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A Comparison of Different Cases for Calculation of Earth Grid Design on the bases of Ieee 80-2000

Keyur Jyotishi
Department of Electrical Engineering
Shroff S. R. Rotary Institute of Chemical Technology
Ankleshwar(393002), India

Deep Patel
Department of Electrical Engineering
Shroff S. R. Rotary Institute of Chemical Technology
Ankleshwar(393002), India

Dhruv Patel
Department of Electrical Engineering
Shroff S. R. Rotary Institute of Chemical Technology
Ankleshwar(393002), India

Gaurang Patel
Sr. Engineer-Elect.& MARKETING
Takalkar Power Engineers & Consultants Pvt. Ltd.
Vadodara, India

***Abstract*: This paper provides stepwise calculation of earth grid with different cases which are affected in calculation of earth grid calculation like 'for different soil resistivity, different material and different human weight'. Also this paper consists of comparison and appropriate graph for those different cases which are provided.**

Keywords: Soil resistivity, Step voltage, Touch voltage, Mesh Voltage, Permissible Body current, Body resistance, etc.

I. INTRODUCTION

A conducting connection, whether accidental or intentional, by which an electric circuit or equipment is connection to the earth or to some conducting body relatively large extent that serves in place of the earth is called Earthing. [1]

Since the early days of the electric power industry, safety of personnel in and around electric power installations has been a prime concern. A mechanism by which Safety of personnel is affected is the ground potential rise of grounded structures during electric power faults and the possibility of humans touching grounded structures and, therefore, subjecting themselves to voltages. [2]

Purpose of substation Earthing system:

The objective of an earthing system in substation is to provide under and around the substation a surface which shall be at a uniform potential and zero or absolute earth potential. The provision of this surface of injury potential under and around the substation ensure that no human being in the substation is subject to shock or injury on the occurrence of a short circuit or development of other abnormal condition in equipment installed in the yard. The primary requirements of good earthing system in a sun-station are:

1) It should balance the circuit potentials with respect to ground and limit the overall potential rise.
2) It should protect human and equipment from over-voltage.

It should provide low impedance path to ground the fault current.

II.STEPS FOR DESIGNING EARTHING SYSTEM

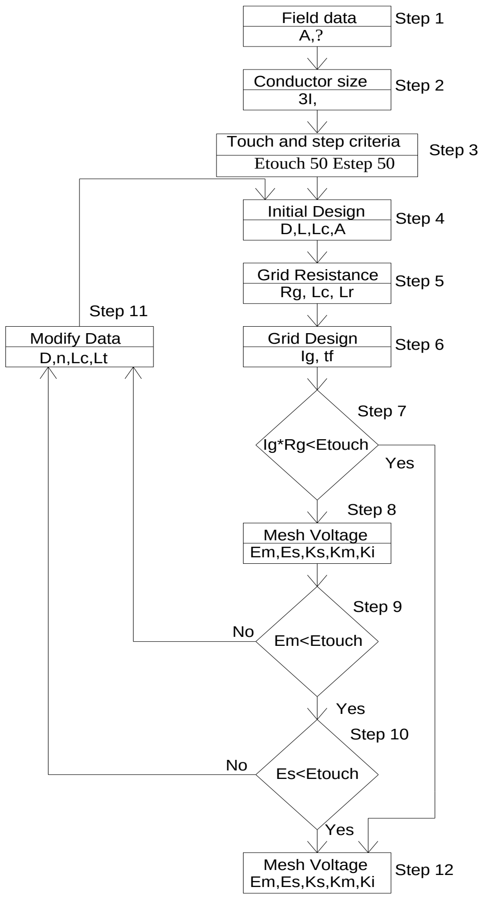

FIG 1 Steps For Designing Earthing System

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Touch Voltage:

The potential difference between the ground potential rise and the surface potential at the point where a person is standing while at the same time having a hand in contact with a grounded structure.

$$\mathbf{E_{touch} = (10000 + 1.5(c_s)(\rho_s)\frac{0.116}{\sqrt{t}}}$$

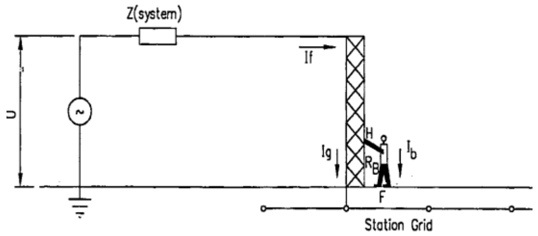

FIG 2   TOUCH VOLTAGE

Step voltage:

The difference in surface potential experienced by a person bridging a distance of 1 m with the feet without contacting any grounded object

$$\mathbf{E_{step} = (10000 + 6(c_s)(\rho_s)\frac{0.116}{\sqrt{t}}}$$

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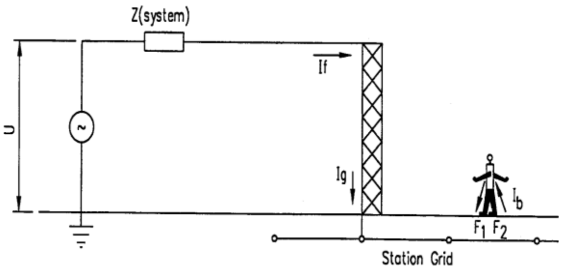

FIG 3   Step VOLTAGE]

Ground potential rise (GPR): The maximum electrical potential that a substation grounding grid may attain relative to a distant grounding point assumed to be at the potential of remote earth. This voltage, GPR, is equal to the maximum grid current times the grid resistance

GPR   =   IG X Rg

Ground current: A current flowing into or out of the earth or its equivalent serving as a ground is called as the ground current.

System earthing: Intentional earthing of neutral conductor for controlling circuit voltage to earthing and detection of unwanted connection between live conductors and earth is called system earthing.

Ground mat: Earth mat is a solid metallic plate or a system of closely spaced bare conductors that are connected to and often placed in shallow depths above a ground grid or elsewhere at the earth's surface, in order to obtain an extra protective measure minimizing the danger of the exposure to high step or touch voltages in a critical operating area or places that are frequently used by people. Grounded metal gratings placed on or above the soil surface, or wire mesh placed directly under the surface material, are common forms of a ground mat. [1]

STEP 1 FIELD DATA

TABLE 1 FIELD DATA

Sr no	Description	Unit	Value
1	Symmetrical fault current in substation	A	40000
2	Duration shock for determining allowable body current	sec	0.5
3	Duration of fault current sizing ground conductor	sec	1
4	Surface layer resistivity	Ω-m	3000
5	Surface layer thickness	m	0.1
6	Grid reference depth	m	1
7	Soil resistivity	Ω-m	59.67
8	Depth of ground grid conductor	m	0.6
9	Length of grid conductor in x direction	m	158.1
10	Length of grid conductor in y direction	m	102.5
11	Spacing between parallel conductor	m	9
12	Length of ground rod/pipe at each location	m	3
13	No of pipe/rod placed in area	nos	30
14	Decrement factor for determining IG	-	1
15	No of grid conductor in x direction	nos	13
16	No of grid conductor in y direction	nos	19
17	Equivalent earthing mat area	m^2	16205.3
18	Total length of buried conductor	m	4272.8
19	Total length of ground rod/pipe	m	90

For all the different cases for same material like steel the entire field will remain same but there is a change in Soil resistivity (i.e. 60 Ω-m, 70 Ω-m, 80 Ω-m, 100 Ω-m,120 Ω-m, 14 Ω-m, 150 Ω-m, 160 Ω-m, 180 Ω-m, 200 Ω-m) and due to that there will be change in Spacing between Parallel conductors and due to that there will be change in no of conductors on X-direction and Y direction and Total change in length of buried conductors and calculated mesh and touch voltage for economical and safe design of Earth grid for sub-station.

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STEP 2: DETERMINATION OF SIZE FOR CONDUCTOR

The size of conductor is depends on the type of material. Hear we take Four Different Material (i.e. Steel, Copper, and Copper with clad, Stainless steel) The size of conductor is depends on the factor like αr, K_o at 0^0c, T_m, ρ_r, T_{cap} which is different for different material.

TABLE 2 MATERIAL CONSTANT

Mate-rial	αr factor at R.t	K_o at 0^0c	T_m	ρ_r	T_{cap}
Steel	0.0016	605	1510	15.9	3.28
Copper	0.0039	234	1083	1.72	3.42
Copper clad	0.0037	245	1084	4.4	3.85
Stainless steel	0.0013	749	1400	72	4.03

Now for calculation of size of conductor

For Steel

$$I = A_{mm^2} X \sqrt{\left(\frac{TCAPX10^{4}}{tc.\rho r.\alpha r}\right) X \ln\left(\frac{K_0 + T_m}{K_o + T_a}\right)} \quad [3]$$

$$A_{mm^2} = \frac{1}{\sqrt{\left(\frac{TCAPX10^{4}}{tc.\rho r.\alpha r}\right) X \ln\left(\frac{K_0 + T_m}{K_o + T_a}\right)}}$$

A_{mm^2} = 520.5348 mm^2

In case of conductors to be laid in soils having resistivity from 25 to 100 Ω-metre -15 percent allowance.

$A_{mm^2} = 1.15\ X\ 520.5348$

=598.6151 mm^2

Similarly

TABLE 3 REQUIRED AREA

Material	A_{mm^2}
Steel	598.6151
Copper	230.888
Copper clad	347.9078
Stainless steel	1227.25

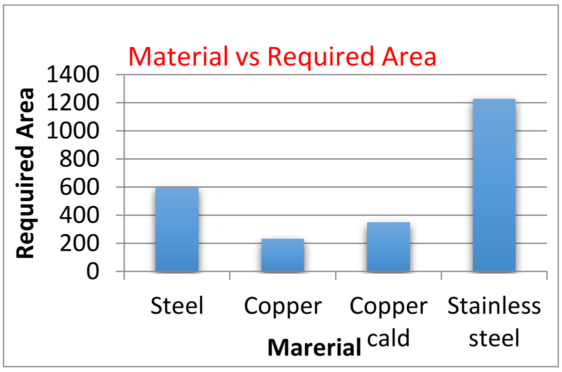

FIG 4 Graph Material Vs Required Area

STEP 3 TOUCH AND STEP CRITERIA

The Tolerable Touch and Step Voltage is mostly depends on the human weight. There is no effect of type of material and soil resistivity. The tolerable touch and step voltage is

$$E_{step} = (10000 + 6(c_s)(\rho_s)) \frac{0.116}{\sqrt{t}} \quad [1]$$

$$E_{touch} = (10000 + 1.5(c_s)(\rho_s)) \frac{0.116}{\sqrt{t}}$$

E.g. for 50 kg human tolerable touch and step voltage using above data is

$$C_s = 1 - \frac{0.09 \times (1 - \rho/\rho_s)}{2hs + 0.09} \quad [4]\ [5]$$

Cs = 0.695827

So,

$$E_{touch} = (10000 + 1.5(c_s)(\rho_s)) \frac{0.116}{\sqrt{t}}$$

$$E_{touch} = 677.722\,V$$

And

$$E_{step} = (10000 + 6(c_s)(\rho_s)) \frac{0.116}{\sqrt{t}} \quad [1]$$

$$E_{step} = 2218.7437\,V$$

Similarly

For 70 kg human

$$E_{touch} = (10000 + 1.5(c_s)(\rho_s)) \frac{0.157}{\sqrt{t}} \quad [1]$$

$$E_{touch} = 931.766V$$

And

$$E_{step} = (10000 + 6(c_s)(\rho_s)\frac{0.157}{\sqrt{t}}$$

$$E_{step} = 3060.91V$$

For different material the value of tolerable step and touch voltage is

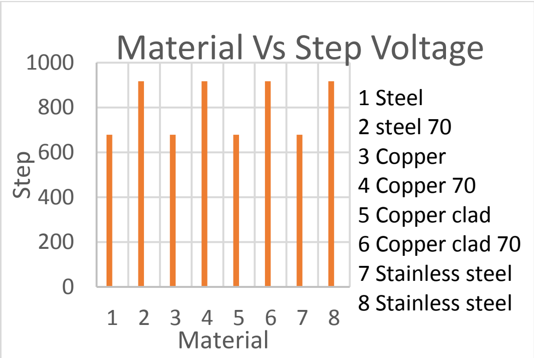

FIG 5 Graph Material Vs Step Voltage

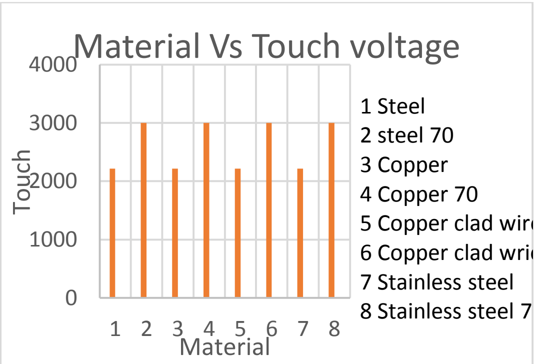

FIG 6 Graph Material Vs Touch Voltage

Conclusion: Tolerable Step voltage and Touch Voltage is not depends on the material it is depends on the weight of human body.

STEP 4 DETERMINE THE GRID RESISTANCE

For ρ = 60Ω-m the grid resistance is

$$R_g = \rho \times \{\frac{1}{L} + \frac{1}{20A^{0.5}}(1 + \frac{1}{1 + (\frac{20}{A})^{0.5}})\} \quad [6]$$

$$R_g = 0.2214 \text{ ohm}$$

For Different cases like for different resistivity there will be change in distance between parallel conductors and there will be change in length of buried conductor.

So the resistivity will be change

TABLE 4 EFFECT OF RSISTIVITY ON GRID RESISTANCE

Resistivity (Ω-m)	Length of buried conductors (mtr)	Grid Resistance (Ω)
60	4272.8	0.2214
70	4635.9	0.2584
80	4645.9	0.2954
100	5259.6	0.3666
120	6143.9	0.4367
140	6143.9	0.5095
150	6143.9	0.5459
180	7130.7	0.6510
200	7130.7	0.7234

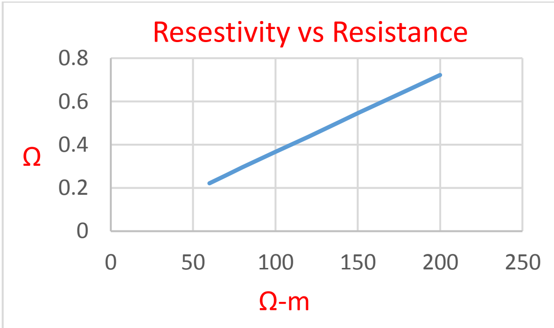

FIG 7 Graph Of Resistivity Vs Resistance

STEP 5
GROUND POTENTIAL RISE

For ρ = 60Ω-m the Ground Potential Rise is

GPR = IG X Rg [1]

GPR = 5407.23 V

TABLE 5 EFFECT OF RESISTIVITY ON GPR

Resistivity Ωm	GPR
60	5407.234
70	5909.804
80	6348.771
100	7056.66
120	7616.903
140	8095.579
Resistivity Ωm	GPR
150	8302.598
180	8807.663
200	9094.702

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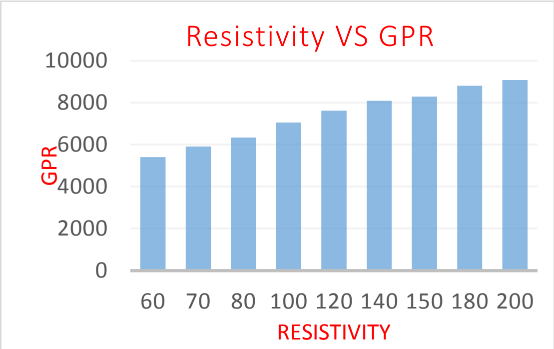

FIG 8 Graph Of Resistivity Vs Gpr

STEP 6 CALCULATE THE MESH VOLTAGE

$$K_m = \frac{1}{2\pi}\{\ln(\frac{D^2}{16hd} + \frac{(D+2h)^2}{8Dh} + \frac{h}{4d}) + \frac{K_{ii}}{K_h}(\ln\frac{8}{\pi(2n-1)})$$ [6]

Where

$n = (n_a \ X \ n_b \ X \ n_c \ X \ n_d)$

Where n_a, n_b, n_c and n_d is depends on the Total length of buried conductors (Lc) and Peripheral length of buried conductor (Lp).

So for resistivity (ρ)=60 Ω-m, The Spacing between parallel conductors =9 m so

$L_c = \{(Lx \ X \ Nx) + (Ny \ X \ Ly)\}$
$L_c = 4002.8$ m

$L_p = \{(2XLx) + (2XLy)\}$
$L_p = 521.2$ m

So
$n = 15.5398$
So
$K_m = 0.6099$
And
$K_i = 0.644 + (0.148 \ X \ n) = 2.943902$

So Mesh Voltage is

$$E_m = \frac{xI_G K_m K_{ii}}{L_c + (1.55 + \{1.22[\frac{L_r}{(L_x^2 + L_y^2)^{0.5}}]\}L_R}$$ [6]

$E_m = 498.044 \ V$

For Calculated Step Voltage

$$K_s = \frac{1}{\pi}(\frac{1}{2h} + \frac{1}{D+h} + \frac{1}{D}(1-0.5^{(n-2)}))$$ [6]

$K_s = 0.33394$

So,

$$E_s = \frac{xI_0 K_s K_{ii}}{((0.75\times L_c) + (0.85\times L_R))}$$

$E_s = 465.32 \ V$

For different resistivity

TABLE 6 EFFECT OF RESISTIVITY ON SYSTEM VOLTAGES

Resistivity(Ω-m)	E_m	E_s
60	465.32	631.37
70	466.82	633.40
80	515.30	631.60
100	553.58	678.52
120	624.18	669.47
140	688.20	620.48
160	731.45	659.47
180	750.16	676.33
200	810.38	585.05

So From the equation of Step and Mesh Voltage, System or Calculated Mesh and Step Voltage is depends on the Soil Resistivity it is not depends on the type of material.

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IV. REFERENCES

[1] IEEE 80-2000., “IEEE Guide for Safety in AC Substation Grounding”, (Revision of IEEE 80-1986) approved 30 January 2000.
[2] Central Board of Irrigation & Power (CBIP) Publication no.223
[3] Sverak, J. G., “Sizing of ground conductors against fusing,” *IEEE Transactions on Power Apparatus and Systems*, vol. PAS- 100, no. 1, pp. 51–59, Jan. 1981.
[4] Dawalibi, F. P., Xiong, W., and Ma, J., “Effects of deteriorated and contaminated substation surface covering layers on foot resistance calculations,” *IEEE Transactions on Power Delivery*, vol. 8, no. 1, pp. 104–113, Jan. 1993.
[5] Meliopoulos, A.P., Patel, S., and Cokkonides, G. J., “A new method and instrument for touch and step voltage measurements,” *IEEE Transactions on Power Delivery*, vol. 9., no. 4, pp. 1850–1860, Oct. 1994.
[6] Sverak, J. G., “Simplified analysis of electrical gradients above a ground grid; Part I—How good is the present IEEE method?” *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-103, no. 1, pp. 7–25, Jan. 1984.