Design of Earthing System for Substation Switchyard A Case Study

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Abstract:- This paper describes the procedure and calculation to design earthing of a switchyard using MATLAB software and IEEE 80-2000. Using Primary data like area to be earthed, soil resistivity, diameter of earth rod, primary calculation is done and design is finalized based on safety criteria step and touch potential.

Keywords:- Earthing, MATLAB, Step Potential, Substation, Touch Potential

I. INTRODUCTION

Substations are the essential part of power system. Earthing of power system is major task in the designing of substation. Earthing is majorly done for the safety purpose. It ensures the safety for the operating personnel as well as the safety for the equipment used in system. The main parameters which are mainly decisive parameters are (i) Step Potential (ii) touch potential (iii) Ground resistance (iv) GPR

Step Potential is the difference in surface potential experienced by person keeping distance between feet as 1m without connecting any grounded object [1]. Touch potential is the difference in potential between metallic object or structure and within the substation site may be bridged by direct hand to hand [1]. If these limits violates it becomes dangerous for the person. Ground resistance can be measured by performing soil testing, four point or fall of potential methods. It measures in Ω unit. GPR refers to Ground Potential Rise means the maximum electrical potential that a substation grounding grid may attain relative to distant grounding point assumed to be potential of remote earth.

II. CALCULATIONS FOR EARTHING PARAMETERS

A. Collection of initial data: This data set requires starting the calculation. It requires area to be earthed, soil resistivity, material which is used as eathing rods, etc. the data regarding soil resistivity can obtained using soil model or from the soil test report.

B. Calculation of diameter of earthing rod the diameter of earthing conductor mainly depends upon the fault current level of earthing grid and the thermal capacity per unit volume. The area of earthing rod can be found out using following equation.

Where

= conductor cross-section area in TCAP= thermal capacity per unit volume in

= maximum temperature in °C

= ambient temperature in °C

In °C

Also as per CBIP publication it is recommended to consider the effect of corrosion also to be considered. They recommended considering allowance of 15-30% based on soil resistivity [4].

C. Step and touch potential criteria: terms step and touch potential is described earlier in introduction. This is calculated for the determination of safe value of step and touch potential. The calculation is bifurcated in two ways. One is for 50Kg weight operating personnel and another is 70Kg weight.
Here the term Cs is the empirical expression for finding the safety criteria. This can be expressed as

For another category i.e. 70Kg the factor 0.116 is replaced by 0.157.

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D.   Resistance of Grounding: this is another parameter on which the design is dependent. For EHV substation the recommended grid resistance Rg is 1 Ω and for HV substation is 0.5Ω. It can be find out using following equation

Where L= length of buried conductor
Generally earth resistance is measured by fall of potential method or four point method.

E.   Calculation of maximum grid current: It is the maximum current flowing through the earthing grid. This mostly depends upon the split factor . Split factor term can be understood by the factor which allows the amount of current through earthing mat. Simply it could be understand as % amount which flows through the earthing mat. It depends on the numbers of incoming and numbers of outgoing lines. The calculation for safety factor is as follow.

Where
Zeq = equivalent impedance of system = system grid resistance
The maximum grid current is denoted as and expressed as follow

F.   Ground potential rise: It termed as GPR and occurs when large amount of current flows through earth. It causes hazardous for personnel as well as the equipment. In practice it is recommended that the GPR should be less than 430 V but due to grid resistance and large amount of fault current it do not falls under the recommended standard. So it is required to have detailed design of earthing. GPR can be finding out from the following expression.

It is been seen that the GPR is high at the point where the current enters to the grid and low at the point where current left the grid.

G.   Mesh voltage calculation: Mesh voltage is nothing but the maximum voltage appears to ground grid. This is an important parameter to check whether the design is proper or not. It ensures the safety because the mesh voltage resembles the worst possible touch voltage inside the substation. Mathematical expression for calculating mesh voltage is given below.
Where
=   geometrical factor expressed as Irregularity factor, expressed as
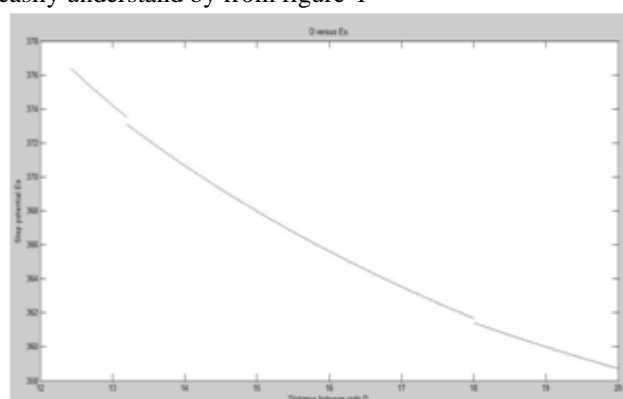=   total length of ground rods

H.   Actual step voltage calculation: After finalizing detail design, to verify the design this is also considered with mesh voltage. The actual step voltage can be calculated as follow.

Where
))…(12) $-$ $-$ $--$ $-$
These are the essential calculation to be done for the design of earthing grid. After performing this calculation the necessary check is done which is the Es should be less than Estep and Em should be less than Etouch. If these conditions simultaneously achieve the design is said to be proper. Also if these conditions is not achieving we can change the primary data set like number of rods, distance between rods, material of rods etc.

The whole procedure can easily understand by from figure-1

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III. CASE STUDY

Case study for 66 kv switchyard:

A MATLAB program is developed to calculate the earthing calculation. This is a generalised program which is use for any substation earthing calculation based upon pre-estimated fault current. Here program reads some data from the users and it will calculate all the parameters until the conditions are not satisfied. Here if the initial user input data is not satisfies the conditions, the detail design can be done by changing either distance between rods or number of rods. The input data set taken for starting the calculation is shown in the table-1 as follow.

Table -1

SR NO	PARAMETER	SYMBOL	UNIT	VALUE
1.	Symmetric fault current	Ig	A	25000
2.	Surface layer resistivity		Ω-m	3000
3.	Soil resistivity	ρ	Ω-m	28
4.	Distance between rods(initially)	D	m	20
5.	Number of rods(initially)	Nr		45

IV. RESULTS

The result is obtained in the MATLAB command window. This gives the value of proper earthing grid design in terms of proper distance between rods D. The figure-2 shows the plot between distance between rods and actual step potential exist in the earth mat. From this plot it is easily understand that step potential decreases with as the distance between rods increases.
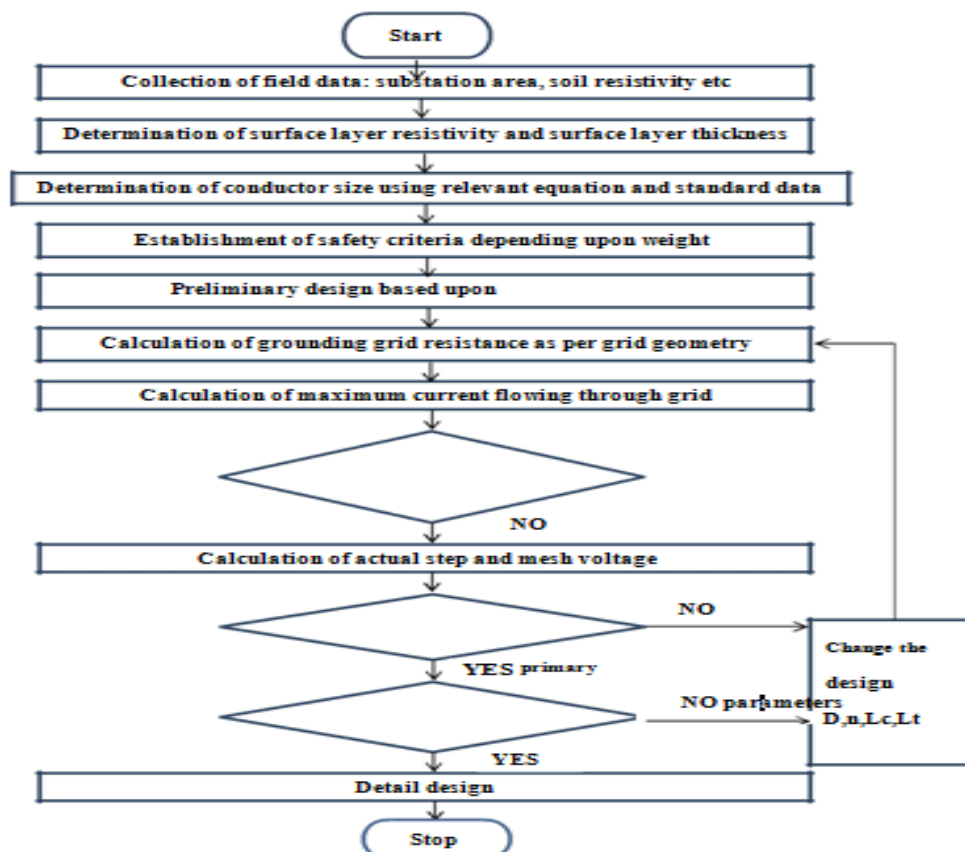

Fig 1- General earthing procedure

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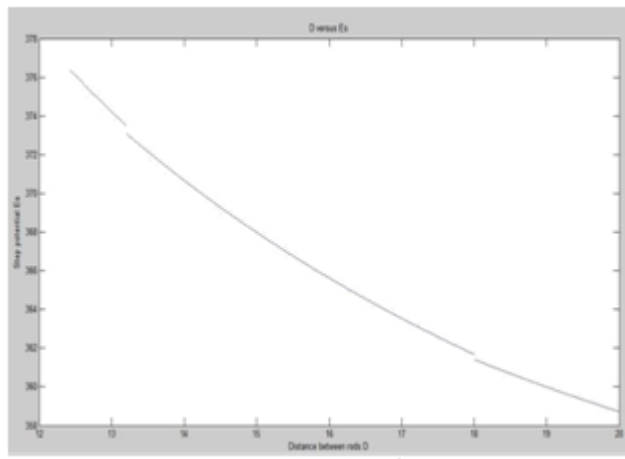(RTEECE 17th – 18th April 2015)

Fig 2- D versus Es

Figure 3 shows the plot between distance between rods and the mesh potential. From this plot it is seen that the mesh voltage is increases with the incerease in distance between rods.
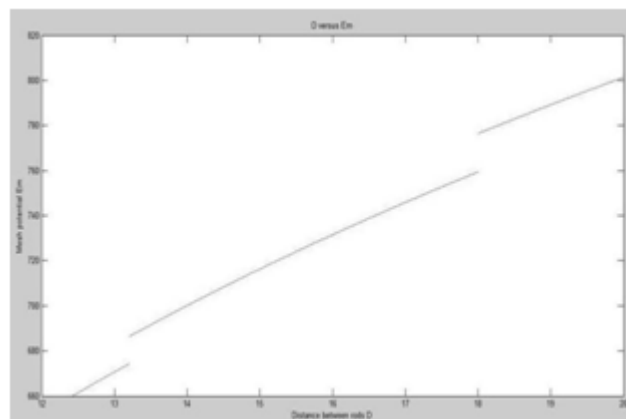

Fig 3 – D versus Em

The program gives the output based on the equations and algorithm given in figure 1. Here the program is changing initial data set using switch statement. The final results for this earthing design are given as in table -2.

Table -2

SR NO	PARAMETER	SYMBOL	UNIT	VALUE
1.	Equivalent earth mat area	A		891
2.	Area for earthing conductor	Aec		374.34
3.	Grid resistance	Rg	Ω	0.4841
4.	Ground potential rise	GPR	Volt	4960.8
5.	Touch voltage	Etouch	Volt	733.5
6.	Step voltage(safe)	Estep	Volt	2441.8
7.	Mesh voltage	Em	Volt	651.85
8.	Step voltage (actual)	Es	Volt	378.10
9.	Distance between rods (final)	D	M	12

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In first case the modification in primary data was done with the distance between rods. Now we are changing the number of rods placed in the area.

Figure 4 shows the plot between numbers of rods versus step potential. By nature the step potential decreases with the increase in number of rods. The same result can be seen in the plot between number of rods and mesh voltage as shown in figure 5.

The final choice of change in parameter depends upon the conditions and requirement decided by the designer on the basis of techno-economical conditions.
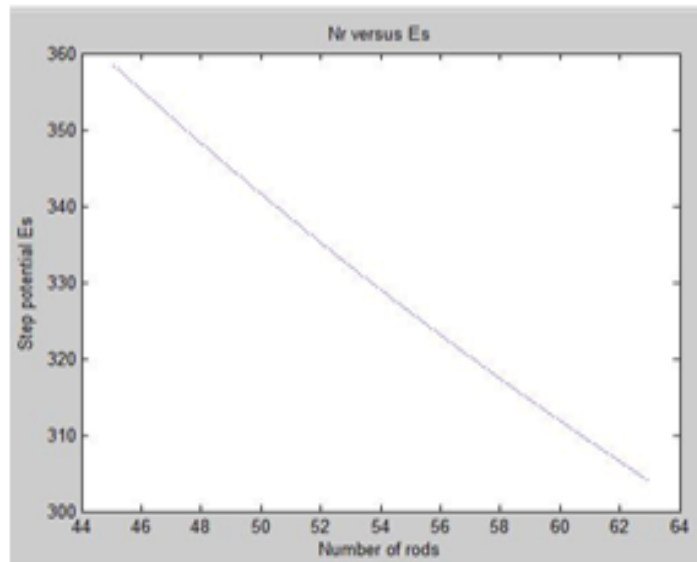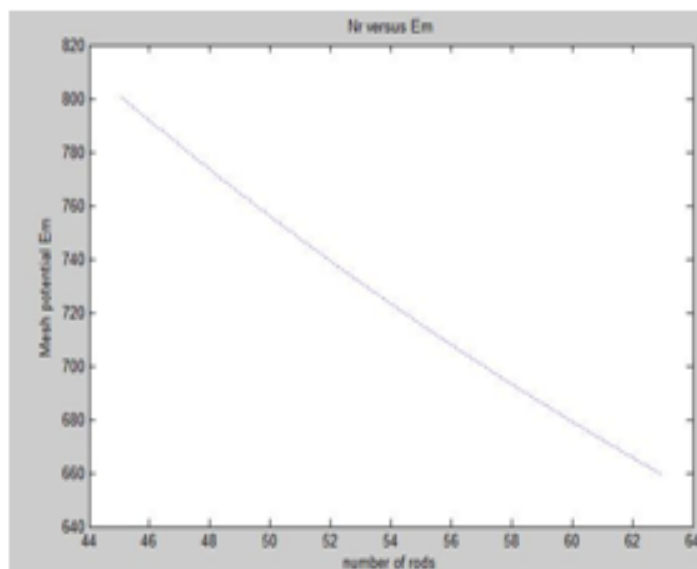

Fig 4- Nr versus Es

Fig 5- Nr versus Em

The final results after changing the number of rods in design are as shown in table-3.

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Table-3

SR NO	PARAMETER	SYMBOL	UNIT	VALUE
1.	Equivalent earth mat area	A		891
2.	Area for earthing conductor	Aec		374.34
3.	Grid resistance	Rg	Ω	0.4841
4.	Ground potential rise	GPR	Volt	4960.8
5.	Touch voltage	Etouch	Volt	733.5
6.	Step voltage(safe)	Estep	Volt	2441.8
7.	Mesh voltage	Em	Volt	659.87
8.	Step voltage (actual)	Es	Volt	304.19
9.	Number of rods (final)	Nr		63

As shown in figure-1 the condition is satisfied if the mesh voltage is little below to touch voltage. Practically for this small difference do not effect too much in safety concern. So for safety criteria 90% touch voltage is considered.

V. CONCLUSION

By this MATLAB programming the calculation for earthing can easily be done provided basic data required as input. The relations between mesh and touch potential with change in distance between rods or change in number of rods placed. Either changing distance between rods or number of rods no wide difference is seen in safety criteria. So the final design can be done on economic factor.

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