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Scope of Improvement in Earthing System for 400 kV AC Substation through Design, Analysis and Load Flow aspects

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ABSTRACT: In this paper a basic concept for Design and Analysis of Load Flow and Earthing System for 400 kV AC Sub-Station and calculations of its parameters has been discussed in detail. For successful working and operation of any power system, it is very much necessary to operate the substations at a very high level of performance. The substations are considered the main working element of any power system. The main objective of an Optimal Power Flow is to obtained the steady state operation point, which minimizes the generation cost, losses and also maximize social welfare, load bearing capacity etc., this phenomenon is only possible when an acceptable system performance or limits on generators active and reactive powers has been maintained at a certain limits or values. For an efficient working of a substation, Earthing at substations plays an important role if it is designed with full of care. Hence, poorly designed and effective Earthing system may result in many types of protecting device failure and non-operation and controlling of other measuring and monitoring protective devices. A complete attention is required to design any Earthing System. Main aim of presenting this paper is to provide the designing of 400kV Substation for safe and low cost Earthing system especially where the deep soil is uneven. In this paper, importance of Earthing have been discussed in detail including methodology of designing. This paper also highlights the calculations as per the factors required to the design of 400kV sub-Stations. Earthing Systems. A case study based data and parameters are considered for remotely located Sub-Station at Ghaziabad, Utter Pradesh Area.

Keywords: Load Flow Analysis (LFA), Earthing, earth grid, 400 kV substations, Power systems, Safety.

I. INTRODUCTION

Since the beginning, when power system introduced for all type of Power, Voltages and Current Transmission and their distributions for AC Electrical Systems. It has been observed a huge change since last several years that, there is a significant addition of the sub-set of high voltage DC as well as AC in Electrical Power Systems. There is always a great importance of Earthing at all types of generation, Sub-Stations and distribution Systems. In some of the cases it has been noticed that Earthing has been ignored widely. It is very much clear that the Sub-Station Earthing is very necessary to provide the working people protection in the premises where there are the chances of electrocution or shock hazards. It is also required to keep the system equipment well protected from the Earth-Faults or Grounding Faults. For the proper design, it has been considered the factor of reliability, safety and security and other legal compulsions. In this paper Earthing carry outs has been highlighted for 400kV Sub-Stations with 50 Hz frequency [1, 2].

Power Flow in any 3-Phace AC and DC System are of same level of interest. It will help us to understand the energy state of system widely. The study of the BUS-Voltages of the system-network is very important with the help of this it will be possible to know the accurate values of power flow between the Electric-Buses. The determination of the solution to the problems of the Load-Flow in any AC-DC Systems is different with that it is available for AC-Systems. To understand this there must be a new methodology to solve the complexity by adopting some modifications.

In this paper a novel and efficient procedure has been introduced for Re-Configuration of Network with Optimal Power Flow Based new Benders decomposition approach to solve power transmission network expansion planning problems

II. IMPORTANCE

The importance of this study is to minimize the power losses and load balance in between feeders. The losses and balancing have following constraints:

– Capacity limit of branches
–Minimum and Maximum limits of Sub-Station/Generators
–Minimum Deviation of Node Voltage and Radial Operations of Network.

Here are the following reasons due to which Earthing is necessary in plants or any facilities are necessary:

–Protection of Equipment and Devices Used for electrical Systems
– Protection of Human Beings
– Optimum operation of Electrical Devices

These equipotential bonding is required for Equipment made with metal, Constructed Buildings Pipes and other structures. These all are required proper Earthing System to provide a barrier towards fault voltages between apparatus to apparatus and apparatus to earth [1-3]. It is required at planning and operational stage of power system to opt Load-Flow technique as a fundamental tool. With the help of this study, an inclusion of stability and reliability of the Power-System Networks can be analyzed. It has been ensure with the help of Load-Flow Studies, the stability for the Electrical Power Flow from Generation to Distribution Systems including stability and reliability of the system. Load-Flow Study ensures the economic stability too.

Investigation of magnitude and phase angle of the voltage at all bus and the flow of Real and Reactive Power flows in the Electrical Modules and apparatuses. Load-Flow Analysis is the spine of Power-System Design and Analysis.

Load-Flow Analysis can be done with the help of Mathematical Method to determine various Bus-voltages, Phase-Angle, Active-Reactive Power flows through various Branches, generator and their load under steady state conditions [4-7].

With the help of Earthing System a great help has been obtained because it offers an orientation potential for electronic circuits due to which there is a certain noise reduction in electrical signals for electronic circuits and instruments used in communication apparatus [1-3].

We follow the Guidelines provided by IEEE Standard given in Guide for safety in AC Sub-Station Earthing.

III. METHODOLOGY FOR DESIGNING OF EARTHING

In any Sub-Station, the Earthing System holds Earth-Grid/Mesh, Earth-Electrodes, Earthing-Conductor.

It is a very complicated and critical part of any Sub-Station.

During the process of design, there must be the Data collection from field, calculation of Two Layer Soil Resistivity Data, determining maximum resistance values of grounding system.

In addition to easily achievable Step-Touch Voltage. IEEE Standard -80 has been referred for the same process.

A. Measurement of Soil Resistance at Sub-Station Situate

The resistivity of the soil is very high because where Sub-Station is situated is almost dry or low moist. If the value of the resistivity is variable at a very significant amount, generally Multi-Layer Soil Model has been preferred for exact measurement [8]. This procedure is very complex and challenging in case of lower ground soil resistivity is higher in comparison to upper Ground soil.

Table 1: Data of Soil Resistivity of Field.

S. No.	Spacing of Resistance Probe(Unit in Meters)	Observed Resistivity (Unit –Ohm-Meters)
1.	1	60.23
2.	2	90.45
3.	2.5	102.78
4.	3	118.54
5.	3.5	138.56
6.	4	145.32
7.	4.5	151.22
8.	5	156.32
9.	5.5	158.41
10.	6	160.47

B. Details of input Data Required

Below is the data required as an input, which has been considered for the design of Earthing System.

(i) **Fault current and duration of fault current:** It is assumed that the maximum Ground-Fault current is going in to Earthing Grid. The duration of the fault is the time considered for which fault condition current flows via Earthing System just before the Switch Gear for protecting the devices are to operate and isolate the current and fault area.

(ii) **Surface layer of the High Resistivity Area of Sub-Station:** It is assumed that for the proper safety and protection from the current, use of High Resistivity is required while designing any Sub-Station Earthing Grid for High Resistivity Top/Lower Soil. [Ref 1 of NIT]

Material selection for Earth Rod and Conductor for Earthing

The common choice for the Earth rod material is Copper-Bonded Steel. Copper-Bonded Steel offers good strength and corrosion resistant and low cost.

IV. DEPTH OF THE STRUCTURE OF GRID

The depth of Structure of grid résistance offers a great effect as per the below equation. This Equation is named as Equation -52 as per the IEEE-80 Standard.

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

Here R_g is resistance of Earthing Grid ρ is the resistivity of soil (Ohm-Meter), L_T is the total length of the conductor inside the ground (meters), A is the total Area acquired by the grid (meter2) h is the total depth of the Earthing Grid.

Is has been recommended to keep the depth in between 0.5 meters to 1.50 meters below the top of the Soil/Surface. In this particular design, it is taken as 0.65 meters nearly 2.13 feet.

Important instruction: The values of earth resistances must be as minimum as possible and not to be exceeded by the following limits described in Below Table:

Table 2: Values of Earth Resistance.

S. No.	Name of the Particular Place	Maximum Allowed Values
1.	Power Stations	0. 5-Ohms
2.	EHT Substations	1.0-Ohms
3.	33 kV Stations	2.0-Ohms
4.	Distribution transformer centers	5.0-Ohms
5.	Tower foot resistance	10.0-Ohms

V. CALCULATION OF THE FACTORS FOR EARTHING PARAMETERS

A. Preconditions for Calculations

Below are the Preconditions to needed to start the Designing Procedure:

– Site Layout.

– Site Soil Resistivity Measurement.

– Value of Maximum Earthing Fault Current entering in to Grid.

– Max. fault clearing Time taken by instruments.
– Temperature of Ambient at Site.
– Resistivity Values for the Surfaces Soil to be layered for Step and Touch Methods Only.

B. Below is the Procedure adopted to designing of Earthing

–Calculate the area of the plan for grid with the help of Sub-Station Layout
–Select the Location for the Test of Soil to measure the Resistivity as given in Figure 1.0
–Calculate the Max. Earth Fault Current Value and Fault Clearing Time required by the Sub-Station Authorities.
–Evaluate the size of Conductors for Earth mat according to Standard of IEEE-80.
–Evaluate correction factor for Determine Oxidation i.e. For Moist and Soft Soil it is taken approximately allowed limit is 20 percent and for stony area, it is taken as Zero Percent.
–Evaluate the Surface Layer Resistivity.

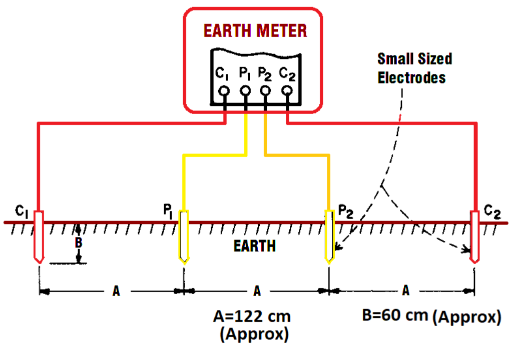

Fig. 1. Earthing Tester by Four Terminal Method.

According to the property of Soil (Resistivity), there must be the recommended order to submerged the Earthing Conductors as per the Table given below:

Table 3: Submerged Length of Earthing Conductors as per the range of its Soil Resistivity.

S.No.	Resistivity of Soil in Ohms/Mtr	Cost Effective Depth of Submerged Conductors in Mtrs
1.	50 – 100	0. 5
2.	100 – 400	1. 0
3.	400 – 1000	1. 5

To keep the Earthing Resistance as minimum as possible, below points must be followed:
–Wrap the Joints with anti-oxidation Layers.
–The joints fasten tightly.
–Dispense Enough Water in Earthing Electrodes.
–Electrode must be connected in Parallel.
–Earth Colliery required being wider Breadth-Depth.
MATLAB Programming for Absolute Potential Calculation by using FDM:

```
 v1=2208.0;
v2=0.0; v3=0.0; v4=2208.0; ni =200;
nx=25; ny=10;
v=zeros(nx, ny); for i=2:nx-1
v(i,1)=v1;
v(i,ny)=v3; end
for j=2:ny-1 v(1,j)=v4;
v(nx,j)=v2; end
v(1,1)=0.5*(v1+v4);
v(nx,1)=0.5*(v1+v2);
v(1,ny)=0.5*(v3+v4);
v(nx,ny)=0.5*(v2+v3); for k=1:ni
fori=2:nx-1 for j=2:ny-1
v(i,j)=0.25*(v(i+1,j)+v(i-1,j)+v(i,j+1)+v(1+j-1)); end
endend
diaryFDM.out
[v(1,1), v(6,2), v(12,4), v(24,9)] [ [1:nx, 1:ny] v(i,j) ] diary off
OUTPUT
ans =
1.0e+003 * [2.1980 2.1971 2.1693 0.7891]
```

VI. RESULTS

Following figures shows the different constant values of Inputs, are referred for design and their calculation, Outputs results of Grid Design and Fabrication The Input Constant values referred for design calculations & Output results of grid Structure shown in Graphs and Tables.

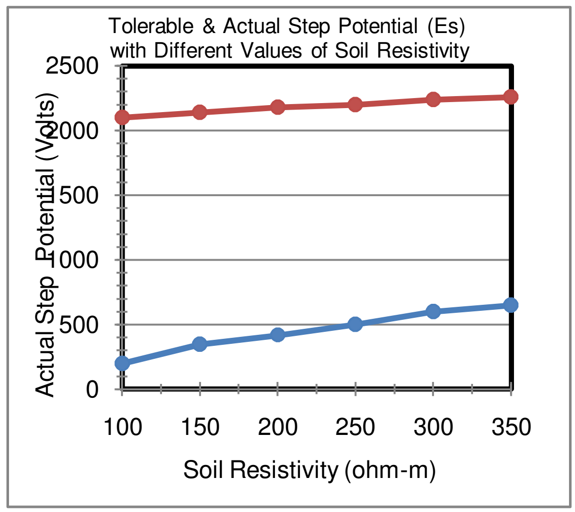

Fig. 2. Values of Acceptable & Actual Step-Potential with different values of Resistivity of Soil.

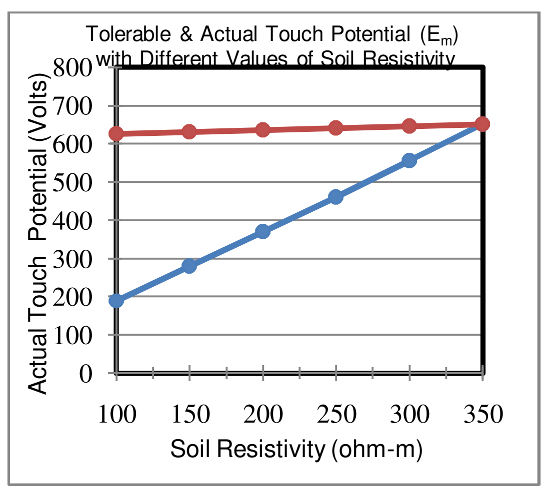

Fig. 3. Values of Acceptable & Actual Step-Potential with different values of Resistivity of Soil.

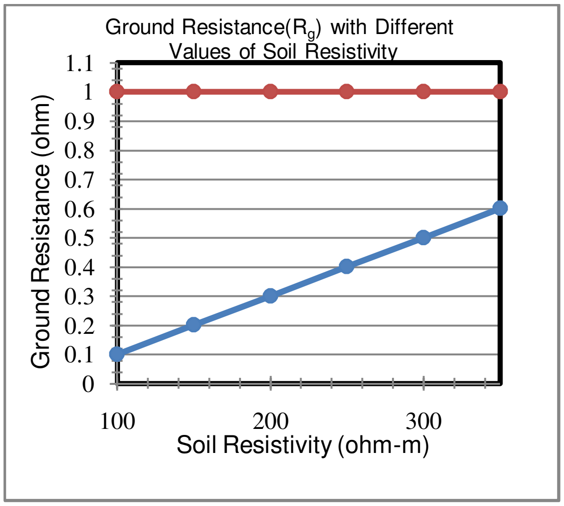

Fig. 4. Values of Earth Resistances according to various values of Resistivity of Soil.

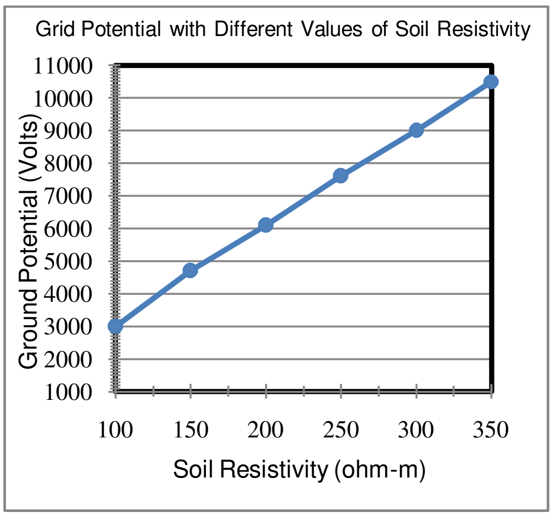

Fig. 5. Values of Earth Potential Increment according to different values of Resistivity of Soil.

Description of Figures: As per the figures Red Color shows allowable values and Blue Color is for real calculated values.
Methodology and Flow Chart for Designing of Earthing Calculations.

VII. CONCLUSION

In this manuscript, the emphasis is actually based on Scope of improvement in Earthing System for 400 kV AC Substation at a Village in Ghaziabad, India through its design, analysis and load flow aspects. Results are obtained with the help of MATLAB-16 software programming.
Apart from this for Earthing of Sub-Stations for the conductors and Earthing Electrodes Mild-Steel has been taken for reference. A Step-by-Step Methodology is offered for the designing of Sub-Stations Earthing Systems. It has been also discussed that if the Voltages are High for Sub-Station Designing, Step-Touch Voltages are to be considered during calculations.

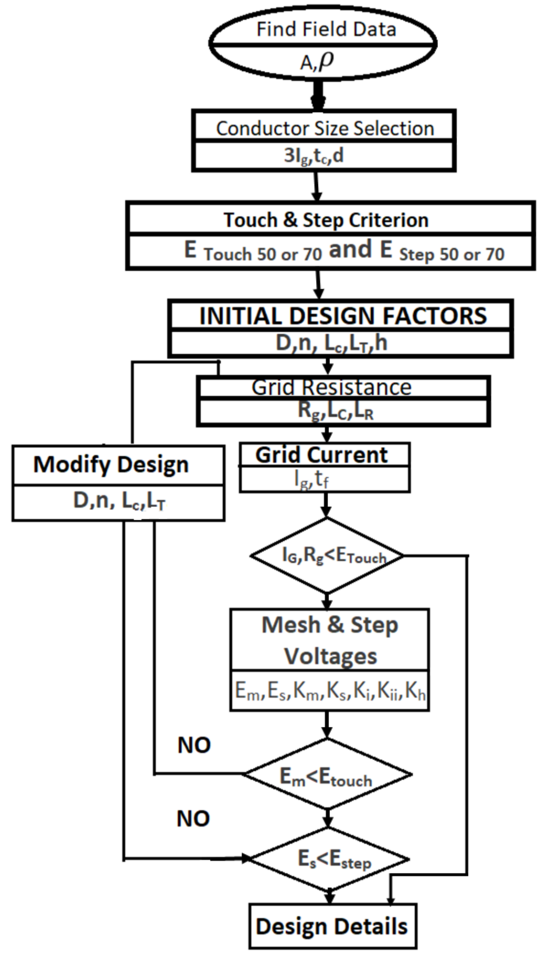

Fig. 6. Flow Chart Diagram Showing Steps of Designing and Selection of Various Parameters.

Including of which there must be an arrangement to transfer or balance the GPR i.e. Ground Potential Rise under Faulty Situations, as it is dangerous for the working people at Sub-Stations.

VIII. FUTURE SCOPE

The future scope of this work is to provide the guidelines to calculate exaxct values and to find out the trend of the eartings, conductor size selection and other initial design factors before the installation of the Earthing System.

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