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INVESTIGATION AND IMPROVEMENT ON THE EARTH RESISTANCE OF THE POWER SUBSTATION IN AMBROSE ALLI UNIVERSITY, EKPOMA NIGERIA

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ABSTRACT: Earthing of electrical appliances, installations and machinery is required to avoid the risk of electric shock to personnel as a damage to equipment. This is achieved by connecting the appliances or machinery through earth electrodes to the earth mass and connecting the electrodes together through low resistance conductors. In this project the earthing system of Ambrose Alli University 1000kVA MIKANO generator located in the power station was evaluated, Its earthing resistance was measured using Kyoritsu digital earth tester, It was discovered that the existing earthing system of the generator has degraded, which can endanger the life of the operating personnel and the generator. The earth resistance measured was 529 ohms thus, necessitating remediation measures. A pit 5 feet long, 3feet wide and 8 feet deep was excavated to place the earth electrode and earth mat. The earth mat was buried and galvanized earth rods of 6 fit with diameter of 32mm were driven into the ground at equidistant from each other. The pit was watered to increase the moisture content of the soil thereby enhancing its

conductivity. The soil was treated with charcoal, magnesium sulfate salt, cow dung, poultry droppings. The combination of these materials enhanced conductivity of the earth electrode in the area around the earthing system. The mixture can also serves as an anti-corrosive agent, thereby ensuring longer life of the earth conductor owing to the fact that coal absorbs water and keeps the soil wet. Furthermore, coal is made up of carbon which is a good conductor, hence it minimizes earth resistance. Salt helps in forming electrolyte which increases the conductivity between the earth rod and ground. The resistance value was measured using a digital earth resistance tester. However, earthing resistance values varies with the time of the year; it is high during the dry season and low during rainy season. Lastly, the value of the earth resistance depends largely on the type and resistivity of soil. The measured minimum earth resistance of 10 ohms was used as a standard to evaluate the earthing resistances of the generator because of the high resistivity of the selected site.

Keywords: *Earth, Electrode, Soil, Resistance, Continuity, Conductor, Lead*

1.0 INTRODUCTION

Background of the Study

Earthing is one of the most important aspects of any electrical installation. The main reason for earthing in electrical installation is for the safety of operating personnel and equipment. When all metallic parts in electrical equipment are grounded then if the insulation inside the equipment's fails there are no dangerous voltages present in the equipment casing. Earthing system simply means to connect the metallic parts of an Electrical appliance, electrical installations, electrical machinery and devices to the earth (ground) through an earth electrode (which is buried in the moisture earth) through a thick conductor wire which has very low resistance.

The main part of an earthing system is the earth electrode set in the ground, and its primary task is to conduct current from the atmospheric discharge and leakage current from electrical installation to the ground in such a way that the earth will not expose to voltage that will put the people in the immediate environment in danger, in case of large fault in electrical installation it’s potential rises. The concept of earthing is based on the fundamental assumption that earth potential is always considered at “zero”; i.e., irrespective of where it is connected to is always a zero potential ground mass. For this reason, any electrical equipment or appliance when connected to earth ("earthed"), also turns to a zero potential. A good earthing is one which gives very low resistance to the flow of current to ground. It is important to see that the earth resistance is kept as low as possible. Therefore, the Prime Objective of Earthing is to Provide Zero Potential Surface in and around and under the area where the electrical equipment is installed, minimizes the danger of electrocution due to earth leakage of current through undesired path and to ensure that the potential of a current carrying conductor does not rise with respect to the earth than its designed insulation. When the metallic part of electrical appliances (parts that can conduct or allow passage of electric current) comes in contact with a live wire, maybe due to failure of installations or failure in cable insulation the metal become charged and static charge accumulates on it. If a person touches such a charged metal, the result is a severe shock. To avoid such instances, the power supply systems and parts of appliances have to be earthed so as to transfer the charge directly to the earth (Lee,2012; Akin, 2017; Axis; Rajput, 2017).

Earthing is essential at every stage of electricity generation, transmission, installation and utilization.

A properly grounded electrical system serves mainly two purposes:

a) It prevents the risk of electrical shocks to any human being coming in contact with the system.

b) It protects the connected equipment from any possible damage occurring due to leakage currents or lightning or voltage surges, by providing a safe passage to these currents to ground.

Earthing of an electrical system is achieved by inserting an electrode (plate type / rod type) in to the solid mass of earth and then connecting this electrode to the earth wire coming from the electrical equipment (Lee,2012; Akin, 2017; Axis; Rajput, 2017).

Requirements for Earthing

According to the regulations of the Institute of Electrical and Electronic Engineers (IEEE), earth electrodes shall be provided at generating stations, substations and consumer premises in accordance with the requirements. All connections shall be carefully made. If they are not properly made or are inadequate for the purpose for which they are intended, loss of life or serious personnel injury may result. Each earth system shall be so devised that the testing of earth electrode is possible. The minimum size of earthing lead used on any installations shall have a nominal cross-section at areas of not less than 3.0 mm^2 of copper and 6.0 mm^2 of galvanized iron or steel. The actual size will depend on the max. Fault current which the earthing lead will be required to carry safely. It is recommended that a drawing showing the main earth connection and earth electrode be prepared for each installation (Akin, 2017; Gomes & Diego, 2011).

No addition to the existing load whether temporary or permanent shall be made, which may exceed the assessed earth fault or its duration until it is ascertained that the existing arrangement of earthing is capable of carrying the new value of earth fault current resulting due to such addition. All materials, fittings etc. used in earthing shall confirm to 1. E. Rules, 1956, Standard specification wherever these exists. In the case of material for which Indian standard specifications does not exists, the material shall be approved by the competent authority (IEEE, 2012, Gerald *et al*, 2023).

1.2 Earth Electrode

An electrode is a metal (copper, galvanized) rod, an underground water pipe or any other conducting material which provides effective contact or connection with the general mass of the earth. The electrode is buried far into the ground reasonably free of stones or rock. The soil must remain practically undisturbed and in very close contact with the electrode surface. It should be noted that the soil resistivity is lower in the deeper strata of the earth which is reasonably wet all the year round. Electrodes shall be corrosion resistant (Gomes &Diego, 2011; Yamara, 2002; Rajput, 2017).

1.2.1 Earth Electrode Material

Electrode material does not affect initial earth resistance significantly. Appropriate precautions need to be taken while selecting the material so that it is resistant to corrosion in the type of soil in which it will be used. Tests in a wide variety of soils have shown that copper, whether tinned or not, is more suitable compared to ferrous materials (for example, cast iron, wrought iron or mild steel). Galvanized mild steel is also observed to be a little inferior to copper in this regard. While selecting and designing earth electrode, care should be taken regarding the thermal rating of the electrode. The electrode must be able to withstand the heat produced due to current that will flow through it. The conditions of the upper layers may be altered considerably. In these cases, deeper driving of the electrode into the ground may be necessary to reach layers of reasonable resistivity and also to reach stable ground, so that the value of the electrode resistance remains stable even if the top layers of the ground is affected. In general, a number of rods in parallel are preferred to a single long rod for obtaining lower resistance value (Akin, 2017; IEEE, 2012). When the diameter of the earth electrode is increased, there is improvement in the mechanical strength of the electrode. Apart from that, no significant changes in earth resistance are observed in terms of increase in contact surface area with the soil. Generally, an electrode with suitable diameter having adequate strength to withstand bending or splitting while being driven into the particular soil conditions is chosen. Larger the diameter of the electrode, the tougher it is to drive it into the earth. Number of earth electrodes required for a particular installation is decided by the optimum value of the earth resistance required for that system. The value of the earth resistance depends upon the reasonable potential rise and setting of the protective devices used (Gomes &Diego, 2011). The main criterion is that the value of the earth return resistance should not be so high that it does not produce the required ground fault current for actuating the protective devices within the stipulated time(Akin, 2017; Gomes & Diego, 2011).

1.3 Materials for Earthing

Earth Mat

Earth mat is made by joining the number of rods through copper conductors. It reduced the overall grounding resistance. Such type of system helps in limiting the ground potential. Earthing mat is mostly used in a placed where the large fault current is to be experienced. While designing an earth mat, the following step is taken into consideration. In a fault condition, the voltage between the ground and the ground surface should not be dangerous to a person who may touch the noncurrent-carrying conducting surface of the electrical system. The uninterrupted fault current that may flow into the earthing mat should be large enough to operate the protective relay. The resistance of the ground is low to allow the fault current to flow through it. The resistance of the mat should not be of such a magnitude as to permit the flow of fatal current in the live body. The design of grounding mat should be such that the step voltage should be less than the permissible value which would depend on the resistivity of the soil and fault required for isolating the faulty plant from the live system.in fig2.1 (Gomes &Diego, 2011; Yamaura, 2002; Rajput, 2017).

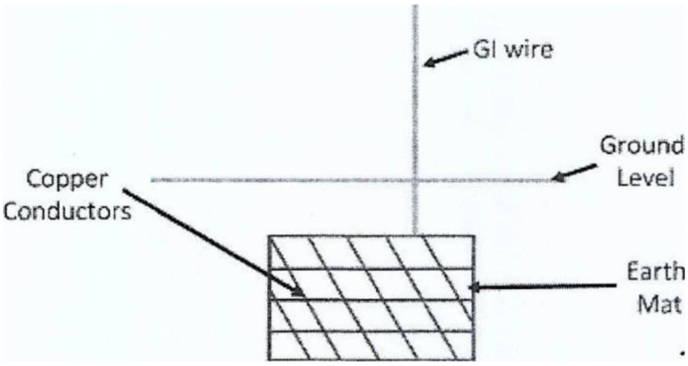
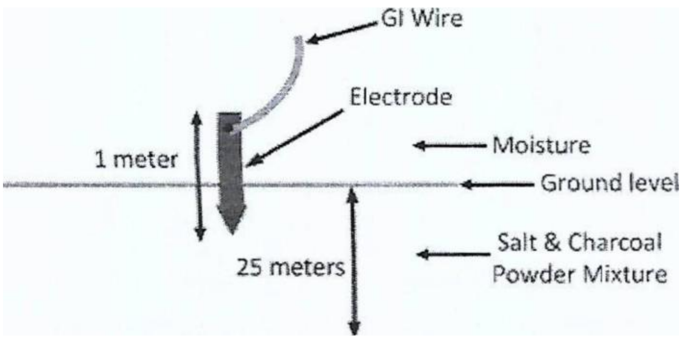


Figure 2.1: Earthing Mat

2.9.2. Earth Electrode

In this type of earthing any wire, rod, pipe, plate or a bundle of conductors, inserted in the ground horizontally or vertically. In distributing systems, the earth electrode may consist of a rod, about 1 meter in length and driven vertically into the ground. In generating substations, grounding mat is used rather than individual rods.in fig 2.2 (Gomes &Diego, 2011; Yamaura, 2002; Rajput, 2017)..



Earthing through Electrode

Figure 2.2: Earthing through each electrode

2. LITERATURE REVIEW

2.1. Design and Analysis of Earth Resistance for Efficient Protection of Photovoltaic Installation (A Case Study of Owerri Municpal).

This research adopted the fall of potential method in performing the earth resistance investigation. The methodology involves mapping out three points on the soil which were used as contacts on the ground comprising earth the test or reference electrode E, probe electrode for current C, and probe electrode for voltage P. The electrodes for current was placed at a range of 20m from the earth test electrode, while the voltage probe electrode was positioned at of 10m from the test electrode. The experiment made use of Kyoritsu Digital earth tester to supply current to the terminal contact of the earth test electrode, so that current can flow through the ground to the electrode for current probe, and then flows back to the meter. A voltage drop will occur across the two points as the current flows through the earth test electrode, and the voltage and current displayed on the digital earth tester were recorded. According to the research report, the experiment was conducted in ten different positions or points in an area of land spanning about 13040 m^2, and an average earth resistance of 0.26Ω was realized in the whole process. The result of measured values however falls within the acceptable earth resistance limit of 1.0 Ω ohm, which can guarantee fast tripping of breaker in the event of lightning or fault current (Gerald *et al*, 2023).

2.2. Analysis of Earth Resistance of Electrodes and Soil Resistivity at Different Environments

The methodology of this research is to determine by calculation, an acceptable value of low frequency earth resistance of a set of individual electrodes, which are connected at various points with different conditions of soil texture. The authors of the research obtained parameters such as the electrode diameter, length, the angle between the installation and the specific resistance (resistivity) in order to get a resistance value that can conform with standard values. The research report shows that the earth resistance of twenty five installed electrodes at different locations with varying soil conditions were measured, and results showed that the measured resistances in sites with high vegetation residential and areas were far above recommended standard values. The research also estimated the accuracy of the measured values by theoretical calculations, and the values obtained through modeling were clearly different from the measured results as observed in vegetation and residential areas. The authors however recommended a three dimensional soil resistivity mapping of any given area of land or site in order to ensure that predicted values obtained from mathematical modeling will tally with measured values gotten from experiments. It was also noted that due to this lack of uniformity of soil resistivity and poor contact resistance of the soil, there is difficulty in deploying existing models designed to predict earth resistance (Lee *et al*, 2012).

2.3. Pipe Earthing

This is the most common and best system of earthing as compared to other systems suitable for the same earth and moisture conditions. In this method the galvanized steel and perforated pipe of approved length and diameter in place upright in a permanently wet soil, as shown below. The size of the pipe depends upon the current to be carried and type of soil.in fig 2.3 (Gomes &Diego, 2011; Yamara, 2002; Lee *et al*, 2012).

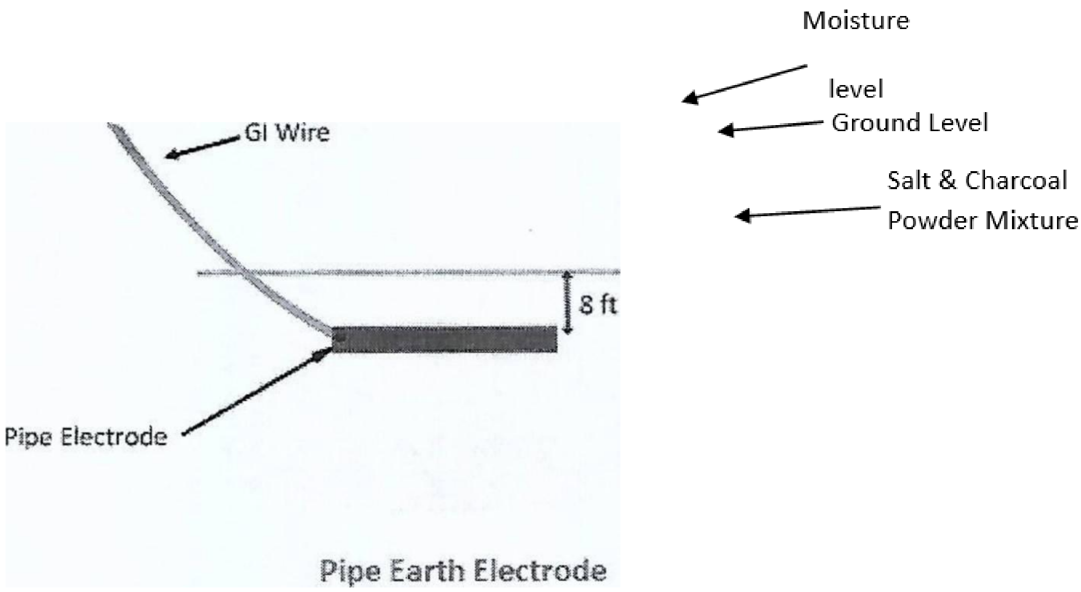


Figure 2.3: Pipe Earthing

Normally, the size of the pipe uses for earthing is of diameter 40 mm and 2.5 meters in length for ordinary soil or of greater length in case of dry and rocky soil. The depth at which the pipe must be buried depends on the moistures of the ground. The pipe is placed at 3.75 meters. The bottom of the pipe is surrounded by small pieces of coke or charcoal at a distance of about 15 cm. Alternate layers of coke and salt are used to increase the effective area of the earth and to decrease the earth resistance respectively. Another pipe of 19 mm diameter and minimum length 1.25 meters is connected at the top of Gl pipe through reducing socket. During summer the moisture in the soil decreases, which causes an increase in earth resistance? So, a cement concrete work is done to keep the water arrangement accessible, and in summer to have an effective earth, 3 or 4 buckets of water are put through the funnel connected to 19 mm diameter pipe, which is further connected to Gl pipe. The earth wire either Gl or a strip of Gl wire of sufficient cross section to carry faulty current safely is carried in a Gl pipe of diameter 12 mm at a depth of about 60cm from the ground (Gomes &Diego, 2011; Yamaura, 2002).

Plate Earthing

In Plate Earthing an earthing plate either of copper of dimension 60cm×60cm×3m of galvanized iron of dimensions 60 cmx 60 cm×6 mm is buried into the ground with its face vertical at a depth of not less than 3 meters from ground level.in fig 2.4 (Gomes &Diego, 2011; Yamaura, 2002; Lee *et al*, 2012).

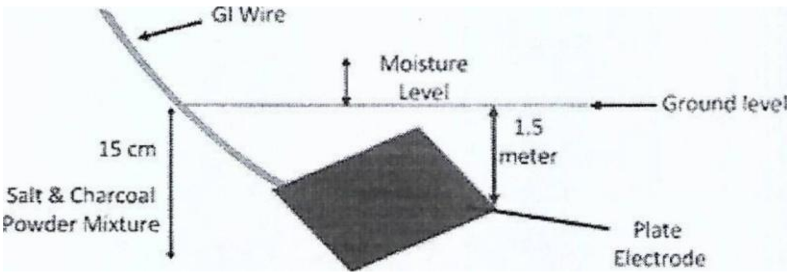


Plate Earth Electrode

Figure 2.4: Plate earthing

The earth plate is inserted into auxiliary layers of coke and salt for a minimum thickness of 15 cm. The earth wire (Gl or copper wire) is tightly bolted to an earth plate with the help of nut or bolt. The copper plate and copper wire are usually not employed for grounding purposes because of their higher cost. The water pipe is made up of metal, and it is placed below the surface of the ground, i.e., directly connected to earth. The fault current flow through the Gl or copper wire is directly get earthed through the water pipe(Gomes &Diego, 2011; Yamaura, 2002; Lee *et al*, 2012).

2.9 Ways of Reducing Earth Resistance

Effective earth resistance depends on factors such as soil condition, temperature and moisture content of soil, areas of earth electrode and depth to which it is driven. The earth resistance can be considerably reduced by digging around the earth electrode to a depth of 6feet, cleaning the surface of the earth plate or pipe of rust, filling with charcoal soaked in salt solution. In summer season the pouring of fresh salt water (copper sulphate solution in case of copper plate earthing) through pipe over all the coal bed will reduce the earth resistance. The additional steps for reducing the earth resistance of the system are increasing of plate areas, increasing of pit depth and increasing of number of electrodes in parallel. The methods of increasing of plate area and increasing of pit depth have got limitations and so cannot prove more useful. Hence where the earth resistance cannot be reduced to a desired value by the methods above number of electrodes interconnected in parallel may be used. This method is suitable only where greater surface area of free soil is available for earthing. The electrodes should be so spaced in parallel so as not to overlap the earthing region covered by the individual electrodes. (Akin, 2017; Gomes & Diego, 2011).

Effect of Rod Size

As you might suspect, driving a longer rod deeper into the earth, materially decreases its resistance. In general, doubling the rod length reduces resistance by about 40 percent. The curve of Figure 2.6 shows this effect. For example, note that a rod driven 2ft down has a resistance of 882ohms. The same rod driven 4 ft down has a resistance of about 50.2ohms

Using the 40 percent reduction rule, $88 \times 0.4 = 35\ \Omega$ reduction. By this calculation, a 4-ft deep rod would have a resistance of 88-35 or 53 2 - comparing closely with the curve values.

Earth resistance decreases with depth of electrode in earth as shown in fig 2.6

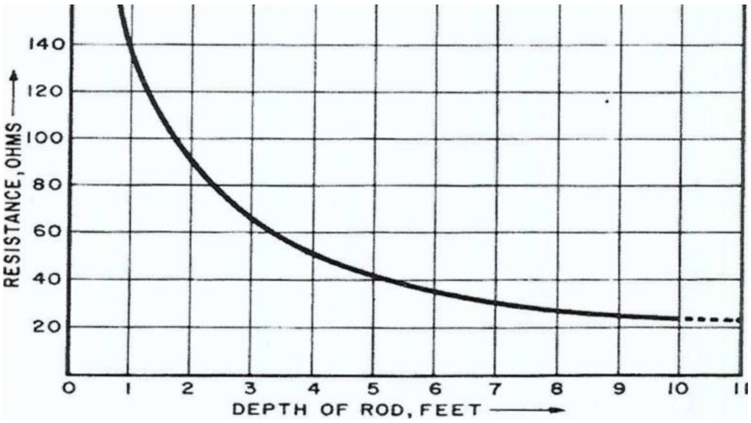


Figure 2.6: The effect of earth rod depth on soil resistance.

Records also show that increasing the electrode diameter lowers the resistance though, but at minimum level. For the same depth, doubling the rod's diameter reduces the resistance only about 10 percent. Figure 2.7 shows this relationship.

For example, a 10-ft deep rod, 5/8 inch in diameter, has a resistance of 6.33ohms. When its diameter is increased by 1to1/4 inch, the resistance reduced to 5.6 Ω. For this reason, one may consider increasing the rod diameter if there is a need to drive it into hard terrain.as shown in fig 2.7 (Akin, 2017; Gomes & Diego, 2011).

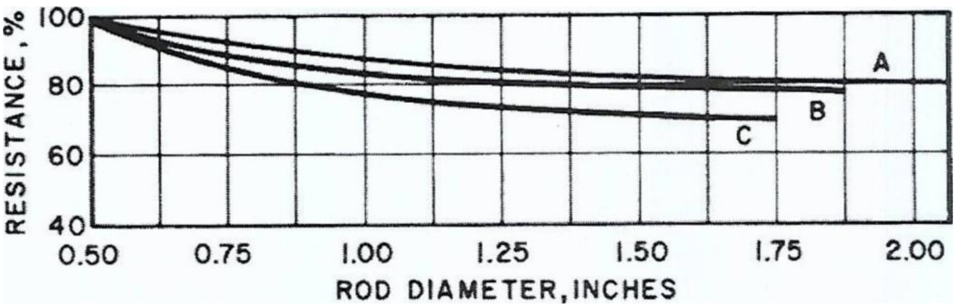


Figure 2.7: Effect of Earth Rod Diameter

Diameter of a rod has little effect on its earth resistance.

2.10.2. Use of Multiple Earth Rods

Two well-spaced Earth rods driven into the earth provide parallel paths. They are, in effect, two resistances in parallel. The rule for two resistances in parallel does not apply exactly. That is, the resultant resistance is not one-half the individual rod resistances (assuming they are of the same size and depth). Actually, the reduction for two equal resistance rods is about 40 percent. If three rods are used, the reduction is 60 percent, if four, 66 percent in figure 2.8 (Gomes &Diego, 2011; Yamara, 2002; Lee *et al*, 2012)..

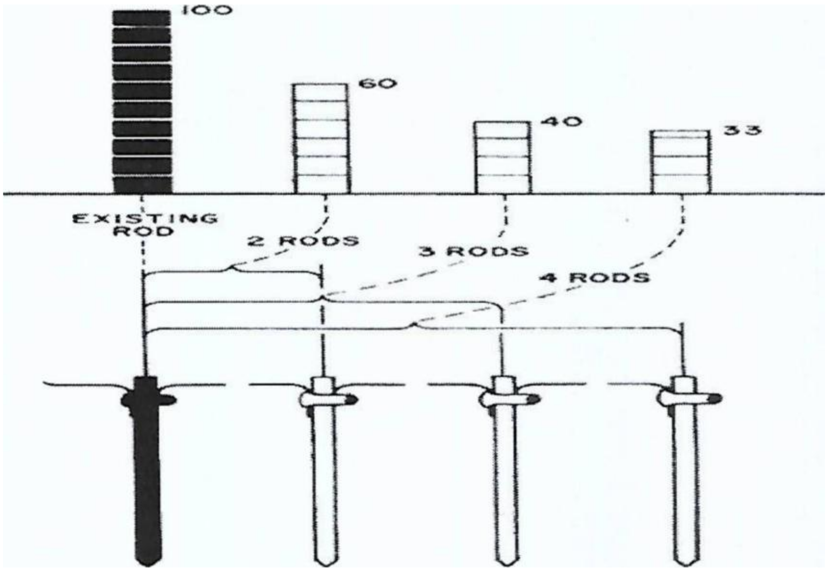


Figure 2.8: Average results obtained from multiple-rod earth electrodes

Using additional ground rods is one of the best means of reducing the resistance to ground; for example, the combined resistance of two rods properly spaced and connected in parallel should be 60 percent of the resistance of one rod; the combined resistance of three rods should be 40 percent of that of a single rod.in fig 2.9(Gomes &Diego, 2011; Yamara, 2002; Lee *et al*, 2012).

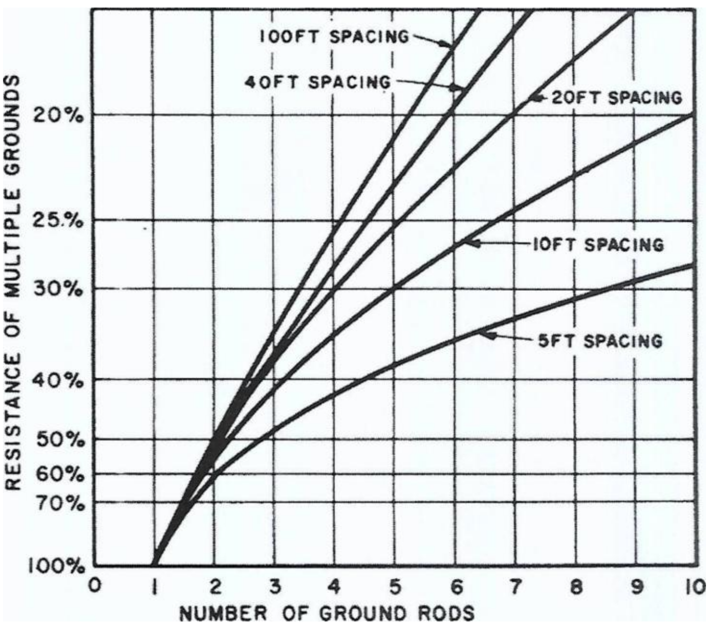


Figure 2.9: Comparative resistance of multiple-rod earth electrodes

When you use multiple rods, they must be spaced apart further than the length of their immersion. For example, if you have two rods in parallel and 10-ft spacing, resistance is lowered about 40 percent. If the spacing is increased to 20 percent, reduction is about 50 percent.

2.10.3 Treatment of the Soil

Chemical treatment of soil is a good way to improve earth electrode resistance when you cannot drive the rod deeper into the ground because of hard underlying rod. Some of the materials used for soil treatment are charcoal, industrial salt, animal (cows, goats, man, chicken etc.) droppings and ashes, etc. Charcoal and animal dung charcoal are a good conductor of electricity and also serves as an anti-corrosive, hence ensuring longer life of the Gl plate. Coal absorbs water and keeps the soil wet. Furthermore, coal is made up of carbon which is a good conductor, hence it minimizes earth resistance. Salt helps in forming electrolyte which increases the conductivity between the earth rod and ground. It is beyond the scope of this project to recommend the best treatment chemicals for all situations. You have to consider the possible corrosive effect on the electrode Magnesium sulfate, copper sulfate, and ordinary rock salt are suitable non-corrosive materials. Magnesium sulfate is the least corrosive, but rock salt is cheaper and does the job if applied in a trench dug around the electrode in figure 2.10 (Gomes &Diego, 2011; Yamaura, 2002; Lee *et al*, 2012)..

Soil Treating Material
Placed in circular Trench
And covered with Earth

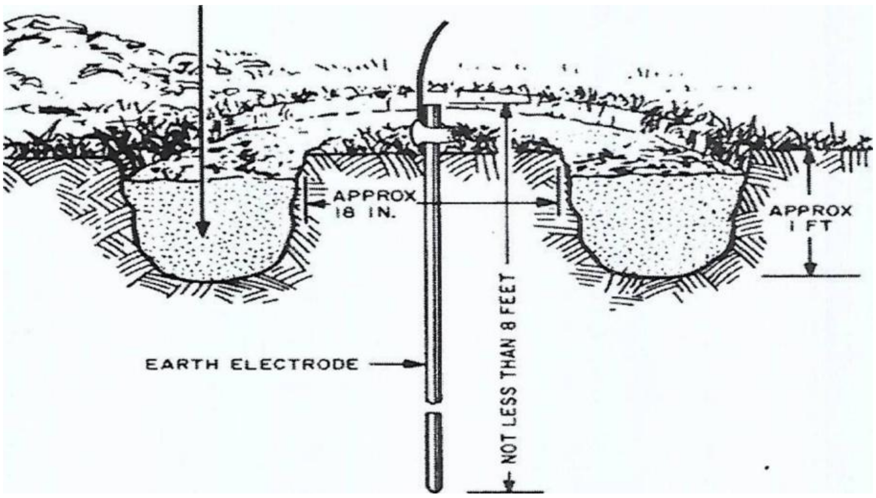


Figure 2.10: Trench method of soil treatment

It should be noted that soluble sulfates attack concrete, and should be kept away from building foundations. Another popular approach is to backfill around the electrode with a specialized conductive concrete. A number of these products, like betonies, are available on the market.

Note: Chemical treatment is not a permanent way to improve your earth electrode resistance.

The chemicals are gradually washed away by rainfall and natural drainage through the soil. Depending upon the porosity of the soil and the amount of rainfall, the period for replacement varies. It may be several years before another treatment is required. Chemical treatment also has the advantage of reducing the seasonable variation on resistance those results from periodical wetting and drying out of the soil. However, you should only consider this method when deep or multiple electrodes are not practical.in fig 2.11 (Gomes &Diego, 2011; Yamaura, 2002; Lee *et al*, 2012).

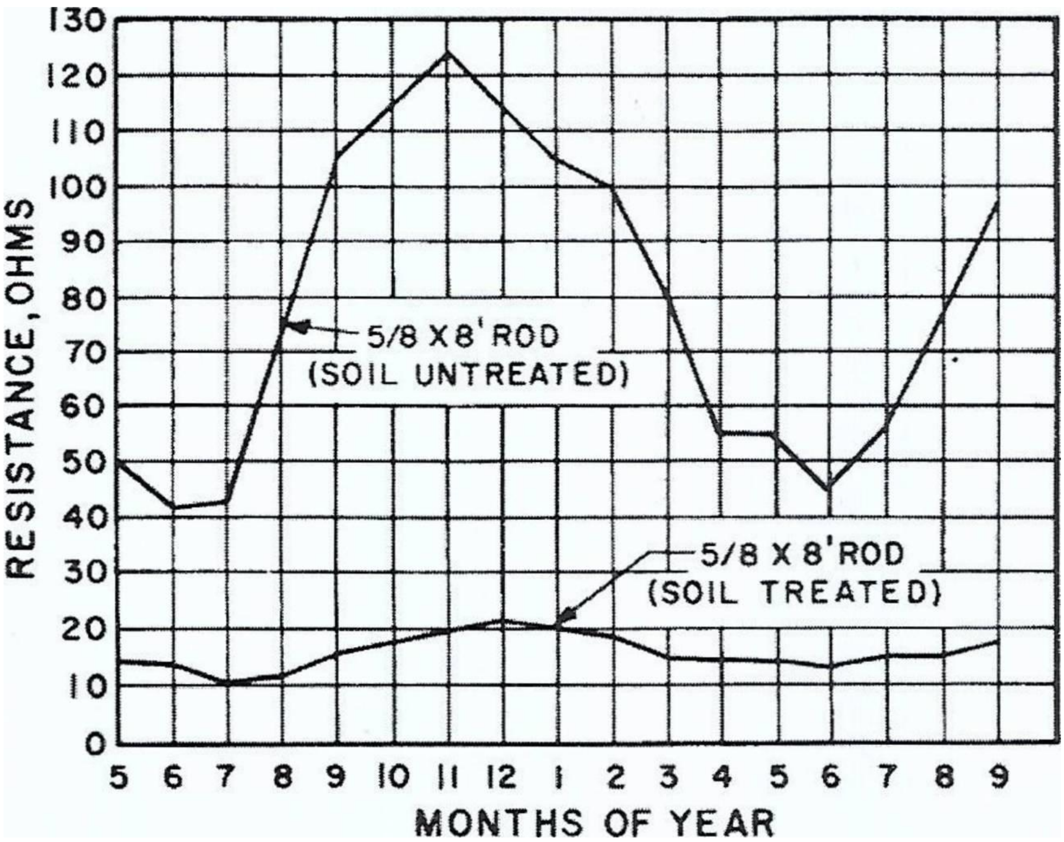


Figure 2.11: Chemical treatment of soil lessens seasonal variation of electrodes' earth resistance

3.0 MATERIALS AND METHODS

3.1 Site and Location of Study

The site of the study is the power substation in Ambrose Alli University comprising a 1000 KVA MIKANO Generator. The university is located in Esan west east local government area in Edo state. The address is Express way, KM 70 Benin Auchi Road, Edo state with latitude and longitude of 6.744634°N 6.084552°E.

NOTE: The remediation for low earth resistance of the selected site was carried out during dry season for a period of 4 days.

3.2 THE MATERIALS USED FOR THE EARTHING

The following materials were used for the earthing:

a) 6 numbers of 6fit galvanize earth rod of 32mm diameter

b) 2 numbers of copper 2ft by 2ft earth mat

c) 30 meters of 16mm copper conductor

d) 1.0m³ volume of cow dung for each pit

e) 0.10m³ volume of chicken dung for each pit

f) 6 kg of magnesium sulphate salt for each pit

g) 709 liters of waters for each pit

h) 2m³ of Treated charcoal for each pit

i) Shovel

j) Digger

k) Hammer

3.3 PREPARING FOR THE EARTHING PROCESS

The methodology employed for proper earthing in this project work is listed below;

(a) A pit of 8 feet measuring 5 feet by 3 feet was excavated to place the earth electrode and earth mat

(b) The earth mat was buried and the Galvanize earth rod of 6 fit with diameter of 32mm was driven into the ground at equal distance.

(c) The pits were watered to increase the moisture content of the soil thereby enhances it conductivity and reduce the resistance values of the pit

(d) The soil was treated with charcoal, magnesium sulfate salt, cow dung, chicken dug. (Treated charcoal is a mixture of wood charcoal and animal dung charcoal). This mixture is a good conductor of electricity and also serves as an anti-corrosive, hence ensuring longer life of the Gl plate. Coal absorbs water and keeps the soil wet. Furthermore, coal is made up of carbon which is a good conductor, hence it minimizes earth resistance. Salt helps in forming electrolyte which increases the conductivity between the earth rod and ground.

(e) Water was poured into the pit to further increase its moisture content.

(f) The ohmic value was measure using Kyoritsu digital earth tester.

EXPERIMENTAL SETUP

The auxiliary earth spikes were pinned to the ground deeply, and they were spaced at an interval of 5-10mm from the earthed equipment under test. The green wire was connected to the earth equipment under test, the yellow wire to the auxiliary earth spike and the red wire to the auxiliary earth spike C from terminals E. P and C of the instrument in order.

Care was taken to ensure that the auxiliary earth spikes are pegged in the moist part of the soil, and water was added to the region where the spikes stuck to the dry, stony or sandy part of the soil so that it can be moisturized enough to produce good result.

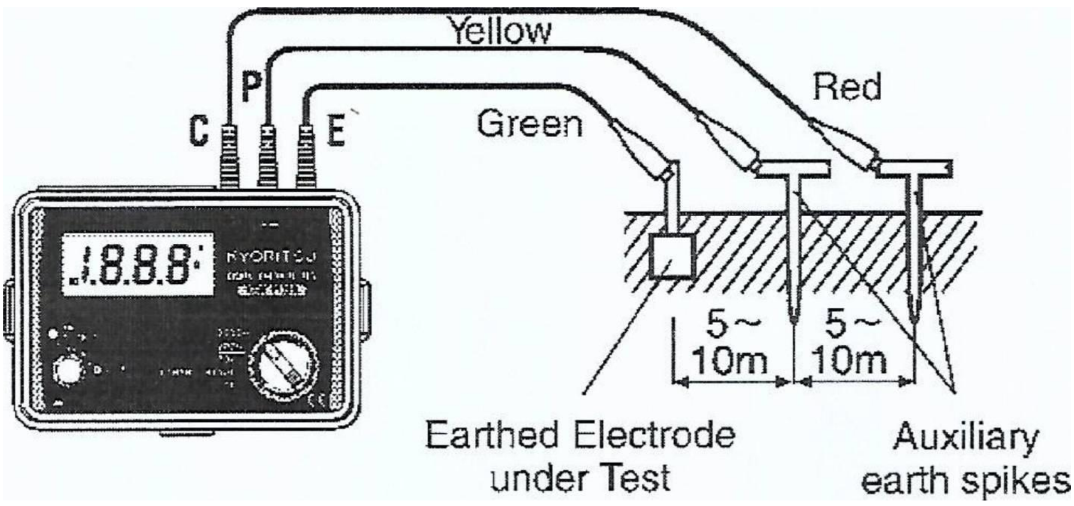


Figure 3.1: Experimental Diagram

Voltage Measurement

During this section, the switch was set to voltage mode to enable the digital tester display the injected voltage to the earth so that the resistance can be determined. A voltage of 2.9V was applied in the process; this value was preferred in order to avoid errors that may occur in getting the actual resistance.

Precise Measurement

The range switch was set to 2000 position and the test button was press thereafter, the LED indicated and it remained during testing. The range switch was adjusted to 200 n and 20 n, when the earth resistance is low. This indicated value is the earth resistance of the earthed equipment under test.

4.0 RESULT AND DISCUSSION

4.1 Results of Experiment

The earth resistance value of the power plant before remediation was 20 ohms.

Earth resistance value of each pit before burying the earth rods and earth mats

Pit 1 = 639 ohms

Pit 2 = 416 ohms

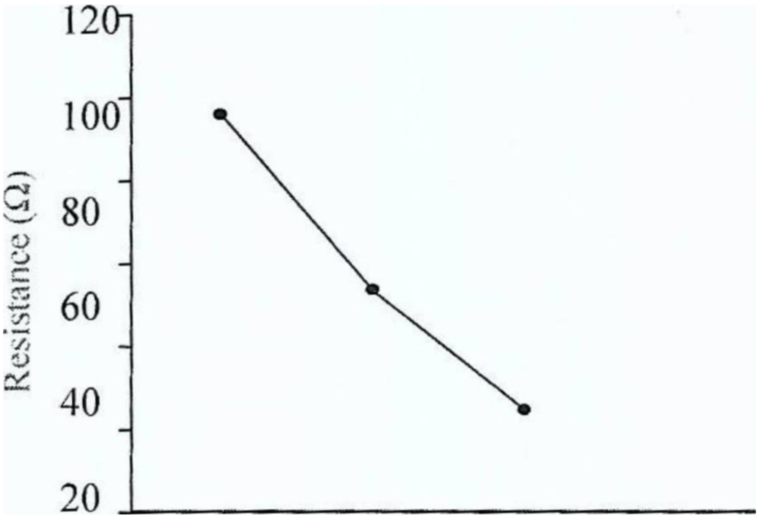
Earth Resistance Values after Soil Watering

Pit 1 = 439 ohms

Pit 2-316 ohm

Table 4:1: Resistance Values of Pit 1

S/N	Soil Treatment	Resistance Value(ohms)
1	Treated Charcoal+magnesium Sulphate salt+cow dung (A)	98.3
2	Treated Charcoal+magnesium Sulphate salt+cow dung+water (B)	51.9
3	Treated Charcoal+magnesium Sulphate salt+cow dung+water +chicken dung (C)	21.7



0 A B C

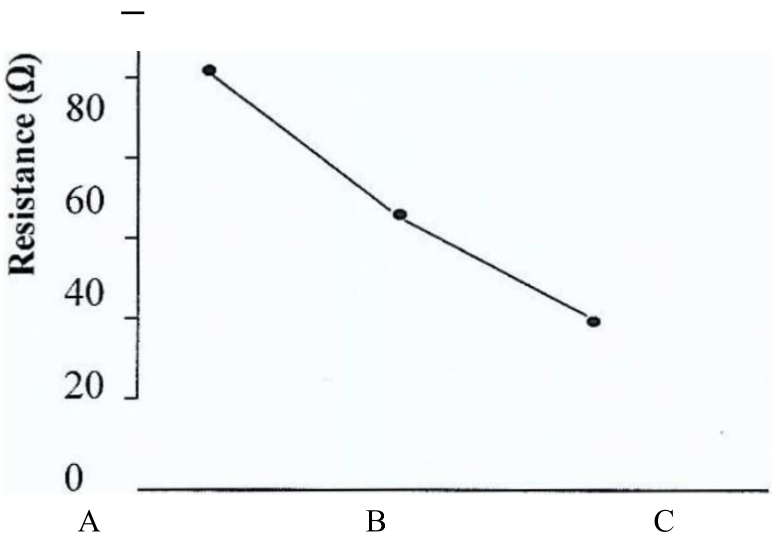
Soil Treatment

Figure 4.1: Graph of Resistance against soil treatment for Pit I

When pit 1 was treated with Treated the combination of Charcoal, magnesium sulphate salt and cow dung (point A), the resistance value was 98.3 ohms. When it was watered (at point B) the resistance value further decreased to 51.9 ohms. When it was mixed with chicken dung, the earth resistance value further decreased to 21.7 ohms. This is a proof that when the moisture content of the soil is improved, the value of earth resistance will decrease.

Table 4: 2: Resistance Values of Pit 2

S/N	Soil Treatment	Resistance Value(ohms) Of Pit 2
1	Treated Charcoal+magnesium Sulphate salt+cow dung (A)	88.6
2	Treated Charcoal+magnesium Sulphate salt+cow dung+water (B)	48.4
3	Treated Charcoal+magnesium Sulphate salt+cow dung+water +chicken dung (C)	22.0



Soil Treatment

Figure 4.2: Graph of Resistance against soil treatment for Pit 2

When pit 2 was treated with the mixture of Charcoal, magnesium sulphate salt and cow dung as seen in point A It value was 88.6 ohms. When it was watered (point B), it value further decreases to 48.4 ohms. When it was further treated with chicken dung the earth resistance value was 22.0ohms

Table 4:3: Total Resistance Values with Pits 1 and 2 Combined

S/N	Soil Treatment	Resistance Value Of both Pits connected in parallel (ohms) (pit 1 and pit 2)
1	Treated Charcoal+magnesium Sulphate salt+cow dung (A)	40
2	Treated Charcoal+magnesium Sulphate salt+cow dung+water (B)	26.6
3	Treated Charcoal+magnesium Sulphate salt+cow dung+water +chicken dung (C)	8.32

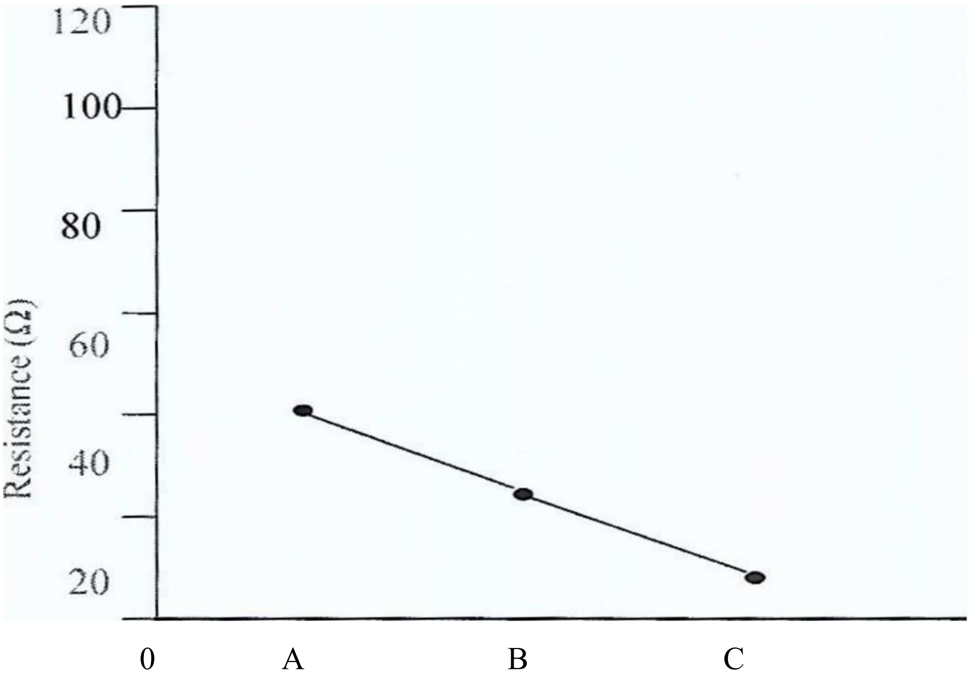


Figure 4.3: Graph of Resistance against soil treatment with Pit 1 and Pit 2 electrodes connected in parallel

When both pits were connected in parallel, (i.e. when the soil was treated, with Charcoal, magnesium sulphate salt and cow dung) at point A on the graph of Figure 4.3 It value was 40ohms.when it was watered

(B) it value further decreases to 26.6ohms.when it was further treated with chicken dung the earth resistance value was 8.32ohm

4.2. Analysis of Results Obtained from Experiment

The resistance values of each pit decreased in value when the soil was treated, and it further decreased to 21.7Ω when the values obtained from the electrodes were connected in parallel. This is the purpose for the parallel connection, as the nature of the soil at the time of carrying out the test could not produce a desirable result to ensure the safety of the generator as regards to earthing. When it was connected to the existing 20 ohms of the generator, the earth resistance was re-enforced, giving better value 4.59 ohms

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