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A Comparative Study on Substation Grounding System by using Different Tools

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Abstract: ***Engineers view grounding mainly as a method to protect equipment from damage or malfunction. Hence, the most important element is operator safety. Proper grounding is a basic protection against AC line disturbances. This applies whether the source of the disturbance is lightning, power-system switching activities, or faults in the distribution network. It is also a key element in preventing radio frequency interference in transmission or computer equipment. Moreover, power quality can be significantly degraded due to improper grounding. Implementing an effective ground network is not an easy task. It requires planning, quality components, and skilled installers. It is not inexpensive. However, proper earthing is an investment that will pay dividends for the life of the facility.***
Index Terms: MATLAB, E-TAP, OCR, EGS, FDM, OGGD

I. INTRODUCTION

From generating station to the end consumers, through extensive transmission and distribution network, electrical power passes through number of different kind of substations. Hence substations can be called as heart of the entire power system because integrity of operation of complete power system depends to a considerable extent on reliable operation of substations. In any safe and reliable substation a well designed grounding system plays a crucial role. Kaustubh A. Vyas, and J.G. Jamnani "Optimal Design and Development of Software for Design of Substation Grounding System" [6].Absence of safe and effective grounding system can result in mal-operation or non-operation of control and protective devices thereby disturbing operation of complete power system. Hence great care should be taken while designing grounding system of any substation, primarily to ensure electrical safety of persons working within or near substations. Kaustubh A. Vyas, , J. G. Jamnani "Optimized Design of Substation Grounding System Using Newly Developed IEEE Compliant Software"[1]. In substation grounding system is essential not only for providing the protection for people working in the vicinity of earthed facilities and equipment against danger of electric shock but also maintain proper function of electrical system. Reliability and security are to be taken in consideration as well as adherence to statutory obligations (IEEE and Indian standards on electrical safety and environmental aspects). Deep B. Desai, "Design and Analysis of Ground Grid System For Substation using E-TAP Software and FDM code in MATLAB"[4]. Grounding systems are one of the most important elements of the power transmission and distribution system. The main purpose of grounding grids of power system substations is to maintain reliable operation and to provide protection for personnel and apparatus during fault conditions. 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"[3]. Optimal design of grounding systems for substations can ensure to equalize the potential distribution of the ground surface above the grounding system. Weimin SUN Jinliang HE, Yanqing GAO, Rong ZENG , Weihan WU Qi SU, "Optimal Design Analysis of Grounding Grids for Substations Built in Nonuniform Soil"[5]

II. BACKGROUND FOR SUBSTATION GROUNDING SYSTEM DESIGN

A. Safety Criteria for Substation Grounding Design

A reliable grounding system should be able to maintain the actual mesh and step voltages within a substation well below the tolerable level. Low step voltage, Low touch voltage and, Low earth resistance .IEEE guide for safety in AC substation grounding, IEEE standard 80, 2000 [3] These tolerable safety criteria have been established based on fibrillation discharge limit of body current. In order to make grounding system safe, equivalent grounding system impedance should be low enough to assure that fault current dissipates mainly through grounding grid into earth. While designing grounding system, main consideration is to be given that under any circumstances actual mesh and step voltages
must not exceed the tolerable values given by following equations[1].

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

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

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

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

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.

B. Determining Compression Ratio

The optimal design of grounding systems for substations is to appropriately arrange the grounding conductors of grounding systems to equalize the leakage current distribution and the potential of ground surface, this would ensure to make all grounding conductors use well and to decrease step and touch voltages. The grounding conductor arrangement with exponent regularity that the conductor span increases gradually from the center to the side of the grounding grid is obviously reasonable, this arrangement not only decreases potential gradient of the ground surface, but also it is called as a safe and economic design method. The main problem is how to determine the exponent regularity. When the grounding conductors are arranged according to an exponent regularity, then the n-th conductor span from the below equation:

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

here,

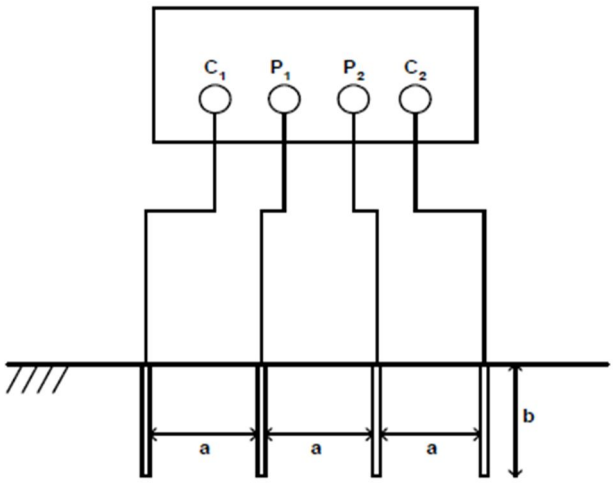
C = compression ratio. If the grounding system is L, and ***N*** conductors then the central conductor span is[5]

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

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

C. Wenner Method

The most accurate practical method to measure the average resistivity of large volumes of undisturbed earth is the four-point method. These four Small electrodes are buried 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. Hence *V/I* gives the resistance *R* in ohms . Figure below shows the mentioned method[3].



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[3].

III. DESIGN AND IMPLEMENTATION OF SUBSTATION GROUNDING SYSTEM

A. MATLAB GUIDE

MATLAB GUI Development Environment (GUIDE) allows creation of GUI so that the code written in script files becomes more user-friendly. With the help of MATLAB GUIDE standalone applications can be developed for professional or educational or training purpose. The software named „Economical Substation Grounding System Designer" (ESGSD) has been developed using MATLAB GUIDE. It implements theoretical concepts given in the software form. It is preliminary developed in order to assist the engineers in the design of substation grounding system. More details about the detailed procedure for grounding system design as per IEEE standard guide lines can be found. This is for the first time that such stand alone application for grounding system design is developed using MATLAB GUIDE. This found the applicability of MATLAB for the purpose of GUI development that helps programmers familiar with MATLAB coding in terms of application deployment. ESGSD is found to be quite useful for electrical engineers for gaining basic knowledge about grounding system design. Also this can be used for educational purpose for students of electrical engineering studying subjects of power system design[1].

B. ESGSD

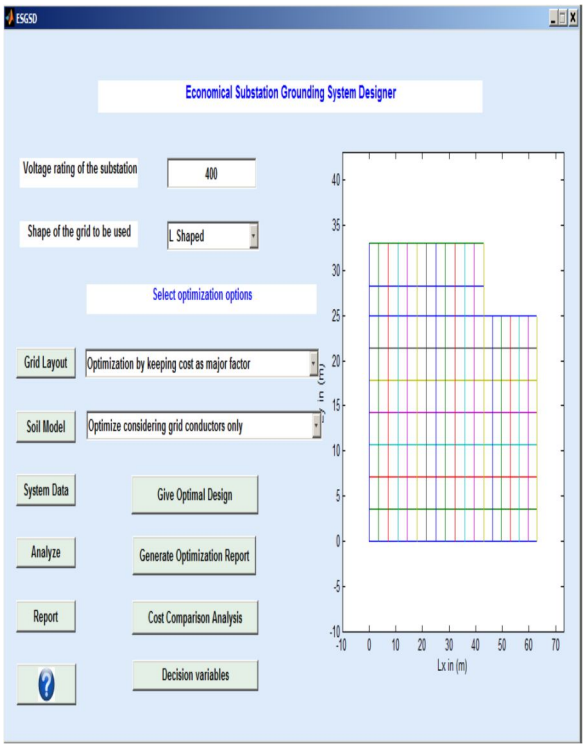


Fig 3.1 ESGSD Window

With little knowledge of software engineering a person can use this MATLAB compiler add on facilitates standalone application deployment easily.

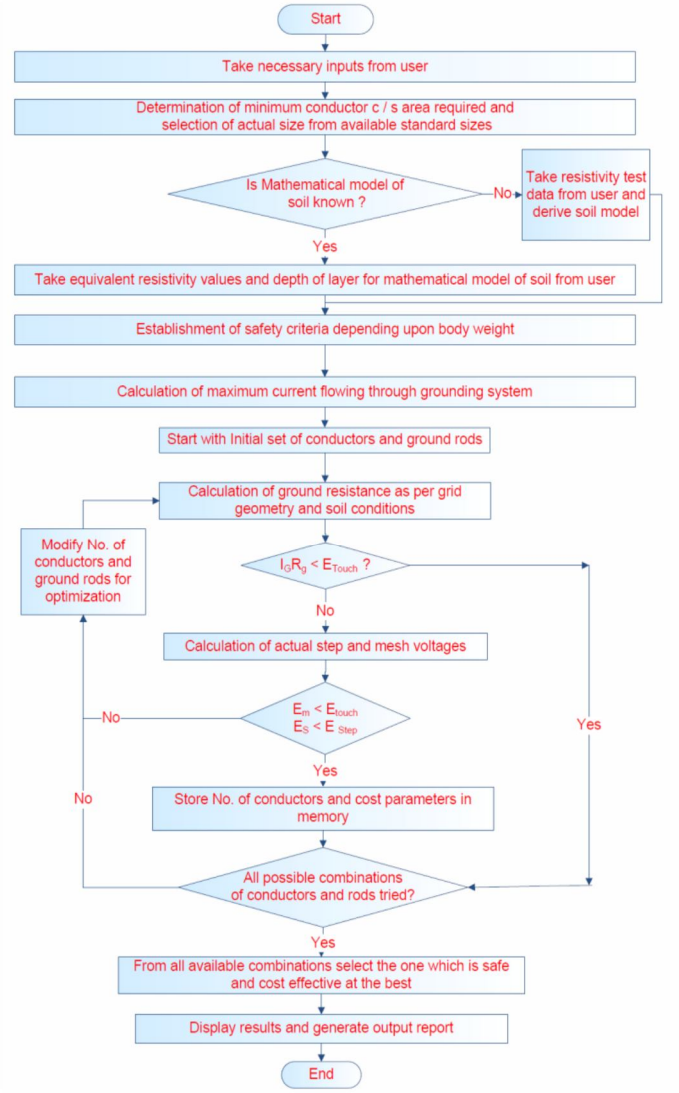


Fig 3.2 Flowchart showing ESGSD Software Algorithm

Hence in order to develop such applications using MATLAB other things are very much important. Main consideration while deploying any GUI as standalone application using MATLAB is that all data transfer between various GUIs should be implicit i.e. data transfer mechanism should be such that it facilitates smooth data transfer between all the GUIs which are packed in a project file to generate executable application.

Certain instances are observed when an application runs properly in MATLAB but fails when deployed as standalone application which has to work with MATLAB run time compiler. Here all such possibilities are avoided by sharing mechanism.

Data to be shared within GUI or among GUIs is set as application data with the help of *'setappdata'*

Handle of the GUI from which data is to be taken is passed to the GUI to which the data is to be sent

Application data is retrieved using appropriate graphic handle and *'getappdata'*

Occasionally important data is passed to the function where the data is retrieved from that function's *'varargin* in opening function of the called GUI. After calculations the results can be passed back to calling function with the help of 'varargout' option available in output function of the GUI. Because of this mechanism the application becomes standalone in a true sense i.e., it works satisfactorily even when MATLAB is not available [1].

C. Simulink Model

The soil and the grounding system were simulated using. the library *SimPowerSystem* of the Simulink software of MATLAB. The analysis of grounding systems is rather complex.A great simplification can be achieved if the problem is partitioned into subproblems.

To build a physical configuration two features must be examined:

1) Soil embedded structures of conductive media (conductors, pipes, etc);

2) The electric power system network (transmission line, transformers, etc) [3].

The number of parameters required to represent a model of the structure is usually great thus it is difficult to choose initial values to these parameters and have a computer algorithm converge to an acceptable solution within a practical time frame. Hence, the selection of initial values becomes a fundamental task in the interpretation process [3]. The simulation was based on a grounding system which will be executed in laboratory. The grounding system has 28 rods, disposed 24 m x 12 m, spaced 4 m and linked by a cable of 50 mm2 on the perimeter and 35 mm2 on the others connections. The grounding system is show in Figure 3.3.

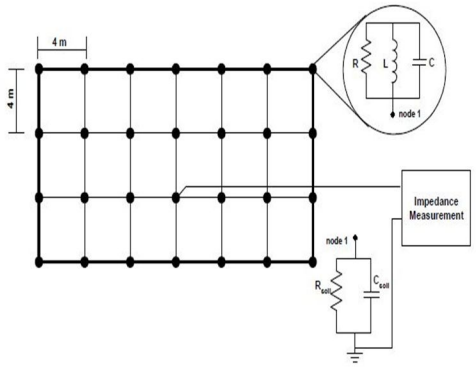


Fig 3.3Equivalent Diagram

The grounding grid simulation was performed in two cases:

a) Case A - only the impedance was measured as function of the frequency variation using a block of SimPowerSystem.

b) Case B - an inverter was added to the circuit and the impedance was measured with a variable frequency [3].

D. Optimal Ground Grid Designer

Fig 3.4 Optimal Ground Grid Designer

Software named ―Optimal Ground Grid Designer has been developed using MATLAB GUI which uses theoretical concepts given in *IEEE standar80 – 2000, 'IEEE Guide for Safety in AC substation Grounding'* for designing grounding system for any substation. This program is able to design grounding system for any substation as per methodology of IEEE guide. In sumation of being able to calculate various parameters of the grounding system for analyzing its performance, this software is also able to suggest the most appropriate safe, effective and optimal design of grounding system for the selected grid shape and given necessary data regarding soil and system parameters. Graphical user interface developed with the help of MATLAB GUI makes it quite user friendly and easy to work with. Optimal Ground Grid Designer program calculates required conductor size and automatically chooses the most appropriate standard conductor size available in the market manual entry is also possible. A list of commonly used conductor materials is provided and program automatically takes the standard values of material constants for the selected conductor material. This software is able to give ground grid design for all the basic shapes of grid and also triangular shaped grid.
It gives well formatted output in Microsoft Word file. Results obtained here are found to be quite matching with those obtained from „Ground Grid Systems‟ module of ETAP – a professional software used for solving problems related to power system by many utilities[6].

E. E-TAP SOFTWARE.

1) Earth mat & earth electrode location shown are indicative. Only minor modification if any may be carried out at site. Wherever earthing conductor infringes with cable trench it shall be land at 300mm below the trench.Main grid conductor shall lad at minimum 600mm
2) Minimum distance of 6000mm shall be maintained between any two adjacent earth electrodes.
3) Wherever earthing grid infringes with foundation, grid conductor shall be diverted suitable at site.
4) Every equipment/structure shall be connected to grid by two distinct earth connections.
5) Every alternate fence post shall be earthed with 25x3mm galvanized iron flat.
6) Gate shall be earthed with 25x3mm galvanized iron flat.8 [4].

IV. CONCLUSION

From above comparative we can conclude that healthy supply of power means the healthy working of substation, and this leads only due to the proper grounding system of the substation. Hence the effort is taken to maintain such reliability by proper practicing grounding system. Here Software for optimal design of grounding system is built by using several software like MATLAB, E-TAP, and ESGSD and so on. The main purpose of using such software is that grounding system has become more reliable for the perfect performance of the supply of continue supply of power to the user end.

V. ACKNOWLEDGEMENT

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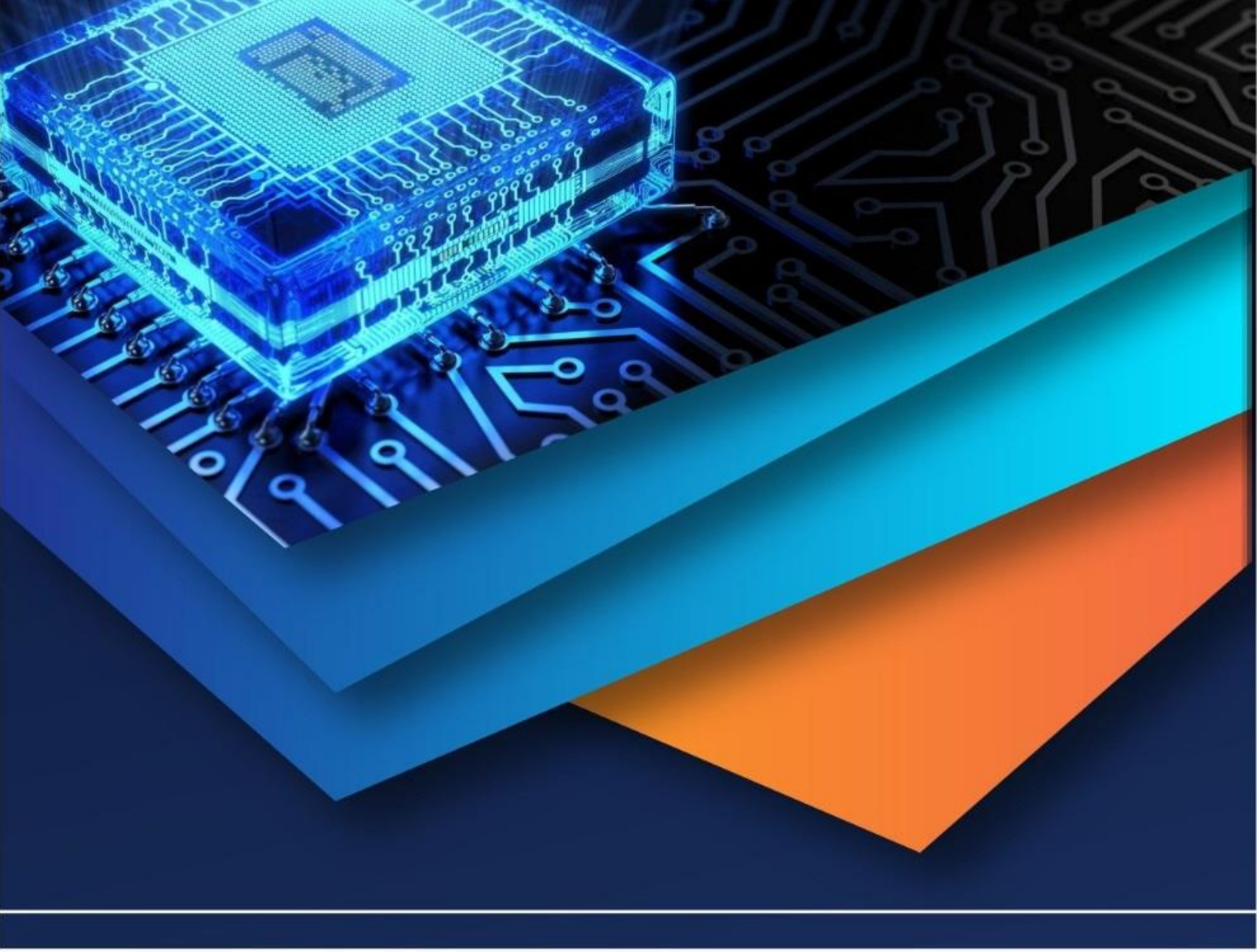

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