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Improved Lightning Protection for Low Voltage Power System using Equipotential Bonding Technique

UKWUEZE, Samuel Chukwuma; D.C. Idoniboyeobu; S.L. Braide

ABSTRACT: *This research significantly analyzed the improved lightning protection for low voltage power system using equipotential bonding technique. The aim of the research is to improve the lightning protection for low voltage power systems in order to address some common power supply problems such as: voltage surges/spikes, voltage dips, under voltages, short circuits, equipment failures and abnormal conditions. The objectives of the study is to install capacitor banks with power factor to improve the existing case study and simulate the existing network in Electrical Transient Analyzer Program (ETAP version 12.6) software environment using Gauss-Seidel Load flow technique. The outcome of the findings shows that the distribution losses make major contribution to the system losses being major share of the system losses special attention for achieving remarkable reduction in loss figure. Bus 2 has the highest losses of 18.17%, it should be considered because this occurs as a result of poor power factor due to reactive current flowing in the system. It is recommended that the capacitor banks should be installed at the service entrance, if the load conditions and transformer size permit. Bus 1 has the highest fault current of 50 A, therefore it should be considered in order to minimize the fault level, since fault condition occurs when one or more electrical conductors short to each other or to ground. It is highly recommended that regular testing and maintenance of lightning protection systems (external and internal lightning protection) is required and the compliance with standards requirements such as separation distances, grounding systems and the suitable selection for installation of Surge Protective Devices (SPDs) should be considered.*

KEYWORDS: *Lightning Protection system, Equipotential Bonding Technique, Power factor, capacitor bank*

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I. INTRODUCTION:

The lightning protection system (LPS)is the complete system used to reduce physical damage due to lightning flashes to the structure and lightning caused surges on power and data lines. The external LPS is intended to intercept direct lightning flashes to the structure and conduct the lightning current from the point of strike to ground and to disperse this current into the earth without causing thermal or mechanical damage, nor dangerous sparking which may trigger fire or explosions. When the thermal and explosive effects at the point of strike, or on the conductors carrying the lightning current, may cause damage to the structure or its contents, the external LPS should be considered.

The evolving nature of power systems and the potential benefits of wide-area protection also apply to distribution system protection. The connection of energy storage, electric vehicles, smart meters, demand-side participation, and the connection of distributed generation are among the challenges faced by distribution networks (DG).Furthermore, these changes must take place against the backdrop of an aging asset base and a growing total load. The increased connection of DG is a particularly significant change, as it has resulted in distribution networks, which have improved the performance of power system protection using wide-area monitoring systems, which have undergone a radical transformation from single-source, radial systems to more complex multi-source systems. Reverse power flows and the contribution of DG to fault currents have been introduced as a result, posing several threats to distribution system protection.

The nature of the threat varies depending on the fault, relay, and DG's relative positions, but it can include false tripping and a loss of sensitivity or selectivity (Allen, 2009). Furthermore, high fault levels at the distribution level may allow fault currents to exceed the limits of the available protection.

The purpose of power system protection is to disconnect faulty/overloaded elements to protect the element from damage, prevent the fault from compromising security, and protect the surrounding area from serious harm (Kanashiro et al., 2004).

This equipment protection is primarily provided by breaker operations, which can be divided into primary and backup equipment protection. By isolating the protected equipment from the rest of the system, primary protection prevents equipment damage. It's very selective and only runs for 3/4 of a cycle. To avoid any failure to clear the fault, the relays used to deliver primary control are usually duplicated one or more times. Backup protection is in charge of clearing any faults that the primary protection hasn't been able to resolve. As a result, it is less selective and operates more slowly than primary protection to ensure proper coordination. Backup protection is more difficult to configure because it protects a larger portion of the system and is, therefore, more reliant on the system's operational state.

Statement of the Problem

An electrical device may malfunction, fail prematurely, or not operate at all if the power system is not properly protected. There are numerous ways in which electric power can be of poor quality, as well as numerous causes for such poor quality power. Some of the most common power supply issues, as well as their potential impact on sensitive equipment in the power system, have resulted in: (i. Voltage surges and spikes.(ii. The power system's voltage dips. (iii. Under voltages. (iv. Short circuits. (v. Equipment failures. (vi. Unusual power system conditions.

Extent of Past Work

. The Authority was also split into four separate divisions: Generation and Transmission, Distribution and Sales, Engineering, and Finance and Administration. An Executive Director was in charge of each division (Oseni, 2011). The Federal Government of Nigeria (FGN) has taken more steps to restructure the Nigerian power sector to create an efficient, reliable, and cost-effective electricity supply across the country that will attract private investment. The major mechanisms by which over-voltages are caused by lightning in both medium and low-voltage overhead power distribution networks, as well as typical surge waveforms, are presented in this research paper. The effectiveness of the most common protective measures for improving line lightning performance is also discussed (Piantini et al., 2004). This research paper presents some typical overvoltage's and discusses the effects of various protection options on reducing the number of line flashovers, with a focus on the use of shield wires and surge arresters (Silva et al., 2003).

Although direct line strikes cause much more severe overvoltages, those caused by nearby lightning occur more frequently and are usually responsible for a higher number of line flashovers and supply interruptions on systems with rated voltages of 15 kV or less. Because of the effects of lightning-induced overvoltages on distribution system performance and power quality, several theoretical and experimental studies have been conducted to better understand their characteristics and evaluate the effectiveness of mitigation methods (Rakov&Uman, 2003). Unless a shield wire earthed at every pole with low earth resistance is used, or surge arresters are installed at very short intervals on all phases, the number of faults caused by direct strokes will remain virtually unchanged. In an area with a ground flash density of 1/(km2 year), a 10 m high distribution line located in open ground collects on average 11 flashes per 100 km. year (Asaoka et al., 2003).

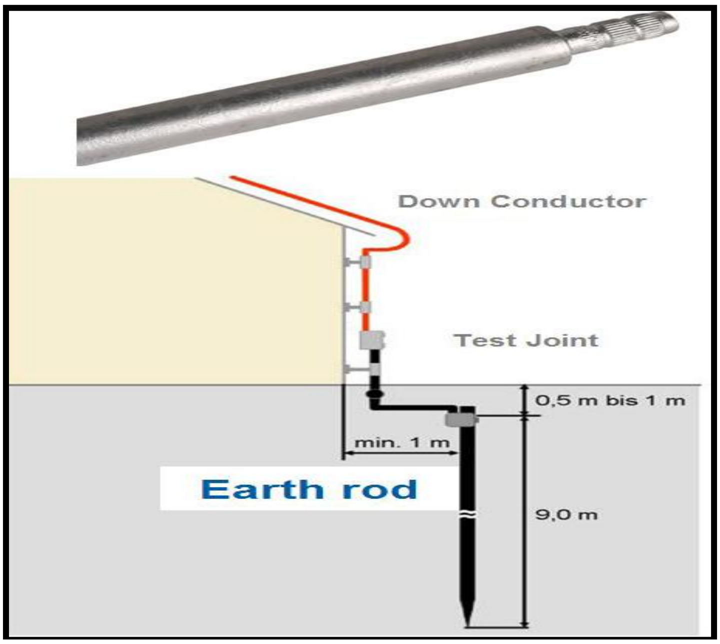
A. Earthing Electrodes

The conducting elements used to connect electrical systems and/or equipment to the earth are known as earthing electrodes. The earthing electrodes are buried in the soil to keep electrical equipment connected to the earth's potential and to dissipate currents. Earthing electrodes include earthing rods, metal plates, conductors in concrete, earthing ring conductors, electrolytic earthing rods, and the metal frame of buildings, as well as foundation earth electrodes (Nucci &Rachidi, 2003).

B. Minimum Site Earthing Requirements

Because the earthing system serves multiple functions in a structure (for example, signal reference ground and lightning protection), the request for a minimum earthing resistance could be for a variety of reasons. The absolute value of the earthing system resistance is less important for lightning and overvoltage protection than ensuring that all equipment and conducting services are connected to a more or less equal potential plane (equipotential bonding is a must).

A mesh of earth conductors with a mesh size of about 5 m x 5 m, which includes towers, objects, and equipment vaults, is suitable for limiting potential differences between installations and at the surface (risk of step-voltage) to acceptable levels.



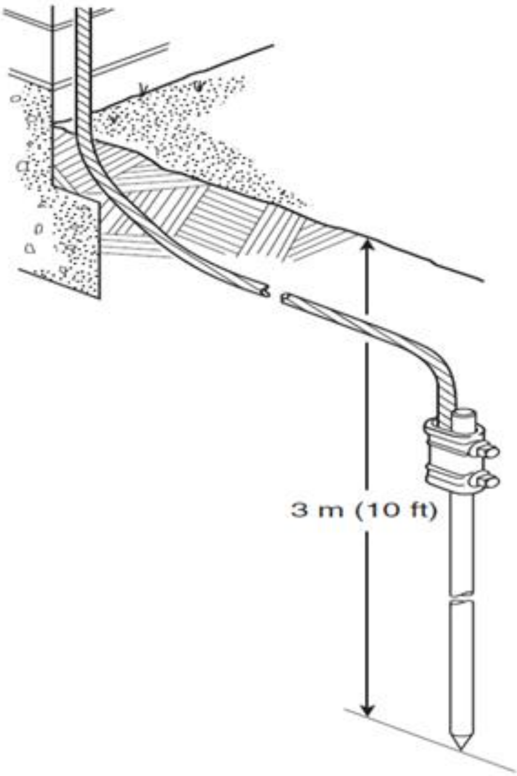


Figure 1: Typical earth electrodes and their installation

The requirements for earthing electrodes are:
The material and dimensions used for earth electrodes should conform to the materials required for earthing electrodes. The requirements for earthing electrodes are:

- The material and dimensions used for earth electrodes should conform to the materials.
- The behavior of the metal in terms of corrosion in the soil and the presence of dissimilar metals should always be considered.
- The vertical earth electrodes shall have a minimum length of 3 m. The actual diameter, length, and several rods required may vary with site dimensions and/or as determined by an engineering study based on the soil resistivity profile of the site.

- Where multiple connected earth electrodes are used, the separation between any two electrodes shall be at least the sum of their driven depths (where practicable).
- The method of bonding earthing conductors to earth electrodes shall be compatible with the types of metals being bonded.
- Earth electrodes shall be free of paint or other nonconductive coatings.
- Where applicable, the earth electrodes shall be buried below the permanent moisture level.
- Earth electrodes shall be buried to a minimum depth of 0.8 m below finished grade, where possible, or buried below the freeze line, whichever depth is larger.
- Earth electrodes that cannot be driven straight down, due to contact with rock formations, maybe driven at an oblique angle of not greater than 45 degrees (Nucci et al., 2005).

C. Equipotential Bonding

Lightning strikes can cause dangerous potential differences inside and outside of a building or structure. The occurrence of potential differences between the conductors of the lightning protection system and other grounded metal bodies and wires belonging to the building is a major concern in the protection of a building/structure. Resistive and inductive effects cause these potential differences, which can result in dangerous sparking or electronic equipment damage. (Galván et al., 2001)

D. Bonding to the Earth Termination System

To eliminate or reduce potential differences between various installations, equipotential bonding is required. Bonding, for example, prevents dangerous touch voltages between the protective conductor of low-voltage electrical power consumer installations and metal, water, gas, and heating pipes.

The equipotential bonding consists of a main equipotential bonding bar (MBB) to which the following extraneous conductive parts must be connected directly;

- the main equipotential bonding conductor
- foundation earth electrodes or lightning protection earth electrodes
- conductive parts of the building structure (e.g. lift rails, steel skeleton, ventilation, and air conditioning ducting)
- metal drain pipes
- internal gas pipes
- earthing conductor for antennas
- earthing conductor for telecommunication systems
- protective conductors of the electrical installation (PEN conductor for TN systems and PE conductors for TT systems or IT systems)
- metal shields of electrical and electronic conductors
- metal cable sheaths of high-voltage current cables up to 1000 V

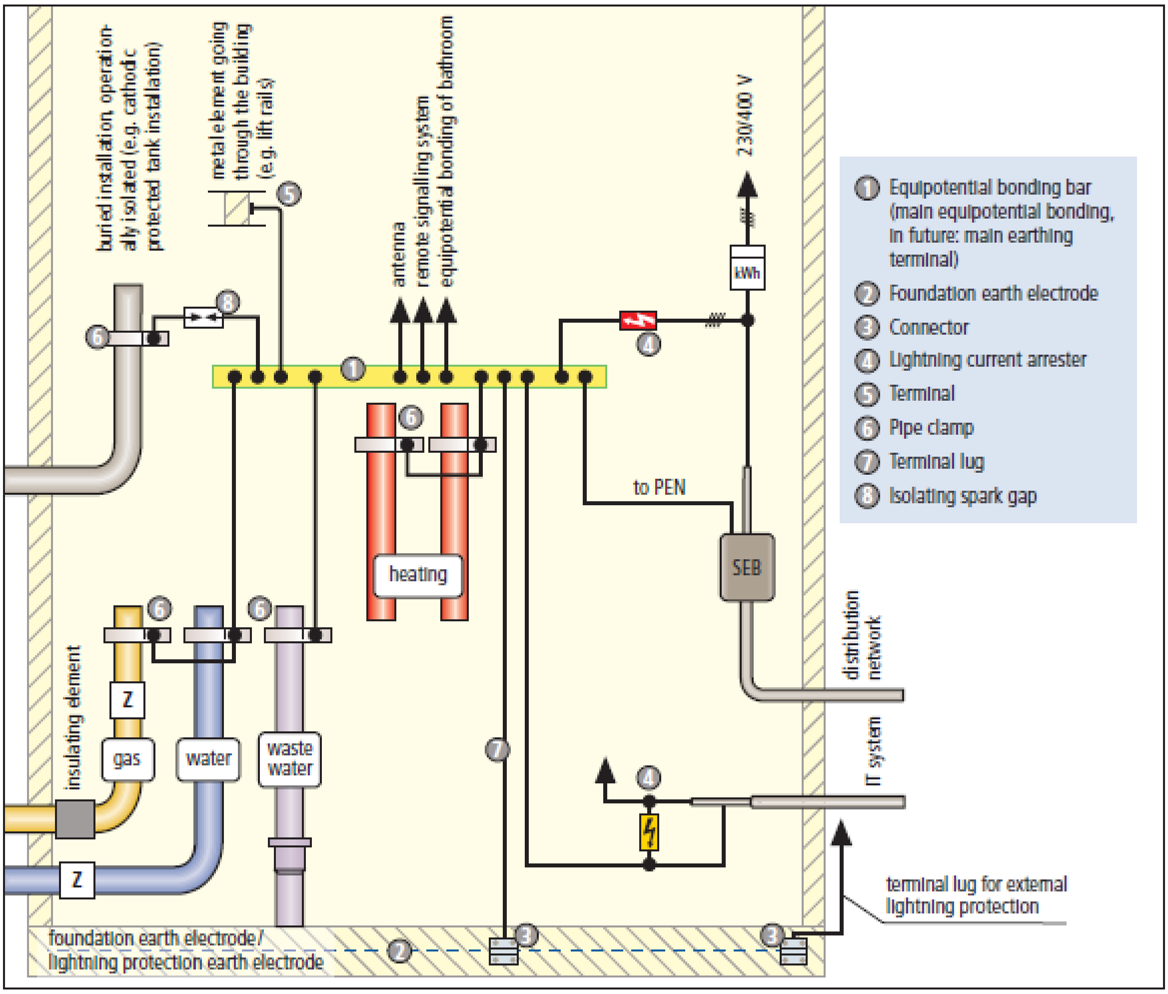


Figure 2: Principle of lightning equipotential bonding consisting of lightning and main equipotential

Figure 2 depicts various types of equipotential bonding bars and their installation. If a direct connection to the bonding bar is not possible, the installation components must be integrated indirectly via isolating spark gaps into the main equipotential bonding (e.g. measuring earth in laboratories, if they have to be separate from the protective conductors). The spark gap will keep the circuits insulated during normal operation, and it will provide short-term interconnection when lightning strikes.

Connections for lightning equipotential bonding must be as direct and straight as possible. Lightning equipotential bonding for external conductive parts should be established as close as possible to the point of entry into the structure to be protected.

Plate 1: Lightning equipotential bonding connections with external conductive parts

Plate 2: Examples of practical design and installation of equipotential bonding bars

II. MATERIALS AND METHOD

A. Materials Used

The distribution data were collected from the Total E& P in Port Harcourt.

I. The power supply network, (the line diagram) showing the power supply from the 132kv transmission line Port Harcourt main's to 33KV distribution line were collected for purpose of analysis and investigation of this study.

II. A load of this system receives a voltage of 415V and the type of load is lump load. The conductor size for 33kV is 50 mm^2 and 95 mm^2 respectively.

III. Aluminum-conductor Steel-reinforced (ACSR) cable is used for incoming and outgoing feeders.

IV. Compensation of capacitor Bank with power factor correction.

V. The distribution system is a radial distribution system and reliability assessment mode in Electrical Transient Analyzer Program (ETAP version 12.6) software is adopted.

B. Method Used

The application load flow analysis and Electrical Transient Analyzer Program (ETAP version 12.6) software for simulation are used due to the complexities of power system analysis and the Improved Lightning Protection for Total E & P Low Voltage Power System in Port Harcourt interface problems.

Equipotential bonding, also known as bonding, is a critical step in minimizing the risk of equipment damage and personal injury. Bonding is the process of joining all metalwork and conductive items that are or may be earthed together so that they are all at the same potential (voltage a component fails, all circuits and conductors in a bonded area will have the same electrical potential, preventing an occupant from touching two objects with significant potential differences. Even if the occupant's connection to distant earth ground is lost, the occupant will be protected from dangerous potential differences that could result in electric shock injury or death.

An important component of a lightning protection system is the earthing system. The main components of a building's structure are usually reinforcing bars, steel frames, and deck slabs. These parts can also be combined to create a low-impedance grounding system.

C. Evaluation and Analysis of the Existing Substation

The Injection of Distribution the Total E & P Low Voltage Power System in Port Harcourt feeds the substations in this study. The substation is served by a 132 kV transmission line. The city's distribution system has a primary voltage of 33 kV and a secondary voltage of 11 kV. The voltages are then stepped down to 415 volts and 220 volts, respectively, to meet the needs of the customer.

The parallel single bus bar system is the bus bar scheme or bus bar layout. The single bus bar scheme has only one three-phase but connects all of the incoming and outgoing circuits. It is not recommended for major substations because it lacks operational flexibility and requires the entire bus to be de-energized in the event of a bus fault or CB failure, but it is low cost, simple to operate, and requires simple protection. The single-line network diagram of the Total E & P Low Voltage Power System in Port Harcourt is shown in Figure 3

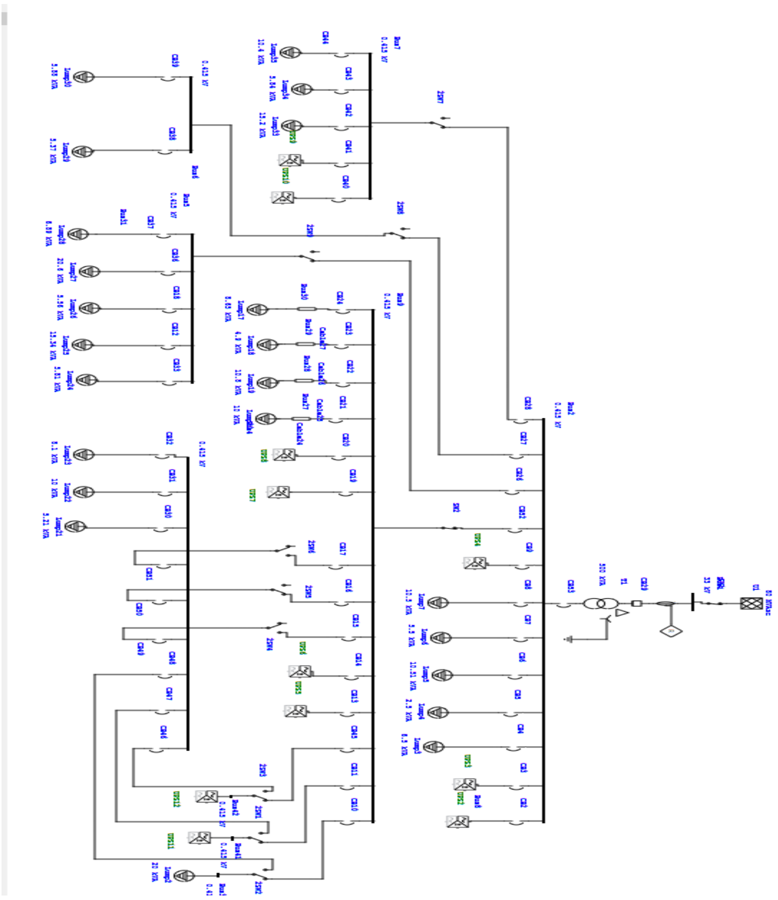


Figure 3 Single Line Diagram for Total E & P in Port Harcourt

VI. RESULTS AND DISCUSSIONS

This work examines how the research aimed at improving lightning protection for Low Voltage power systems for Total E & P Port Harcourt using equipotential bonding technique was examined for investigation. At a few substations, power distribution issues arising from both the customer and the electric utility side were investigated.

Similarly, the existing distribution network system's accessibility and evaluation were investigated. Furthermore, using various methods to address the problem of lightning protection of low voltage power systems, the following solutions were determined: nominal discharge current, calculating maximum continuous operating voltage (MCOV or UC), calculating line to ground voltage, the maximum continuous line to ground voltage, minimum protection conductor cross-sectional area, compensation of static cabling.

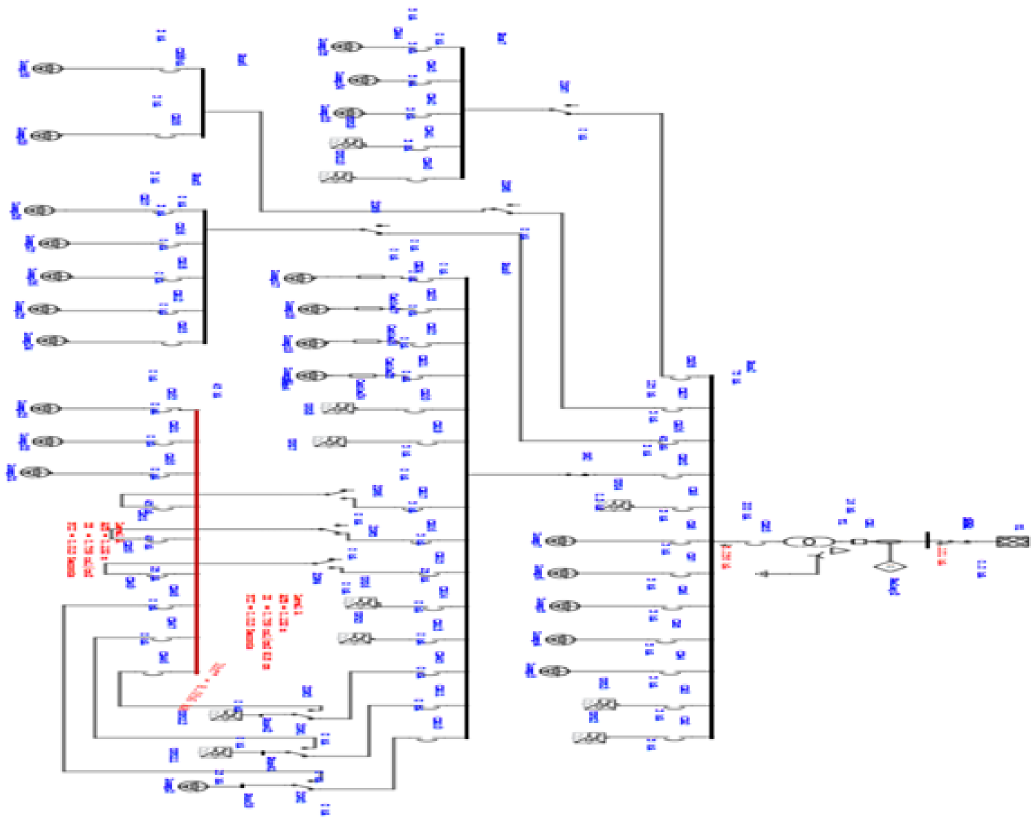


Figure 4.: Existing Study Case (Simulated) of Total E & P in Port Harcourt

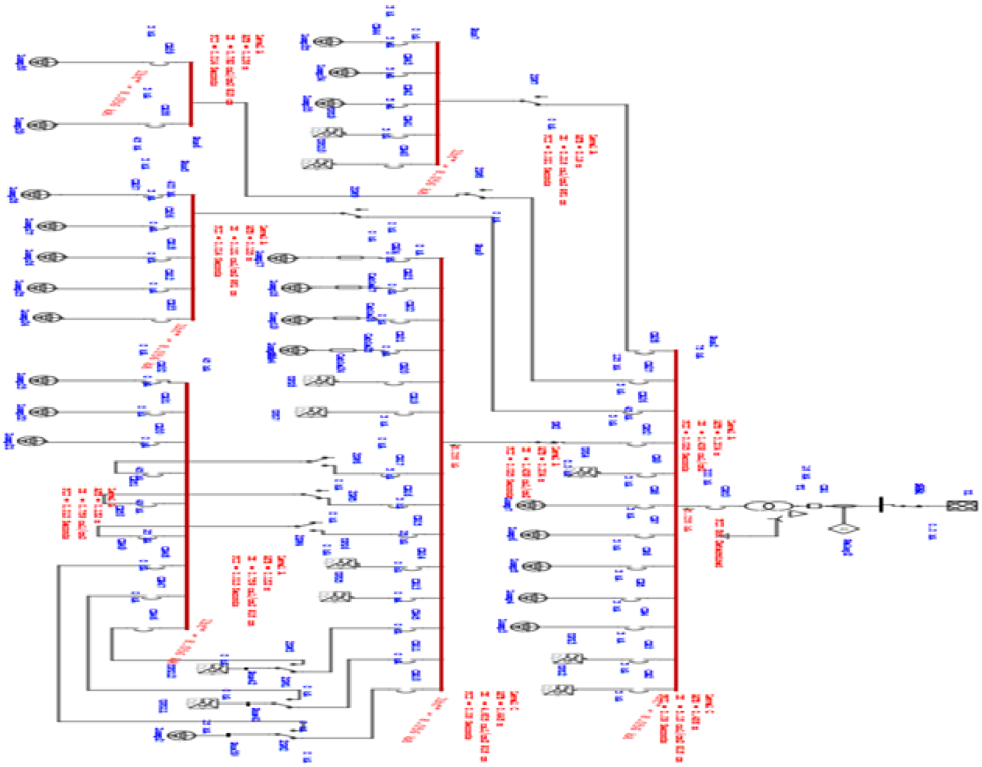


Figure 5: Existing Study Case (Simulated with fault current) of Total E & P in Port Harcourt

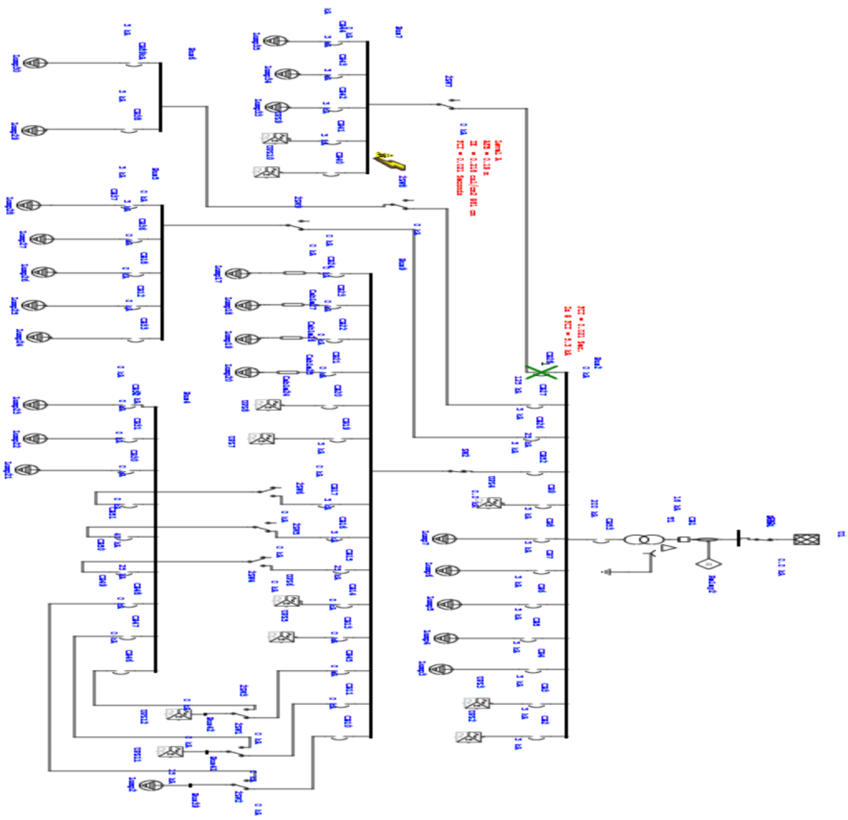


Figure 6: Existing Study Case (Simulated without fault current) of Total E & P in Port Harcourt

Analytical formulation, data processing, interpretation of tables and bar chart of the case study
All the tables and figures listed below revealed the formulation, data processing, interpretation of tables and bar chart of the case study.

Table 1: Existing and Improved Power factor versus Bus Location

BUS ID	Existing (% power factor)	Improved (% power factor)
Bus 1	82.3	90.2
Bus 2	82.5	91.2
Bus 3	85.5	90.4
Bus 4	85.4	90.2
Bus 5	82.5	90.1
Bus 6	83.5	90.4
Bus 7	82.7	89.5
Bus 8	85.3	90.2
Bus 9	85.2	91.5
Bus 10	83.8	90.5
Bus 11	85.2	91.5
Bus 12	83.5	90.6
Bus 13	84.9	90.5
Bus 14	85.2	92.4
Bus 15	83.9	90.6
Bus 16	84.9	90.2
Bus 17	85.5	92.1
Bus 18	85.6	92.7
Bus 19	85.2	92.2
Bus 20	85.3	92.8
Bus 21	85.6	92.1
Bus 22	85.2	90.1
Bus 23	85.4	91.0
Bus 24	84.5	90.1
Bus 25	85.2	91.0
Bus 26	85.4	90.8
Bus 27	85.3	92.3
Bus 28	83.4	90.5
Bus 29	85.2	90.3
Bus 30	85.1	91.0
Bus 31	85.4	90.4
Bus 32	84.4	90.5
Bus 33	83.9	90.0

The above table shows the variation of the Bus ID with the existing and improved power factor.

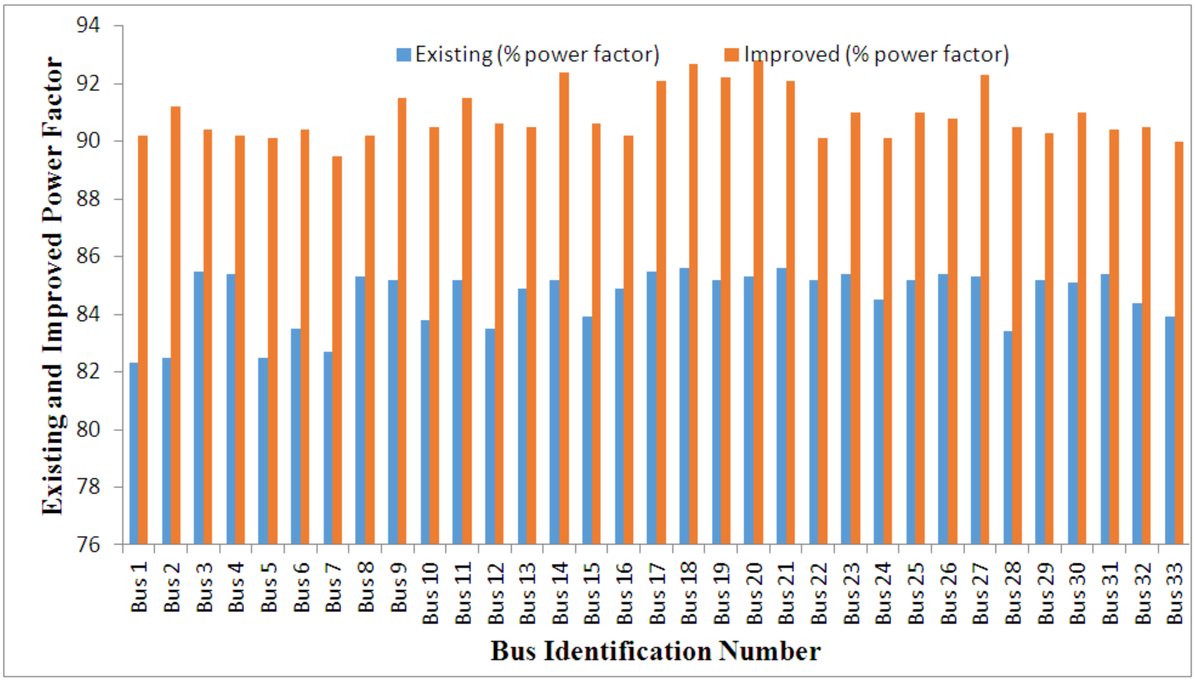


Figure 7: Existing and improved power factor concerning the variation of Bus Identification Number

Concerning the Bus ID, Figure 4.10 depicts the relationship between the existing and improved power factor. The results show that the power factor was improved from 0.85 to 0.91.

Figure 7 depicts the results of the current and improved power factor for each bus location. The existing power factor ranges from 0.82 to 0.85, while the improved power factor ranges from 0.90 to 0.92, according to our findings. As a result of the power factor correction, the problem of low voltage caused by excessive current draw causes the electrical system to be sluggish and overheated can be solved. Total line current increases as power factor decrease, causing a further voltage drop.

VII. DISCUSSION OF RESULTS

The apparent power, required capacitor, and percent reduction in losses are shown in Figure 1-7. The effect of changing Bus ID with maximum peak current, nominal system phase to phase, and maximum continuous operating voltage on the maximum value of the power system's loading parameter is shown in Table 1 The distribution losses, which account for a significant portion of the system losses, require special attention to achieve significant reductions in loss figures. According to our findings, Bus 2 has the highest losses of 18.17 percent, which is due to a low power factor caused by the reactive current in the system, while Bus 4 has the lowest losses of 10.36 percent.

If the load conditions and transformer size allow, the capacitor banks can be installed at the service entrance. Some capacitors can be installed at individual motors if the amount of correction is too large. As a result, disconnect and overcurrent protection must be provided when capacitors are connected to the bus, feeder, motor control center, or switchboards. Bus 20 has the highest capacitor bank of 245.52 kVAR, while Bus 7 has the lowest capacitor bank of 32.42 kVAR, according to our findings. Including power capacitors in your new construction and expansion plans can help you save money by reducing the size of transformers, buses, switches, and other components.

VIII. CONCLUSION

This research significantly analyzed the improved lightning protection for low voltage power systems for Total E & P Port Harcourt using equipotential bonding technique was simulated and analyzed for the purpose of investigation. The outcome of maximum peak current, nominal system phase to phase, and maximum continuous operating voltage, fault current, fault current time, the existing and improved power factor and outcome of apparent power, required capacitor, and reducing of losses were determined.

The data collected from Total E & P Port Harcourt were implemented in the existing case study, installation of capacitor banks with power factor to improve the existing case study and to model and simulate the existing network in Electrical Transient Analyzer Program (ETAP version 12.6) software environment using Gauss-Seidel Load flow technique.

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