International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 20, Issue 1 (January. 2024), PP. 16-24

Improvement of Power Quality : A Case Study of Eneka Town Hall, Eliozu and Akani Distribution Substations

Hachimenum Nyebuchi Amadi[1], Kingsley Okpara Uwho[2]; Ebitari Amaitari Tebepah[3]

[1]*Head of Department of Electrical Engineering, Faculty of Engineering, Rivers State University, Port-Harcourt, Nigeria.*

[2,3]*Doctor of Philosophy (PhD) Students of the Department of Electrical Engineering, Power Option, Faculty of Engineering, Rivers State University, Nigeria*

ABSTRACT

The study looked at the improvement of Power quality of Eneka Town Hall, Eliozu and Akani injection substations, Port-Harcourt, Nigeria. The network was modelled in Electrical Transient Simulation software (ETAP19.1) and load flow conducted using Newton-Raphson technique to know the operating condition of the network. The result of the already network from the simulation shows that the following buses violated the statutory limit condition of 0.95-1.05p.u:Elimgbo (88.98%), Igwuruta (88.98%), Old Aba Rd (85.90%), Rumuogba (85.90%) and Rumurolu (85.90%). Similarly, over loaded transformers are T11 (98.10%) and T14 (143.90%) while the total real and reactive power losses are 667.50kW and 761kVAr. However, a cost effective optimization technique (capacitor bank) of 5000kVAr and 7000kVAr were modelled and installed in the network to improve its power quality. The operating values after optimization for the buses are now Elimgbu (97.45%), Igwuruta (97.45%), Old Aba Road (96.45%), Rumuogba (96.45%) and Rumurolu (96.45%). Similarly, over loaded transformers(T11 and T14) values are now 41.870% and 60.167%. Also, the total real and reactive power loss after optimization is 506.0kW and 569.0kVAr. From the result obtained it is obvious that the proposed optimization techniques helped significantly in the improvement of the distribution network.

***Keywords**: Improvement of power quality, Eneka Town Hall, Eliozu, Akani, Injection Substations, Reactive power.*

Date of Submission: 22-12-2023 Date of Acceptance: 03-01-2024

I. INTRODUCTION

Quality electrical power supply is the main stay of infrastructural development, wealth creation, job opportunities and human capital development. However, the power sector is facing perpetual decay currently. Remedies have been suggested by the power sector experts and researchers which must be given utmost priority because of the crucial role electricity plays in our economic life on daily basis [1].

The major function of a distribution system is to receive power from the large power source and distribute it to the consumers at a particular voltage level and with a degree of continuity. This continuity can be acceptable to various kinds of consumers as stipulated by the Institute of Electrical Electronic Engineers' (IEEE) compliance and practice which states that for highest grade of service, the voltage at the consumers' switch should not vary by ± 5% about the rated or normal value for the distribution system based on the voltage levels which are classified as secondary and primary system. The sub-transmission system supplies power to the primary distribution network by transferring energy from the transmission to distribution systems. Due to rapid shift for urbanization for economic development, wellbeing for man and society, overloading conditions in the distribution network emerges that resulted in voltage drop, power loss and shortage of power supply to the consumers along with loss of the equipment and decline in production. The major objective of an electric power sector is the availability of electric power supply thereby satisfying the system load requirement with great assurance of sustainability and quality [2]. Reactive power is the difference between active power and apparent power[3]. Limitation of reactive power in distribution system can cause instability such as increase in load demand, change in system condition which causes a progressive decrease in voltage[4]. Capacitor bank has been used in reducing the power loss of a distribution network from 284.9kW and 317.4kVAr to 224kW and 226kVAr real and reactive power respectively[5].

The major cause of under voltage in distribution system is the shortage of reactive power. He added that reactive power cannot be transmitted very far especially under heavy loading conditions and so must be generated close to the point of consumption. He further buttressed that voltage on a power system is only ± 5%

of nominal and this small voltage difference does not cause significant reactive power to flow over long distance. However, he suggested that for the voltage level at the load centres not to go down, reactive power must be available at the load centres[6].

1.1 Methods of Reactive Power compensation

1.1.1 Load Compensation

This involves reactive power standard aimed at enhancing the level of energy given out in line that is stable with good power factor. In the actual sense, the reactive part of the energy received equals the magnitude created, which give rise to a stable energy. In any case, losses give rise to reactive energy fluctuations in the network. To sustain stable energy to a great extent, means managing the reactive components by using compensating techniques[7]. There is the urgent need to lower the cost of higher conductors, and thus lower transmission line loss by creating a transmission system based on the ability of active power transfer and also, reactive energy be met nearby by linkingshunt compensating gadgets (capacitors and inductors) at the load centre where they are demanded[8].

1.1.2 Line Compensation

Line compensation has to do with the act of using electrical circuits to vary the electrical lines features in most cases, the line length, in order to improve power transfer capacity, maintain a near flat voltage profile, and achieve a cost-effective method of reactive power management. In all, compensators that are linked in series and in shunt (capacitors and inductors), are installed at the right location in the network to change the useful transmission line impedance, making formore power to be conveyed[8].

1.1.3 Voltage Uprating

This involves increasing the nominal voltage from one level to another. This type of method increases transmission line transfer capacity, minimizes losses and alleviate overloading. However, it requires the construction of new support system or reinforcement of existing ones. Building new substations and upgrading existing substation equipment. Huge capital cost investment is required and it takes long time to plan[9].

1.1.4 Re-Conducting of Lines with Bundle Conductor

Bundle conductor is made of two or more sub-conductors used as a single phase conductor. It is capable of transferring more power if the existing line conductor is inadequate, reduces voltage gradient in the vicinity of the line and also, reduce corona discharge. Bundle conductor can be single or double circuit. This method reduces the line impedance and increases current-carrying capacity of the line. However, it requires high capital cost, may require a higher or reinforced support system as it increases the conductor weight on the existing line structure, increases charging KVA and Increase ice and wind loading[10].

1.1.5 Shunt Controller

Traditionally, shunt compensation is done by using fixed capacitors, rotating synchronous condensers or reactors. With continuous research for a more stable compensation and for improved efficiency of a transmission or distribution line by researchers and power utility companies, shunt compensation can now be effectively accomplished using static switches or power electronic based devices, example static synchronous compensator (STATCOM), static VAR compensator (SVC) to regulate voltage in the connected buses of an electrical network[11].

The main function of the SVC is to maintain bus voltage by injection of reactive power. It was described in their paper the basis for selection of SVC location and size in the power system. The proposed approach used a scalar quantity; voltage instability index (L) that denotes each load bus[12]. The most critical bus that has the most tendency to have a voltage collapse is always the bus with the maximum value of L. This approach also analysed a test system and a practical Extra High Voltage network . The objectives of this study are to :

i. Improve voltage profile of the network
ii. Minimize power loss and improve power quality
iii. Determine overload transformers

II. MATERIALS AND METHODS

2.1 Materials

i. Load Data of the power transformer in various substations.
ii. Line Data: ACSR/Gz with cross sectional area of 182mm^2
iii. Electrical Transient Analyzer Program (ETAP 19.1) simulation software.
iv. Power Transformers

v. Single Line Diagram
vi. Capacitor Bank.

2.1.1 Load Data

Table 1: Load Data

ID	Transformer Rating	11kV Feeder	MW
Eneka Town Hall	2x15MVA	Igwuruta Rd	5.2
		Elimgbu	7.0
Eliozu	1x15MVA	OPM	4.2
		Shell Estate	3.4
		Pipeline	3.2
Akani	2x15MVA	Rumuorolu	4.3
		Old Aba Rd	6.5
		Rumuogba	6.6
		Rumuibekwe	0.8
		Rumukalagbo	3.2
		Glass factory	5.7

Table 1 gives detail of the loads that make up the stations. Eneka Town Hall station has two 15MVA transformers and two feeders-Igwuruta road and Elimgbu. Eliozu station has one 15MVA transformer and three feeders-OPM, Shell Estate and Pipeline while Akani station has two 15MVA transformers and six feeders-Rumurolu, Old Aba Road, Rumuogba, Rumuibekwe, Rumukalagbo and Glass factory.

2.1.2 Line Data

i. Resistance of line per kilometer

Resistance, $R = \frac{\rho}{A}\Omega/m$ (1)

Where;

ρ =Resistivity of Aluminum=$2.65x10^{-8}\Omega m$

A = Area of conductor=$182mm^2$

L= Route length of the feeder (m)

ii. Reactance of line per kilometre

$r = \sqrt{\frac{A}{\pi}}$ (2)

$GMD = \sqrt[3]{D_{ab} \times D_{ac} \times D_{bc}} = 1.26D$(3)

$X = \mu_0\left(\frac{GMD}{r}\right)\frac{\Omega}{m}$ (4)

Where

A =Area of conductor

r= radius of the conductor

GMD= Geometric mean distance of conductor

D= conductor spacing =4.1m

μ_0= permeability of free space

$$R = \frac{2.65 \times `10^{-8}}{182 \times 10^{-6}} = 0.0001456\ \Omega/m$$

$$r = \sqrt{\frac{182 \times 10^{-6}}{3.142}} = 0.0076108\ m$$

$$D_{GMD} = 1.26 \times 4.1 = 5.166m$$

Table 2 : Line Characteristics

Line ID	From	To	L(km)	R(Ω)	X (Ω)
Line 13	PH Mains	Eneka Town	2.4	0.34944	0.98352
Line 14	PH Mains	Eliozu	9.4	1.36864	3.85212
Line 15	PH Mains	Akani	7.0	1.01920	2.86860

Table 2 shows the line characteristics of the stations which are the inductance, resistance and reactance. The supply to the stations is from the Port-Harcourt Mains 132kV.

2.1.3 Description of Existing Network

Eneka Town Hall, Eliozu and Akani injection substations are found in Obio/Akpor local government area in the metropolis of Port Harcourt located 4° 48’43” N latitude and 7°2’14” E longitude. It is one of the major centers of economic activities in Rivers State and Nigeria at large and play host to many multinational companies and is considered the richest local government in Nigeria. Power supply to the Obio/Akpor local government area is via two (2) 132kV transmission station namely Port Harcourt mains and Rumuosi 132kV. The Port Harcourt Mains is duly linked to Afam power station while the Rumuosi is linked to Omoku power station.

2.2 Methods

2.2.1 Determination of Operating Condition

The Newton-Raphson Power Flow Techniques was used to determine operating condition of the network
For any ith bus,
Let $V_i = V_i \angle \delta_i$ and $V_i^* = V_i \angle - \delta_i,$ (5)
For kth bus,
$V_k = V_k \angle \delta_k$ and $Y_{ik} = Y_{ik} \angle \theta_{ik}$ (6)
The real and reactive power injected in the network is given by
$S_i = V_i I_i^* = P_i + jQ_i$ (7)
$I_i = \left(\frac{S_i}{V_i}\right)^* = \frac{P_i - jQ_i}{V_i^*}$(8)
$I_i = \frac{P_i - jQ_i}{V_i^*} = \sum_{k=1}^{n} \quad Y_{ik} V_k$ (9)
$P_i - jQ_i = V_i^* (\sum_{k=1}^{n} \quad Y_{ik} V_k)$ (10)
$P_i - jQ_i = V_i^* (\sum_{k=1}^{n} \quad Y_{ik} V_k \angle \delta_k + \theta_{ik} - \delta_i)$ (11)
$P_i - jQ_i = \sum_{k=1}^{n} \quad |Y_{ik}||V_i||V_k|[cos\,cos\,(\delta_k + \theta_{ik} - \delta_i) + j\,sin\,sin\,(\delta_k + \theta_{ik} - \delta_i)\ ]$ (12)
Separating (3.8) into real and imaginary parts we have,
$P_i = \sum_{k=1}^{n} \quad |Y_{ik}||V_i||V_k|\,cos\,cos\,(\delta_k + \theta_{ik} - \delta_i)$ (13)
$Q_i = -\sum_{k=1}^{n} \quad |Y_{ik}||V_i||V_k|\,sin\,sin\,(\delta_k + \theta_{ik} - \delta_i)$ (14)
Where
Y_{ik} = the admittance matrix
P_i = the injected real power
Q_i= the injected reactive power
δ_i= phase angle

Expanding (13) and (14) in Taylors series neglecting higher order terms we have

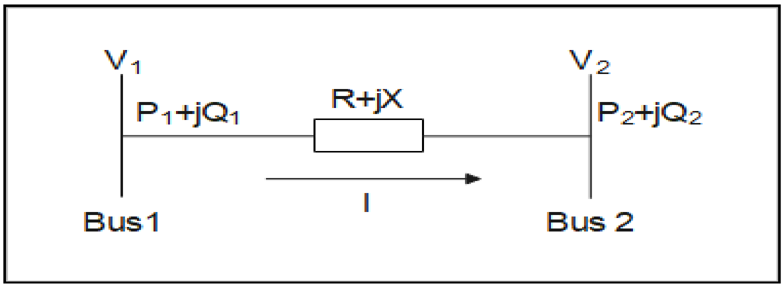
$$\left[\Delta P_2^{(k)} \ \vdots \ \frac{\Delta P_n^{(k)}}{\Delta Q_2^{(k)} \vdots \Delta Q_n^{(k)}}\ \right] =$$

$$\left[\left|\frac{\partial P_2^{(k)}}{\partial \delta_2} \cdots \frac{\partial P_2^{(k)}}{\partial \delta_n} \ \vdots \ddots \vdots \ \frac{\partial P_n^{(k)}}{\partial \delta_2} \cdots \frac{\partial P_n^{(k)}}{\partial \delta_n}\right| \left|\frac{\partial P_2^{(k)}}{\partial |V_2|} \cdots \frac{\partial P_2^{(k)}}{\partial |V_n|} \ \vdots \ddots \vdots \ \frac{\partial P_n^{(k)}}{\partial |V_2|} \cdots \frac{\partial P_n^{(k)}}{\partial |V_n|}\right| \left|\frac{\partial Q_2^{(k)}}{\partial \delta_2} \cdots \frac{\partial Q_2^{(k)}}{\partial \delta_n} \ \vdots \ddots \vdots \ \frac{\partial Q_n^{(k)}}{\partial \delta_2} \cdots \frac{\partial Q_n^{(k)}}{\partial \delta_n}\right| \left|\frac{\partial Q_2^{(k)}}{\partial |V_2|} \cdots \frac{\partial Q_2^{(k)}}{\partial |V_n|} \ \vdots \ddots \vdots \ \frac{\partial Q_n^{(k)}}{\partial |V_2|} \cdots \frac{\partial Q_n^{(k)}}{\partial |V_n|}\right|\right] \left[\Delta \delta_2^{(k)} \ \vdots \ \frac{\Delta \delta_n^{(k)}}{\Delta \left|V_2^{(k)}\right| \vdots \Delta \left|V_n^{(k)}\right|}\ \right]$$

(15)

The Jacobian matrix gives the linearized relationship between mall changes in voltage angle $\Delta \delta_i^{(k)}$ and magnitude $\Delta \left|V_i^{(k)}\right|$ with small change in real $\Delta P_i^{(k)}$ and reactive power $\Delta Q_i^{(k)}$ respectively.
$[\Delta P\ \Delta Q\ ] = [J_1\ J_3\ J_2\ J_4\ ][\Delta \delta\ \Delta |V|\ ]$ (16)
Where
$J_1,\ J_2, J_3, J_4$ are the elements of the Jacobian matrix

2 .2.2 Determination of Line Losses



$$P_L = I(R + jX) = (P_1 - P_2) + j(Q_1 - Q_2) \quad (17)$$

2.2.3 Determination of Capacitor Bank Sizing

2.2.3.1 Initial Reactive Power

$$pf_1 = cos\ cos\ \theta_1 \quad (18)$$

$$\theta_1 = (pf_1) \quad (19)$$

$$P = S_1\ cos\ cos\ \theta_1 \quad (20)$$

$$Q_1 = P\ tan\ tan\ \theta_1 \quad (21)$$

Where

pf_1: Initial power factor

θ_1: Initial power angle

S_1: Apparent power

P: Real power delivered

2.2.3.2 Desired Power Factor

$$pf_2 = cos\ cos\ \theta_2 \quad (22)$$

$$\theta_2 = (pf_2) \quad (23)$$

$$Q_2 = P\ tan\ tan\ \theta_2 \quad (24)$$

Where

pf_2: Desired power factor

θ_2: Desired power angle

S_2: Desired apparent power

P: Real power delivered

2.2.3.3 Capacitor Bank Size

$$Q_c = Q_1 - Q_2 \quad (25)$$

$$Q_c = P\ tan\ tan\ \theta_1 - P\ tan\ tan\ \theta_2 \quad (26)$$

$$Q_c = P(tan\ tan\ \theta_1 - tan\ tan\ \theta_2) \quad (27)$$

2.2.3.4 Determination of Transformer Loading

$$API = \frac{Operating\ MVA}{Rated\ MVA} \quad (28)$$

III. RESULTS AND DISCUSSION

3.1 Result Presentation for Pre-Upgrade Simulation

Figure 1 shows the simulation report of the existing network in ETAP 19.1. The red colour indicates that the voltage level has been violated.

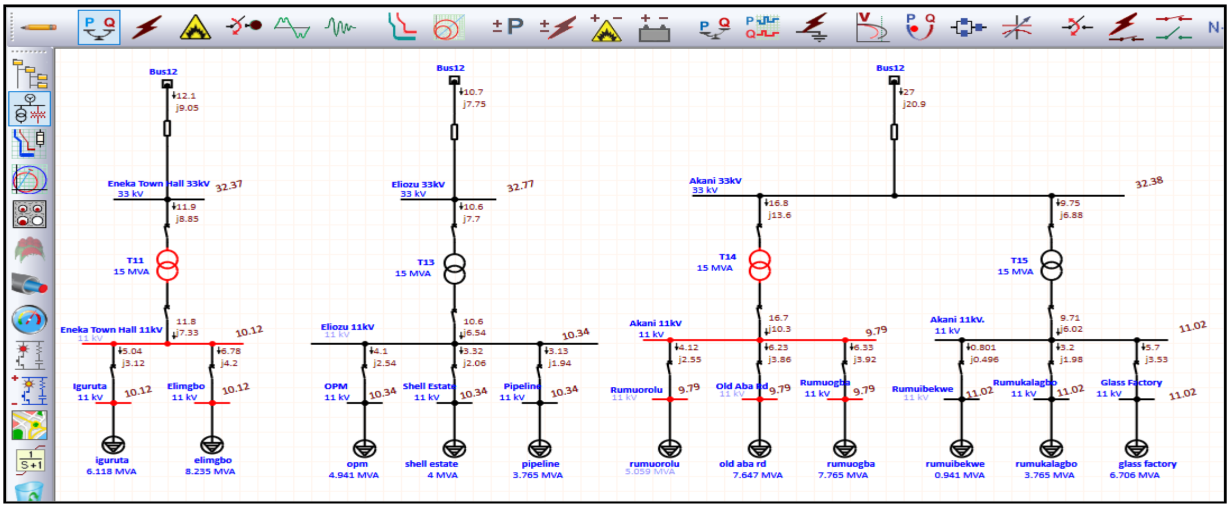


Figure 1: Pre-Upgrade Simulation for Eneka Town Hall. Eliozu and Akani Injection Substation

T11 and T14 transformers are overloaded as indicated with a red colour while Eneka Town Hall and Akani buses violated the minimum voltage threshold of 0.95pu to 1.05pu

Table 3 : Weak Buses

S/N	Bus ID	Nominal (kV)	Operating (kV)	% Operating
1	Elimgbo	11	9.788	88.98
2	Igwuruta	11	9.788	88.98
3	Old Aba Rd	11	9.449	85.90
4	Rumuogba	11	9.449	85.90
5	Rumuorolu	11	9.449	85.90

Table 3 shows the result from load flow simulation carried out on the existing distribution network using ETAP 19.1 software with the system's minimum and operational voltages. Table 3 reveals that five (5) buses are in violation of the 0. 95p.u. to 1. 05p.u. bus voltage statutory limit requirement.

Table 4: Determination of Overloaded Transformers

S/N	Device ID	Nominal MVA	Operating MVA	% Operating
1	T11	15	14.72	98.13
2	T14	15	21.59	143.93

Table 4 shows the nominal, operating and loading of the distribution transformers after performing load flow analysis in the pre-upgrade network condition. In the distribution system, overcrowded transformers are identified using the performance index of the transformer, and those with a performance index value more than 70% are regarded as being overloaded. This explains the cause of the low voltage profile of the buses duly linked to the affected substations.

Table 5 : Determination of Line Losses

Line ID	Power Flow						Losses	
	From Bus numeration	Active power kW	Reactive power Kvar	To Bus numeration	Active power kW	Reactive power kvar	Active power kW	Reactive power Kvar
13	9	11963	9048	16	11772	8837	191.1	211.2
14	9	10877	7819	17	10821	7758	56.6	61.4
15	9	26735	20951	18	26315	20462	419.8	488.5
Total							**667.50**	**761.10**

Table 5 shows the result of line flow and line losses obtained from load flow simulation in the pre-upgrade network condition. The total real and reactive power losses are 667.50kW and 761.10kVAr. A quick look at Table 5 shows that the highest real and reactive power loss occurred on bus 18 .

2.2 Post-Upgrade Result

Figure 2 shows the improved network after the placement of capacitor banks in the network.

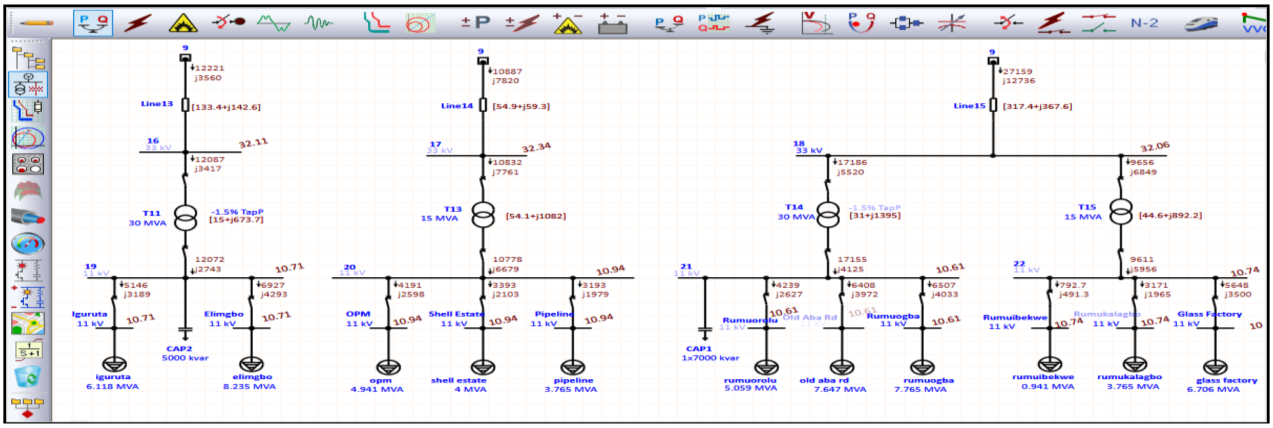


Figure 2: Post-Upgrade Simulation for Eneka Town Hall. Eliozu and Akani Injection Substation

Two capacitors of 5000kVAr and 7000kVAr were installed at bus 19 and 21 respectively to enhance the power quality. This technique has improved the voltage profile of the following buses : Elimgbu, Igwuruta, Old Aba Road, Rumuogba, and Rumuorolu from 88.98 to 97.45%, 88.98 to 97.45%, 85.90 to 96.45%, 85.90 to 96.45% and 85.90 to 96.45% respectively as shown in Table 6. This implies that the statutory voltage is not violated as shown in Table 6 and Figure 3.

Table 6 : Improvement of Bus Voltage

S/N	Bus ID	Nominal (kV)	Operating (kV)	% Operating
1	Elimgbo	11	10.72	97.45
2	Igwuruta	11	10.72	97.45
3	Old Aba Rd	11	10.61	96.45
4	Rumuogba	11	10.61	96.45
5	Rumuorolu	11	10.61	96.45

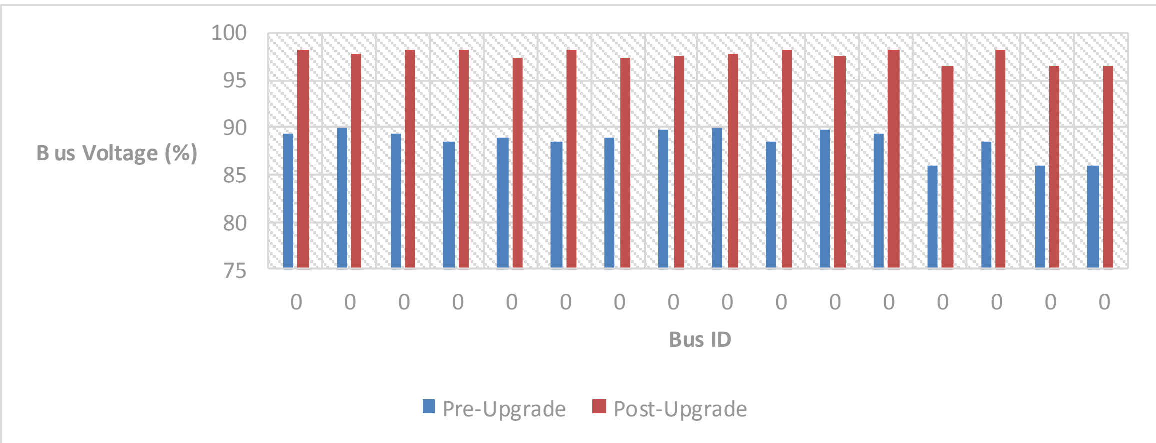


Figure 3 : Comparison Plot of Bus Voltage Profile

Figure 3 shows the graph of voltage profile for Obio Akpor distribution network for both existing and improved state. The blue colour shows the existing state when no capacitor bank is connected to the network. Similarly, the brown colours shows the improved state when a capacitor bank is connected to the network. The figure shows that the voltage profile of the network improved significantly when capacitor bank was connected to the system.

Table 7 : Reduction of Line Losses

Line ID	Power Flow						Losses	
	From Bus numeration	Active power kW	Reactive power Kvar	To Bus numeration	Active power kW	Reactive power kvar	Active power kW	Reactive power Kvar
13	9	12221	3560	16	12087	3417	134.0	143.0
14	9	10887	7820	17	10832	7761	55.0	59.0
15	9	27159	12736	18	26842	12369	317.0	367.0
Total							506.0	569.0

Table 7 shows the result of line flow and line losses obtained from load flow simulation in the post-upgrade network condition after fortifying the network. The total real and reactive power loss after optimization is 506.0kW and 569.0kVAr as against 667.50kW and 761.10kVAr. Which is an indication that the proposed optimization performed helped the network.

Table 8: Mitigation of Transformer Overload

S/N	Device ID	Nominal MVA	Operating MVA	% Operating
1	T11	30	12.56	41.870
2	T14	30	18.05	60.167

Table 8 shows the nominal, operating and loading of the distribution transformers after performing load flow simulation for post-upgrade network condition. The overloaded distribution transformers (T11 and T14) were upgraded from 15MVA to 30MVA and after which, A second load flow simulation was conducted. The performance index obtained thereafter shows that no transformer was over loaded in the network. Figure 4 shows the initial and upgraded condition of the transformers specifically T11 and T14.

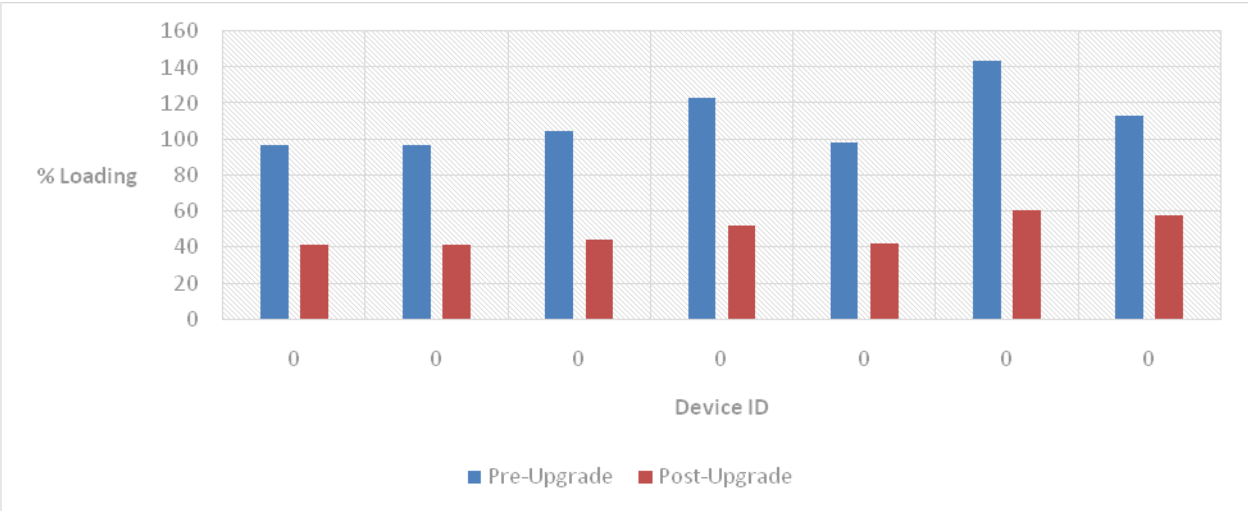


Figure 4: Comparison Plot of Transformer Load Profile

Figure 4 shows the graph of transformer load profile for Obio/Akopr distribution network for both existing and improved state. The blue colour shows the operating capacity of the over loaded transformers in the network. While the brown colours shows the operating capacity of the improved transformers in the network. Figure 4 shows that there was an improvement in transformer loading when weak or stressed transformers were upgraded.

IV. CONCLUSION

It is important for the quality of power to be maintained within a given stipulated limit to ensure steady and stable power supply to the last stage of electricity users and for good turn over to the utility company. The method utilized in this study is load flow using Newton Raphson's technique to identify the operating status of the substations. Capacitor banks compensation method was also applied to the network to improve the power quality. The methods applied was resourceful as the voltage profile of the weak buses were improved from 88.98 to 97.45%, 88.98 to 97.45%, 85.90 to 96.45%, 85.90 to 96.45% and 85.90 to 96.45%, the real power loss was minimized from 667.50kW to 506.0kW while the reactive power loss was reduced from 761.10kVAr to

569.0kVAr and the overloaded transformers were upgraded from 15MVA to 30MVA thus, improving the power quality of Eneka Town Hall, Eliozu and Akani injection substations.

REFERENCES

[1]. Abu-Mouti, F. S. & El-Hawary, M. E. (2018). 'Heuristic Curve-Fitted Technique forDistributed Generation Optimization in Radial Distribution Feeder Systems', IET Generation, Transmission &Distribution, 5(2), 172-180

[2]. Devaraj, D. & Roselyn, J. P. (2019). "Genetic algorithm based reactive power dispatch for Voltage stability improvement," International journal of Electrical Power and Energy Systems, 32(10), 1151-1156.

[3]. EDF Energy. (2013). Electricity and power factor. Retrieved from https://www.edfenergy.com/sites/default/files/Power_factor_information_sheet.pdf

[4]. Hamouda, A., & Zehar, K. (2017). Improvement of the power transmission of distribution feeders by fixed capacitor banks. Acta Polytechnica Hungarica, 4(2), 47-62.

[5]. Nwachukwu, K., Idoniboyeobu, D. C., Braide, S. L. & Bala, T. K. (2023). Improvement of Power Supply in Distribution Network : A Case Study of Okporo, Rumuodomaya and Woji Substations, Nigeria. Journal of Research and Advancement in Electrical Engineering, 6 (2), 11-18.
https://doi.org/10.5281/zenodo.8054950

[6]. Mohan, G., & Aravindhababu, P. (2019). A Novel Capacitor Placement Algorithm for Voltage Stability Enhancement in Distribution Systems. International Journal of Electronics Engineering, 1(1), 83-87.

[7]. Zaeim, K.F., Razmi, H., & Doagou, M.H., (2018) Multi-objective Transmission Congestion Management Considering Demand Response Programsand Generation Rescheduling,Applied Soft Computing, 7(10), 169-181.

[8]. Whitaker, J. C., (2018). AC power systems handbook, CRC Press,USA, 5-9

[9]. Gonen T. (2018). Electric Power Distribution System Engineering 2nd Edition CRC Press.

[10]. Hingorani, N. G (2015) Introducing custom power, IEEE Spectrum, 32(6), 41–48

[11]. Hosseinzadeh, F., Alinejad, B., & Pakfa, K. (2019). A New Technique in Distribution Network Reconfiguration for Loss Reduction and Optimum Operation. In CIRED 2019-20th International Conference and Exhibition on Electricity Distribution-Part 1. 1-3. IET.

[12]. Metia, A., & Ghosh, S. (2015). A Literature Survey on Different Loss Minimization Techniques used in Distribution Network. International Journal of Scientific Research and Education, 3(6), 3861-3877.