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Analysis of electrical grounding design of substation and lines

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Abstract

This work analyzed the electrical grounding design of substation and lines. Substations are a crucial component of the electrical power system, so it is important to have properly designed grounding systems to protect people working nearby earthed facilities from electric shock risk, protect equipment from breakdowns, and ensure steady operation of the entire electrical system. There is frequently a concern that earth faults can produce hazardous voltage gradients in the earth at the site of the fault when energy is produced remotely and there are no other return channels for earth faults except the earth itself (called ground potential rises). In other words, someone standing close to the fault runs the risk of getting an electrical shock due to two factors: first, a potentially dangerous potential difference between the earth and any metallic objects they may be touching; and second, a potentially dangerous voltage gradient between their feet and the ground. The goal of constructing a safe grounding system is to give fault currents the simplest and shortest path without going above equipment and operating restrictions and negatively compromising service continuity. This work proposes a suitable grounding system design for alternating current (A.C.) substations based on the relevant IEEE Standards and International best practices. The study outlines the detailed calculations required to arrive at the mesh, touch, and step potential values appropriate for a good grounding system model for the A.C. Electrical substation. The suggested design provides for the safe functioning of all substation facilities, the safety of substation staff, and greater system dependability.

Keywords: Grounding; Substation; Protection; Continuity service; Fault

1 Introduction

Substations can be regarded as the hub of the overall power system. In any substation, a well-designed earthing system is essential [1]. Poor electrical installation and a weak earthing system on substations are the major causes of the electrical risks that exist there for maintenance workers and end users. To guarantee that the workers near earthed facilities are not exposed to electrical shock during fault situations, a distribution substation's earthing system has to be evaluated. Additionally, it may guarantee that currents have a low impedance path to the ground. For relaying and equipment insulation, good substation grounding is crucial, but the primary consideration for substation grounding design should be worker safety [2]. In the Nigeria supply industry today safety is one of the key factors that is gradually being ignored and constantly not practiced. Power supply authorities, as well as the government, labor employers, people, and the general public, have all expressed serious concerns about the safety of those who use electricity. Using electricity could be hazardous, this is because electricity can cause irreparable damage to life and property if not properly handles and certain safety measures are not observed. Therefore, the responsiveness and efficacy of protection schemes and safety devices, the coordination of relays, and the effectiveness of circuit breakers in substations all depend on the effectiveness of the earthing system. These factors also affect the safety, integrity, and reliability of any electrical installation, power system [3].

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Allotment skims is the largest portion of network in electrical power skim. Allotment substations, which may be the first step, may be supplied by one or more sub-transmission lines [4].

A substation for the generation, transmission, and distribution of electricity uses transformers to change voltage from high to low or the other way around. A substation may include transformers to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages. Electricity may travel at various voltage levels through many substations between the producing plant and the customer. Because of the possibility of direct lightning strokes, switching surges, etc. Grounding is necessary to safeguard people walking by, the substation's machinery, and nearby electrical workers from risks associated with or posed. An essential component of planning and building an electric power system’s subsystem, such a substation, is adequate grounding [5]. Because various soils have varied grounding resistivities, it is wise to constantly take these variances into account when constructing grounding systems. Maximum safety is ensured by a good grounding arrangement that offers a low-impedance path for fault and lightning-induced currents to flow through the earth.

Although grounding is used for a long time by field engineers, there is a common misunderstanding on the meaning of grounding. Grounding, also known as earthing, is the process of connecting equipment's exposed electrical components—which, under normal conditions, do not carry current—to one another and to the primary grounding terminal, which is then linked to an earth electrode by the earthing wire. This assertion has two misunderstandings.

The electrical power system is involved in grounding as well as equipment, and in certain situations, the two terms may refer to the same physical structure. Second, grounding and earthing are not the same thing, despite the terms being used interchangeably. Only when the physical earth is involved in the grounding process and some current returns to the source through the earth as a result of a malfunctioning component of the system can it be referred to as "earthing."

One of the most crucial components of the transmission systems and electric power distribution architecture is the grounding system. Power system substation grounding grids is primarily used to ensure dependable operation and to safeguard people and equipment from harm when there is a malfunction. The controller harmonics and drain can earth the fault currents thanks to the grounding system. In accordance with the fibrillation discharge limit, a good grounding grid design should be able to keep the touch and step voltages inside the substation within allowable ranges. Due to the non-uniformity of soil and measuring error of soil resistivity data and some other factors which cannot be considered in simulating calculations, the designed value of the grounding system impedance must be checked by the measured one after the grounding system is constructed, on the other hand, exist any variables that are in many cases established for designer. The design methods and simplified calculation can originate high construction cost, combining high construction and insecure conditions. Numerous researchers have examined the issue related to the grounding system grid construction in substations in an effort to optimize the grid design and address the fundamental technical issues. Some investigators have studied the grounding system design problem in search of the more efficient of the best behavior grounding system grid, taking into considerations bi-stratified and multi-stratified soils, induced voltage, and fault currents among others, establishing some cost benefit approaches.

Significance of the Research Work

Grounding system is one of the most important points inside the transmission systems and electric power distribution design. In order to maintain reliable operation and protect people and equipment during fault conditions, power system substation grounding grids serves a primary purpose. As a result, this work will not only contribute to the body of knowledge already existing the electrical grounding design of substation and lines, but it will also give electrical engineers an opportunity to understand the dynamic and the relevance of the need for proper grounding, in order to improve the safety of equipments.

The fact that it will act as a source of information for additional research on the issue or similar topics will also be of great use to research students.

2 Literature Review

2.1 Electrical grounding

One of the most crucial components of any electrical system is electrical grounding. Earthing or Grounding is a technique which is as old as the use of electrical power on a commercial scale [6]. The method was created in the early days of electricity when all of the systems in use were unground, which frequently resulted in dangerous situations brought on by electric shocks. Simply connecting the electrical system or equipment to the ground using a suitable conductor is what is meant by the terms "earthing" or "grounding."

A common return channel for electricity to safely discharge to the earth is provided by such a ground connection. In general, an electrical system that is correctly grounded serves two purposes: a) It reduces the risk of electrical shocks to any people who come into touch with the system. b) By giving these currents a safe route to ground, it shields the linked equipment from any potential harm caused by leakage currents, lightning, or voltage spikes. Earthing of an electrical system is achieved by inserting an electrode (plate type / rod type) into the solid mass of earth and then connecting this electrode to the earth wire coming from the electrical equipment.

In the early days of electricity distribution, direct current (DC) generators were connected at loads at the same voltage. The generation, transmission and loads had to be of the same voltage because there was no way of changing DC voltage levels. Low DC voltages were used since that was a practical voltage in incandescent lamps, which were the primary electrical loads then. The adoption of alternating current (AC) for electricity generation dramatically changed the situation. Power transformers, installed in power stations, could be used to raise the voltage from the generators, and transformers at local substations reduced it to supply loads. Increasing the voltage reduced the current in the transmission and distribution lines and hence the size of conductors and distribution losses. This made it more economical to distribute power over long distances. The distribution network is typically of two types: radial network and interconnected network. Without having a typical link to any other supply, a radial network departs from the station and travels through the network region.

Long rural lines with isolated load zones frequently look like this.

A network that is linked has several connections to additional supply points. Although these ports of connection are typically open, the operating utility can change their configuration by closing and opening switches.

These switches can be operated by a lineman or remotely from a control center. The advantage of the linked model is that, in the case of a problem or the need for maintenance, a small portion of the network may be isolated while the rest is kept operational. The producing stations and their immediate surroundings cannot use all of the produced power. Therefore, it must be distributed at suitable voltage to points and consumers. Distribution involves primary and secondary transformation of high voltage to the standard medium and low voltage by the appropriate transforming equipment. Primary Distribution System consist of high voltage (11 and 33KV) networks from primary and sub-primary substations. These substations are interconnected with high voltage transmission lines. In most cases, large industries, consumers like cement factories, refineries, breweries, flour mills, steel rolling mills and so on take the supply of at primary distribution system with associated transformers, switchgears and breakers.

Low voltage feeder networks from secondary transformers built along major thoroughfares and streets make up secondary distribution systems.

Service cables from these networks' feeder lines provide service connections to specific customers.

The several alternating current distribution systems available to home users include:

2-wire single-phase system

3-wire single-phase system

3-wire, 3-phase system

Four-wire, three-phase system

The two systems that are most frequently utilized in Nigeria are the single phase 2-wire and the three phase 4-wire systems. A mechanism for distributing alternating current has been mentioned so far. There are applications for direct current distribution, notwithstanding its infrequent use. Rotary converters are often used to convert alternating electricity to direct current. Direct current (DC) is supplied to substation bus bars and distributed locally by feeders, distributors and service lines. Usually DC is distributed by single phase 2-wire system at 230 volts and three-phase 3-wire at 460/230 volts.

2.2 Basic Principle of Grounding System

The main purpose of this project is to study the transient property of the impedance by using grounding grids. There are some factors affecting the transient performance of the grounding system. Some of them are : 1. The point where the current is injected.

- The resistivity of the soil used that are surrounding the ground areas.
- The grounding's dimensions and also the shape of the grounding.
- Ionization of the soil. Whether it is developed or it is not.
- The injected current wave shape can also affect. As a matter of fact, the impedance of grounding system in steady state is clearly lower than in a transient state. The reason this is because the soil might be dry due to highly injected current's value which can enhance the resistivity of the soil. The decrease of the effective length of ground conductor which has happened as the result from front time decrement of impulse current injection. The short period of time whereby it affects the conductors' reactance and connection's reactance. The reactance of both parameters is becoming higher which then leads the impedance of the earth also higher. The skin effect which causes the increment of earth conductor impedance. This is due to the frequency that is higher.

Understanding how grounding systems respond to transient states of current is essential to developing the effectiveness of the lightning protection system provided by the electrical installation of protective devices. The components that make up the transient impedance's impulse are determined by the potential difference in the injection current ratio. The formula for calculating impedance is:

$$z(t) = \frac{u(t)}{i(t)}$$

2.3 Grounding Methods

Alternative grounding methods can be classified into two groups as conventional methods and finite element methods. In the following sections, these methods are introduced.

3 Review of related works

Aydiner [7] investigated grounding design analysis. This thesis investigates problematic cases in AC substation grounding system design. Particularly, the grounding design for substations that are built on high resistivity soil is considered. Here, possible physical rectification schemes are introduced and compared for their effectiveness from safety and cost efficiency perspectives. For this comparison, the CYMGRD program (a finite element analysis tool for AC substation grounding) is used for detailed analysis of the various schemes. An additional computer program is developed to implement the formulations of the related AC substation standards (IEEE, IEE, and Turkish National Regulations). The output of this program is compared with the finite element analysis of the high-resistivity-soil rectification schemes to investigate the validity of the formulations in these standards.

Folarin, [8] investigated the effect of resistivity on the electrical grounding system. He found out that earthing of electrical networks and installations is important to ensure correct operation. It also serves a vital safety role - facts which are amply reinforced in legislation and codes of practice. This may arise when investigating equipment failure, unsatisfactory power quality, interference or ensuring that safe conditions are provided for staff working on electrical equipment. This paper has been done to help overcome the effect of high soil resistivity on electrical and electronics gadget and the operators of these machines relating to electrical grounding (Earthing). The work starts by digging dip into the introduction of the topic in question, the reasons for earthing, the alternative types of earthing system and the main emphasis is on practical approach to the soil resistance measurement, soil moisture content test, the analysis of the values gotten with the use of SPSS software with a standard interpretation of these value analyzed. The paper coverage areas are some mega city in Osun State. The outcome indicated that an efficient electrical grounding can be obtained with a high consideration of the depth of the excavation and earth electrode required for lightning protection, domestic electrical wiring and large industrial or power plants. The study also looked at the available methods to treat a high resistive soil, with series of recommendation to ensure effective and efficient earthing system.

According to Ramamoorty et al. [9], there are a number of significant parameters that influence the transient response in various grounding arrangements. The first element is grounding resistance, which refers to the resistance that each component of grounding systems causes. The second is inductance, which is dispersed over wide areas like grids and the antidotes to transitory behavior.

The second parameter is the ohmic resistance of the electrode, and the fourth parameter is the capacitance of the grounds.

Another study, Gupta and Thapar, [10] used analogous parameters to quantify the impulse impedance of the grounding grids, which is a very distinctive methodology. In terms of discharging and the lightning impulse, Thapar's work is incredibly distinctive and helpful for the study of grids inserted in grounding systems.

However, there are some flaws in the modeling that he established. For instance, in the process of dissipation of the current impulse, the impact of the rods which is buried in the ground is not being considered. The analysis is only based on the square type of grids whereby in actual the configuration of the grids can be different and complex. The starting current distributed in the grids is assumed obtain from the equally distributed currents in the grids itself. The computation of the resistance of the ground is carried out by considering the grids as a plate that equivalently circular and the principle of balancing energy is used to calculate the effective inductance.

4 Methodology

General physical inspection of the various substation equipment was first examined. This was done to ensure that all the substation facilities were in place and well-grounded before carrying out the respective earth resistance test. The lightening arresters were checked to ascertain their present condition. Secondly, the earth resistance of each substation in Yenagoa town was conducted using earth resistance tester and the earth resistance of the substations recorded, the average earth resistance of the substation equipment was calculated since the earthing of the substation equipment are all looped. The earth resistance, mainly implies the resistance between the electrode and the point of zero potential. Mathematically, it is equal to the ratio of the potential of the earth electrode to the current dissipated by it.

The resistance between the earth plate and the ground is measured by the potential fall method. The flow of current into the grounds depends on the resistivity of the soil wherein the earth electrode is placed. The resistivity of the soil may vary from 1 to 1000 ohm-m depending on the nature of the soil. The resistivity of the soil depends on its temperature. When the temperature is greater than 0˚C, then its effect on ground resistivity is negligible, but at 0˚C in the water in the soil starts freezing which increases their resistivity [11]. The resistance of the earth varies from layer to layer. The lower layer of soil has more moisture and lower resistivity. If the lower layer contains hard and rocky soil, then their resistivity increases with depth following NEMSA act 2015 the acceptable earth resistance value is 2.0 ohms below.

The substations (Relief) locations visited in Yenagoa town for the exercise is Ede-epie substation, OpoIo substation, Agudama substation, Swali substation, Kpansia substation, Azikoro substation, Agbura substation. The substation locations visited for point load is the transformer substation at Yenizue-gene, substation, Igbogene substation, Bosy Pure water factory substation, UBA Swali substation. Figure 1 shows the tests conducted at two of the locations in Yenagoa town on the 8th of July, 2017.

General For most substations, it is possible to design a satisfactory grounding system provided that the earth resistance is low; i.e. in the range 10-400 Ω·m. In these cases, conventional grounding techniques can be utilized to get the desired level of grounding. However, if the earth resistance is excessive, i.e. larger than 400 Ω·m, then special techniques are required to obtain the low resistance grounding. Further, if the substation is GIS type, where the area covered is smaller when compared to conventional outdoor substations, it comes out to be more difficult to have an effective and acceptable grounding resistance value. In the following sections, special methods, which would enhance the effect of conventional design techniques, are discussed and analyzed.

4.1 Current in the Grounding Systems

The utility practices given for the short circuit currents are 50kA for 380kV systems and 31.5kA for 154kV systems. These values are the ultimate short-circuit levels and the present values are very much lower. On the other hand, the grounding systems designed for these voltage levels are 35 kA at 380 kV systems and 20 kA for 154 kV systems. This is due to the fact that some of the fault current is diverted to the ground wires of the transmission lines, and therefore the current going through the substation grounding will be smaller. This reduction factor is taken to be 0.65 independent of the number of transmission lines terminating at the substation. In addition, effect of overhead lines entering the substation is omitted in the fault current division in determination of current. When a fault takes place in the vicinity of one of the grounding grids, the connections (overhead line grounding wires, cable shielding and armoring) to the other grounding grids participate in clearing the fault current. Accordingly, the first step of the design strategy is calculating the exact fault current that needs to be cleared by the high-resistivity-soil grounding grid (to satisfy the ultimate criteria on step voltage, touch voltage and GPR). This calculation is system specific and accounts for the current that is cleared by the connections to the surrounding grounding grids. The end result is a safe design for the high resistivity-soil grounding grid despite the fact that its computed fault current is less than the regulation values (recall, for these values, a design is not even possible). In the following analysis, overhead line effects on fault current that is carried through the overhead line earth wire is discussed. Then, by the help of the overhead line effect, computation of overhead-line-reduction-factor (that is a factor that represents the reduction because of the mutual impedance effect between earth wires and parallel phase conductors), current division factor (which represents part of the fault current passing through the grounding grid) and decrement factor (that accounts the effect of initial dc offset and its attenuation during the fault) will be introduced to compute the fault current that flows through the grounding grid .

The figure below shows a sample overhead line structure for an infinite number of earth wires. The equivalent impedance seen from one end of the infinite chain overhead line is called as the driving point impedance (ZP).

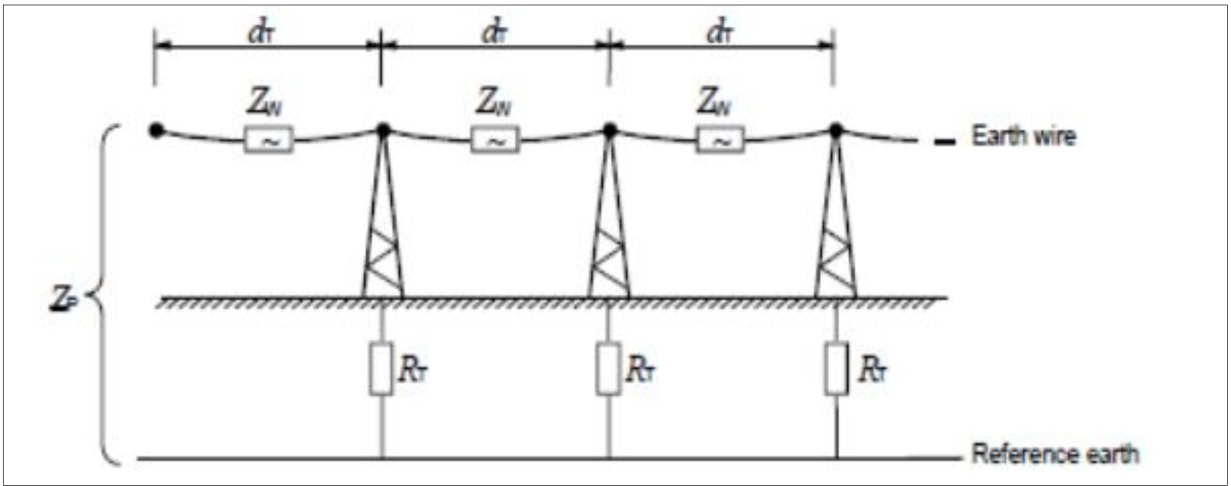

Figure 1 Overhead lines impedance model for the infinite chain case

The infinite chain formulation for ZP [18] yield

$$\underline{Z}_P = 0.5\underline{Z}_W + \sqrt{(0.5\underline{Z}_W)^2 + \underline{Z}_W R_T}$$

Where ZW is the earth wire impedance between two towers, and RT is the footing resistance of towers at a distance of dT. The validity of the infinite chain assumption is found by computing, far-from-station distance (DF). If the distance between the substation that has the fault and the nearby station connected with overhead lines is bigger than DF computed from Eq. (3-2), an infinite chain formulation can be used and vice versa.

$$D_F = 3\sqrt{R_T}\,\frac{d_T}{\mathrm{Re}\left\{\sqrt{\underline{Z}_W}\right\}}$$

According to the validity of the infinite chain assumption, if the chain of towers cannot be assumed to be infinite, the following Eq. (3) is utilized for n towers.

$$\underline{Z}_P = \frac{\underline{Z}_P(\underline{Z}_{EB}+\underline{Z}_P)\cdot \underline{k}^n + [\underline{Z}_P(\underline{Z}_{EB}-\underline{Z}_P+2\underline{Z}_W)-\underline{Z}_W(\underline{Z}_{EB}+\underline{Z}_W)]\cdot \underline{k}^{-n}}{\underline{Z}_P(\underline{Z}_{EB}+\underline{Z}_P)\cdot \underline{k}^n - (\underline{Z}_{EB}-\underline{Z}_P+\underline{Z}_W)\cdot \underline{k}^{-n}}$$

Where ZEB is the earth impedance of an outer substation that is located at the end of the overhead line.

5 Results

In this section, the effectiveness of the revised methods will be discussed and found out through numerical calculations for different system parameters. The results obtained are composed with usage of the FEM analysis, and deviations are observed. Actual problems are considered and solved in multiple ways to investigate the effectiveness of results.

5.1 One Rod Grounding

One rod grounding design methods|| that there are three different formulations of grounding with one rod. A grounding problem is considered to compare these methods with the results taken from FEM analysis.

The following data are given for the determination of ground resistance.

- Resistivity of earth is given as 5 to 10 Ω·m.
- Rod length (L) is taken between 244cm and 350cm.
- Rod radius (d) is taken between 1.9 cm and 5 cm.

According to the results given in Table 1, Method II and Method III give very close results to each other and to FEM analysis. The maximum error between them never exceeds %5 percent compared with FEM for these two methods. On the contrary, error between FEM analysis and Method I is about %10 percent. Moreover, this method is more dependant on changes of rod diameter. Increased diameter of rod affect the ground resistance hugely compared to the other two methods and FEM.

Table 1 One rod grounding solutions

P(Ω))	L (cm)	D (cm)	R (cm)	Method 1R (n)	Method 2 R (Ω)	Method 3 R (Ω)	FEM R R (Ω)
10	250	1.9	0.95	3.96	3.79	3.79	3.86
10	350	1.9	0.95	2.99	2.86	2.91	2.11
10	250	2.5	1.25	3.01	3.62	3.11	3.44
10	350	2.5	1.25	2.27	2.74	2.45	2.74
10	250	5	2.5	1.50	3.18	1.99	3.18
10	350	5	2.5	1.14	2.42	1.28	2.42
50	250	1.9	0.95	19.79	18.96	19.29	18.96
50	350	1.9	0.95	14.94	14.31	14.54	12.31
50	250	2.5	1.25	15.04	18.09	15.24	14.09
50	350	2.5	1.25	11.36	13.69	11.11	12.69
50	250	5	2.5	7.52	15.89	7.52	14.89
50	350	5	2.5	5.68	12.11	12.11	11.21

Results in Table 1, indicate that in the order of 10 Ω·m soil resistivity, it is possible to keep resistance-to-ground in the region of 1 to 5 Ω which is fair enough for low voltage system grounding. However, in AC substation grounding GPR and touch voltage levels have to be checked. For 20kA High Voltage Fault current case, it is impossible to keep touch and step potentials in their safety limitations. In Figure 1, potential distributions of one rod grounding for 20kA case are given.

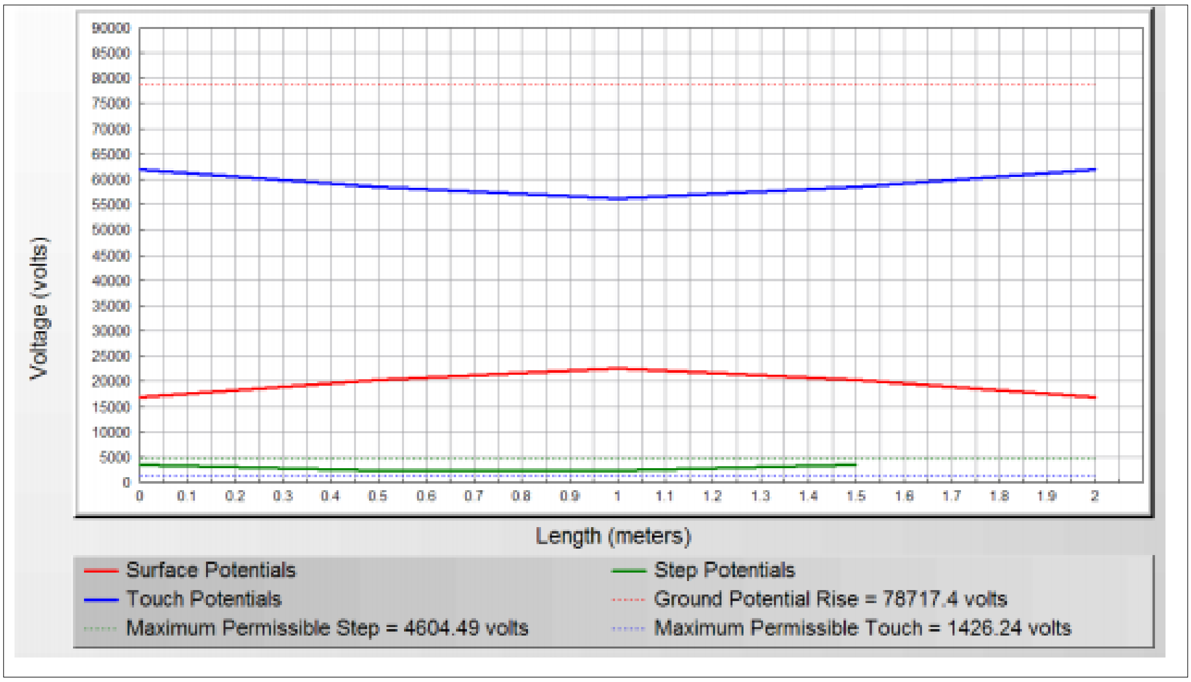

Figure 2 Potential distributions of one rod grounding

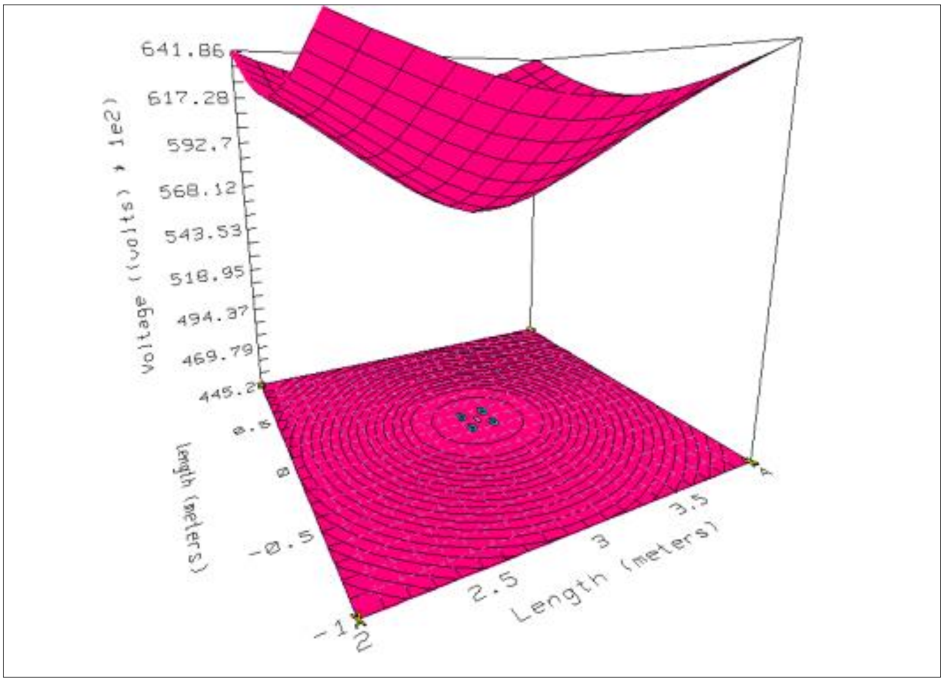

Figure 3 Touch potential for one rod grounding

Touch potential distribution of a one rod grounding system is simulated in Figure 3. In this simulation following data are used: - Fault current: 20000A - Rod Length: 2.5m - Rod buried: 0.5 meter below the ground - 50kg man weight GPR is computed from CYMRD simulation and its value is 78717 Volts. Maximum permissible touch voltage is computed and is found as 1426 Volts. As indicated in Figure 3, touch voltages are varying between 64186 Volts and 44520 Volts from 2 meters distance to the rod. GPR is enormously bigger than 20kV levels. Both GPR limitation and touch voltage criteria are unsatisfactory and are far from their maximum limits. So this kind of design is not applicable to HV and EHV AC substations. However, this kind of grounding can be used for LV systems where fault current and its duration are much smaller.

6 Discussion

In the event that the grid design fails to meet the tolerable touch voltage requirements, it is advisable to reduce the available ground fault current. Owing to the fact that this is not always practicable, however, the grid is usually modified by changing any or all of the following: grid conductor spacing, total conductor length, grid depth, addition of ground rods, etc. in order to achieve the required conditions. Earthing resistance and earth's surface potential distribution are the main parameters characterizing electrical properties of the earthing system. Electrical parameters of the earthing system depend on both soil properties and earth electrode geometry. Soil properties are characterized by earth resistivity, which changes over a wide range from a few m up to few thousand m, depending on the type of ground and its structure, as well as its humidity. As a result, it is difficult to calculate an exact value of earthing resistance. All relationships describing earthing resistance are derived with the assumption that the ground has a homogenous structure and constant resistivity. Ideally, the earth surface potential should be flat in the area around the earth electrode. This is important for protection against electric shock, and is characterised by touch and step voltages. Rod electrodes have the most unfavourable surface potential distribution, while meshed electrodes have a much flatter distribution. The behaviour of the earthing system for high transient currents should be considered. Very high current values diminish earthing resistance due to the strong electric field between the earth electrode and the soil, while fast current changes increase earthing impedance due to earth electrode inductance. The earthing impedance is, in this case, a superposition of both these events.

7 Conclusion

From the results obtained, it is seen that almost all the substations earthing resistance were above the safe limit as stipulated by the Regulation. A high earthing resistance signify that if there is lightning strikes, line surges, unintentional contact of the supply with higher voltage lines and any ground fault on the system, the operation and sensitivity of over-current devices coordination will not be effective and that the substation equipment are exposed to electrical hazards posing treat/danger to lives and property at the consuming point. In view of the tested earthing resistance values, the earthing system of almost all the substations in Yenagoa town was poorly constructed/designed and there is a need for improvement of the earthing system to enhance the reliability of substation equipment and to prevent electrical accident to maintenance personnel and the general public.

Engineering design of grounding grid in substations is an iterative process that is facilitated if design systems attended by computer are used, which allows us to detect the best technical-economic results In this work outlined and solved an optimization problem that allows the optimum selection of grounding grid arrangement including the installation considerations of transmission line complementary electrodes, for condition of minimum investment cost fulfilling the technical constraints of the system. This work investigated possible design improvements for problematic grounding regions, which are high earth resistance and small area for grid applications, in AC-substation grounding design. These problematic cases such as inconsistent and high resistivity soil conditions cannot be resolved satisfactorily by the routine procedures of a field engineer that come from related standards. Specifically, the design improvement items that are considered are (I) fault current determination, (II) soil treatment, (III) deep driven rods, (IV) explosion, and (V) parallel grid. In all of these techniques, the primary aim is to reduce both grounding resistance (R) and ground potential rise (GPR). Each of the above design improvements are analyzed with finite element analysis and the results with the output of the related conventional methods. In this way, these analyses reveal the accuracy and cost effectiveness of design improvements.

It is important for a facility to have a good grounding system. The safety of all personnel and equipment is at stake. In order to be sure that a good grounding system is in place, it is necessary to maintain a low resistance to remote earth of all the electrodes, and a low resistivity of the local soil. There are different methods for obtaining these measurements. Due to variations in the electrodes and soil, a number of measurements should be taken and evaluated for a consistency. There is a good conclusion that a safe soil resistance should be non-corrosive which should not be above 5ohms if otherwise, it should be treated with the artificial soil earth gel. Finally, it was conclusively concluded that, only the earth depth has a great effect on the soil resistance, and that, earth voltage, can only affect the soil resistance if the earth depth is not deep; this is the only time that earth voltage can have upper hand on the soil resistance. The spike distance itself, have un-noticeable or no effect on the soil resistance. This might be negligible.

Compliance with ethical standards

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Disclosure of conflict of interest

We make the following declarations; there is no conflict of interest in this research and this research has not been published anywhere and we acknowledge the work of various authors quoted or mentioned by proper referencing.

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