Unequally Spaced Grounding Grid of Substation Grounding for Enhancement of Human Safety and Cost Reduction

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Abstract—The authors offer a new approach for producing an unequally spaced substation grounding grid, in which the grid conductor spacing increases progressively from the perimeter to the centre. Formulas are used to compute the distance between conductors. It is explained how to make a grid with irregular spacing. The suggested approach can construct an unequally spaced grid that makes current density in conductors more uniform, resulting in considerable reductions in earth surface (potential) gradients. In addition, the grounding grid uses 30% less material. Numerical computations are used to determine the outcomes of field tests.

Keywords— Uneven spacing, conductors, grounding grid, potential distribution, mesh potential, contact voltage, safe and affordable design, substation design

I. INTRODUCTION

Ground fault current has increased in tandem with the power system's ever-increasing capacity. The research and design of a grounding system is critical for the reliable and safe functioning of a power substation. The goal of this study is to assure personnel safety by designing a ground grid that satisfies all safety criteria while being inexpensive. The goal of this project and study is to create an application capable of modelling and optimising regular shape (rectangular, square) ground grids under the premise of a two-layer soil model. A grid model can be created using one of two modelling approaches. One of them is IEEE standard equations, which is a method for approximation modelling. The Resistance Matrix approach and Green's function are employed in this study, the second one, for more precise modelling and computation.

Large ground fault currents will cause electrical systems to become unstable, posing a risk to people and network equipment in the meanwhile. For the sake of safety, the grounding grid design should take into account the step voltage, contact voltage, ground potential rise (GPR), and ground resistance limitations. The grounding system is an important aspect of the entire electrical system in modern substations, and its design is crucial. The grounding grid resistance must be low enough to ensure that fault currents dissipate via the grounding grid into the soil, and the ground potential increase on the earth's surface must be kept within predefined tolerances, according to the IEEE 80 standard.

The ground potential rise (GPR) and step and touch voltages of the grounding grid structure during grounding failures of electrical networks are known to impact people's safety, which is one of the key aims of grounding systems. To guarantee that the GPR is limited to acceptable levels, it is vital to construct a proper grounding grid that efficiently interfaces with the substation's metallic structure. Unevenly spaced grids were offered by some investigators and designers as a way to save around 34% of the grounding grid material. Some grounding grid characteristics, such as grounding resistance and step and touch voltages, can be estimated using simplified assumptions, while others are impossible to calculate using a simplified method and must be found through experimental procedures. The earth surface potential, contact voltage, step voltage, and grounding resistance have all been calculated using formulae presented by several researchers. Others carried out the computations using the charge simulation approach. Other researchers employ experimental models to come up with the same results.

II. LITERATURE SURVEY

Every substation must have enough grounding. A grounding system's purpose is to assure personnel and public safety, reduce the risk of transmitted potential, safeguard equipment, offer a discharge channel for lightning strikes, and provide a low-resistance path to ground. To reduce ground potential increase, an effective grounding system has a low resistance to remote earth (GPR). A grounding design must offer a method to transfer electric currents into the ground under both normal and faulted situations in order to be safe. It must also give confidence that no one in the nearby will be harmed. Because there is no straightforward relationship between the resistance of the grounding system and the maximum shock current a person may receive, a thorough study must be conducted, taking into account a variety of factors such as the position of the grounding system electrodes in the ground, soil properties, and so on. People believe that they may safely touch any grounded item, however this is not always the case. The presence of a low substation ground resistance does not imply that the substation is safe.

To solve the disadvantage of equally spaced grounding grid, [1] describes a way for designing a safe and cost-effective unequally spaced grounding grid for a 220/132 kV substation without employing ground rods in uniform soil. Grounding grid materials can be saved by creating it in an unequally spaced manner.

In [2,] a technique is presented for designing two grounding system models, determining acceptable touch voltages and permissible step voltages, and simulating both designs with CYMGrd Software, with both designs being compared to produce the best grounding system for the 275 KV Betung Substation. Both models did not surpass allowable touch voltages of 1409.58 V and permissible step voltages of 5050.1 V, with touch voltages and step voltages of 1387.97 V and 364.6 KV in the first model and touch voltages and step voltages of 1247.2 V and 112.39 V in the second model.

In [3,] the grounding model was built in COMSOL, and the impulse grounding resistances of substation grounding grid in different distributions, lengths, and quantities of vertical grounding electrode were simulated and calculated to study the influence of vertical grounding electrode on impulse grounding resistance of substation ground network. The results reveal that the lower the impact grounding resistance is the closer the vertical ground is to the lightning current injection point. With the rise in vertical grounding electrode length, the impulse grounding resistance, which has a minimum value, falls first and subsequently increases.

[4] investigates the lightning impulse behaviour of substation grounding grids using various grounding designs around the down lead, including connection points, local refining, and the placement of vertical grounding poles around down leads. Special designs surrounding down leads, such as multi-point connection, local refining, and vertical grounding poles, improved the transient behaviour of the substation grounding grid, according to the findings. Meanwhile, just increasing the number of vertical grounding poles will not greatly enhance transient behaviour.

The safety performance of the grounding grid was tested in [5] using a moment approach under a power frequency grounding fault and a substation lightning strike. The results demonstrate that while the traditional assessment standard grounding grid's grounding impedance fulfils the standards, the contact voltage under a grounding grid power frequency grounding fault and the mesh potential difference under a lightning strike do not.

The ideal design of the grounding system of a typical 500/220 kV Egypt high voltage substation is explored in [6]. The development of several M-Scripts in the Matlab software programme is used to construct the grounding system in order to obtain the best values of the necessary parameters. The Ground Grid System is used to design the substation grounding system in order to validate the acquired results. Using the Electrical Transient and Analysis Program's Module, the acquired results are confirmed (ETAP). The substation's optimal grounding system will be utilised to ensure that equipment and personnel inside the substation are exposed to the least amount of danger possible in both normal and abnormal situations.

The enhancement measures of the grounding system for reducing lightning overvoltage at the railway substation's rectifier associated equipment are explored in [7]. It is difficult to obtain total equipotential of all equipment, including rails, at railway substations. We investigated a simple improvement method to reduce the lightning overvoltage generated in the rectifier related equipment, which has a relatively weak dielectric strength, as an example of an old substation that required improving the grounding system.

Different grounding solutions for a 500/220 kV substation in Egypt are presented in [8]. The development of several M-Scripts in the Matlab software is used to construct the grounding system in order to obtain the best values of the desired parameters. The substation grounding system is constructed utilising the established Ground Grid System to validate the acquired findings. Using the Electrical Transient and Analysis Program's Module, the acquired results are confirmed (ETAP).

The goal of [9] is to create a cost-effective ground grid given a set of criteria. For cost reduction, factors such as conductor spacing, burial depth, number of ground rods, ground rod length, and grid material type are taken into account. To produce a set of solutions, one parameter is adjusted at a time while the rest of the parameters remain fixed. The technique is repeated for the other parameters, resulting in a huge number of possible solutions.

Kaustubh A. Vyas and J. G. Jamnani [10] developed software that is capable of calculating various performance parameters of grounding systems for given input data related to grid geometry, soil, and system conditions for all basic shapes of grounding grid in uniform and two layered soils using methods described in IEEE standard 80– 2000. Furthermore, within safety limitations, our programme offers an optimal and safe design of the grounding system.

III. MOTIVATION OF RESERACH

Kaustubh A. Vyas and J. G. Jamnani [10] created software capable of calculating various performance parameters of grounding systems for given input data related to grid geometry, soil, and system conditions for all basic shapes of grounding grid in uniform and two layered soils using methods described in IEEE standard 80– 2000. Furthermore, under safety constraints, our software provides an optimum and safe design of the grounding system.

IV. PROPOSED METHODOLOGY

The system's inputs include fault duration (fd), positive sequence equivalent system impedance (Z1), and zero sequence equivalent system impedance (Z0) (Z0), The current division factor (Sf), Line-to-line voltage at the worst-case failure site, Soil resistivity (s), crushed-rock resistivity (s), The thickness of crushed-rock surfacing (hs), Grid burial depth (h), Available grounding area (A), Transformer impedance (Z1 and Z0).

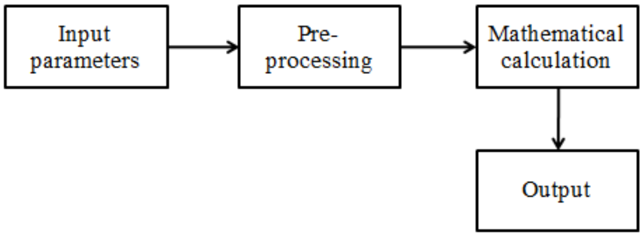

Fig 1 *block diagram of proposed system*

Data preprocessing is a data mining technique which is used to convert raw data into a usable and efficient format There may be numerous useless and missing portions in the data cleansing. Data cleansing is performed in order to handle this section. It entails dealing with missing data, noisy data, and so on. When some data is absent, it can be addressed by filling in the missing values. Noisy data is useless data that cannot be processed by machines. It can be formed as a result of inaccurate data gathering, data input problems, and so on. Data transformation is used to convert data into relevant formats for the mining process. Because data mining is a strategy for dealing with massive amounts of data. When dealing with large amounts of data, analysis becomes more difficult. We employ a data reduction approach to get rid of it. It seeks to improve storage efficiency while lowering data storage and analysis expenses.

After data pre-processing, a mathematical calculation is performed. We shall use mathematical calculations to determine if the input parameters are correct or not. The system's output is a grounding shield.

Grounding

When a structure is constructed it requires a solid foundation that connects the structure to the earth. Grounding for electrical systems and outfit serves as the foundation for the electrical system or service. Whether a structure or structure on a property is supplied by a service or by a confluent, a grounding electrode is generally always needed. The electrode provides two important electrical functions. First, where electrical outfit and systems are connected to the earth through the grounding electrode or grounding electrode system, differences of eventuality between the earth and those conductive rudiments are minimized. This connection to the grounding electrode reduces shock hazards and maintains the same eventuality during normal operation. During abnormal events, similar as ground faults and short circuits, the connection to base workshop to minimize implicit differences during the duration of the overcurrent device clearing time. The alternate important benefit of the grounding electrode at the separate structure or structure is limiting voltages assessed by lightning, line surges, or unintentional contact with advanced voltages.

Grounding electrical systems also provides benefits of stabilizing voltage to base during normal system operation. It should be noted that the grounding electrode and grounding electrode captain have little or no effect in the operation of overcurrent defensive bias. The earth or grounding doesn't give an effective fault current path. There are two important delineations one must completely understand to grasp the performance generalities and criteria for grounding and cling. Let’s take a look at these two delineations and establish the difference between the two terms.

Predicated connected to earth or to some conducting body that serves in place of the earth.

Cling (clicked) the endless joining of metallic corridor to form an electrically conductive path that ensures electrical durability and the capacity to conduct safely any current likely to be assessed.

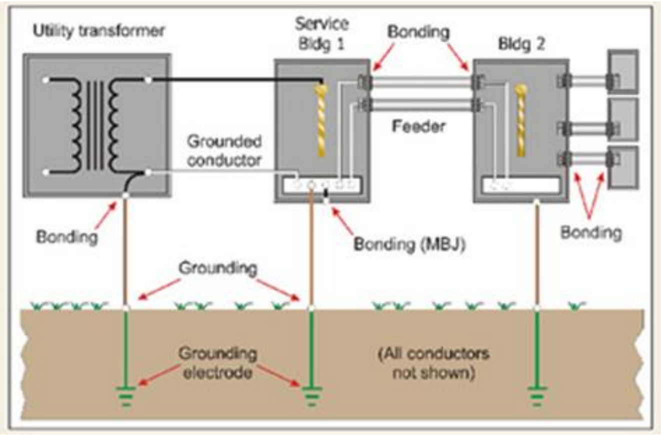

Fig.2 Grounding and bonding functions

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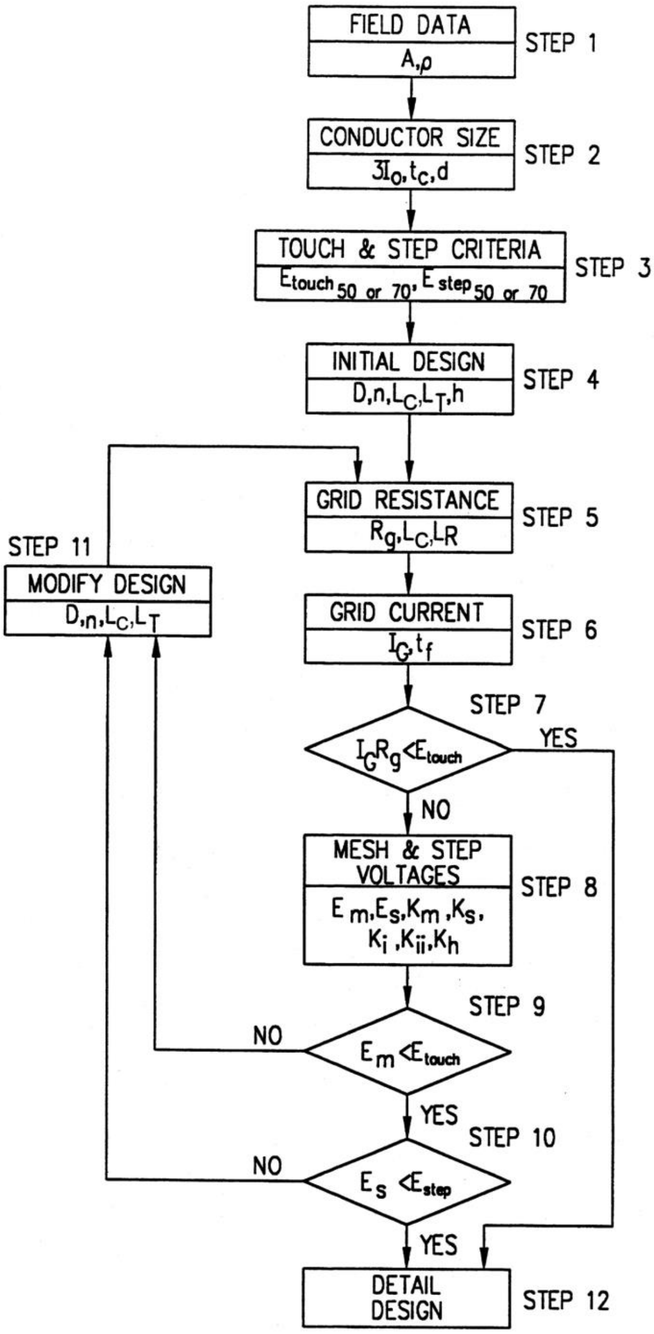
Flow Chart



IV. RESULT

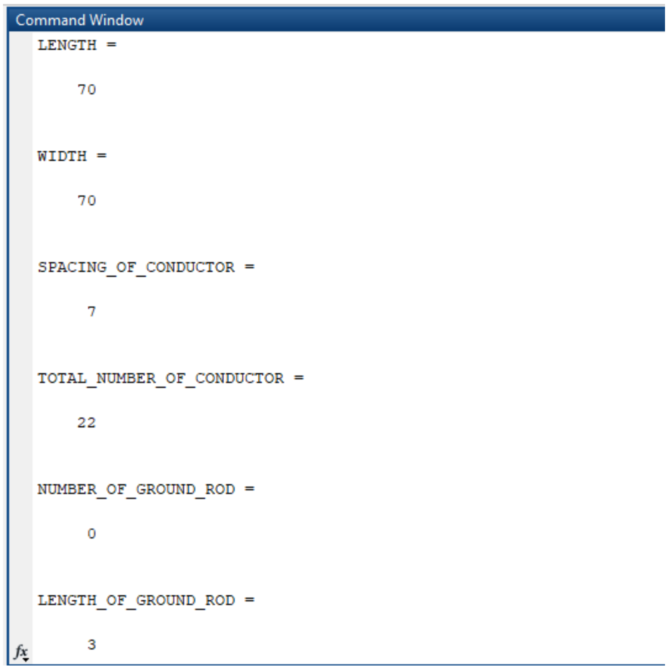


Fig. 3. Equally

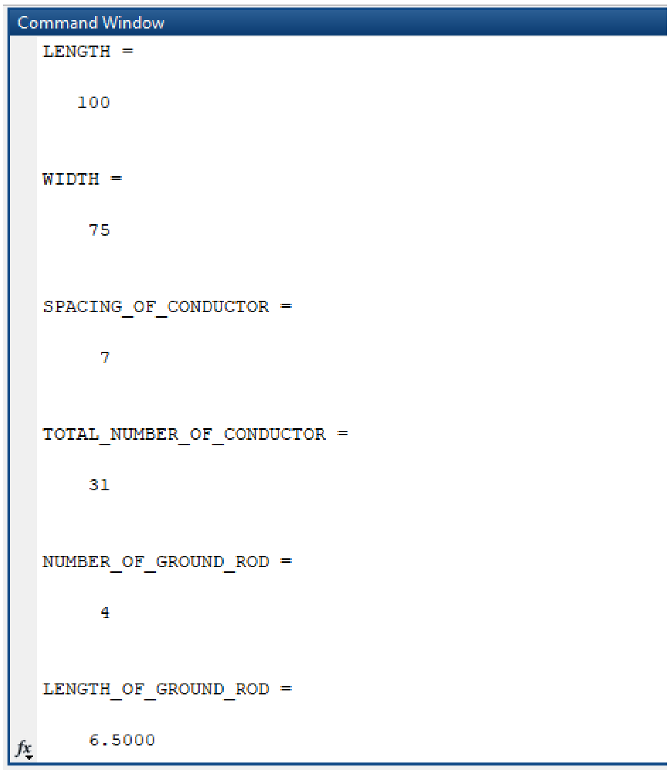


Fig.4. Unequally

Substation of 220kV is selected for the experimental purpose. Rectangular area is selected for the same. Length and width are selected to be 120m and 80m respectively. The experiment is performed on 9600 square meters.

Fault duration is selected to be 0.6 seconds while soil resistance is selected as 500 ohms. Resistance of crashed rock is selected as 3000 ohms by observing standard documents. Calculated value of Hs and Cs comes out to be 0.102 and 0.722352941.

It gives number of equally spaced conductors by using standard formula as 73.35963398

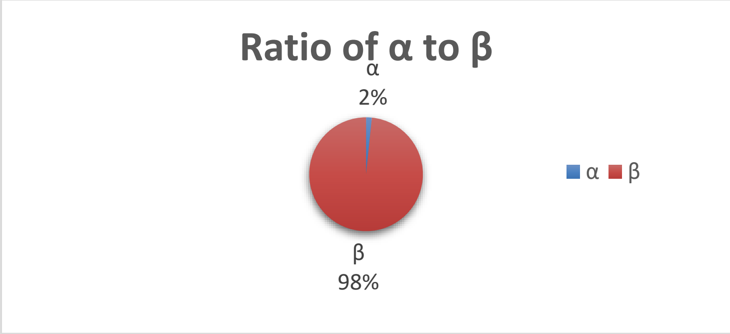


Fig. 5. Ratio of percentage of α to β

Value of α and β is evaluated to be 1.1 and 65.79195 units.

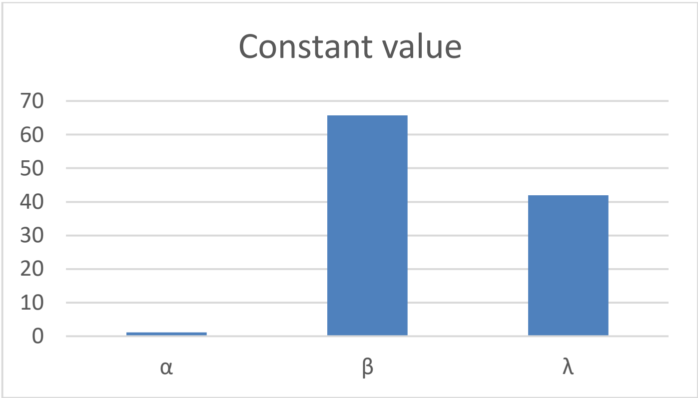


Fig. 6. Constant values of α, β and λ

Table:1 Constants with their calculated values

Constant	Value
α	1.1
β	65.79195
λ	41.98565

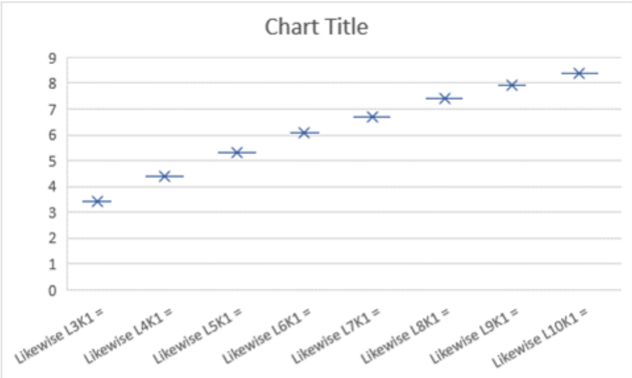


Fig. 8. Spacing between conductors increases gradually

Table:2 Constant Value best on Different Values of K

k	b,	b2	B
7	-0.312	0.369	0.287
8	-0.281	0.339	0.2SI
9	-0.237	0.322	0.2 I4
10	-0.211	0.312	0.191

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11	-0.185	0.304	0.165
12	-0.175	0.235	0,1 62
13	-0.162	0.23J	0.131
14	-0.161	0.199	0.15
15	-0.158	0.167	0.14 9
16	-0.146	0.157	0.139
17	-0.136	0.146	0.131
18	-0.132	0.133	0.127
19	-0.126	0.127	0.121
20	-0.119	0.122	0.1 l7

V. CONCLUSIONS

This document explains the equations that go into grid design. Finally, real-world data is used to generate an equation. This example was created to fulfil the requirements for a safe ground grid design. In this work, two techniques were used to produce the optimum grounding grid design options. It is necessary for the design to be both safe and dependable. There are several phases involved in creating a safe and productive grid. Calculating by hand can be time-consuming and complicated. Calculating and making changes to the design might take a long time. Substation grounding design has become easier and more precise thanks to computer programmes. Step touch voltages must be calculated and values must be maintained when designing high voltage substations. Transfer of ground potential increase during a fault state to protect the public, customers, and utility personnel.

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