at such a point where there is a voltage difference between those two points of contact. Fault current passes through the mortal body depends on the magnitude, frequency, and duration of the current passing[3].

Clearing the fault current in a very quick time protects the human from electric shock and lower the time duration of the current flow via the human body. Secondary protection relay plays an important role while we discuss the fault current. In view of the safety, security, and welfare of personnel who get in touch with the conductive media. We can say that the primary purpose of designing a grounding system is to avoid injury to humans working inside the substation premises during fault occurrence. It is mandatory to do proper and actual analysis and calculation of the substation grounding system this is designed to bring off safe touch and step voltages within the substation switchyard area[4].

Selection of Grounding Method:

It is very difficult to select a method to calculate the grounding of the substation in a power system, many more factor is considered before choosing the method to calculate safe grounding i.e., grounding commonly used are solidly grounded, resistance grounded, reactance grounded, and ground fault neutralizer grounded[5]. It is based on the following factor

- Magnitude of the fault current
- Transient overvoltage
- Lightning protection
- Application of protective devices for selective ground fault protection
- Types of loads served, such as motors, generators, etc.

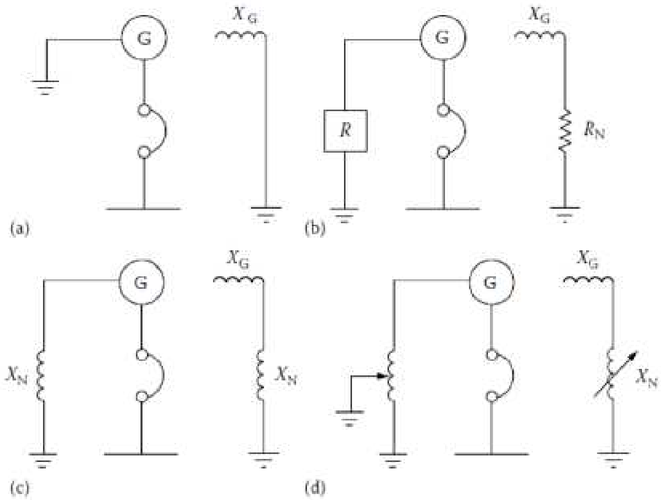

Fig.1- Various grounding methods - equivalent schemes

An example of 220/132/33 kV GIS Substation Badeshi, India, under the supervision of Uttar Pradesh state transmission utility (UPPTCL) taken to understand the physical calculation easily[7].

Table -1 input parameters

Sl.	Description	Symbol	Value	Unit
1	Symmetrical fault current in substation	I_f	40000	A
2	Grid current in the substation for conductor	I_G	24000	A
3	Duration of fault current for sizing of conductor	t_c	1	s
4	Duration of fault current for step and touch potential	t_s	0.5	s
5	Surface layer resistivity of switchyard	r_s	18.08	Ω–μ
6	Surface layer thickness inside switchyard	h_s	0	m
7	Average soil resistivity of entire substation	r	18.08	Ω–μ
8	Depth of ground grid conductors	h	0.6	m
9	Number of rods(electrodes)	N_r	200	
10	Length of the ground rod at each location	L_r	3	m
11	Length of 220kV switchyard considered for earthing (Width of Equivalent square area)	L1	105	m
12	Width of the 220kV switchyard is considered for earthing (Width of Equivalent square area)	W1	10	m
13	Length of 132kV switchyard is considered for earthing	L2	100	m
14	Width of 132kV switchyard is considered for earthing	W2	80	m
15	Length of 33kV switchyard is considered for earthing	L3	60	m
16	Width of 33kV switchyard is considered for earthing	W3	25	m
17	Length of switchyard considered for earthing (Length of Total Equivalent square area)	L	104.7	m
18	Width of the switchyard is considered for earthing (Width of Total Equivalent square area)	W	104.7	m
19	Number of conductors along the length (Length of Total Equivalent square area)	N_L	22	

20	Number of conductors along width (Width of Total Equivalent square area)	N_W	22	
21	Proposed dia. of conductor for Earth Mat M.S. rod	dia	40	
22	Diameter of conductor	d	0.4	m
23	Considered Proposed Spacing of Main Conductor	D	5	m

Table-2 sizing of earthling conductor:

Sl.	Description	Symbol	Value	Unit
1	Type conductor	Mild Steel		
2	Reference temperature for material constants	T_r	20	°C
3	Thermal co-efficient of resistivity at a reference temperature (as per Table-1)	α_r	.00160	°C
4	Fusing temperature of the conductor (as per Table-1)	T_m	1510	°C
5	Design ambient temperature	T_a	45	°C
6	$K_0 = (1/\alpha_r) - T_r$ (as per Table-1)	K_0	605	°C
7	Resistivity of conductor at a reference temperature	ρ_r	15.9	µΩ-cm
8	Specific heat of material (To be used when table does not have TCAP value)	SH	0.114	Cal/gm/°C
9	Density of material (To be used when table does not have TCAP value)	SW	7.86	gm/cc
10	Thermal capacity per unit volume (Table 1-Material Constant for Steel-1020) (page 42)	T_{CAP}	3.28	J/cm³/°C
11	Current for sizing of earth mat conductor (for tc=1 Sec)	I	24	kA
12	Soil resistivity considered for corrosion (As per soil resistivity report submitted)	ρ	18.08	Ω-m

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

Corrosion allowance is recommended as per the following rule[8,9]

- In case of conductor to be laid under soil having soil resistivity greater than 100 W-m-10% allowance.
- In case of conductor to be laid under soil having soil resistivity from 20 to 100 W-m-15% allowance.
- In case of conductor to be laid under soil having soil resistivity lower than 25 W-m-30 % allowance.

Cross section of selected conductor = 1257.2 mm² Mild Steel rod

Which is sufficient to meet the design requirement.

Problem formulation:

The reduction factor C_s can be calculated as:

$$C_s = 1 - a\left(\frac{1-\frac{\rho}{\rho_s}}{2*h_s+a}\right) \quad (2)$$

The tolerable touch and step voltage can be calculated as:

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

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

Table-3 Calculated tolerable touch, step voltage, reduction factor with A_{mm^2} (mm^2)

E_{touch}(V)	E_{step} (V)	C_s	A_{mm^2} (mm^2)	A_{mm^2} (mm^2) (With corrosion)
168.5	181.8	1	323.32	421.62 mm²

$$L_m = L_m + \left(1.55 + 1.22 + \frac{L_r}{\sqrt{L_x^2+L_y^2}}\right)*L_R \quad (5)$$

$$E_m = \frac{\rho*I_g*K_m*K_i}{L_m} \quad (6)$$

$$E_s = \frac{\rho * I_g * K_m * K_i}{L_s} \quad (7)$$

Main mat configuration:

I.	Area of 220 kV Switchyard		=	1050 sqm
		L1	=	105 m
		W1	=	10 m
II.	Area of 132 kV Switchyard		=	8000 sqm
		L1	=	100 m
		W1	=	80 m
III.	Area of 33 kV Switchyard		=	1500 sqm
		L1	=	60 m
		W1	=	25 m
	Total Area (A)		**=**	**10550 sqm**

Length of the switchyard considered for earthing (Length of Total Equivalent square area)	**L**	=	104.7 m
Width of the switchyard considered for earthing (Length of Total Equivalent square area)	W	=	104.7 m
Number of conductors along length	N_L	=	22
Number of conductors along length	N_w	=	22
Total Length of conductor along in grid [hoz/ver.	**Lc**		
Total length of ground rods(electrodes), m	L_R		
Total effective length of grounding system conductor, including grid and ground rods, m	L_T		
Peripheral length of the grid, m	L_P	=	418.9 m
No of electrodes,	N_r	=	200 nos
Length of individual electrodes,	L_R	=	3 m

$$L_c = (L * N_L) + W * N_w \quad (8)$$

$$L_R = (N_R * N_L) \quad (9)$$

$$L_T = (L_c) + L_R \quad (10)$$

Table-4 Calculated L_c,L_R and L_T

L_c	L_R	L_T	Total area of earth mat, A
4595.3 m	600m	5195 m	10964.85 m^2

Grid resistance R_g can be calculated as

$$R_g = \rho * \left(\frac{1}{L_T} + \frac{1}{\sqrt{20A}}\right)\left(1 + \frac{1}{h\sqrt{20/A}}\right) \quad (11)$$

Grid potential rise can be calculated as:

$K_h = \sqrt{91 + h)}/h0$ (12)

Where,

h_0= 1m (Grid reference depth)

Geometric Factor:

$N = n_a * n_b * n_d$ (13)

$n_a = (2XLc)/$ Lp

$n_b = \sqrt{(Lp/(4x\sqrt{A}))}$

n_c= 1 for square and rectangular grid

n_d= 1 for square, rectangular and L shaped grid

Table-5 calculated n_a, n_b, n_c

n_a	n_b	n_c	n_d	n
2.19	1	1	1	21.94

Results:

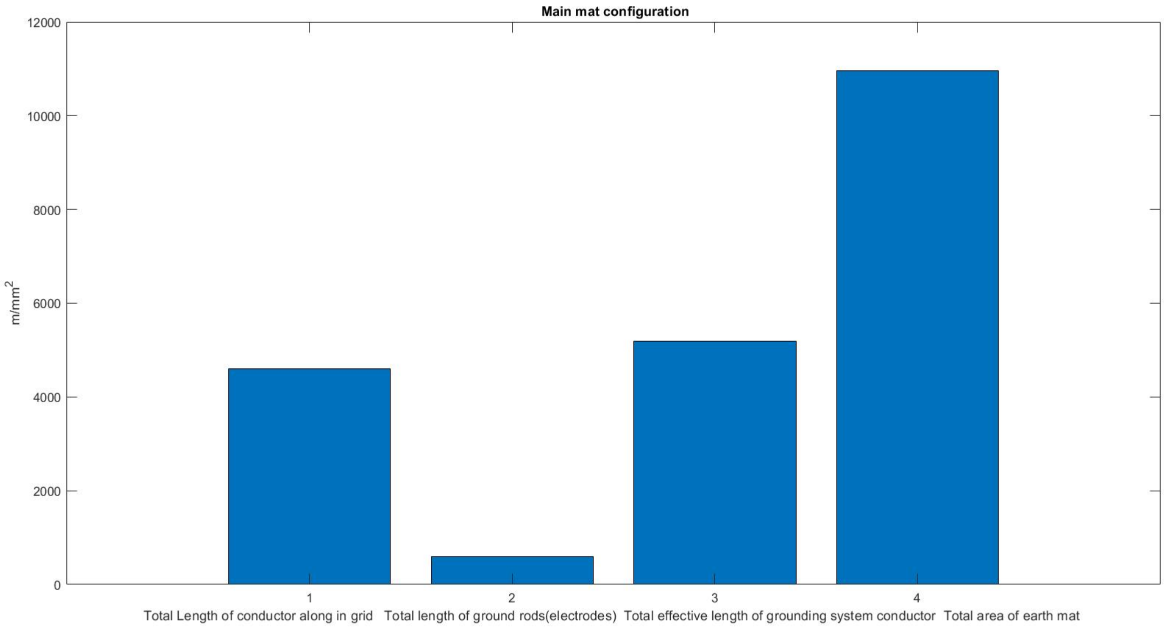

Fig- 2 Main mat configuration

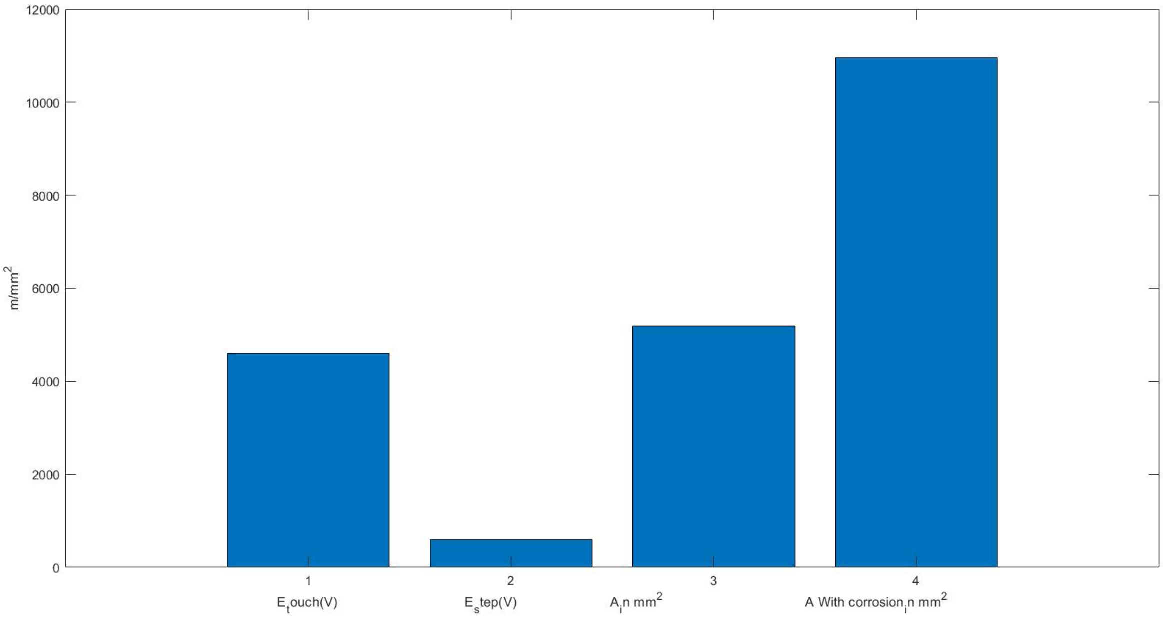

Fig -3 Tolerable touch, step voltage, reduction factor with A_{mm^2} (mm^2)

Conclusion:

Final results show low asymmetric strength even at very high resistance points. Considering the above results, systemic asymmetry seems to have a greater impact on dynamic asymmetry than the resistance difference between the straight layers. Ground modeling is considered a daunting task and we recommend using computers and computer software designed for this purpose. This avoids additional errors due to the use of image methods and analytical methods. For the safety earthing design, attainable step & touch voltages should be less that the tolerable values respectively,

	Attainable	Tolerable
Touch voltage in V	107.58	168.5
Step voltage in V	164.72	181.8
Grid resistance in Ω	0.08	1

The attainable touch as, well as step voltages is well below the tolerable limit. Also, the value of Grid Resistance is less than 1Ω.

Hence the design is safe.

Acknowledgement:

I would like to thank Prof. Mr MOHD Shahid for his valuable guidance and support on grounding grid design analysis calculation.

References:

[1] "IEEE Guide for Safety in AC Substation Grounding", IEEE Std. 80, USA, 2000.

[2] S. J. Schwarz, —Analytical Expressions for the Resistance of Grounding Systems‖, AIEE Transactions, Vol. 73 part III-B, pp.1011-1016, 1954.

[3] "Definitions", NEC Std. 100, USA, 1993

[4] "IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book0", IEEE Std. 142, USA, 2007.

[5] K. C. Agrawal, Industrial Engineering and Applications Handbook, Newnes, Great Britain, 2001.

[6] "IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.", IEEE Std. 81, USA, 1983

[7] John D. Mcdonald, Electric Power Substations Engineering, CRC Press, New York, 2001

[8] "Currents during two separate simultaneous line-to-earth short-circuit currents flowing through earth", CEI IEC Std. 60909 – 3, November 2003.

[9] International Council on large Electric Systems {CIGRE) Study Committee B3: Substations Springer Reference.