# Improved Performance of Elelenwo 11kv Electric Power Distribution Network Using Newton Raphson Load Flow Technique.

ETTA, BUSA-OSOWO[1], D.C. IDONIBOYEOBU[2]
[1, 2] *Electrical Engineering Department, Faculty of Engineering, Rivers State University, Port Harcourt.*

***Abstract- The research examined how to improve the performance of Elelenwo 11kV electric power distribution network using Newton Raphson load flow technique. The existing distribution network consists of 1x15MVA, 33/11kV injection substation with two (2) feeders located at the premises of Elelenwo, Port Harcourt. Feeder 1 has a peak load of 4 MW and feeder 2 has peak load of 6 MW respectively, the power supply is connected to the network passes through a 33kV feeder at Port Harcourt Town Sub-Transmission Station with installed capacity 165MVA,123/33kV. The major problem associated in the Rivers State Television distribution line is the low voltage experienced in most areas covered by the study network, drop in the voltage profile due to the size and distance covered by the distribution lines feeding the areas, inadmissibly poor voltage profile due to substandard source-end voltage and poor reliability and high losses, which results into lots of power interruption. The aim of this research work is to improve the performance of Elelenwo 11kV electric power distribution network using Newton Raphson load flow technique. The objectives of this research work are as follows: Collection of time series load data from PHED on the sample feeder was analyzed to evaluate feeder failure rates, loading and voltage profiles of the network were evaluated using direct measurements at distribution transformers and computation of loading coefficient and currents and modelling of the study network using Electrical Transient Analyzer Program (ETAP version 12.6) software environment using Newton Raphson Load flow Technique. This research work has contributed to knowledge as follows: The examination of the 11kV distribution network revealed the effect of poor power quality on the expected voltage of the distributed line in the study case, therefore the case of overload on the existing transformers and cables should be considered, and the existing power factor of Bus 1 and Bus 4 should be improved from 0.81 to 0.92.***

***Indexed Terms- Load Flow, Distributed Network, Buses, Newton-Raphson, feeders***

## I. INTRODUCTION

Recent advances in electrical engineering sciences have brought a revolution in the field of electrical engineering after the development of powerful computer-based software [15]. Load flow methods might take a long time to be calculated; therefore, it prevents achieving an accurate result for a load flow solution because of continuous changes in power demand and generation. The principal information obtained from a load flow analysis is the magnitude and phase angle of the voltage at each bus, and the real and reactive load flowing in each line [14]..

The fundamental purpose of power systems is to provide an economic and reliable channel for electrical energy to transfer from points of generation to customer locations [9].

The distribution substation is the interconnection element between the distribution system and the upstream power delivery system. At the substation the step-down (HV/MV) transformer reduces the sub-transmission voltage level to an appropriate value for primary distribution lines.

The primary distribution lines spread across the consumption area served by the substation; these primary distributions lines are also known as feeders. One or more lateral lines (or laterals) branch from distribution feeders and extend until they reach the step-down (MV/LV) distribution transformers, which are responsible for performing the final voltage reduction in order to obtain a voltage level adequate for customer use (e.g., 400 and 230 V). The secondary distribution lines operating at a low-voltage level transport the energy to the customer's interconnection point; these lines are usually one-phase but there can also exist in three-phase circuits. Overhead lines are primarily used in rural circuits, whereas in urban circuits distribution lines are mostly underground; in suburban areas there can be a mixture of overhead and underground circuits. Big industrial zones are usually served by dedicated circuits as they represent large loads that can affect the service of other loads [5].

## II. PAST REVIEW WORK

Distribution system is the largest portion of the electrical power system [4]. It can be defined as the part of a power system that distributes power to various customers in ready-to-use form at their place of consumption [16]. Distribution system is the medium through which electric power is conveyed in bulk from the power distribution station to the various end users [2]. It holds a very significant position in the power system since it is the main point of the link between bulk power and consumers [6];[11]. Admittedly, the shocks from the electricity crisis in Nigeria have created some wedges in the national wheel of effective management of industrial and the other socio-economic development programmes in Nigeria [12].

The occurrence of power outages is very high and alarming in Nigeria. There are several areas of national life that power outage should never occur but power outage for several days is common and could happen just anywhere in the country. The single line diagram of the substation is simulated in ETAP based upon actual data, and it is seen that at the 11kV feeder buses. To overcome the under voltage at the 11kV feeder buses capacitor bank of suitable ratings are added [1]
[3] presented a paper, in which it was presented an analytical method which is easy to understand and gives detailed mathematical model to conduct the reactive energy compensation in an optimal way i.e. to have less power and energy losses. Indeed, this method allows the electrical energy suppliers to choose either to optimise either capacitor location or size or both of them at the same time.

### A. Performance of Newton-Raphson technique in load flow analysis using Matlab

The main objective for the calculation of power flow study is to find the magnitude of voltage /*V*/ and the phase angle (δ) of the power losses at each bus section, the real and reactive power flowing in each line of the power system. It was observed that Newton-Raphson's approach has made the calculations easier because the number of buses increased while the number of iterations decreased.

### B. Radial distribution network (RDN) of load flow algorithm

[10] state that RDN used the same convex formulation to obtain the optimal configuration to minimizes its real power waste. The modeling of the load power of Radial Distribution Network as Quadratically constrained convex optimization problem (QCCOP) convexification of the continuous decision variables of the optimization problem guaranteed the global optimality of the acquired solution. Moreover, the solution was obtained using interior – point method algorithm through CPLEX optimization software after passing the parameters from MATLAB. The proposed algorithm has shown high computational efficiency, which paves the way for real time optimization problems regarding the operation of Radial Distribution Network.

### C. A promising method for uncertain load flow studies

In this method the linearized power flow equations should be preconditioned by an M-matrix in order to guarantee convergence. The scholar also said that the set of non-linear equations were solved by Gauss-Seidel method. Preconditioning is required but if interval input is too cumbersome, convergence is not guaranteed, that is why this method cannot give an exact solution. Fast Decoupled power flow using interval arithmetic has been used to obtain the solution to the power flow with uncertainty. This algorithm converges very fast and considers retaining the midpoint of the load flow studies. This is a specific feature that ensures the convergence in accordance with the punctual load flow studies. The algorithm is effective and avoids unnecessary computation effort like preconditioning.

D. Distribution system elements

The safe operation of a power distribution system requires much dedicated equipment; this equipment is installed throughout the distribution system and it includes elements, such as power transformers, circuit breakers, and control and monitoring apparatuses.

E. Main causes of technical losses

F. Lengthy distribution lines

In practically 11 kV and 415 volts lines, in rural areas are extended over long distances to feed loads scattered over large areas. Thus the primary and secondary distributions lines in rural areas are largely radial laid usually extend over long distances. This results in high line resistance and therefore high $I^2R$ losses in the line. Haphazard growths of sub-transmission and distribution system in to new areas, large scale rural electrification through long 11kV and LT lines [9].

G. Inadequate size of conductors of distribution lines

The size of the conductors should be selected on the basis of KVA x KM capacity of standard conductor for a required voltage regulation but rural loads are usually scattered and generally fed by radial feeders. The conductor size of these feeders should be adequate.

H. Installation of distribution transformers away from load centers

Therefore in order to reduce the voltage drop in the line to the farthest consumers, the distribution transformer should be located at the load center to keep voltage drop within permissible limits.

I. Low power factor of primary and secondary distribution system

A more appropriate manner of improving this PF of the distribution system and thereby reduce the line losses is to connect capacitors across the terminals of the consumers having inductive loads.

By connecting the capacitors across individual loads, the line loss is reduced from 4 to 9% depending upon the extent of PF improvement [8]

J. Feeder phase current and load balancing

One of the easiest loss savings of the distribution system is balancing current along three-phase circuits. Feeder phase balancing also tends to balance voltage drop among phases giving three-phase customers less voltage unbalance. Amperage magnitude at the substation does not guarantee load is balanced throughout the feeder length. Feeder phase unbalance may vary during the day and with different seasons. Feeders are usually considered "balanced" when phase current magnitudes are within 10.

Plate 1: Electrical Feeder Pillar

K. Load factor effect on losses

Lower power and energy losses are reduced by raising the load factor, which, evens out feeder demand variation throughout the feeder. The load factor has been increase by offering customers "time-of-use" rates. Companies use pricing power to influence consumers to shift electric-intensive activities during off-peak times (such as, electric water and space heating, air conditioning, irrigating, and pool filter pumping). Utilities can try to design in higher load factors by running the same feeders through residential and commercial area [7].

L. Newton-Raphson Load Flow Technique (N-R)

Newton-Raphson technique is used for solving power flow solution. The technique uses Taylor series expansion with terms limited to first approximation. The technique was used in this research due to its powerful convergence characteristics compared to other techniques.

## III. MATERIALS AND METHOD

A. Materials Used in the Analysis

I. The distribution data were collected from the Port Harcourt Electricity Distribution Company (PHED).
II. Incoming line is 33kV and there are three 11kV outgoing line. Step down power transformer is used to distribute power and its rating is 10MVA. Some distribution transformers are not fully loaded.
III. Load of this system receives a voltage of 400V and type of load is lump load.
IV. Conductor size for 33kV is 95mm$^2$ and 11kV is 95mm$^2$ and 50 mm$^2$ respectively.
V. ACSR conductor is used for incoming and outgoing feeders.
VI. Model and simulate the existing network in Electrical Transient Analyzer Program (ETAP version 12.6) software environment.

B. Determination of injected real and reactive power

From equations the current entering the power system is giving by

$$I_i = \frac{P_i - jQ_i}{V_i^*} = \sum_{k=1}^{n} Y_{ik} V_k$$

$$P_i - jQ_i = V_i^* \left(\sum_{k=1}^{n} Y_{ik} V_k\right)$$

Let $V_i^* = V_i\angle - \delta_i, V_k = V_k\angle\delta_k$ and $Y_{ik} = Y_{ik}\angle\theta_{ik}$

$$P_i - jQ_i = V_i^* \left(\sum_{k=1}^{n} Y_{ik} V_k\angle\delta_k + \theta_{ik} - \delta_i\right)$$

$$P_i - jQ_i = \sum_{k=1}^{n} |Y_{ik}||V_i||V_k| \left[\cos(\delta_k + \theta_{ik} - \delta_i) + j\sin(\delta_k + \theta_{ik} - \delta_i)\right]$$

Separating (3.24) into real and imaginary parts we have,

$$P_i = \sum_{k=1}^{n} |Y_{ik}||V_i||V_k| \cos(\delta_k + \theta_{ik} - \delta_i)$$

$$Q_i = -\sum_{k=1}^{n} |Y_{ik}||V_i||V_k| \sin(\delta_k + \theta_{ik} - \delta_i)$$

Where

$Y_{ik}$ is the admittance matrix
$P_i$ is the injected real power
$Q_i$ is the injected reactive power

Table 1: Transformers in Elelenwo 11kV Injection substation

| S/N | Transformers Rating (KVA) | Red phase (A) | Yellow Phase (A) | Blue Phase (A) | Neutral |
|---|---|---|---|---|---|
| T1 | 300 | 165 | 172 | 192 | 18 |
| T2 | 500 | 242 | 251 | 264 | 27 |
| T3 | 300 | 238 | 209 | 216 | 23 |
| T4 | 500 | 245 | 260 | 258 | 28 |
| T5 | 200 | 158 | 173 | 196 | 19 |
| T6 | 300 | 190 | 216 | 220 | 25 |

*Source: Port Harcourt Electricity Distribution Company (PHED)*

C. Calculation of distribution line parameter for Elelenwo 11kV distribution system

Line 1 Calculation

From equation (2) resistance of line per kilometer, is giving by

$$R = \frac{\rho}{A}\Omega/km$$

$$R = \frac{2.8 \times 10^{-8} \times 0.35 \times 10^3}{150 \times 10^{-6}}$$

$$R = 0.065\ \Omega$$

Using equation (2.7) reactance of line per kilometer

$$r = \sqrt{\frac{150 \times 10^{-6}}{3.142}}$$

$$r = \sqrt{0.0004774}$$

$$r = 0.0069\ m$$

$$D_{GMD} = 1.26 \times 0.88 = 1.108\ m$$

$$X = \left[0.1445 \ln\left(\frac{1.108}{0.0069}\right) + 0.0157\right] \times 0.35$$

$$X = 0.037\ \ \Omega$$

Line 2 Calculation

Using equation 3.6 resistance per kilometer, is giving by

$$R = \frac{\rho}{A}\Omega/km$$

$$R = \frac{2.8 \times 10^{-8} \times 0.37 \times 10^3}{150 \times 10^{-6}}$$

$$R = 0.065\ \Omega$$

Using equation 3.7, reactance of line per kilometer

$$r = \sqrt{\frac{150 \times 10^{-6}}{3.142}}$$

$$r = \sqrt{0.0004774}$$

$$r = 0.0069\ m$$

$$D_{GMD} = 1.26 \times 0.88 = 1.108\ m$$

$$X = \left[0.1445 \ln\left(\frac{1.108}{0.0069}\right) + 0.0157\right] \times 0.37$$

## IV. RESULT AND DISCUSSION

After simulation on the system it shows that some buses are under existing operating condition, such buses are Bus 1, Bus 5, and Bus 6 are not within the acceptable normal voltage of ± 5% of the require voltage as a result of overloading, poor transmission feeders, power or inefficient voltage control system due to lack of planning, faulty distribution system on the part of the electrical supplier (PHED) and as such case it creates voltage instability in the system network.

The examination of the 11kv distribution network revealed the effect of poor power quality on the expected voltage of the distributed line in the study case Elelenwo, especially, the case of overload on the existing transformers and cables.

### A. Pre-Upgrade Network Simulation

Figure 1−4 shows the presentation and the results of the simulation for unimproved case diagram.

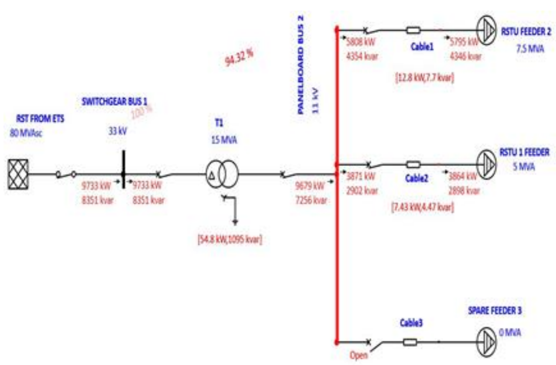

Figure 1: RSTV Load Flow Analysis Unimproved Case Diagram 1

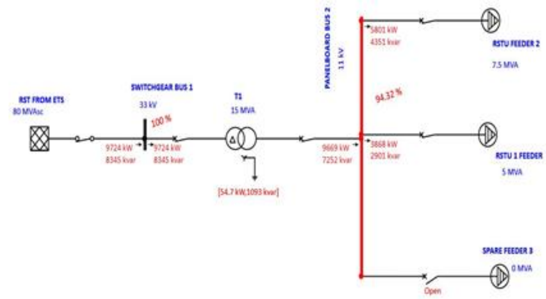

Figure 2: RSTV Load Flow Analysis Unimproved Case Diagram 2

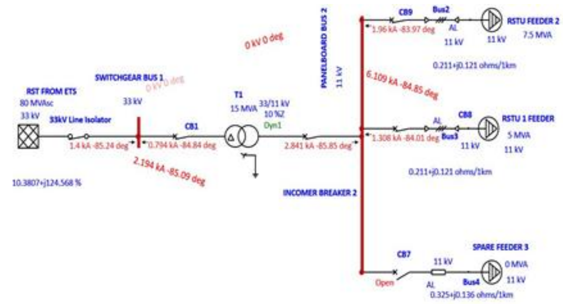

Figure 3: RSTV Load Flow Analysis Unimproved Case Diagram 3

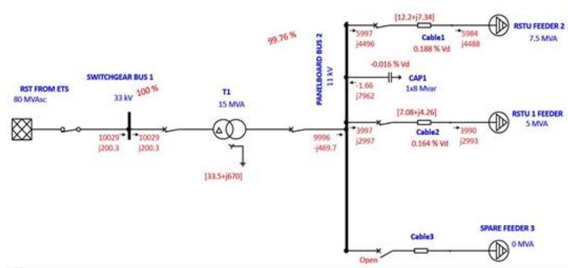

Figure 4: RSTV Load Flow Analysis Improved Case Diagram 1

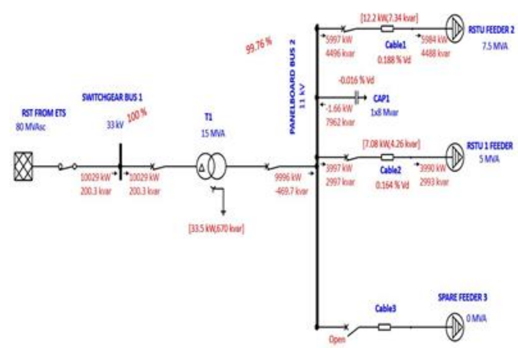

Figure 5: RSTV Load Flow Analysis Improved Case Diagram 2

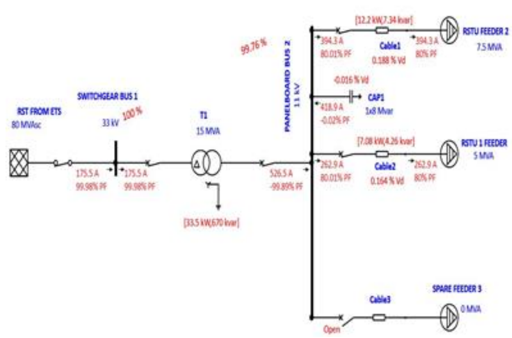

Figure 6: RSTV Load Flow Analysis Improved Case Diagram 3

Presentation of calculated values of the distribution transformers in Elelenwo, RSTV Network, with their locations capacity, load current, lump load, active power and reactive power

Table 1: Transformers Locations, Percentage loading, active power, reactive power in Elelenwo Distribution Network

| BUS ID | Transformers Rating (kVA) | Transformer Capacity (kVA) | Load Current (A) | Lump Load (kVA) | Reactive Power (kVAR) | Active Power (kW) |
|---|---|---|---|---|---|---|
| BUS 1 | 300 | 130.82 | 182 | 132 | 78.49 | 106.66 |
| BUS 2 | 500 | 187.60 | 261 | 315 | 112.56 | 150.08 |
| BUS 3 | 300 | 164.6 | 229 | 165 | 131.68 | 98.76 |
| BUS 4 | 500 | 189.76 | 264 | 290 | 151.81 | 113.86 |
| BUS 5 | 200 | 143.38 | 175 | 127 | 114.70 | 86.03 |
| BUS 6 | 300 | 132.26 | 182 | 132 | 105.81 | 79.36 |

Table 1 shows the transformers locations, percentage loading, active power, reactive power in Elelenwo distribution network.

However, to improve the distribution network capacitor bank was used to reduces loss ($I^2$ R loss) associated with transmission and distribution of the current to the consumer's loads, improve voltage regulation, quality of power, power factor, voltage profile of the system. Therefore, capacitor bank were introduce to regulate control and compensate for power loss, reactive power losses and voltage profile inadequacy.

To improve the efficiency of the system, the capacitor bank rated at 1 x 8Mvars each were optimally sized and allocated to support the voltage at the critical buses (Bus 1, Bus 2, Bus 3, Bus 4, Bus 5, and Bus 6) in order to enhanced power system operation by minimizing losses and improve the profile of the voltage. It will also help to enhanced power flow on the critical part of the system network.

Therefore, the problem of voltage fluctuation and harmonies can be overcome by the penetration of the FACTS-controller. After the penetration of the capacitor bank in the Elelenwo network, the network was improved perfectly.

## CONCLUSION

The research work discussed effectively on how to improve the performance of Elelenwo 11kV electric power distribution network using Newton Raphson load flow technique. The existing distribution network consists of 1x15MVA, 33/11kV injection substation with two (2) feeders located at the premises of Elelenwo, Port Harcourt. Feeder 1 has a peak load of 4 MW and feeder 2 has peak load of 6 MW respectively, the power supply is connected to the network passes through a 33kV feeder at Port Harcourt Town Sub-Transmission Station with installed capacity 165MVA,123/33kV.

To improve the efficiency of the system, the capacitor bank rated at 1 x 8Mvars each were optimally sized and allocated to support the voltage at the critical buses (Bus 1, Bus 2, Bus 3, Bus 4, Bus 5, and Bus 6) in order to enhanced power system operation by minimizing losses and improve the profile of the voltage. It will also help to enhanced power flow on the critical part of the system network. Therefore, the problem of voltage fluctuation and harmonies can be overcome by the penetration of the FACTS-controller. After the penetration of the capacitor bank in the Elelenwo network, the network was improved perfectly.

The distribution network system was model and simulated in the Electrical Transient Analyzer Program (ETAP version 12.6) software environment using Newton Raphson Load flow Technique with the application of power flow equation, voltage equation sizing of capacitor equation.

REFERENCES

[1] Asaduzzaman, M.S., Muhit, M. S., & Khaled-Hossain, M.D. (2014). Fault Analysis Electrical Protection of Distribution Transformers. Global Journal of Research in Engineering, 14(3), 12-20.

[2] Anderson, M., & Fouad, A. (1994). Power System Control and Stability. New York: IEEE Press,10(9), 24-35.

[3] Grainger, J. J., Lee, S.H., Byrd, A.M. & Clinard, N. K. (2005). Proper Placement of capacitors for Losses reduction on distribution primary feeders", *in Proceedings, American :Power Conference, 42(12), 593-603.*

[4] Goran, A. (2008). Modelling and Analysis of Electric Power Systems, Lecture 227-0526-00, ITET ETH, Zurich, 11(21), 34-42.

[5] Guerra, G. & Martinez, J.A. (2014). A Monte Carlo method for optimum placement of photovoltaic generation using a multicore computing environment, *IEEE PES General Meeting*, National Harbor, USA, 12(16), 56-67.

[6] Gupta, J. B. (2013). A Course in Power Systems, (Generation and Economic Considerations; Transmission and Distribution, Switchgear and Protection), S.K. Kataria and Sons, 48(15), 10-19.

[7] Nassereddine, M., Rizk, J., Nagrial, M., & Hellany, A. (2015). HV substation earth grid commissioning using current injection test (CIT) method: Worst case scenario determination, International Energy and Environment Foundation, 6(4), 347-356.

[8] Mohmmedfuzail, B., Ankaliki, S., Engg, S., & Dharwad, T. (2019). Performance Analysis of 33/11kv Substation and its Feeders International Journal of Scientific & Engineering Research, 10(5), 36-41.

[9] Luis, G. S. (2016). Analysis of Power Distribution Systems Using a Multicore Environment. 13(18), 11-25.

[10] Jabr, R.A, Singh, R., & Pal, B.C (2012). Minimum Loss Network Reconfiguration Using Mixed-Integer Convex Programming. *IEEE Transactions on Power Systems,* 27(2), 1106-1115.

[11] Obadote, D. J. (2009). Energy Crisis in Nigeria: Technical Issues and Solutions, Power Sector Prayer Conference, 23(10), 25-27

[12] Kersting, W. H. (2002). Distribution System Modeling and Analysis, CRC Press, LLC, 2000 N.W, Corporate Blvd., Florida, 23(12), 31-45.

[13] Ramesh, L., Chowdhury, S., Natarajan, A., & Gaunt, C. (2009). Minimization of power loss in distribution networks by different techniques, International Journal of Energy and Power Engineering, 2(1), 18-24.

[14] Ibeni, C, (2017). *Load Flow Analysis* of Port Harcourt Electricity Network by Fast Decoupled and Newton- Raphson Techniques. 4(12), 26-34.

[15] Nibedita, G., Sharmistha, S., & Subhadeep, B. (2012). A load flow based approach for optimum allocation of distributed generation units in the distribution network for voltage improvement and loss minimization, International Journal of Computer Applications, 50(15),15-22.

[16] Ramesh, L., Chowdhury, S., Natarajan, A., & Gaunt, C. (2009). Minimization of power loss in distribution networks by different techniques, International Journal of Energy and Power Engineering, 2(1), 18-24.