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Energy Audit in BUA Cement Plant Okpella Edo State using ETAP and MATLAB Software for Improved Performance

Oche Abigel Emmanuel[1*], Jacob Mariekpen Evbogai Edekin[1], Henry Erialuode Amhenrior[1]

[1]Department of Electrical Engineering, Edo State University Uzairue, Edo State Nigeria.
Corresponding author: precious4oche@gmail.com

ABSTRACT

This research work depicts the study of Electrical energy audit analysis of a cement plant, using BUA cement plant Okpella line one as a case study. A survey of single line diagram distribution network of 11/0.415kv was analyzed using Electrical Transient Analyzer Program ETAP 12.6 and MATLAB Simulink/PSAT R2018a software, for modeling and simulation to perform a load flow analysis so as to provide optimal voltage profile for the purpose of optimizing energy efficiency, minimizing reactive losses, and to improve the Power Factor to a desired value. The sizes of the capacitor bank required to compensate the load reactive power was analyzed. The critical voltage Buses on the feeders were improved with placement of shunt capacitor using optimal placement capacitor tool in ETAP 12.6 and MATLAB Simulink/PSAT software. The application of ETAP and MATLAB Simulink/PSAT// software with the integration of shunt capacitor improved the real power and reactive power from 0.374476 p.u to 0.431572 p.u and 0.223837 p.u to 0.327201 p.u respectively. It is shown that there is a great reduction of power losses along the lines with the network compensation. This reduced the total amount of losses on the lines from (0.00276+ j0.00763) p.u to (0.0023+ j0.0035) p.u. The distribution system achieved an optimized power system that becomes reliable sustainable for production in BUA cement plant. The total optimal sizing capacitor bank with the capacitor of 909KVAR was used to compensate the entire network to improve the condition of the 11kv distribution network of BUA cement plant Okpella. The simulation results obtained gave a 0% violation on both Buses profile.

Keywords: MATLAB Simulink (PSAT), ETAP, Capacitor, BUA Cement, Reactive power, Real power, Power factor

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INTRODUCTION

Energy audit is a systematic process aimed at analyzing energy use within a facility, identifying opportunities for energy efficiency improvement and optimizing energy consumption patterns. It involves a detailed assessment of energy flow, equipment performance and operational practices to uncover distribution inefficiencies. Energy audit can be conducted by internal staff with expertise in energy management or by external energy consultant. The audit process typically involves data collection, analysis, recommendation for energy Efficiency measures and comprehensive report outlining findings and proposed action. Total energy audits serve as a fundamental tool for business and organization seeking to enhance operational efficiency, reducing energy cost and contribute to sustainable goals by optimizing energy use (Ruparathna et al., 2016).

Electrical energy audit is a systematic process of evaluating and analyzing the electrical energy consumption patterns, efficiency, and usage within a facility or plant. The primary goal of an electrical energy audit is to identify opportunities for improving energy efficiency, reducing energy consumption, and optimizing the use of electrical resources (Adewale et al., 2018).

Energy audits and preservation at a cement factory constitute a difficult method with a large number of different elements that Needs, to be evaluated, and analyzed in a systematic order to discover different method of energy Reduction, an important influence on the reduction in energy consumption as well as the cost of savings associated with energy in a cement plant. In addition, energy audit project in cement plant, as well as assessment techniques and analyses to bring forth relevant and significant possibilities for energy reduction. it simple for them to conduct an energy audit in a professional capacity at a plant as complicated as a cement mill. The use of energy by industries accounts for anywhere between thirty and seventy percent of the total energy utilized in some nations. The cement industry consumes a substantial quantity of energy in its daily operations. Therefore, whether on a local or global scale, there is a pressing need to devote a significant amount of attention to the reduction of environmental emissions associated with energy use. According to some estimates, this sector is responsible for around 15 percent of the world's overall energy use, because of the high amount of energy required, this sector of the industry frequently accounts for between fifty and sixty percent of total manufacturing costs The auditing of energy consumption in the BUA cement plant is the primary goal of this project. In order to accomplish this goal, we started by selecting all the substation and MCC blocks of a cement plant (MCC-1, MCC-2, MCC-3, MCC-4, MCC-5 and calculating the total load for each substation, as well as the energy consumption per day. Finally, we determined the energy without power factor correction and we made comparisons with the power factor adjustment with a view to achieve efficient distribution network of BUA Cement plant was carried out to ensure the availability of equipment in the plant.The research aim is to conduct an energy audit in BUA cement PLC plant Obu-Okpella, using ETAP 12.6 and MATLAB Simulink/PSAT R2018a for modeling and simulation in order to achieve: a power flow analysis to determine the buses voltages and power factor in the electrical network; to improve the voltages and the efficiency of the power system by using Optimal Capacity Placement tool (OCP); and to compare the simulated results of the ETAP software and MATLAB software.

Model description

The BUA Cement plant in Okpella, Edo state Nigeria, have challenges related to energy efficiency and power factor management. Despite significant advancement in industrial process, the plant encounters inefficiencies in power consumption and sub-optimal power factor levels these inefficiencies not only resulted to the increase in operational cost but also contributed to excessive energy consumption. Moreover, the existing methods for assessing energy usage and power factor optimization lack the precision and the real time monitoring capabilities required to efficiently address these challenges. Traditional energy audit methods may not fully capture the dynamic nature of the plants energy demand, while conventional power factor correction methods may fall short of achieving optimal performance. Therefore, there is a pressing need to carry out a comprehensive energy audit in BUA Cement plant, utilizing advance software tools such as ETAP and MATLAB Simulink/PSAT Software. This audit aims to analyze the plant energy consumption patterns, identify areas of inefficiency, and propose tailored solutions for power factor improvement. By integrating ETAP and MATLAB, Simulink/PSAT software for power system analysis and dynamic simulation to make comparisons. This research work seeks to provide a holistic approach to energy management and power factor optimization in BUA cement PLANT manufacturing process. The production process as seen in (Table 1) of cement manufacturing plants is typically energy-intensive and requires large amounts of resources (Xu & Fleiter, 2012). A typical well-equipped plant consumes about 4 GJ of energy to produce one ton of cement, while the cement production in the world is about 3.6 billion tons per year. It was estimated that the cement manufacturing process consumes around 7% of industrial energy consumption, which, in turn, accounts for 30–40% of the global energy consumption (Atnaca & Yumrutas, 2014).

Table 1: Cement production process

Raw material processing	Clinker production	Finished grinding
Crushing	Pre-heating	Final milling
Pre-blending	Heating	Cement storage in silos
Grinding raw material	Cooling	Packaging
Blending	Clinker storage in silo	??

Electricity accounts for 12% of the energy used in production. The total electricity consumption in the dry process between the raw material preparation and clinker production is 50%, then 42% for cement grinding, and the remaining for raw material extraction and packaging. Both relative shares in the energy mix can change in the nearest future due to modification of the process system (Cembureau the European Cement Association, 2020).

In many European countries, improvement effort was made to decrease power consumption by investing in new equipment and retrofitting existing ones, a cement plant, such as the BUA cement plant Okpella have over 1000 motors in operation such as medium voltage motors and low voltage motors which includes: Cement mill motors; Raw mill motors; ID fans motors; Crushers e.g. Hammer crusher, laterite crusher, jaw crusher, cone crusher etc; LV motors that are too numerous to count. Exampls, dampers, centrifugal fans purposes, motorized actuator; Kiln Motors; Cooler Motors and Drag Chain Motors.

Energy supply for economic activities has been a major challenge in Nigeria; it appears that reliable power supply is not yet realistic. Consequently, consumers, (industrial, residential and commercial) have all resorted to self-generation, to compliment the supply that comes from the unreliable national grid for example; the available power supply to the entire nation fluctuates between 3000MW and 3500MW. When the monthly power generation in Dangote cement plant for a typical year was carried out, the result was compared with the entire Nigeria grid system in 2013. The total energy generated by Dangote power plant was 406762.33 MWH, while the total energy consumed is 401903.72 MWH (Okoye et al., 2018). Dangote's total energy generation in that year represent 1.4% of Nigeria total generation from the grid. The difference between energy generated and energy consumed including line loss done, to inductive and capacitive reactance in transformers, motors and three phases. Parallel lines represent the total energy loss.

Distribution losses

Distribution losses can be minimized by the addition of capacitors and the resulting increase in power factor. These losses given by $P = 1^2 R$ are the summation of all the losses in the transformer, cables and motors etc. This reduction is the resultant effect in the decrease in current in the distribution network.

Methods of improving power loss in a distribution system

In distribution network, efficient voltage control methods can improve the systems voltage profile, reduce losses and improve the voltage regulation of the network. These methods include:

i. Activating voltage regulating equipment at the substations bus using capacitors.
ii. Balancing of loads on primary feeders,
iii. Increased size of feeder conductor,
iv. Transferring loads to new feeders,
v. Installing new substations and primary feeders,
vi. Installing shunt capacitors or SVCs on primary feeders.

The capacitor banks for voltage improvement are usually located at the same buses for both peak and off peak periods, the need for automatic switching of capacitor bank, is to avoid injecting too much of reactive power, when the load on the network buses drops. This is part of the concepts that brings about the smartness of the grid, i.e. the ability of the grid to automatically adjust itself in order to ensure voltages at the consumer end stays within acceptable limits under all load conditions.

Power factor

Electrical power is usually generated and distributed over transmission lines; this power is used to operate electric machines and various kind of load. The power delivered to equipment, constitute two major components. Active power and reactive power. Power factor is the most significant feature in electrical power system with numerous technical and financial advantages. During power transfer from source to load, irregular expansion of load integrated into the electrical network could lead to low power factor in a power distribution system, especially when it is an after-thought modifications. Active power is consumed in performing valuable task, such as running Air condition, pumps, motors and producing light etc. Reactive power is magnetizing power consumed in establishing magnetic fields in induction motors. Motors, transformers and other rotating equipment experience extraordinary high flow during start up called in rush current. The Motor stator winding and transformer conductors acts as a short circuit current flow, until the magnetic field linking the stator and rotor winding for the motors as well as the primary and secondary winding of transformers are established. Once the field of motor and transformer are established, the current required to maintain the field is significantly reduced and the relationship between active and reactive power.

Low power factor increases the system (Generation and transmission) cost. If the power factor of the system is low as 0.7, the apparent will double as 1.4 times of the real power used by the load. Electrical consumers will usually be penalized or change to pay penalties charge (Novitskiy & Scham, 2010). Low power factor also increases the reactive power, so in order to drive a load of same power, more will be needed, therefore generating capacity and line conductor will be insufficient.

METHODOLOGY

This research study employed empirical method, quantitative analysis and simulation processes in achieving the research objectives. The empirical determination and values involved the collection of data from the test bed (BUA Cement plant Okpella substation and CCR). Quantitative analysis involved the analysis of the quantities of values in the generated reports obtained from the simulation processes in ETAP 12.6 software and MATLAB 2018b software. Simulation processes entail the evaluation of the collected empirical data and measured real- time data using Electrical Transient & Analysis Program (ETAP 12.6) software and MATLAB SIMULINK/ PSAT 2018b to model the test bed of (Figures 1 and 2) to run the network model in the software so as to generate reports for further evaluation and analysis.

System implementation on BUA cement plant 11kv distribution network using collected data

Analysis was done on the 11kV BUA cement plant feeder using the single line diagram in (Figure 1 and 2) to determine the voltage profile, voltage phase angle, active and reactive power losses. Bus voltage magnitudes below the permissible limits (V = 1.0 ± 5% p.u) are not normal, hence the need for the improvement. All calculations have been carried out in per unit system with the three-phase complex power base S_B =100MVA and base voltage V_B = 11KV. The feeder having total installed power of 3 times 19MVA with an average power factor of 0.85.

Figures 1 and 2, show the line diagram in ETAP and MATLAB/Simulink environment to achieve the desired load flow report on the distribution network. The governing equation for reactive power compensation is given by:

$$Q_c = \frac{P}{pf_1} \times \sin\phi_1 - \frac{P}{pf_2} \times \sin\phi_2 \tag{1}$$

where;

Q_C = Reactive power factor correction (KVAr).
P = the total load active power (KW).
pf_1 = Existing power factor of the load.
pf_2 = Desired power factor to be used for correction.

$$\emptyset_1 = \cos^{-1}(pf_1) \tag{2}$$

$$\emptyset_2 = \cos^{-1}(pf_2) \tag{3}$$

$$Q_{CB} = \frac{P}{pf_1} \times \sin\left(\cos^{-1}(pf_1)\right) - \frac{P}{pf_2} \times \sin\left(\cos^{-1}(pf_2)\right) \tag{4}$$

From the mathematical model shown above, capacitor was successfully installed on buses violating the accepted level of (V = 1.0 ± 5% p.u). The buses affected after load flow analysis are buses 4, 5, 66 and 67. Capacitors were successfully installed to boost the Kvar of the buses to meet the accepted standard in both ETAP and MATLAB software as shown in (Figures 3 and 4).

Power flow analysis of the Bua cement plant Okpella line 1 network

To determine the reliability of the BUA cement plant network in supplying power to the entire distribution transformers connected to its feeders, one had to conduct power flow study of the distribution network, before conducting the power flow study for the network, from 1st January 2022 to 31st December 2023, empirical data showing the daily load readings for the feeders for twenty-four-month period were collected. The average load readings for each week were calculated by adding the twenty- four samples daily load readings in kilo-watt per hour divided by 24 and used in the simulation. In (Figure 2), the system modeling in Power System Analytical Tool (PSAT) of MATLAB/Simulink environment were carried out as can be seen. The buses affected after load flow analysis are buses 4, 5, 66 and 67. Capacitors were successfully installed to boost the Kvar of the buses to meet the accepted standard in both ETAP and MATLAB software as shown in (Figures 3 and 4).

RESULTS AND DISCUSSION

The results from the power flow analysis on the existing state and improved state of the distribution network

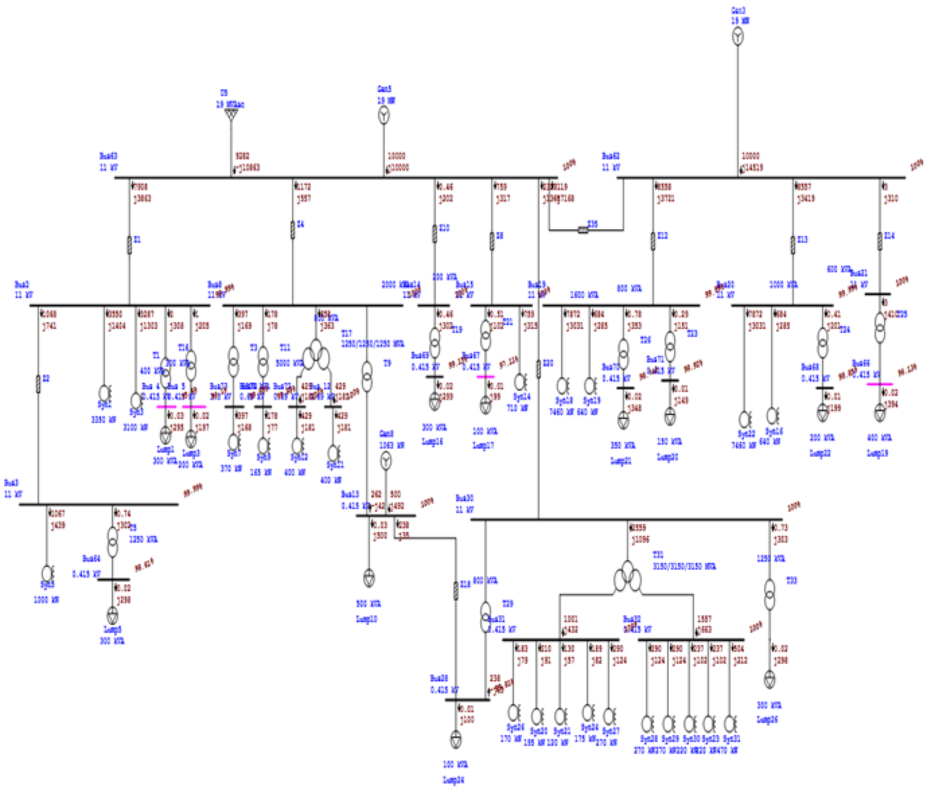

Figure 1: The load flow diagram of BUA cement plant on ETAP software.

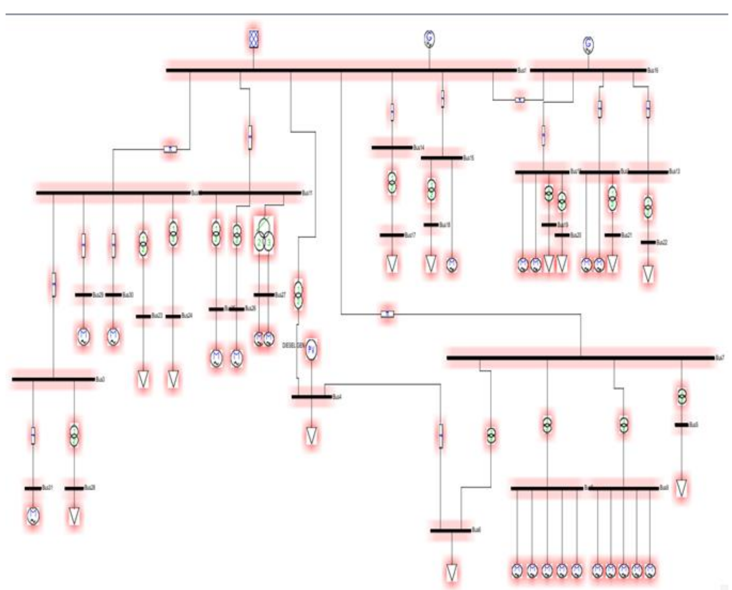

Figure 2: Power flow diagram of the BUA cement plant on MATLAB software

presented in (Figures 3 and 4) can be evaluated. The voltage profiles and power losses at the substations for both existing and improved state are also shown. The (Figures 5 and 6) show the bar graph of the results obtained from the load flow analysis before and after the optimal placement of the capacitors to the affected buses in ETAP Simulation. Similar to ETAP results, from the (Figures 7 and 8) it can be seen also in MATLAB that buses 17, 22, 23, and 24 did not meet the permissible limits (V = 1.0 ± 5% p.u), therefore capacitor placement is

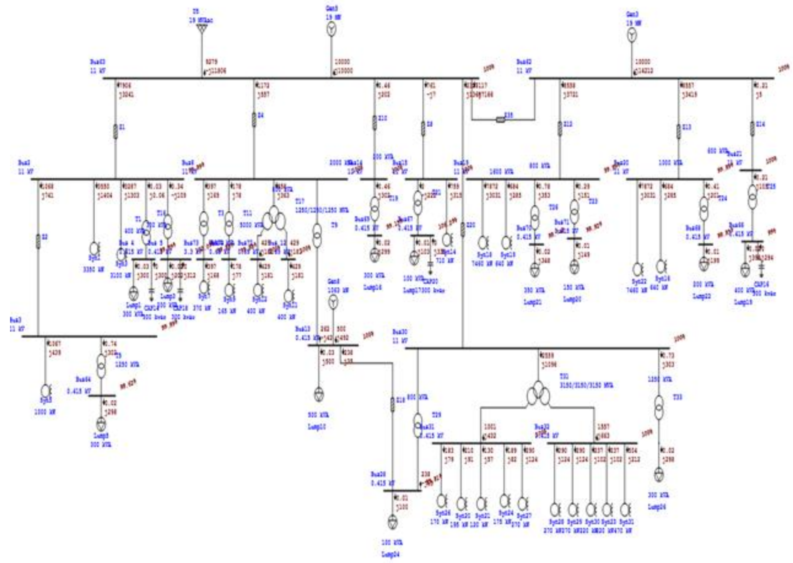

Figure 3: Power flow analysis after successful installation of capacitors on ETAP software

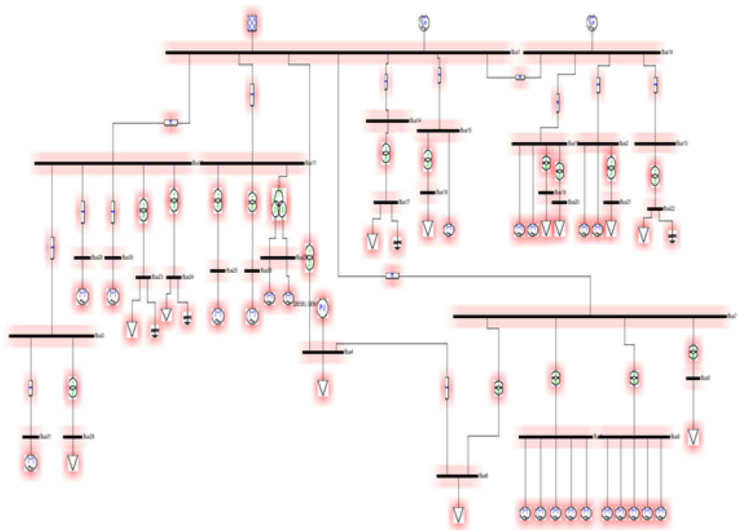

Figure 4: Power flow analysis after successful installation of capacitors on MATLAB software

needed in the affected buses. This shows the quantity of voltage value that was added at each of the load buses in the network by the Capacitor banks during the voltage compensation for both the peak and off-peak period. This compensated voltage value directly improved the quality of voltage value received by power consumers within BUA cement plant distribution network. Having discovered that BUA cement plant distribution network was not reliable in supplying quality power to all consumers in the network after conducting the load flow study/analysis of the BUA base whereby some load buses during peak period and off-peak loading period violated the ANSI C84.1 standard. Load flow simulation of BUA cement plant network carried out in ETAP 12.6 software And MATLAB Simulink / PSAT software for both peak and off-peak loading periods with the optimally selected capacitor banks installed at their appropriate buses revealed the improvement in the voltage profile of the network and to ascertain if there were still load buses that violate the ANSI voltage standard. The load flow reports generated indicates that the voltage compensation process was successful and that no load bus voltage in the network still violates the ANSI C84.1 voltage standard.

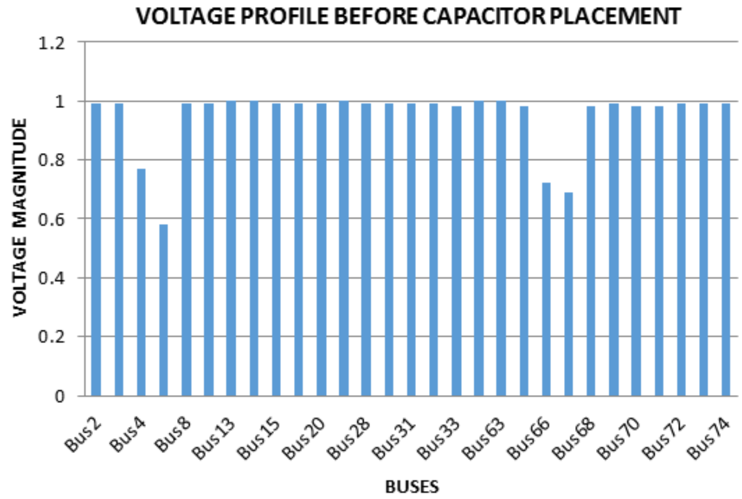

Figure 5: Bar graph of Voltage Magnitude before capacitor placement on ETAP software

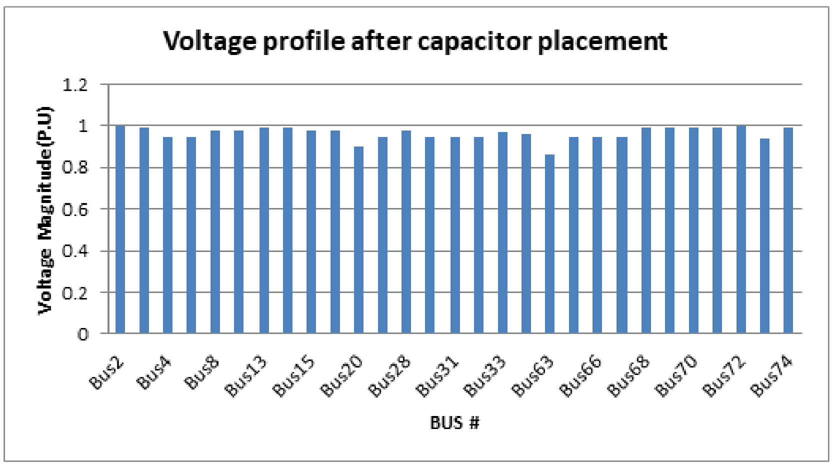

Figure 6: Bar graph of Voltage Magnitude after capacitor placement on ETAP software

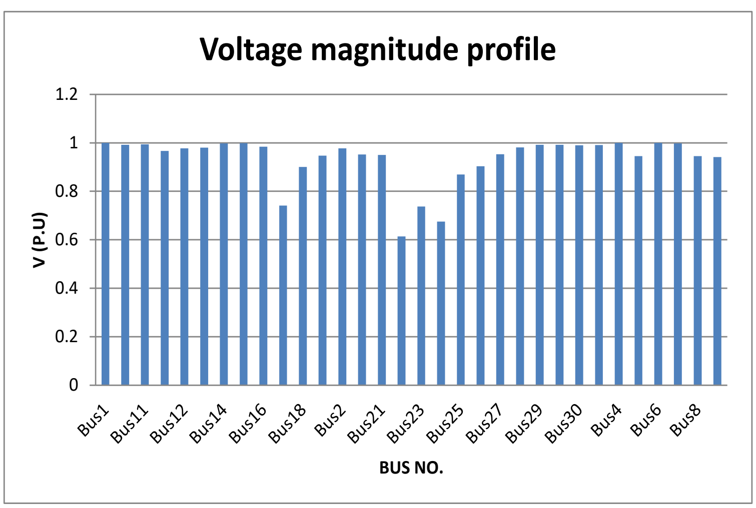

Figure 7: Voltage magnitude profile before compensation on MATLAB software

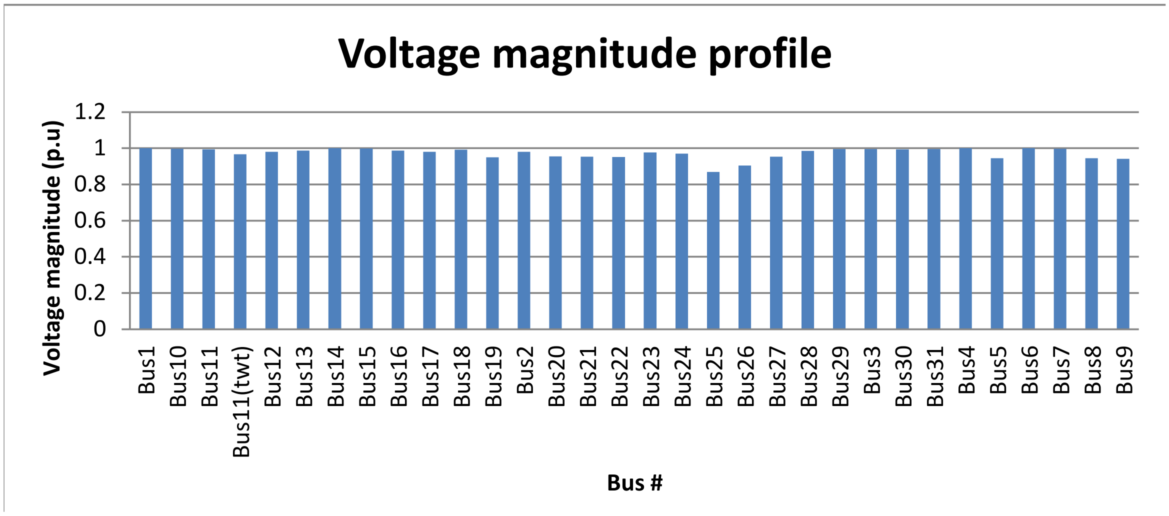

Figure 8: Voltage magnitude profile after compensation on MATLAB software

Conclusion and Recommendations

In conclusion, an electrical energy audit is a vital tool for organizations looking to enhance their energy efficiency, reduce costs, and achieve sustainable operations. It provides a structured approach to identifying and implementing energy-saving opportunities tailored to the specific needs and characteristics of the facility. In this research work, based on the power system parameters of 11KV, 50Hz Distribution network of BUA Cement Plant implemented in ETAP and PSAT of MATLAB/SIMULINK environment to compensate for losses and to safe cost of production in order to maximize profit. From the results after simulations, the compensated and uncompensated voltages at each of the buses were evaluated. It was observed from the analysis that some circuit (buses) in the network have low voltage profile which may be due to so many factors like the flow of reactive power or losses on the line. It is, therefore, important to incorporate power factor correction or compensation on those lines that are weak. It can be concluded that in order to enhance the transmission system performance of the BUA Cement Factory Power System, the control of the voltages at certain buses through the application of power factor correction is required. This euphemistic technique adopts optimal capacitor placement and improved the network performance and could be practically implemented on the BUA Cement Network to improve the huge demand of power and to safe cost.

REFERENCES

Adewale, A. A., Adekitan, A. I., Idoko, O. J., Agbetuyi, F. A., & Samuel, I. A. (2018). Energy audit and optimal power supply for a commercial building in Nigeria. Cogent Engineering, 5(1), 1546658.

Atnaca, A., & Yumrutaş, R. (2014). Analysis of the parameters affecting energy consumption of a rotary kiln in cement industry. Applied Thermal Engineering, 66(1-2), 435-444.

Cembureau the European Cement Association (2020). “The view of cement sector powering the cement industry”. accessed 24 June, 2024 from https://cembureau.eu/media/ckkpgrg1/cembureau

Okoye, C. U., Bitrus, I., Alao, M. J., Adelakun, N. O., & Abdulhamid, I. G. (2018). A Study and Analysis Of Energy Generation And Consumption In Dangote Cement Plant, Ibese, Ogun State, Nigeria. Global Journal of Advanced Engineering Technologies and Sciences, 5(11), 20-28.

Novitskiy & H. Scham (2010) “Energy saving effect due to the voltage reduction in industrial electrical work power Quality supply Rei . conf. (pq) PP. 67-72

Ruparathna, R., Hewage, K., & Sadiq, R. (2016). Improving the energy efficiency of the existing building stock: A critical review of commercial and institutional buildings. Renewable and sustainable energy reviews, 53, 1032-1045.

Xu, J. H., Fleiter, T., Eichhammer, W., & Fan, Y. (2012). Energy consumption and CO_2 emissions in China's cement industry: A perspective from LMDI decomposition analysis. Energy policy, 50, 821-832.