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Research Paper

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

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Abstract
Lightning is one the major causes of disastrous breakdown in any electrical installations, so it is always important and necessary to design an efficient earthing system to protect health of electrical equipment and personnel from inimical effect lightning or and fault currents. In this paper, the fall of potential method was adopted in performing the earth resistance investigation. This procedure considered a three points of ground contacts which comprises earth electrode (E) under test, a current probe (C) and voltage probe (P). The current and voltage probes were placed at a distance of 20m and 10m from the earth electrode while Kyoritsu Digital earth meter was used to inject current into the foot of the earth electrode, and current allowed to flow from the ground to the current probe and returns to the meter. As the current flows through the earth electrode a voltage drop was produced. The current and voltage reading were taking. The results of 10 different points in an area covering 13040 m² of land was investigated which gave an average earth resistance value of 0.26Ω. The value is within the acceptable earth resistance limit of 1.0 Ω ohm, and guaranteed fast tripping of breaker in the event of lightning or fault current.

Keyword: *Earthing Audit, Grounding, Agrivoltaic, Soil Resistivity, System stability and Security.*

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I. Introduction

One of the major challenges of any electrical installation is earthing. It is a technique used by power system Engineers to safeguard personnel and electrical appliances from hazard. Earthing and grounding are normally used interchangeably, but there exist a major difference between the two words. Grounding involves connecting current carrying path of the system to the general mass of the earth (e.g the neutral of transformer). Earthing deals with the connection of non-current carrying path (dead part) to the general mass of the earth. Earthing is the connection between electrical appliances and devices with earth plate or electrode via thick wire of low resistance to provide safety (Akin, 2017). The metallic bodies, frames, and structures of all the electrical apparatus and equipment are examples of earthing. For proper and effective earthing design to be carried out, an adequate investigation of the earth resistance and soil resistivity must be carried out in accordance with the guidelines, national and international safety standards (IEEE Std 81 2012).

Research have shown that Owerri is among the regions of the country that are prone to high lightening density. The figure I.0a below shows the map of regions of Nigeria with average lightning strikes (NLSRC, n.d.). It is imperative to carry out detailed investigation of earth resistance during earthing design to confirm that the system is capable to withstand discharge any fault related disturbances to the ground. Earth resistance depends largely on the type and resistivity of the soil upon which the electrode is inserted. Figure 10b shows the map of average lightning strokes per square kilometer in regions of Nigeria. The ten states in Nigeria with the highest number of lightning strikes per square meter per year are Cross River (53), Abia (43), Akwa Ibom (42), Enugu (41), Delta (39), Ebonyi (38.5) Rivers (36), Imo (31), Bayelsa (30) and Benue (25) (NLSRC, 2023).

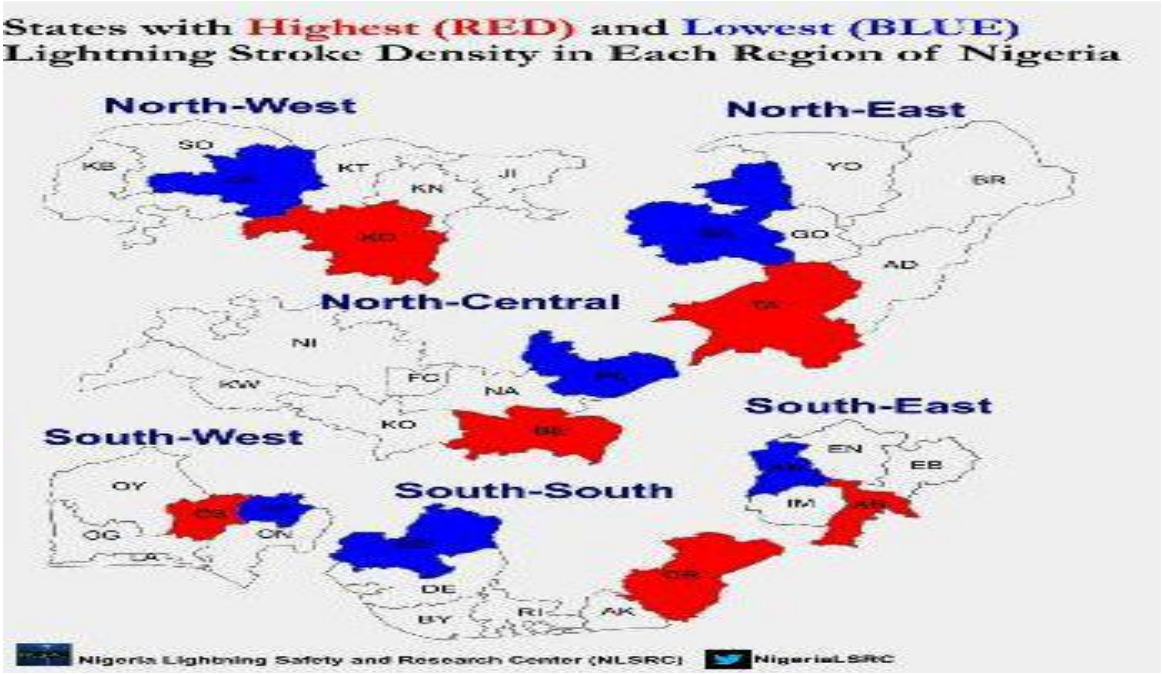

Figure 1.0a: Map showing Lightening stroke density in Regions of Nigeria

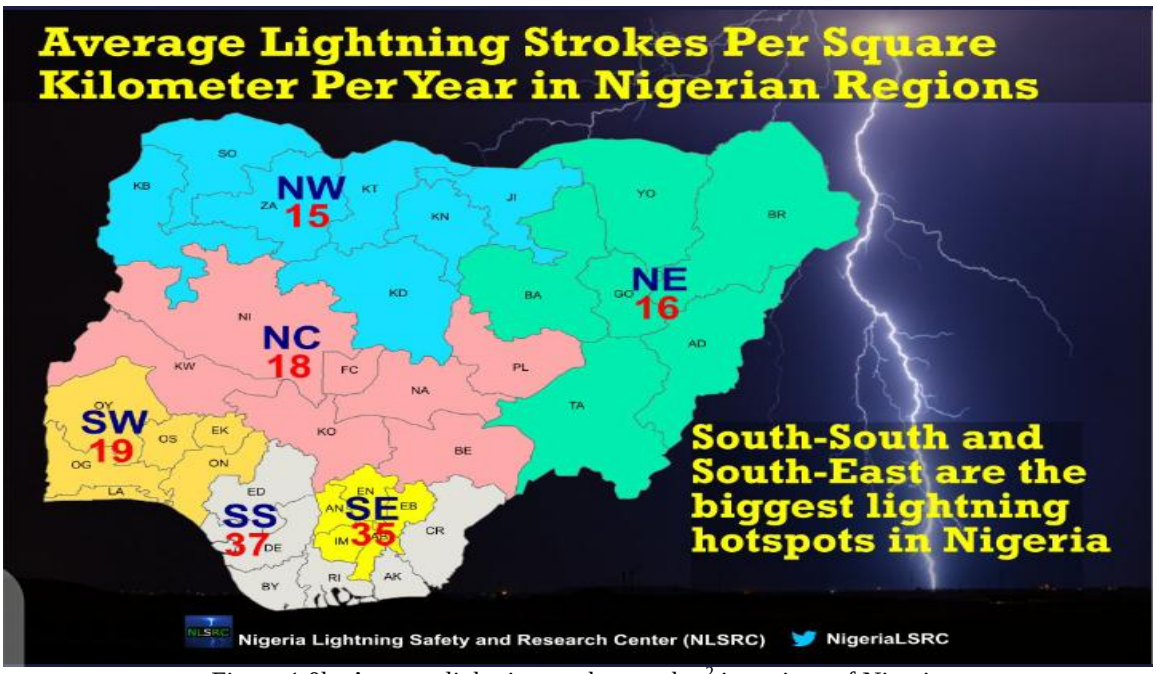

Figure 1.0b: Average lightning strokes per km^2 in regions of Nigeria

In last two decades, the use of renewable energy sources, more especially solar power as an alternative to fossil fuel source of power generation has increased exponentially. In spite this technological advancement, not much have been done on the earthing design of solar PV system. Inverters have inbuilt transformers that step-up the voltage generated through solar panels**.** Photovoltaic modules are usually installed in metallic support structures like galvanized iron, painted or stainless steel or aluminum structures. These structures are highly conductive so they are more prone to electrical shocks and must be earthed to provide the easiest path for abnormal current or lightening strikes to be discharged to the ground via earth electrode. N.(2023, February 20).

Earth audit investigation is highly recommended to performed for effective and efficient earthing design. Earth audit is a process of performing periodic inspection and investigation of the system connection. This is necessary because, earthing is usually installed underground and is always inaccessible (out of sight syndrome). It enhances the health and performance of general earthing system without posing any threat to system security and stability. Earthing components like electrode, mat and conductors (wires) etc, seem to be

neglected because they are buried in the ground. N. (2023, February 20). These components are meant to offer a low resistance route for abnormal current to flow. A low resistance value of 1.0 ohms or below will guarantee fast tripping of breakers to prevent accident or electric shock , fire and short circuit etc. The diagram of photovoltaic module support structure is shown figure 2.0 below. The orange color mark-up at the foots of the structures are the earth electrodes attached to ensure proper earthing of the panel structure. Earthing the panel structure will ensure safety of the personnel and solar installations in event of lightning strikes or transient fault current.

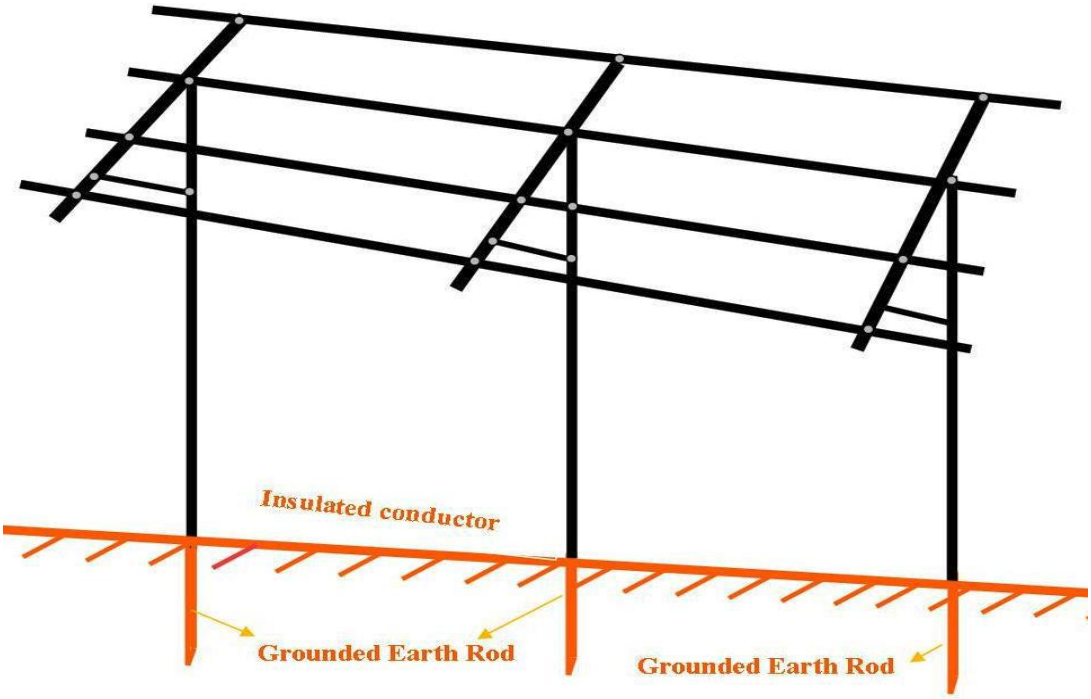

Figure 2.0: Diagram of photovoltaic module support structure

Solar PV installations is highly capital intensive, so adequate earthing system is needed to be carried out to prevent damage of the equipment by fault current or lightning strikes. Moreover, the effect or impact of these disturbances is capable of reducing the performance of the solar panels or even total breakdown prematurely. The cost of repair or replacements such equipment may require exorbitant amount of money. When lightning strikes a solar installation without earthing protection, it is usually catastrophic because,it induces high voltages into the system and break down conductors and components like PV modules, Inverters panels. Most times, the incident produces dangerous sparking that can ignite combustible material as shown in figure 3.

Figure 3: Fire involving photovoltaic panels (Silva et al, 2018)

In determining the requirements for a solar earthing, it is necessary to consider a number of factors that affect the installations. These factors include nature of soil, dissolved salts, moisture content of the soil, location of earth pit, physical composition and climatic condition. Due to the above mentioned factors, the suitable earthing electrodes and conductors should be selected, and the system should be designed and installed to provide an effective earthing system. The most important among all the factors mentioned above is soil resistivity. It is actually used to confirm that the system has enough capacity to dissipate abnormal current and lightning strike to the earth via ground electrode. Low soil resistivity is responsible for obtaining low earth resistance values Axis, (n.d.)**.** There are various measurement methods used in carrying out earth resistance investigations. The methods includes the following**:**

- Four-point method (Wenner method)
- Three terminal methods (fall off potential method)
- Two-point method (dead earth method)
- Clamp-on test method
- Slope method
- Star delta method

II. Overview

Agrivoltaic energy under study is located at within Owerri municipal Imo State Nigeria. The city is located on latitude 5.49^0N and Longitude 7.03^0E as shown in figure 4.0 below. Agrivoltaic energy involves the use same land space for both solar energy and agricultural products, The power plants consists of about 8000 pieces 315Wp of monocrystalline photovoltaic panels forming an array of 4 x2000 strings connected in series and covers an area of 13040 m² of land. It has installed of capacity 2.5MW that are connected to a common DC collection point which is then inverted via 2x1250kVA three phase hybrid inverter. The AC power output from the inverter is stepped up with 20kVA, 1x2.5MVA transformer and transferred through a collector system of medium voltage cables to switchgear control room and finally delivers power to Enugu Electricity distribution company network. The system also contains a lithium ion battery bank of 240kWh storage capacity which will be converted back to electrical energy for usage when needed.

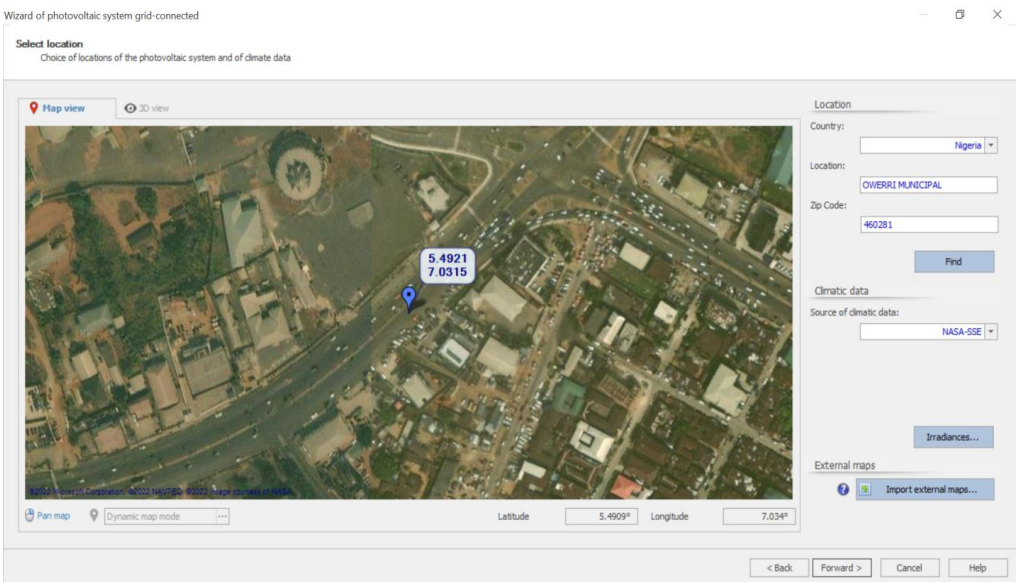

Figure 4.0: Map view of location of the solar power plant

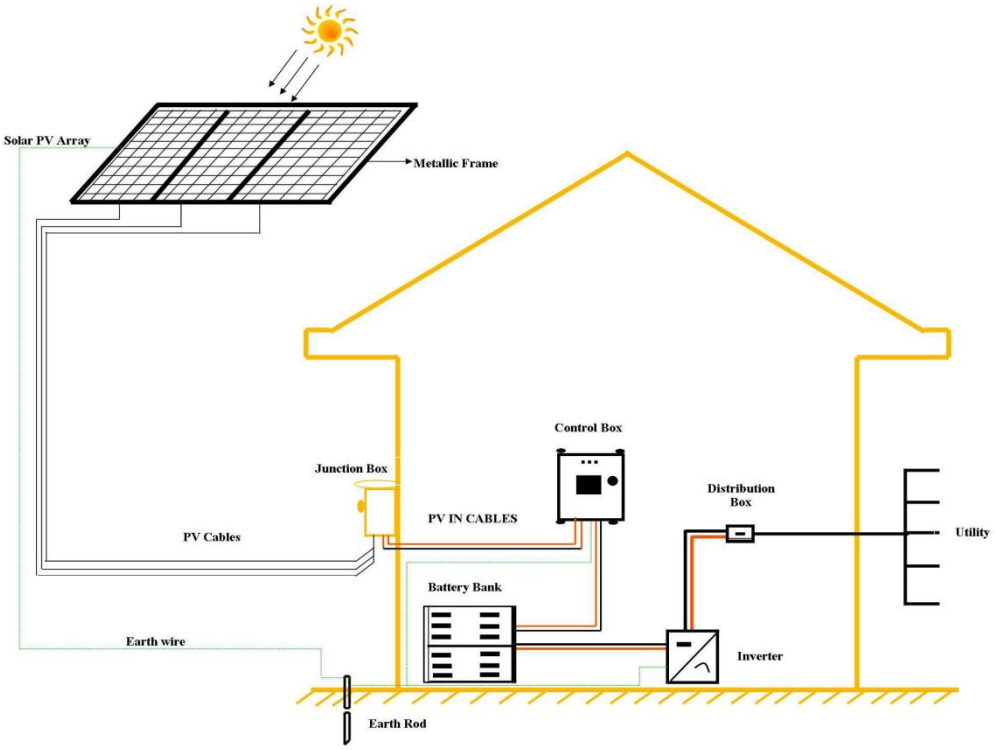

Figure 5.0: Diagram of PV System with Electrical earthing configuration

The Figure 5.0 above shows the diagram of PV System with electrical earthing configuration. Each row of the solar panel equipment and the metallic support frames is connected to the main earth system. A blue dotted wires run around the panel structures, Inverter equipment control box and linked to the earth electrode to reduce touch potentials either at each end or in some designs a continuous copper earth cable will be run from end-to-end of a row either above or below ground level.

III. Design methodology and Procedure

The field work was conducted in March 2023 with Kyoritsu digital earth tester. The fall of potential methodology was adopted in carrying the earth resistance investigation. This method considered a three points of ground contacts which comprises earth electrode under test, a current probe (C) and Voltage probe (P). The current probe was placed at 20m from the earth electrode (E) while as the voltage probe was also placed 10m the earth electrode. The Kyoritsu Digital earth meter was used to inject current into the foot of the earth electrode (E), the current the flows from the earth to the current probe and returns to the meter. As the current flows the resistive material (earth) a voltage drop was produced. The voltage probe was also used the measure the voltage drop while the tester displays both the current and voltage. As the current flows through the earth electrode a voltage drop was produced. The current and voltage reading were taking. The green wire is clamped to the earthed equipment, the yellow wire to the auxiliary earth spike P and the red wire to the auxiliary earth spike C from terminals E, P and C of the instrument in order. The red, yellow and green wires are plugged to the digital tester according to the colour code as shown in figure 6a, b and c respectively. This digital tester is placed at the centre of the assessment location. The results of 10 different points in an area covering 13040 m² of land was investigated which gave a satisfactory result of an average earth resistance value of 0.26Ω. as shown in table 4.1 below

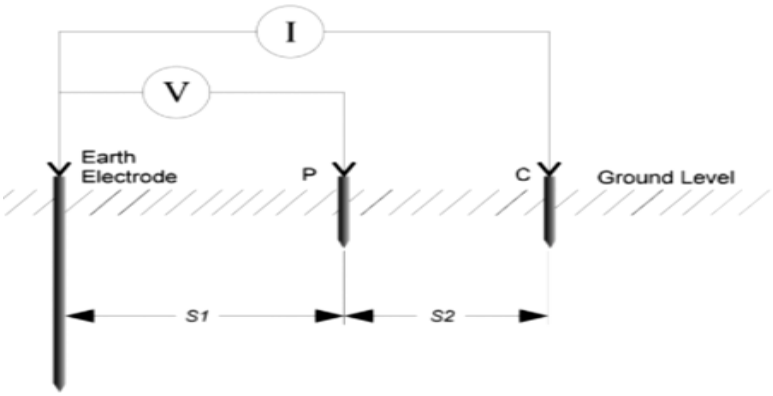

Fig: 6a: Fall of potential method (Classroom, E. 2022, November 6)

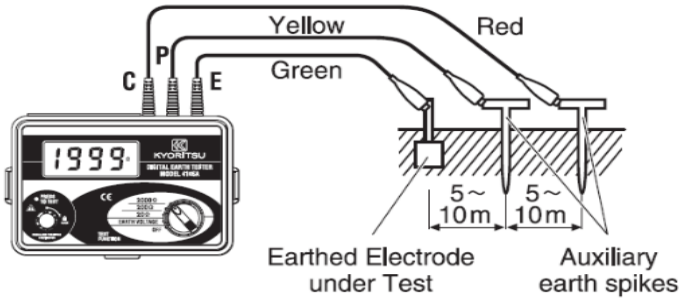

Figure 6.b: Precise Measurement with digital Earth tester

Figure 6c: Pictorial view of Earth resistance setup using Kyoritsu digital Tester

3.1 Materials required for proper earthing system of a solar farm are as follows:

i. 1 nos standard pit of 6ft x 6ftx 12ft
ii. 4nos of 6ft Earth rods
iii. 1 no of earth mat
iv. 30m/70mm2 copper earth wire (Bare Conductor) as earth lead
v. 5 bags of powdered animal dung. (Pig dung preferable with fertilizer
vi. 5 bags of powered charcoal.

IV. Test Result

Table 4.1 shows the table of earth resistance test results at various locations of the solar plant .

Table 4.1 Earthing Resistance test result at 10 meters apart

No.	Positions tested On: Earth Pit	Measured value @ 10m (Ω)
1.	Point 1	0.20
2.	Point 2	0.30
3.	Point 3	0.30
4.	Point 4	0.20
5.	Point 5	0.40
6.	Point 6	0.30
7.	Point 7	0.20
8.	Point 8	0.30
9.	Point 9	0.20
10.	Point 10	0.20
	Total	2.6
	Average value	0.26

The average reading of the earth resistance = 0.26(Ω)

The average reading of the earth resistance = 0.26(Ω) which is within the recommended limit of 1(Ω) as stipulated by guidelines, national and international safety standards (IEEE Std 81 2012).

V. Conclusion and Recommendations

5.1 Conclusion

An extensive discussion and investigation of earth resistance have been performed in this research paper with a view of designing an adequate earthing system for solar installation in Owerri municipal.Setting up a solar power generating station or plant is highly capital intensive , it involves purchasing a large number of solar panels, inverters, and other electrical equipment, as well as installing the necessary infrastructure, such as support structures, electrical wiring, and earthing systems. It is sacrosanct for the installations to be properly earthed to secure the health of the equipment and personnel in order to extend its lifespan and ensure its continued efficiency. In realization of this objective, an earth resistance analysis was performed in 10 different points in area covering 13040 m² of land using digital earth tester. The average value of the earth resistance investigation gave a satisfactory result of value 0.26Ω. This result guaranteed fast tripping of breaker in the event of abnormal current or lightning to prevented hazard.

5.1 Recommendation

1. Earth audit is recommended to ensure that earthing connection is in good condition for proper earthing protection of solar devices.
2. Green earthing is also recommended. This is an appropriate substitute that allow protection against disasters without impacting the earth and its resources negatively.

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