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ANALYSIS OF 11KV DISTRIBUTION SYSTEM CONSIDERING POWER LOSS MINIMIZATION AND ENHANCEMENT OF VOLTAGE PROFILE

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Keywords: *Electrical Transient Analysis Program Software (ETAP), Distribution Network, Capacitor Banks, Reactive power compensator, Statutory Voltage limit. Power Loss.*

Abstract: *Power losses and voltage control are vital problems associated with distribution system, which is injurious to the consumers, power system personnel and equipment on the power system. The penetration of reactive power through inclusion of capacitor is commonly used in distribution systems to solve these problems. In this paper a power flow analysis of 11kV distribution network system was assessed using Newton's Raphson method. Electrical Transient Analysis Program (ETAP 20.0 version) was used for the simulation of the base case. Sizable capacitor banks (300kVar) were deployed to the critically impacted buses, then load flow simulation was performed once more. The simulation results indicated that the totally different in voltage drops without and with Capacitor Bank penetration in the consideration Buses were 18.5%, and 4.44% respectively. The totally reduction in voltage drops with Capacitor Bank penetration in the consideration Buses was 14.06%. The totally different in real power loss without and with Capacitor Bank Penetration in the Buses in consideration were 19.86kW, and 8.12kW respectively. The totally different in real power loss with Capacitor Bank penetration in the three (3) Buse was 11.74kW. The total percentage Load Bus Magnitude with and without Capacitor Bank penetration in the Buses inconsideration were 294.21%, and 279.51% respectively. The totally different in the percentage Load Bus Magnitude with and without Capacitor Bank penetration in the Buses inconsideration was 14.7%. in conclusion all the Buses all the bus voltage profile falls within the IEEE declared limit of* $\pm 5\%$ *of nominal voltage.*

INTRODUCTION

Socio economic development, industrialization and technological advancement of every nation depends on adequate and reliable power supply (Igbogidi *et al.*, 2024)**.** The power supply system consists of generation, transmission, and distribution systems.

The most visible part of the power system sections that is exposed to the critical observations of the consumers is the distribution system. Delivery of electric power to the consumers is the main reason of building the distribution system (Ighalo *et al.,* 2012).

According to Dumkhana *et al.,* (2021), distribution systems are linked with high value of

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resistance to reactance ratio, huge number of nodes with networks that are radial in structure. So, there exists real and reactive losses power which consequently reduces the efficiency of the power system. Power loss minimization is a remedy to enhance efficiency and improve the voltage profile. One of the known methods of minimizing losses in distribution systems is the deployment of suitable capacitor banks in the distribution network when affordable cost and easy maintenance is of paramount consideration (Sun & Abe, 2018). To achieve optimal compensation of any distribution network, the capacitor banks sizing should be accurate, then rightly placed for effective loss minimization and voltage magnitude enhancement (Acharya *et al.,* 2006; and Atwa *et al.,* 2018).

The economic enticement of distribution companies (DISCOS) was to minimize losses in their network. This enticement was the difference in cost obtained between real losses and standard losses when the real losses are more than standard losses, there may be black out and DISCOS suffer financial loss (Orovwode *et al.,* 2022).

2. Related Works

Power loss minimization problem is a well suitable researched topic, several authors have proposed different strategies on the transmission and distribution systems to reduction losses and of minimize voltage instability, then improve the power system at higher reliability and efficiency. They are different from each other by choice of loss reduction strategy, problem formulation and as well as method employed, and the solutions obtained. So, these are some relevant literatures on power loss minimization technique and how it enhances the power system performance.

According to Ekeriance & Wokoma, (2024), they presented a work on the assessment of 11kV distribution network for power loss minimization using analytical technique. Load flow study was carried using embedded Newton Raphson algorithm in Electrical Transient Analysis Program (ETAP) software. Simulation was carried out for both existing case and improved case of the 11kV distribution network. The results obtained shows that in the base case network, three (3) out of the thirteen (13) distribution transformers were critically overloaded and real and reactive power losses were 57.92kW and 86.9kVar respectively. When an analytically sizable capacitor banks (300kVar) was injected to the system, all the transformers were better loaded, the real and reactive power losses were reduced to 46.18kW and 69.27kVar respectively.

According to Ohanu *et al.,* (2020), they carried out a study on minimization of power loss in distribution grid using Heuristic Approach for capacitor placement and sizing technique was tested on a realistic network at Enugu state.

The Newton Raphson load flow method was applied in modeling the single line diagram of the study case network in PSAT enabled in MALAB/Simulink software environment. The study case network is made up of 30 bus, 11kV, 15 MVA transformer with an initial power factor rating 0.85. the result obtained show that real power losses was minimized from 0.556MW to 0.277MW on the application of maximum capacitor bank rating of 1200KVar, while the reactive power was also reduced from 750KVar to 450KVAar. The technique also present a less computational time.

According to Ntombela *et al.,* (2020), they presented a work on power loss minimization and voltage

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profile improvement by combination of system reconfiguration and distributed generation (DG) sizing and placement using Hybrid Based Optimization Algorithm consisting of the Genetic Algorithm and the Improved Particle Swarm Optimization algorithm for minimizing active power loss and maintaining voltage magnitude at about IPU. The buses at which DG should be injected were identified based on optimal real power loss and reactive power limit. The proposed reconfiguration was tested on IEEE 30 bus network system with DGs allocations, and the simulations were carried out using MATLAB. The results obtained show that the IEEE 30 bus test system with DGs integrated at various location revealed reductions in overall real power loss of 40.7040%, 36.2403% and 42.9406% for type 1, type 2 and type 3 DGs allocation respectively. The highest bus voltage profile goes to 1.01 PV in the IEEE 30 bus. They concluded that the combination Hybrid GA & IPSO (HGAIPS) method has a smaller iteration and more efficient in optimization problem.

According to Okelola *et al.,* (2021), they presented a paper aimed at power loss minimization and reduction of cost due to losses, as well as network voltage stability improvement in distribution system through using shunt capacitor allocation. Whale optimization algorithm technique was used to determine the optimal size of the shunt capacitor. The proposed technique as tested on IEEE 33 bus and Dada 46 bus distribution network. The result obtained gave a percentage loss reduction of 33.74% with 27.6% annual net savings for IEEE 33 bus and 22.24% loss reduction with 25.60% annual net savings for Dada 46- bus network.

According to Ngang *et al.,* 2021), they presented a work on improving loss reduction on 33KV power distribution network using optimized genetic algorithm. They run a load flow of a characterized 33KV distribution network and determine losses, the losses were minimized using Optimized Genetic Algorithm (OGA) and model was implemented in MATLAB/Simulink. The result obtained show that there was a 75% percentage power loss in the 33KV distribution network without OGA. But when Optimized Genetic Algorithm (OGA) is incorporated in the system, the percentage loss is 72.9%, that is, there is improvement of 2.1% percentage power loss when OGA was used.

3.1 Materials & Methods

The materials used were Capacitor Banks, the network diagram. Electrical software used was Transient Analysis Program Software (ETAP). The Newton-Raphson method (NR) was used for load flow simulation.

3.2 The 11kV Marine Base Distribution Network

The 6.35km, 33kv/11kv power distribution network in Marine Base, Port Harcourt was modelled in ETAP software, which integrates eighteen (18) distribution transformers as shown in Figure 1.

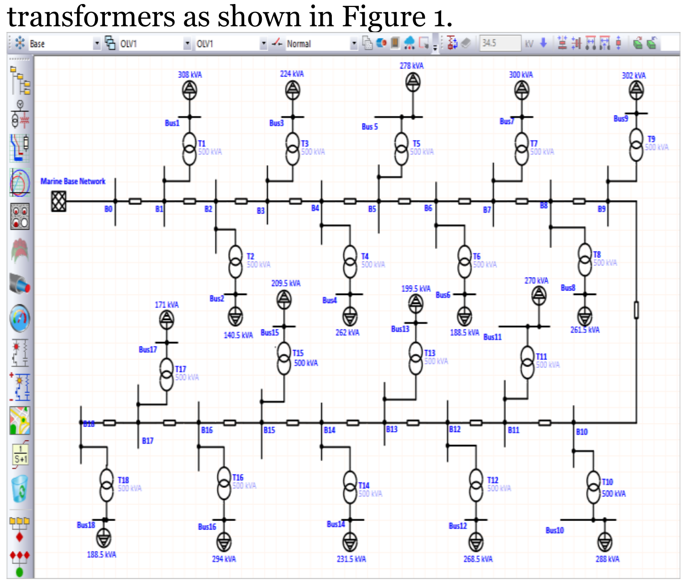

Figure 1: The 11kV Marine Base Distribution Network in Port Harcourt

Table 1. Shows the transformer load data on each of the transformer in the Network.

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Table 1: *The transformer load data at 11KV Distribution Network Marine Base.*

Bus	Load Bus Name	Input/output	Load (KW)	Distance (KM)
1	Hospital Road	11/0.415KV	246.4	0.35
2	Pott Johnson street	11/0.415KV	112.8	0.37
3	Barthus Street	11/0.415KV	179.2	0.36
4	Degema Street	11/0.415KV	209.6	0.36
5	Lagos Street	11/0.415KV	128.8	0.33
6	CPS	11/0.415KV	150.4	0.3
7	Police W/Shop	11/0.415KV	275.2	0.38
8	Prime Rose 1	11/0.415KV	208.8	0.37
9	Prime Rose 2	11/0.415KV	241.6	0.32
10	Radio Rivers	11/0.415KV	134.4	0.35
11	St. Cyprian Church	11/0.415KV	79.04	0.38
12	Accra Street	11/0.415KV	214.4	0.33
13	Illorin Street	11/0.415KV	159.2	0.35
14	Osu Street	11/0.415KV	185.6	0.34
15	barrack Street	11/0.415KV	168	0.32
16	Eberi Street	11/0.415KV	235.2	0.35
17	King Ogan Street	11/0.415KV	136.8	0.38
18	Free town	11/0.415KV	150.4	0.38

3.3 Power Flow Problem Formulation

The Newton-Raphson method (NR) was used for its high-speed convergence, suitability for large power systems and the adaptability to most power system modelling.

Expressing the power system network current flow in polar form was given as

$$I_i = \sum_{j=1}^{n} |Y_{ij}||V_t| \angle(\theta_{ij} + \delta_j) \qquad (1)$$

The determination of the real power at a specified bus was given as;

$$P_i = |V^* I_i + jQ_i| \qquad (2)$$

The rearrangement of (1) and (2) in polar form as shown in (3);

$$P_i = |V_i| \angle(-\delta_i) \sum_{j=1}^{n} |Y_{ij}||V_t| \angle(\theta_{ij} + \delta_j) + jQ_i \qquad (3)$$

The real and reactive power in (1), was detached for easy evaluation to achieved (2), and (3), respectively.

$$P_i = \sum_{j=1}^{n} |Y_{ij}||V_t||V_j| \cos(\theta_{ij} + \delta_j - \delta_i) \qquad (4)$$

and

$$Q_i = \sum_{j=1}^{n} |Y_{ij}||V_t||V_j| \sin(\theta_{ij} + \delta_j - \delta_i) \qquad (5)$$

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The real and reactive power in (4), and (5), was expanded using Taylor series to obtained linear equations connecting a Jacobian matrix, which shows clear- link relating small variation of real power with voltage angle and the variation of voltage magnitude with reactive power. This was simplified in (6).

$$\begin{vmatrix}\Delta P \\ \Delta Q\end{vmatrix} = \begin{bmatrix} j_1 & j_2 \\ j_3 & j_4 \end{bmatrix}\begin{bmatrix}\Delta\delta \\ \Delta V\end{bmatrix} \qquad (6)$$

ΔP and ΔQ represent differences between specified values and calculated values respectively. ΔV and $\Delta\delta$. Represent voltage magnitude and voltage angle respectively in incremental forms and sub-matrices J_1 through J_4 form the Jacobian matrix.

3.4 Capacitor Bank Size Determination

The size of capacitor bank was determined analytically using the (7).

$Q_c = P\{\tan(\cos^{-1}(pf_1)) - \tan(\cos^{-1}(pf_2))\}$ (7)

Where;

P: Injected Power to the bus

pf_1 Initial power factor

pf_2 Desired power factor

4.1 RESULTS AND DISCUSSION

The result in Figure 2. Shows the ETAP modeling of the network under consideration which comprises of eighteen (18) Buses, without capacitor bank. The network indicated that three (3) Buses (bus 5, bus 10 and bus 11) of the eighteen (18) Buses were overloaded.

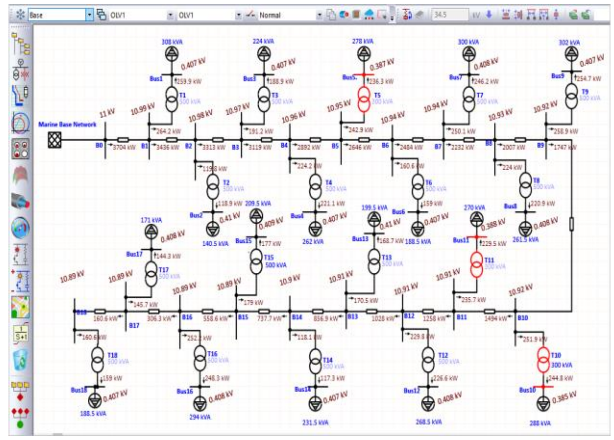

Figure 2: The 11kV Marine Base Distribution Network in Port Harcourt, without Capacitor Bank.

The result in Figure 3. Indicated that the three (3) Buses (bus 5, bus 10 and bus 11) that were overloaded were penetrated with 100KVar Capacitor Bank size respectively, as the overloaded transformers were successfully upgraded to standard loading conditions.

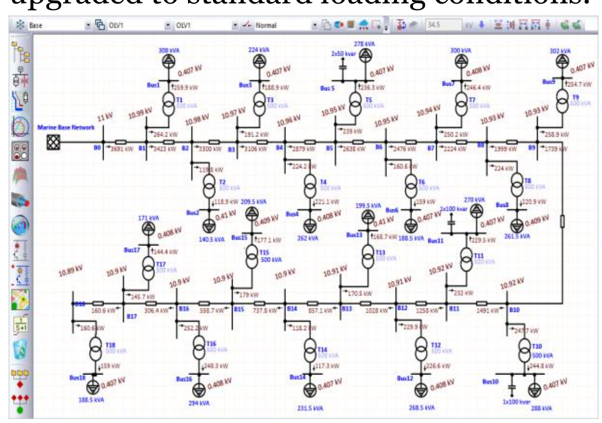

Figure 3: The 11kV Marine Base Distribution Network in Port Harcourt, with Capacitor Bank

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3.1 The Network Voltage Drop, with and without Capacitor Bank

The result in Figure 4. Shows that the value of voltage drops without Capacitor Bank penetration within the three (3) Buses (T5- B5, T10 – B10, and T11 – B11) were 6.3%, 6.48%, and 5.72% respectively, which shows that the voltage drops values were very high.

The three (3) Buses inconsideration were penetrated with 100kVar Capacitor Bank each to reduces the voltage drop, which the value (1.48%) was the same respectively. The different in voltage drop, without and with capacitor bank penetration in which of the three Buses (T5- B5, T10 – B10, and T11 – B11) were 4.82%, 5%, and 4.24% respectively. The totally different in voltage drops without and with Capacitor Bank penetration in the consideration Buses were 18.5%, and 4.44% respectively. The totally reduction in voltage drops with Capacitor Bank penetration in the consideration Buses was 14.06%.

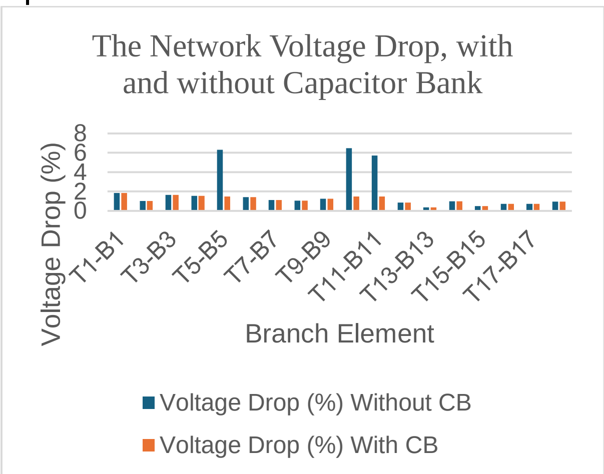

Figure 4: The Network Voltage Drop, with and without Capacitor Bank

3.2 The Network Real Power Loss with and without Capacitor Bank

The result in Figure 5. Indicates that the value of the real power loss without Capacitor Bank penetration in the three (3) Buses (T5- B5, T10- B10, and T11 – B11) were 6.58kW, 7.11kW, and 6.17kW respectively, which shows that the real power loss values were very high. The value of 100Kvar Capacitor Bank was penetrated to the three (3) Buses respectively, to reduce the real power loss in the Buses (T5- B5, T10- B10, and T11 – B11) which values were 2.69kW, 2.91kW, and 2.52kW respectively. The different in the real power loss without and with Capacitor Bank penetration in the three (3) Buses (T5- B5, T10 – B10, and T11 – B11) were 3.89%, 4.2kW, and 3.65kW respectively. The totally different in real power loss without and with Capacitor Bank Penetration in the Buses in consideration were 19.86kW, and 8.12kW respectively. The totally different in real power loss with Capacitor Bank penetration in the three (3) Buse was 11.74kW.

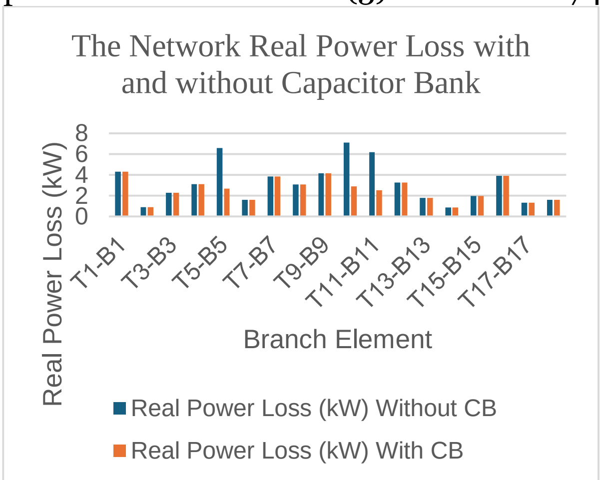

Figure 5: The Network Real Power Loss with and without Capacitor Bank Penetration

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3.3 The Percentage Load Bus Magnitude with and without Capacitor Bank.

The result in Figure 6. Indicates that the penetration of 100Kvar Capacitor Bank in the system increases the percentage Load Bus Magnitude in the three (3) Buse, which indicated that values (98.07%) were the same respectively. The percentage Load Bus Magnitude without Capacitor Bank penetration in the three (3) Buses (B5, B10, and B11) were 93.25%, 92.77%, and 93.49% respectively. The different in the percentage Load Bus Magnitude without and with Capacitor Bank penetration in the three (3) Buses (B5, B10, and B11) were 4.82%, 5.3%, and 4.58% respectively.
The total percentage Load Bus Magnitude with and without Capacitor Bank penetration in the Buses inconsideration were 294.21%, and 279.51% respectively.
The totally different in the percentage Load Bus Magnitude with and without Capacitor Bank penetration in the Buses inconsideration was 14.7%.

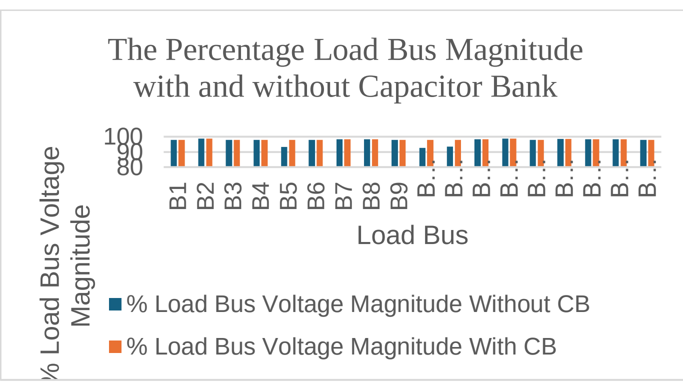

Figure 6: The Percentage Load Bus Magnitude with and without Capacitor Bank.

4. CONCLUSION

In conclusion, the network data were gotten from Port Harcourt Electricity Distribution Company (PHED). The 33kv/11kv Marine Base Distribution Network was model with ETAP software, the Embedded Newton Raphson method was used for the load flow. The network under consideration comprises of eighteen (18) transformers and Buses respectively. The Voltage Drop, Real Power Loss, Power Losses and Percentage Load Bus Magnitude were determined. The network indicated that three (3) Buses (bus 5, bus 10 and bus 11) of the eighteen (18) Buses were overloaded. The value of 100Kvar Capacitor Banks were penetrated to the imparted Buses.
The totally different in voltage drops without and with Capacitor Bank penetration in the consideration Buses were 18.5%, and 4.44% respectively. The totally reduction in voltage drops with Capacitor Bank penetration in the consideration Buses was 14.06%.
The totally different in real power loss without and with Capacitor Bank Penetration in the Buses in consideration were 19.86kW, and 8.12kW respectively. The totally different in real power loss with Capacitor Bank penetration in the three (3) Buse was 11.74kW.
The total percentage Load Bus Magnitude with and without Capacitor Bank penetration in the Buses inconsideration were 294.21%, and 279.51% respectively. The totally different in the percentage Load Bus Magnitude with and

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NOMENCLATURE

DGs	Distributed Generations
MATLAB	Matrix Laboratory
PHED	Port Harcourt Electricity Distribution Company
ETAP	Electrical Transient Analysis Program
GA	Genetic Algorithm
IPSO	Improved Particle Swarm Optimization
IEEE	Institute of Electrical and Electronic Engineers
OGA	Optimized Genetic Algorithm
ETAP	Transient Analysis Program Software.
NR	The Newton-Raphson method
DISCOS	Distribution Companies
PHED	Port Harcourt Electricity Distribution Company

REFERENCES

Acharya, N., Mahat, P. & Mithulanantha, N. (2006). An analytical Approach for DG Allocation in Primary Distribution Network. *International Journal of Electric Power Energy System*, 28(10), 669-678.

Atwa, Y., El-Saadany, E., Salama, M. & Seethapathy, R. (2018). Optimal Renewable Resources Mix for Distribution System Energy Loss Minimization, IEEE Transaction on Power System, 25(2), 360-370.

Dumkhana, L., Ahiakwo, C. O., & Idoniboyeobu, D. C. & Braide, S. L. (2021). Analysis and simulation of High Voltage Alternating Current Connectivity of Afam-Bonny Island. Iconic Research and Engineering Journals. 5(3), 91-97.

Ekeriance, D. E., & Wokoma, B. A., (2024) Assessment of 11KV Distribution Network for Minimization using Analytical Technique for capacitor sizing. International Journal of Innovation Research in Electrical, Electronic, Instrumentation and Engineering. 12(2): 1-6.

Igbogidi, O. N., Amadi, H. N., & Ekeriance, D. E., (2024) Analysis of High Voltage Direct Current Transmission Line Bus Voltage

Using Load and Component Sizing Method. Journal *of Recent Trend In Electrical Power Systerm*,7(1) 1-9.

Ighalo, G. I., & Williams, A. A. (2012). Simulating Power Distribution Network in Nigeria. The Ikpoba –Hill District Network as A case Study. *International Journal of Scientific Technology Research,* 1(9), 1-8.

Ohanu, C. P., Ohanu, I. B. & Ogbuefi, U. C. (2020). Power Minimization in the Distribution Network: Heuristic Approach for Capacitor Placement. LGT-ECE-UNN. International Conference: Technological Innovation for Holistic Sustainable Development. (TECH IS D2020).

Orovwode, H., Simeon, M., Amuta, E. & Alashiri, O. (2022). Losses in the Nigerian Distribution Systems: A Review of Classification and Strategies for Mitigation. *International Journal of Engineering Research and Technology,* 13(11)3251-3254.

Okelola, M.O., Adebisi, O.W., Salimon, S. A., Alayande, S.O. & Amoo,A.L.(2021). Optimal Sizing and Placement of Shunt Capacitor on the Distribution System Using Whale Optimization Algorithm. Nigeria Journal of Technological Development, 9(1),40-47.

Ngang, N. B., Bakare, K., Ugwu, K.I. & Aneke, N. E. (2021). Improving Loss Minimization in 33kV Power Distribution Network Using Optimized Genetic Algorithm. International Journal of Systems Engineering,5(1),34-42.

Ntombela, M., Musasa, K. & Leoaneka, M. C. (2020). Power Loss Minimization and Voltage Profile Improvement by System Configuration, DG Placement and Sizing, *MDPI Journal*, 10(10), 180-185.

Sun, D. I. & Abe, S, (2018). Calculation of Energy Losses in a Distribution System, IEEE Transactions on Power Apparatus, and system, 3(2), 45-49