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A MATLAB Software Based Designing of an Substation Grounding System

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Abstract: A substation grounding system is an essential part of the overall electrical power system. This grounding system includes all of the interconnected grounding facilities in the substation area, including the ground grid, overhead ground wires, neutral conductors, underground cables, foundations, and deep well. There are many parameters that affect on the voltages in and around the whole substation area. Hence to provide a safe and secure condition for personnel within and around the substation area, the grounding system design limits the potential difference a person can come in contact with it to the safe values. Therefore the substation grounding system design should limit the electric current flow through the body of the person working there to a value the fibrillation current. Some essential components of the substation grounding system like overhead ground wires, neutral conductors, and directly buried pipes and cables conduct a portion of the ground fault current away from the substation ground grid and need to be considered when determining the maximum grid current. This paper work presents the overall behaviour study of a simulated grounding system using Simulink/Matlab.

Index Terms: Etouch, Estep, Soil resistivity, Grid, Inverter Suppression Coil, Simulink, Simulation, MATLAB

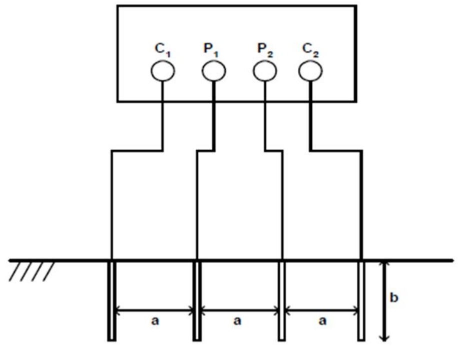
I. INTRODUCTION

The substation plays an very important role in generation, transmission, and distribution parts of the power system. We can also say that the substation is the heart of the power system as many of important or the basic most functions are carried out by the substation of the power system. Hence the protection of such important most part of the power system is the first priority. So for the protection of substation from lightning, thunder and sudden severe faults there should be the proper grounding of the substation should be done. Most important functions of grounding system of substation include ensuring the safe and reliable operation of power system, and ensuring human safety in case of grounding fault in power system. Hence safety of power apparatus in substation can be reached by decreasing grounding resistance and grounding potential rise of substation; whereas the safety of people must be reached by equalizing the potential distribution of the ground surface and reducing step and touch voltages. So, it is necessary to know that how to equalize the potential distribution of the ground surface above the grounding system, which is the key to ensure the safety of grounding system for substation. Weimin SUN Jinliang HE, Yanqing GAO, Rong ZENG , Weihan WU Qi SU, "Optimal Design Analysis of Grounding Grids for Substations Built in Non uniform Soil"[4]. The grounding system comprises of all of the interconnected grounding facilities in the substation area including ground grid, overhead ground wires, neutral conductors underground cables etc. ground grid being the main component. Where the ground grid consists of horizontal interconnected conductors often supplemented by vertical ground rods. The overall grounding components of the grounding system, design of grounding grid should be such that total grounding system is safe and at the same time it is cost effective. . Kaustubh A. Vyas, and J.G. Jamnani "Optimal Design and Development of Software for Design of Substation Grounding System"[5]. Grounding system allows controller harmonics and drain to earth the fault currents. H. M. Khodr, Member, IEEE, G. A. Salloum, and Vladimiro Miranda, Fellow, IEEE "Grounding System Design in Electrical Substation: An Optimization Approach"[3].

II. MATHEMATICAL DESIGN OF SUBSTATION GROUNDING SYSTEM DESIGN

A. Wenner Method

The practical method to measure the average resistivity of large volumes of undisturbed earth is the four-point method. The four Small electrodes are buried deep hole in four holes in the soil, all at deep *b* and spaced (in straight line) at intervals *a*. Test current *I* is passed between the two outer electrodes and the potential *V* is measured between the two inner electrodes with the help of potentiometer or a high impedance voltmeter. Where these *V/I* gives the resistance *R* in ohms . Figure below shows the mentioned method[1].



The soil resistivity can be measured by using following expression (1)

$$\rho = k.R$$

Where *k* is:

$$K= \frac{4\pi a}{1\pm\frac{2a}{\sqrt{a^2+4b}}-\frac{a}{\sqrt{a^2+b^2}}}$$

Where:
ρ - Soil resistivity (Ωm)
a - Distance between the probes (m)
b - Deep of the probe (m)
k - Characteristic impedance of the resonant circuit. A.B.M. Aguiar, R.B. Godoy, G. S. Pires, L. F. Abe, R. A. Capitanio and J.O.P. Pinto "Modeling And Simulation Of A Grounding System Using Simulink"[1]

B. Touch Voltage and step Voltage

The safety Criteria for Substation Grounding Design is given in following equation:

$$E_{step\ 50} = \left(1000 + 6\rho_{s.C_s}\right).\frac{0.116}{\sqrt{t_s}} \quad ....(1)$$

$$E_{step\ 70} = \left(1000 + 6\rho_{s.C_s}\right).\frac{0.157}{\sqrt{t_s}} \quad ....(2)$$

$$E_{touch\ 50} = \left(1000 + 6\rho_{s.C_s}\right).\frac{0.116}{\sqrt{t_s}} \quad ....(3)$$

$$E_{touch\ 70} = \left(1000 + 6\rho_{s.C_s}\right).\frac{0.157}{\sqrt{t_s}} \quad ....(4)$$

Where
Estep_50 and Estep_70 are tolerable step voltages for person weighing 50 Kg and 70 Kg respectively
Etouch_50 and Etouch_70 are tolerable touch voltages for person weighing 50 Kg and 70 Kg respectively. Kaustubh A. Vyas, J. G. Jamnani "Optimized Design of Substation Grounding System Using Newly Developed IEEE Compliant Software"[2]

C. Compression Ration

When the grounding conductors are arranged according to an exponent regularity, then the n-th conductor span is determined from the below equation:

$$d_n = d_{max}C^n$$

here,
C = compression ratio. If the grounding system is L, and ***N*** conductors then the central conductor span is[4]

$$d_{max} = \frac{L\,(1-C)}{1+C-2C^{\frac{(N-1)}{2}}} \qquad \text{is even}$$

$$d_{max} = \frac{L\,(1-C)}{2\left(1-C^{\frac{(N-1)}{2}}\right)} \qquad \text{N Is Odd}$$

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D. System Modelling

The rod resistance, the rod capacitance and the rod inductance can be calculated by (1), (2) and (3), respectively:

$$R = \frac{1}{2\pi\sigma z}\left[In\left(\frac{2z}{r}\right)\right] \text{ OHM} \qquad (1)$$

$$C = \frac{2\pi\varepsilon z}{In(\frac{2z}{r})} \; F \qquad (2)$$

$$L = \frac{\mu z}{2\pi}\left[In\left(\frac{2z}{r}\right)\right]H \qquad (3)$$

Where:

R - Rod resistance (Ω)
C - Rod capacitance (F)
L - Rod inductance (H)
σ- Soil conductivity (S/m)
μ□- Soil magnetic permittivity constant (H/m)
ε- Soil dielectric permittivity (F/m)
r - Rod radius (m)
z - Rod length (m)

$$Z^{*}_{soil} = \left[\frac{1}{R_{soil}} + jwC_{soil}\right]^{-1} \Omega$$

$$R_{soil} = \alpha \cdot \rho_{soil}$$

$$C_{soil} = \beta \cdot \varepsilon_0 \cdot k'_{soil}$$

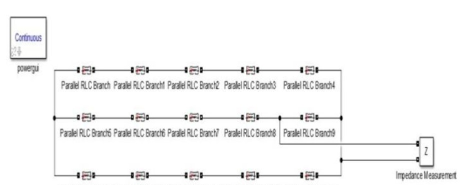
Where:

α - Resistance factor
β - Capacitance factor
ε0 - Vacuum permittivity (ε0=8.85*10-12 F/m)
k'soil - Soil permittivity
Soil permittivity – ability to hold the electric charge[1].

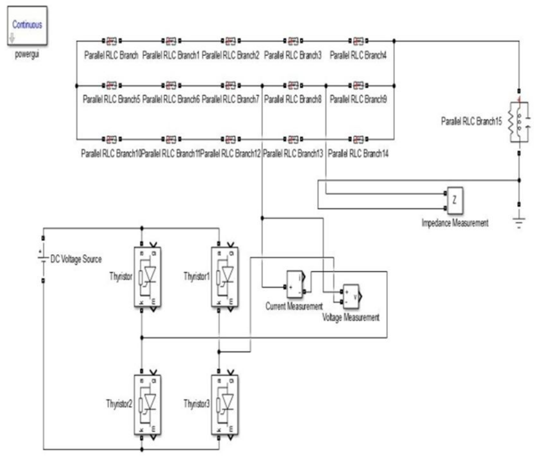
III. MATLAB SIMULATION MODEL

Equivalent grid design gives a detailed information about the actual optimized grid. Each branch is consist of an RLC parameters with the certain values of R, L, C. As shown in figures[1]

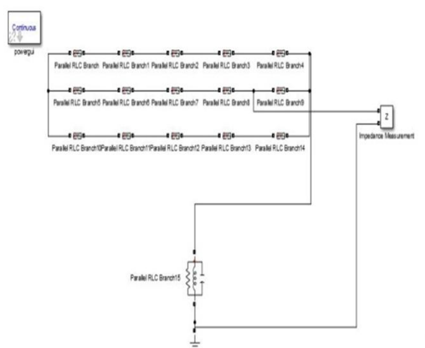
A. Grid Design



B. Grid With Inverter



C. Grid With Suppression Coil



From above configuration model of the grid is clear that what kind of changes are taken place in the simple grid design or we can say that it is the need of the todays updated world where time is matter of all at last. So much more upgradation had taken place in the simple grid like adding of the filters like suppression coil and inverter which cause fault current which already in the very large amount that flow through the system during the faulty condition this filter will avoid or compensate such current by diverting to the earth and provide the protection to the whole entire substation system .

IV. SIMULATION RESULT

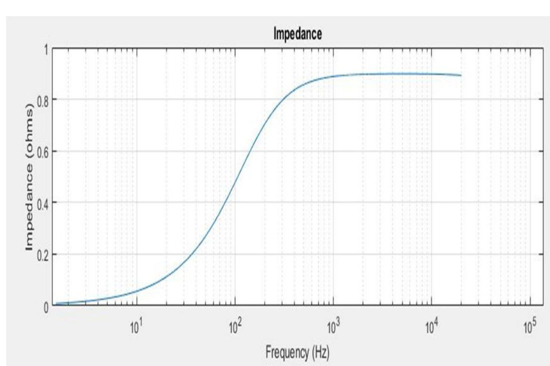


Fig.4.1Grid Impedance Vs Frequency Curve

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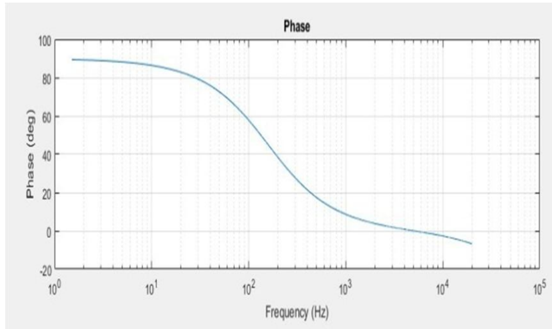

Fig.4.2Grid Phase Vs Frequency Curve

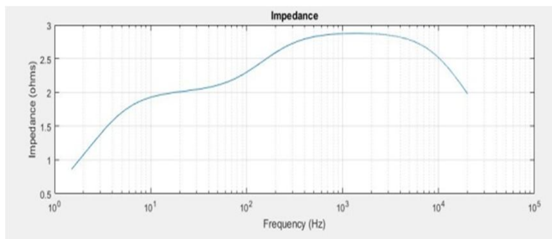

Fig.4.3 Grid (with inveter)Impedance Vs Frequency Curve

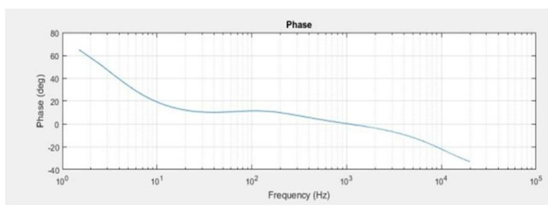

Fig.4.4 Grid(with inverter) PhaseVs Frequency Curve

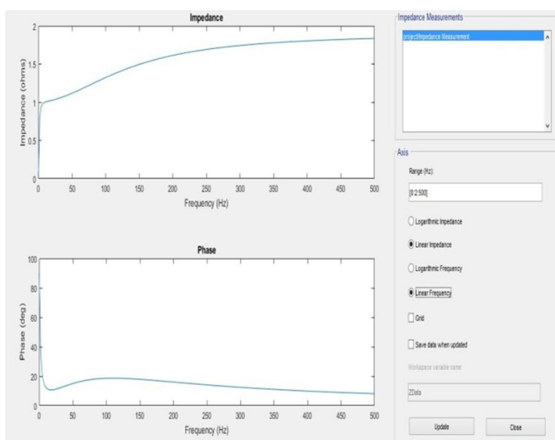

Fig.4.5 Grid (with suppression coil) Impedance and phase Vs Frequency Curve

V. CONCLUSION

From above we came to an conclusion that Engineering design of grounding grid in substations is an iterative process that facilitated if the design systems is attended by computer , which allows human to detect the best technical-economic results. With much we come to know that the grounding grid effects on the soil model are small whereas only with the soil, and the soil resistance shows a non linearity behaviour. Hence the switching frequency limit is depending on the type of semiconductor that are used in inverter and this we can see in inverter based design of the grid.

VI. ACKNOWLEDGEMENT

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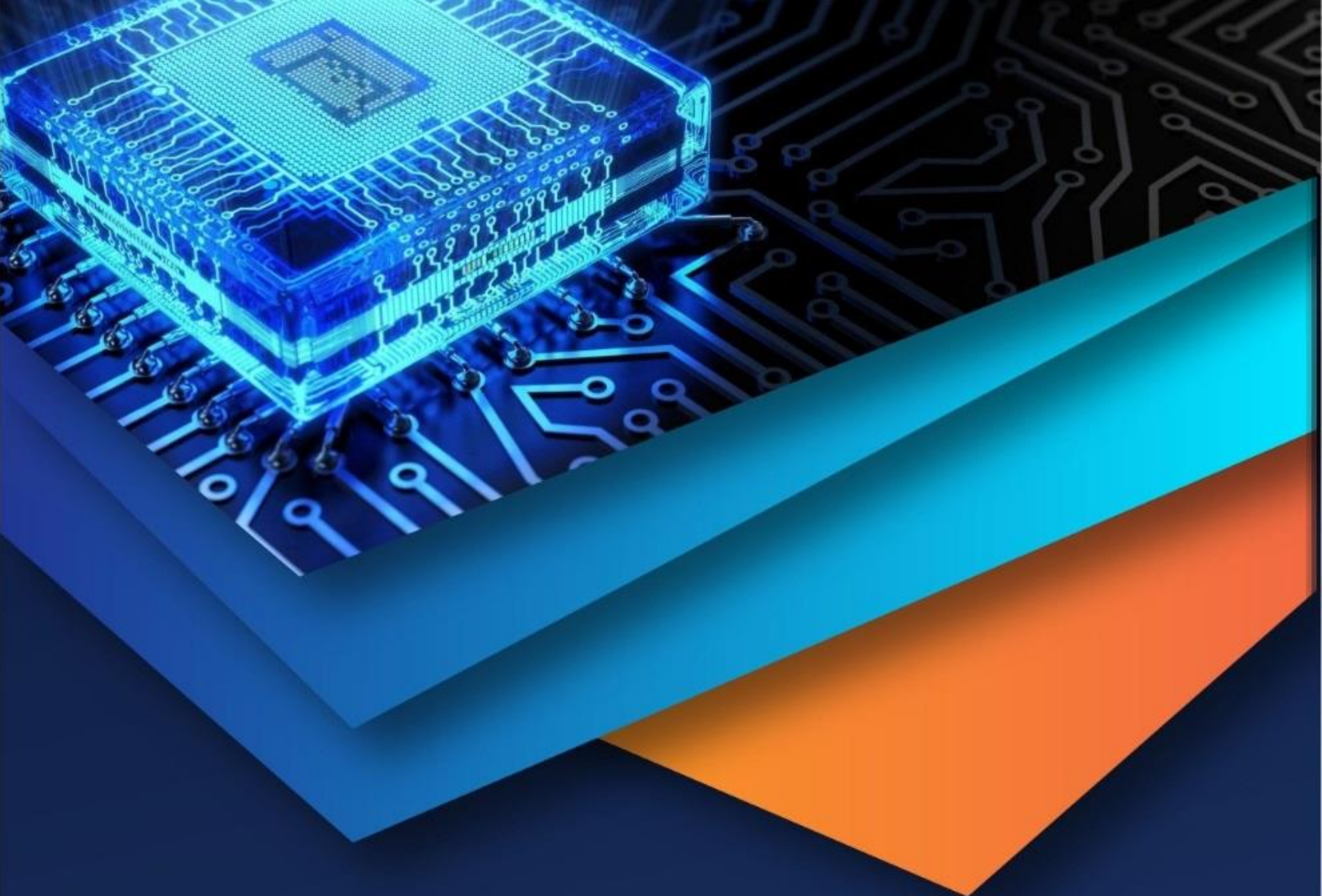

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