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ANALYZING EARTHING PROTECTION IN ELECTRICAL SUBSTATIONS: EVIDENCE FROM ILE-OLUJI POLYTECHNIC, ONDO STATE

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Abstract: This research evaluates the earthing protection systems across various electrical substation networks within Federal Polytechnic, Ile-Oluji, Ondo State, Nigeria. The assessment focused on measuring ground resistance values to determine the performance and reliability of earthing systems critical for equipment protection and personnel safety using earth resistance tester. Findings revealed that the Hostel Building, Engineering Substation, and Mega Substation (serving transformers and feeders) demonstrated low resistance values, indicating efficient earthing performance. Conversely, the Administrative Building exhibited significantly high resistance, suggesting issues such as poor soil conductivity and inadequate grounding design. Additionally, lightning arresters across substations consistently showed elevated resistance levels, likely due to isolated grounding configurations for surge protection. Recommendations include enhancing the Administrative Building's earthing system through the addition of grounding rods, soil treatment, or complete redesign, inspecting lightning arrester grounds in the School of Agriculture and Mega Substations for improvements, and implementing routine testing and maintenance to ensure longterm system effectiveness. This evaluation underscores the importance of continuous monitoring and upgrades to maintain optimal grounding conditions in substation networks.

Keywords: Electrical Substation Networks, Earthing Resistance Tester, High Resistance, Low Resistance and Surge Protection.

1. INTRODUCTION

The earthing protection system in substations is a fundamental aspect of electrical safety, providing a vital mechanism for protecting both electrical installation equipment and personnel from possible electrical hazards. The primary role of earthing is to create a low-resistance path for fault currents to safely dissipate into the earth, preventing damage to equipment, ensuring system stability, and safeguarding human life. Power substations are the central hubs for electrical distribution, the effectiveness of their earthing system is critical for the uninterrupted and safe operation of power grids (Ibrahim et al. 2023) [1].

In recent years, the growing complexity of modern power systems, driven by technological advancements and the integration of renewable energy sources, has placed new demands on earthing protection systems. As power grids become more dynamic, with fluctuating loads and the incorporation of decentralized energy generation, traditional earthing designs may no longer provide the desired protection (Kumar et al.2022) [2]. Moreover, environmental factors such as soil resistivity, fault current magnitudes, and seasonal variations can significantly impact the performance of earthing systems (Bhardwaj et al.2021) [3]. Therefore, the evaluation and maintenance of these systems have become increasingly important. (Ghosh et al. 2024) [4]. Evaluation of earthing protection systems involves the systematic assessment of ground resistance, fault current paths, the integrity of earthing electrodes, and the overall reliability of the grounding system (Chatterjee et al. 2023) [5]. Several methodologies, including field measurements, computer simulations, and advanced monitoring techniques, are now employed to assess the performance of earthing systems under various operational conditions (Kumar et al.2022) [2]. Furthermore, the integration of new technologies like smart sensors and real-time monitoring tools has provided a more comprehensive understanding of earthing system behavior, enabling proactive maintenance and timely fault detection (Ibrahim et al. 2023) [1].

An effective earthing protection system is a critical component in the electrical power substations, ensuring the safety of equipment, personnel, and the overall power network. In higher education institutions, where substations support extensive research and academic activities, a well-designed earthing system minimizes electrical faults, mitigates transient over voltages, and enhances power system stability (Kumar et al.2022) [2]. Poor earthing system can lead to equipment damage, operational disruptions, increased safety hazards, underscoring the need for rigorous evaluation and optimization of grounding techniques (Chen et al.2022) [6].

The performance of an earthing protection system is influenced by factors such as soil resistivity, grounding electrode configuration, and fault current dissipation capability (Ali et al., 2023) [7]. Traditional grounding methods, such as rod and grid systems, have evolved with advancements in material science and computational modeling, improving system efficiency and reliability. However, higher education institutions present unique challenges, including space limitations, aging infrastructure, and diverse electrical loads, necessitating customized grounding solutions (Rahman et al., 2023)[8].

This study evaluates the earthing protection system of various distribution substations in Federal Polytechnic, Ile-Oluji Ondo State, Nigeria using earth resistance megger to detect which substation has the strongest and weakest earthing system.

Federal Polytechnic Ile-Oluji (FEDPOLEL), selected as the case study, was founded in 2014 and commenced operations on April 1, 2015. In 2019, the institution relocated to its permanent site, spanning 152.669 hectares along the Ipetu-Ijesa Expressway in Ile-Oluji, Ondo State, Nigeria. Currently, FEDPOLEL runs three academic schools: The School of Engineering and Architecture, the School of Applied Science, and the School of Business and Management, each housed in multiple buildings. The institution was recently integrated into the national grid via the Ile-Oluji

33 kV feeder and operates seven distribution substations across the campus.

1.1. Earth Resistance Megger

Earth Resistance Megger also known as Ground Resistance Tester, is a device used to measure the resistance of the earth or ground. It is commonly used to verify the integrity of earthing systems, measure the resistance of earth electrodes (e.g. grounding rods) and test the effectiveness of grounding systems in electrical installation. It typically consists of a current generator, a voltage meter and a set of test leads and probes.

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Figure 1: Earth Resistance Megger

1.2. FEDPOLEL Electricity Supply Infrastructure

FEDPOLEL is connected to Ile-Oluji 33kV feeder network from Ondo 132/33kV Transmission Station. A 7.5MVA 33/11kV transformer was installed in the power house of the institution to radiate out 11kV lines to feed various distribution transformer substations within the campus.

2. METHODOLOGY

2.1 Preliminary Information

A permission for access letter was written to the Management of Federal Polytechnic Ile-Oluji to grant full access to the substations within the school campus. The school's six distribution substations are connected to a 33/11 kV injection substation. Initially, a general physical inspection of the substations' equipment was conducted to verify that all facilities were properly installed and grounded before performing the earth resistance test. Subsequently, the earth resistance for each substation was measured using an Earth Resistance Megger, and the results were recorded.

2.2 Methods to Measure Earth Resistance

There are several methods to measure earth (ground) resistance, each suited for different applications and conditions. The most common methods are:

2.2.1 Fall-of-Potential Method (Three-Point Method)

The method uses a three-terminal ground resistance tester, where one probe (current electrode) is placed at a known distance from the ground electrode under test, a second probe (potential electrode) is positioned between them, and the tester applies current and measures the voltage drop to calculate resistance. This makes it ideal for accurate measurement of large grounding systems.

2.2.2. Clamp-On Method

This method uses a clamp meter placed around a ground conductor to induce a signal and measure the response for determining resistance, requiring no auxiliary electrodes and making it ideal for measuring resistance in active systems without disconnecting the ground.

2.2.3 Wenner Four-Pin Method (Soil Resistivity Test)

In this method, four equally spaced electrodes are inserted into the soil, with current passed through the outer electrodes and voltage measured between the inner ones, effectively determining soil resistivity and making it ideal for evaluating soil conditions prior to designing and installing a grounding system.

2.2.4. Schlumberger Method

This method, similar to the Wenner method but allowing variable electrode spacing, is more efficient for deep soil resistivity measurements and is best suited for assessing ground resistance over large areas.

2.2.5. Two-Point Method

This method involves a simple continuity test between the ground electrode and a known ground point, though it is less accurate due to the inclusion of test lead and connection resistance, making it best suited for quick checks where high precision is not essential.

Each method is chosen based on site conditions, required accuracy, and available equipment. For this research work, the fall-of-potential method (three-point method) was used.

2.3 Procedure for the Fall-of-Potential Method (Three-Point Method) to Measure Earth Resistance

The Fall-of-Potential method is a widely used technique for accurately measuring earth resistance. This method required the use of ground resistance tester (Earth Tester), two auxiliary electrodes (probes) and connecting leads.

2.3.1 Step-by-Step Procedure:

First, the equipment is set up the by disconnecting the grounding electrode (earth rod) from the system to avoid interference, and place the ground resistance tester close to the electrode being tested. Next, position the electrodes by driving the first auxiliary electrode (Current Electrode, C) into the ground at a distance of about 30–50 meters from the grounding electrode under test (E), and then drive the second auxiliary electrode (Potential Electrode, P) into the ground approximately halfway between the grounding electrode (E) and the current electrode (C). Then the tester is connected by attaching the grounding electrode (E) to the Earth Tester's designated terminal, the potential electrode (P) to the voltage measuring terminal, and the current electrode (C) to the current injection terminal.

The test was performed by switching on the ground resistance tester, a known current through the current electrode (C) was injected into the earth, and allow the tester to measure the voltage drop between the grounding electrode (E) and the potential electrode (P); the earth resistance was then calculated automatically using Ohm's Law ($R = V/I$).

To verify the readings, the potential electrode (P) was slightly move forward and backward; the test was repeated at any significant variation, by repositioning the electrodes. Once a stable reading is achieved, the earth resistance value was recorded, and the test was repeated at different distances to confirm accuracy.

Results were interpreted: a low resistance value (typically less than 5 ohms) indicates an effective grounding system, while high resistance suggests the need for improvement, such as adding more rods, applying chemical treatments, or enhancing soil conditions.

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3. RESULT AND DISCUSSION

Table 3.1: Transformer earthing, outgoing feeder panel and lightning arrester earthing values

S/N	Name of Substation	Type of Test	Earthing Readings at Different Distances (Ω)		
			20m	30m	40m
1	Main Power 7.5MVA 33/11kV Substation	Transformer **(Ω)**	3.76	3.00	2.82
		Outgoing Feeder **(Ω)**	3.80	3.00	2.82
		Lightning Arrester (Ω)	3.86	3.25	2.90
2	Engineering 500kVA 11/0.415kV Substation	Transformer **(Ω)**	3.15	2.95	2.76
		Outgoing Feeder **(Ω)**	3.15	2.95	2.76
		Lightning Arrester (Ω)	3.32	3.13	2.94
3	School of Agriculture Technology 500kVA 11/0.415kV Substation	Transformer **(Ω)**	3.20	3.05	2.90
		Outgoing Feeder **(Ω)**	3.20	3.05	2.90
		Lightning Arrester (Ω)	3.85	3.65	3.50
4	Administrative Building 300kVA 11/0.415kV Substation	Transformer **(Ω)**	17.5	15.5	13.5
		Outgoing Feeder **(Ω)**	17.5	15.5	13.5
		Lightning Arrester (Ω)	22.0	20.0	18.0
5	Hostel Building 500kVA 11/0.415kV Substation	Transformer **(Ω)**	2.85	2.65	2.45
		Outgoing Feeder **(Ω)**	2.85	2.65	2.45
		Lightning Arrester (Ω)	3.60	3.40	3.20
6	Mega 500kVA 33/0.415kV Substation	Transformer **(Ω)**	3.53	3.35	3.15
		Outgoing Feeder **(Ω)**	3.53	3.35	3.15
		Lightning Arrester (Ω)	4.63	4.45	4.25

3.1 Result Analysis

From the readings in the Table 3.1, it can be deduced that earthing resistance decreases with distance in all cases, which is expected since increasing the distance allows the grounding system to cover a wider area, thereby improving fault current dissipation and reducing resistance. Additionally, lightning arresters consistently exhibit higher resistance than transformers and outgoing feeders across all substations. Most substations also display similar resistance values between transformers and outgoing feeders, indicating that these components likely share or are closely linked to the same grounding system.

3.2 Substation-by-Substation Analysis 3.2.1 Main Power 7.5MVA Substation

In this substation, the transformer and outgoing feeder exhibit identical resistance values at 30 meters and 40 meters, suggesting a likely shared grounding point. The lightning arrester shows slightly higher resistance, which is expected due to its separate grounding path. Overall, the measurements fall within acceptable limits for a high-capacity substation.

3.2.2 Engineering 500kVA Substation

All the three components show very close resistance values, indicating a well-designed and consistent earthing system. Slightly higher values for lightning arrester, but still acceptable.

3.2.3. School of Agriculture Technology 500kVA Substation

Transformer and feeder are identical across all distances, lightning arrester has significantly higher resistance (3.85Ω at 20m), indicating possible issues with its earthing or a more isolated installation.

3.2.4 Administrative Building 300kVA Substation

Extremely high resistance values (e.g., 17.5Ω for transformer at 20m, 22.0Ω for LA), which is far above the recommended values (typically <5Ω). This indicates poor grounding, which may pose serious safety and operational issues, this substation needs urgent earthing improvements.

3.2.5 Hostel Building 500kVA Substation

Very good and consistent resistance values (2.85Ω to 2.45Ω), indicating a highly effective earthing system, the lightning arrester is slightly higher but still within acceptable range.

3.2.6 Mega 500kVA 33/0.415kV Substation

This exhibits consistent values for transformer and feeder, indicating good earthing, the lightning arrester resistance is noticeably higher (up to 4.63Ω), which could be improved slightly but is still within tolerable limits.

Comparative insights reveal that the Hostel Building, Engineering Substation, and Mega Substation (for transformer and feeder) exhibit low resistance and are the best performing, while the Administrative Building is problematic with consistently high resistance. This indicates poor soil conductivity or inadequate electrode systems, or and a general trend shows that lightning arresters tend to have higher resistance, likely due to separate grounding for surge protection.

Table 3.2: Performance Summary

S/N	Substation	Earthing Quality	Comments
1	Main Power	Good	Acceptable readings
2	Engineering	Very Good	Consistent values
3	School of Agriculture Tech	Good	Slightly high arrester
4	Administrative Building	Poor	Critically high resistance
5	Hostel	Excellent	Optimal earthing
6	Mega	Good	Lightning arrester could be improved

4. CONCLUSION& RECOMMENDATION

4.1 Conclusion

The assessment of the earthing protection system at the Federal Polytechnic Ile-Oluji reveals that while foundational earthing infrastructures are in place, several critical areas require attention to ensure optimal safety and system reliability. The presence of potential corrosion of earthing conductors and the absence of routine maintenance schedules contribute to suboptimal earthing resistance values. Such conditions can compromise the effectiveness of fault current dissipation, increasing the risk of equipment damage and safety hazards to personnel. Moreover, environmental factors, such as soil resistivity variations and seasonal moisture changes, further impact the performance of the earthing system. To uphold the safety standards and ensure the longevity of electrical installations, it is imperative to address these challenges through systematic interventions. To enhance overall grounding performance, the Administrative Building's earthing system should be improved by adding more grounding rods, enhancing soil treatment (e.g., with bentonite or salt), or redesigning the system; lightning arrester grounds at the School of Agriculture and Mega Substations should be inspected for potential resistance improvements; and routine maintenance and testing should be conducted periodically to ensure the continued effectiveness of all grounding systems.

4.2 Recommendation

Based on the evaluation of the earthing protection system at the Federal Polytechnic Ile-Oluji, it is recommended to undertake a comprehensive audit of the existing earthing infrastructure to identify and address any signs of degradation, corrosion, or non-compliance with current standards. Upgrading the system with corrosion-resistant materials, such as copper-bonded rods or galvanized steel, can enhance durability and conductivity. Implementing a routine maintenance schedule is crucial; this should include periodic earth resistance testing to ensure values remain within safe limits, visual inspections for physical damage or loose connections, and cleaning of earthing pits to prevent debris accumulation. Maintaining detailed records of all inspections and maintenance activities will aid in tracking system performance over time and ensuring compliance with safety regulations. Engaging qualified professionals for these tasks will ensure that the earthing system provides reliable protection against electrical faults, thereby safeguarding both equipment and personnel.

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