International Journal of Artificial Intelligence Trends (IJAIT)
Vol. 4, Issue VIII; No. 57, August, 2025, pp. 593-604

DETERMINATION OF POWER LOSSES AND ANALYSIS OF NSUKKA 33KV POWER DISTRIBUTION NETWORK

Ani Anthony. E[1], Ilo Frederick Udebunu[2], Emetu Chukwuma Kalu[3]

[1,2,3]Department of Electrical and Electronic Engineering Faculty of Engineering Enugu State University of Science and Technology (ESUT) Enugu, Nigeria

Article Info
Received: 23/7/ 2025
Revised: 9/8/2025
Accepted 17/8/2025
Corresponding Authors Email:
tonyani@yahoo.com[1]
Corresponding Author's Tel:
[1]+ 2348065792628

ABSTRACT

Power losses in distribution systems have been a big disadvantage to both the distribution company and to the consumers who always pay more than they consume. The aim of this research is to provide a technique of minimizing power losses in 33kV distribution network at Nsukka. In a distribution network, power losses can be classified as either technical or non-technical. Only technical losses are of interest in this report. Energy dissipated in conductors, transmission line equipment, transformers, sub-transmission lines, distribution lines, and magnetic losses in transformers are the main causes of technical losses. Characterizing the current 33kV distribution system at Nsukka was the first step in resolving the aforementioned issue. This was carried out in order to prove that power losses in the 33kV distribution network do occur and to identify the root cause of those losses. In order to effectively carry out this operation, a SIMULINK model of the distribution network was developed. The results of Characterization shows that Feeders 2 has power loss of 3.2% , Feeders 3 has power loss of 4.2%, Feeders 6 has power loss of 2.9% and Feeders 8 has power loss of 1,1%. The next thing done was to develop an algorithm for particle swarm optimization that can minimize the losses in the distribution systems. The developed algorithm was integrated into the developed Simulink Model. A Matlab program was written while Simulink environment in Matlab aided the simulation processes. The results obtained based on the performance of particle swarm optimization for minimizing power losses in distribution network were compared to the results obtained from Conventional systems. From the Values obtained, in feeder 2 the conventional Power loss was 16% while that of Particle swarm optimization Power loss was 15.285%, in feeder 3 conventional Power loss was 21% while that of Particle swarm optimization Power loss was 20.065%, in feeder 6, conventional Power loss was 14.5% while that of Particle swarm optimization Power loss was 13.855% and in feeder 8, conventional Power loss was 5.5% while that of Particle swarm optimization Power loss was 5.255%. The above results show that the use of Particle swarm optimization has reduced the quantity of power loss in 33kV distribution network.

Keywords: Power Losses, Load Flow Analysis, Nsukka 33kV Power Distribution Network, FACTS Devices, Optimization, Energy Efficiency

1. INTRODUCTION

Energy losses happen during the process of delivering electricity to customers for technical reasons. Power losses typically occur when the amount of electricity delivered to customers is less than the amount generated. Some other factors responsible for power losses include undesired heating of resistive components, losses due to transformer windings and cores, skin effects as well as magnetic losses due to eddy currents. Transformer overloads, over sizing of generation, transmission, and distribution equipment, voltage drop at line ends, rising supply cable temperatures, and over sizing of load protection due to harmonic currents are the main causes of power losses in transmission and distribution networks (Onah and Agu, 2012). In the opinion of Komolafe and Udofia (2020), losses are seen to be inevitable in power system Networks. The authors continued by saying that even technological advanced countries cannot make all the generated electricity available to consumers without any loss.

1.2 Justification of the Study

Electricity is modern society's most convenient and useful form of energy. Without it, the present social and physical infrastructure would not all be feasible. The increasing per capita consumption of electricity throughout the world reflects a growing standard of living of the people (Gyugyi, 2009). The greater the per capita consumption of electrical energy in a country, the higher is the standard of living of its people. To reflect this global *tr*end, the Electric Power Research Institute (EPRI) in the US launched the Flexible Alternatin*g* Current Transmission System (FACTS) initiative in the later 1980's with two main objectives: To increase the power transfer capability of electric power system and to conveniently keep voltage constant over designated routes.

1.3. Problem Statement

The instability of power supply in NSUKKA metropolis is as a result of the per unit volts not falling within the range of 0.95 through 1.05. This has equally led to inefficiency in power supply in NSUKKA metropolis this has liquidated some companies or establishments that solely depend on power to run their routine business. This is surmounted by introducing Improving energy y efficiency using FACTS device Technique in NSUKKA 33kv distribution network

1.4 Significance of the Study

In a modern powers system, there are several elements between the generating station and the consumers. Several voltage control equipment are used at various points in the system for the following reasons (Gupta 1995):

The power network is extensive and there is considerable voltage drop in transmission and distribution system the various circuits of the power system have dissimilar load characteristics. For these reasons, it is necessary to provide individual means of voltage control for each circuit or groups of circuit. In view of the above analysis, the significance of this technical research work includes:

a) Helping government agencies like the Nigerian Electricity Regulatory Commission (NERC) to postulate and implement power policies like statutory limit of voltage variation, optimization and improved power quality.

b) This technical research work has equally shown that power electronic high speed control FACTS-DEVICE is a more efficient method of voltage control than the electromechanically controlled synchronous condenser presently in use at ogui power distribution network control of power system parameters and enhancement of power quality using FACTS devices.

1.5 Scope of the Study

The scope of this research work covers the reduction of power losses in NSUKKA distribution network only. It does not extend to restructuring of the distribution networks.

2. METHODOLOGY

This work is built upon the principle of steady-state operation and modeling of FACT controller describes the power flow theory. Newton-Raphson model was developed because of their strong convergence characteristics have proved the most successful and have been embraced by power industry. This work employed an elegant method for accommodating models of controllable equipment namely STATCOM Flexible Alternating Current Transmission System controller into the Newton-Raphson power flow algorithms. The algorithm was simulated using MATLAB 2015a Two different power flow programs of EECD Distribution Network are written in MATLAB environment, MATLAB program to calculate positive sequence power flows using the conventional Newton-Raphson method and MATLAB program to incorporate the static compensator (STATCOM) FACTS controller within the Newton-Raphson power flow algorithm. Data was collected to test-run the model from EECD Enugu. The model was compared with network that has FACT DEVICE and NO FACT DEVICE.

3. TO CHARACTERIZE THE 33KV NSUKKA POWER DISTRIBUTION NETWORK TO ESTABLISH POWER LOSSES.

Power loss is the outage of power from the power system which occurs unexpectedly. However the loss in power transmission lines could be as a result of the voltage level, distance of transmission, the level of current and so on etc.

Table 1 collected data of NSUKKA distribution network

S/n	Feeders	P_{Actual}(MW)
1	Township	3.98
2	Wilson	1.04
3	UNN	2.67
4	Onuiyi	0.97

Table 2 empirical data for 33KV distribution network in NSUKKA metropolis.

Bus No	Bus code	|V| P.U	Ang Degree	Load MW	Load MVar	Gen MW	Gen Mvar	Gen Min	MVar Max	Injected MVar
1	1	0.86	0	0	0	0	0	0	0	0
2	0	0.91	0	0	0	0	0	0	0	0
3	0	0.81	0	150	120	0	0	0	0	0
4	0	1.0	0	0	0	0	0	0	0	0
5	0	1.0	0	120	60	0	0	0	0	0
6	0	0.6	0	140	90	0	0	0	0	0
7	0	1.0	0	0	0	0	0	0	0	0
8	0	1.0	0	110	90	0	0	0	0	0
9	0	1.0	0	80	50	0	0	0	0	0
10	2	1.025	0	0	0	200	0	0	180	0
11	2	1.05	0	0	0	160	0	0	120	0

Table 3: load distribution in the network after running the load flow

S/n	Feeders	(V)P.U.	P_{Actual}(MW)	P_{Load}(MW)	%Loss
1	Township	0.869	3.98	3.81	4.3
2	Wilson	0.880	1.04	0.965	7.2
3	UNN	0.966	2.67	2.67	0
4	Onuiyi	0.959	0.97	0.97	0

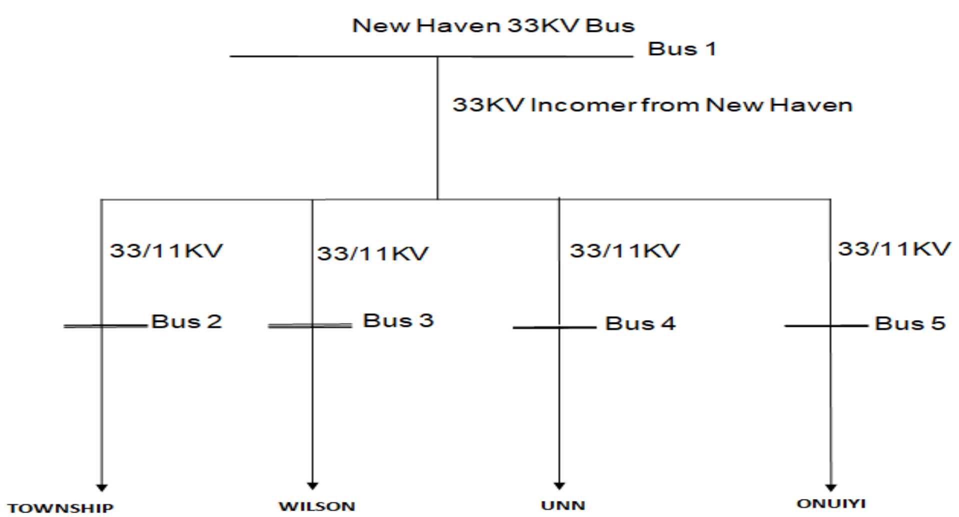

Fig 1: Single Line Diagam of the Nsukka 33 KV Power Distribution Network

International Journal of Artificial Intelligence Trends (IJAIT)
Vol. 4, Issue VIII; No. 57, August, 2025, pp. 593-604

The Nsukka 33KV distribution network consists of five buses, four feeders, four transformers and five transmission lines. it receives its incoming 33KV supply from the New Haven 330/132/33KV transmission network. The 33KV voltage is then stepped down to 11KV using four 5MVA, 33/11KV transformers and feeds Township, Wilson, UNN and Onuiyi on 11KV as shown in fig 1 above.

The formula for the percentage loss in a power system can be calculated using the formular:

$$\%PowerLoss = \left(\frac{ActualPower - LoadPower}{ActualPower}\right) \times 100 \qquad (1)$$

% power loss at Township

% power loss= (3.98 -3.81) x 100% = 4.3%

% power loss= (1.04 -0.965) x 100% = 7.2%

% power loss at UNN (2.67 -2.67) x 100% = 0%

% power loss at Onuiyi = 0%

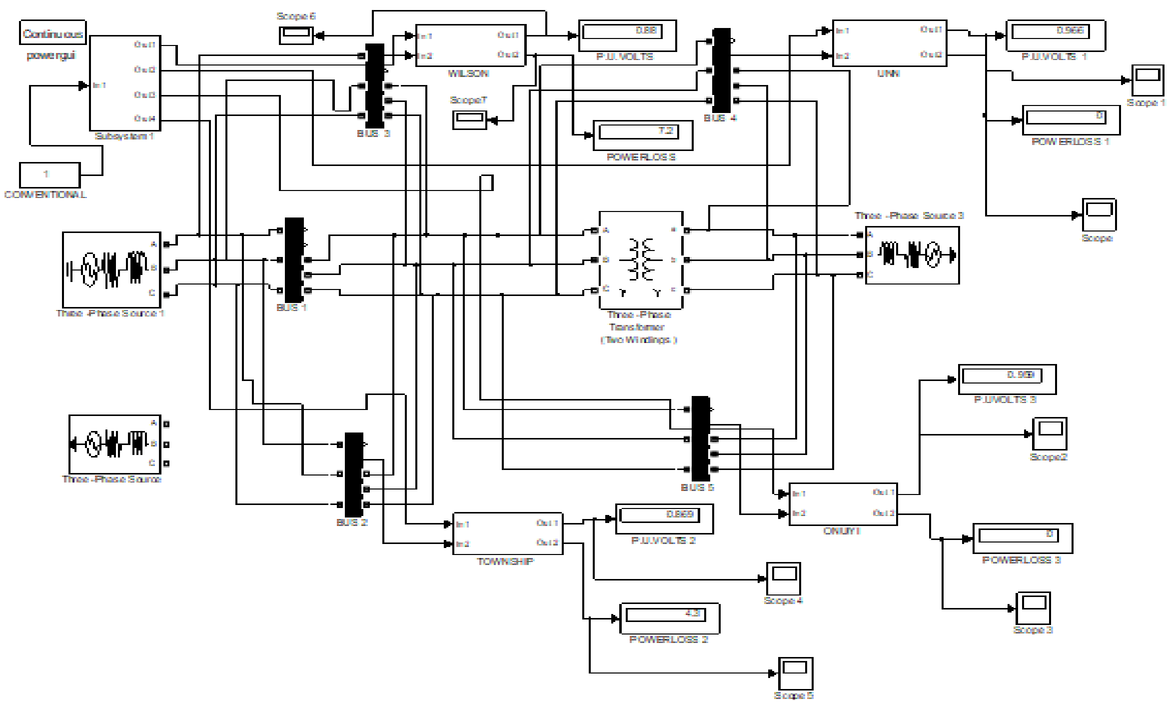

Fig 2: Conventional SIMULINK model for improving energy y efficiency in NSUKKA 33kv distribution network

Fig 2 shows conventional SIMULINK model for improving energy y efficiency in NSUKKA 33kv distribution network. The results obtained are as shown in figures 5 through figure 8.

To use SIMULINK to model FACTS device for minimizing Power losses in the NSUKKA 33KV Power Distribution Network

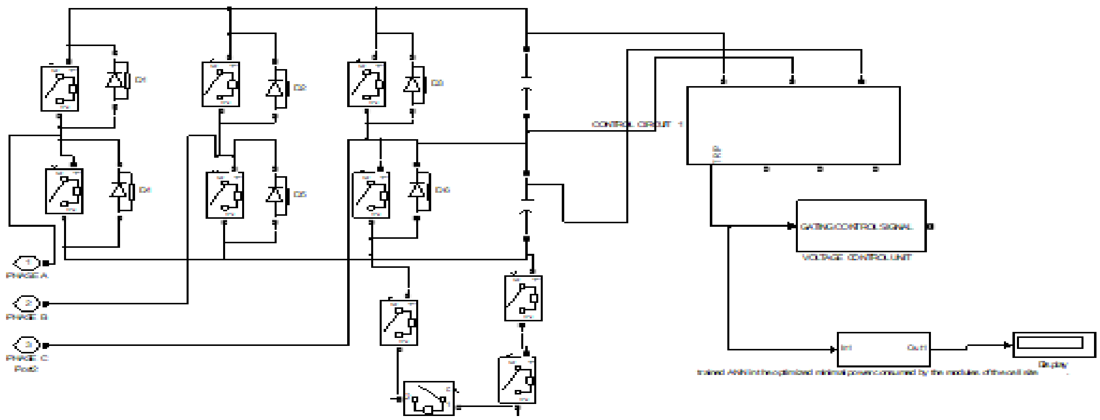

Fig 3: FACTS device SIMULINK model for minimizing Power losses in the NSUKKA 33KV Power Distribution Network

To repeat the load flow analysis with the FACTS device and its control circuit integrated into the SIMULINK Model of the NSUKKA 33KV Power Distribution network for minimizing power losses

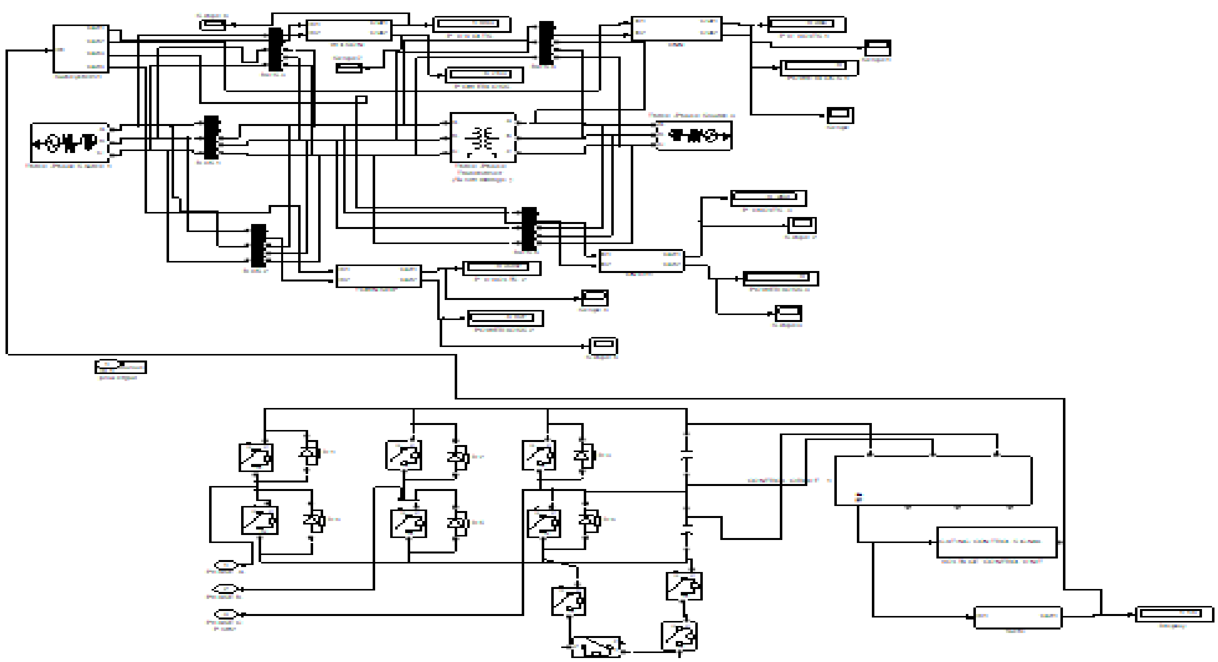

Fig 4: Repeated load flow analysis with the FACTS device and its control circuit integrated into the SIMULINK Model of the NSUKKA 33KV Power Distribution network for minimizing power losses

International Journal of Artificial Intelligence Trends (IJAIT)
Vol. 4, Issue VIII; No. 57, August, 2025, pp. 593-604

Fig 4 shows repeated load flow analysis with the FACTS device and its control circuit integrated into the SIMULINK Model of the NSUKKA 33KV Power Distribution network for minimizing power losses. The results obtained after extensive simulation are as shown in figures 5 through figure 8.

3. RESULTS AND DISCUSSIONS

Table 4 comparing conventional and facts device P.U. volts in bus 3(WILSON) in Improving energy y efficiency in NSUKKA 33kv distribution network. Fig 5 shows comparing conventional and facts device P.U. volts in bus 3(WILSON) in Improving energy y efficiency in NSUKKA 33kv distribution network. Fig 4.1 shows that the conventional per unit volts in bus 3 is 0.88 which implies that the power supply therein is unstable because it did not fall within the stable range of 0.95 through 1.05. On the other hand, when Facts device is incorporated in the system it boost the per unit volts to 1.003 thereby enhancing energy efficiency in bus 3. Fig 6 shows comparing conventional and facts device power loss in bus 3 (WILSON) in Improving energy y efficiency in NSUKKA 33kv distribution network. In bus 3 the conventional percentage of power loss in NSUKKA 33kv distribution network is7.2% thereby reducing the energy efficiency of the distribution network at Wilson in NSUKKA metropolis.

Time(s)	Conventional P.U. volts in Bus 3(WILSON) in Improving energy y efficiency in NSUKKA 33kv distribution network.(volts)	FACTS device P.U VOLTS(WILSON) in Improving energy y efficiency in NSUKKA 33kv distribution network.(volts)
1	0.88	1.003
2	0.88	1.003
3	0.88	1.003
4	0.88	1.003
10	0.88	1.003

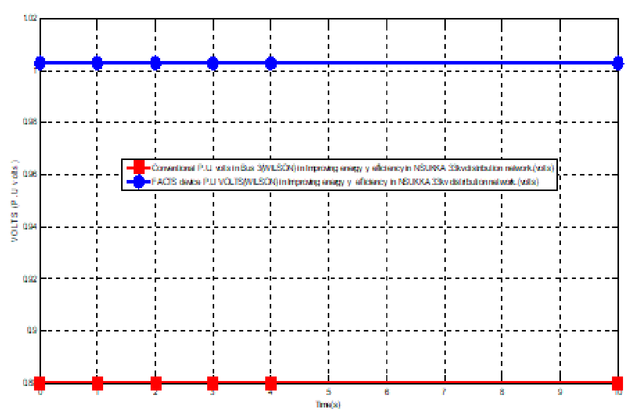

Fig 5 comparing conventional and facts device P.U. volts in bus 3(WILSON) in Improving energy y ef``12ficiency in NSUKKA 33kv distribution network.

Meanwhile, when Facts device is imbibed in the system it reduced the power loss in bus 3 to 6.743% thereby improving the energy efficiency in bus 3 to 0.46%. Fig 7 comparing conventional and facts device P.U. volts in bus 2 (Township)) in Improving energy efficiency in NSUKKA 33kv distribution network. In fig 4.3 the conventional per unit volts of bus 2 in NSUKKA metropolis is 0.869 which is definitely out of range of 0.95 through 1.05 per unit volts that determines voltage stability. With this result it depicts that there is intermittent power supply in bus 2.

On the other hand, when Facts device is incorporated in the system it stabilizes the voltage to 0.9907 per unit volts thereby improving energy efficiency in bus 2. Fig 8. Shows comparing conventional and facts device power loss in bus 2 (Township) in Improving energy efficiency in NSUKKA 33kv distribution network. In fig 8; the conventional power loss in bus 2 in NSUKKA distribution network is 4.3% while that when Facts device is incorporated in the system is 4.027%. With these results obtained, it shows that the energy efficiency improvement is 0.273% when Facts device is incorporated in the system.

Table 5 comparing conventional and facts device power loss in bus 3(WILSON) in Improving energy y efficiency in NSUKKA 33kv distribution network

Time(s)	Conventional power loss in Bus 3(WILSON) in Improving energy y efficiency in NSUKKA 33kv distribution network.(%)	FACTS device power loss in bus 3 (WILSON) in Improving energy y efficiency in NSUKKA 33kv distribution network.(%)
1	7.2	6.743
2	7.2	6.743
3	7.2	6.743
4	7.2	6.743
10	7.2	6.743

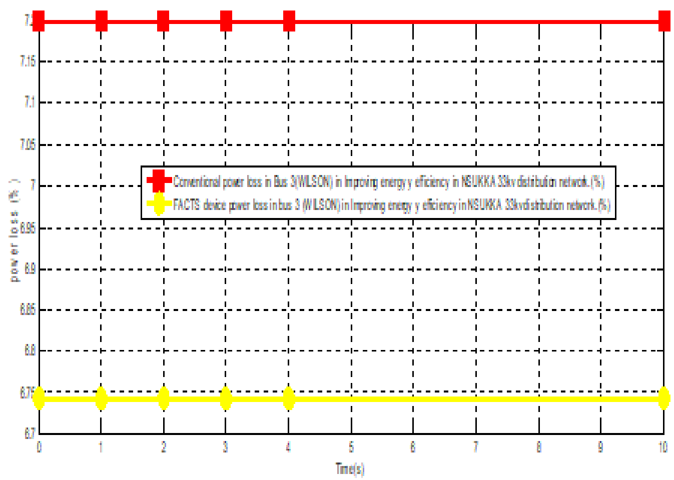

Fig 6 comparing conventional and facts device power loss in bus 3 (WILSON) in Improving energy y efficiency in NSUKKA 33kv distribution network

Table 6 comparing conventional and facts device P.U. volts in bus 2 (Township)) in Improving energy y efficiency in NSUKKA 33KV distribution network

Time(s)	Conventional P.U. volts in Bus 2 (Township) in Improving energy y efficiency in NSUKKA 33kv distribution network.(volts)	FACTS device P.U VOLTS in bus 2 (Township) in Improving energy y efficiency in 33kv distribution network.(volts)
1	0.869	0.9907
2	0.869	0.9907
3	0.869	0.9907
4	0.869	0.9907
10	0.869	0.9907

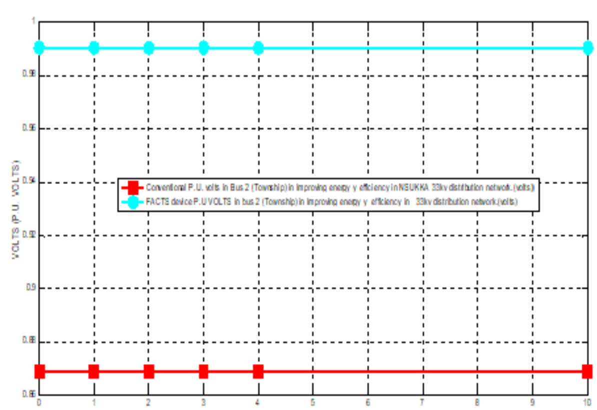

Fig 7 comparing conventional and facts device P.U. volts in bus 2 (Township)) in Improving energy efficiency in NSUKKA 33kv distribution network

International Journal of Artificial Intelligence Trends (IJAIT)
Vol. 4, Issue VIII; No. 57, August, 2025, pp. 593-604

Table 7 comparing conventional and facts device power loss in bus 2 (Township) in Improving energy efficiency in NSUKKA 33kv distribution network

Time(s)	Conventional power loss in Bus 2(TOWNSHIP) in Improving energy y efficiency in NSUKKA 33kv distribution network. (%)	FACTS device power loss in bus 2 (TOWNSHIP) in Improving energy y efficiency in NSUKKA 33kv distribution network. (%)
1	4.3	4.027
2	4.3	4.027
3	4.3	4.027
4	4.3	4.027
10	4.3	4.027

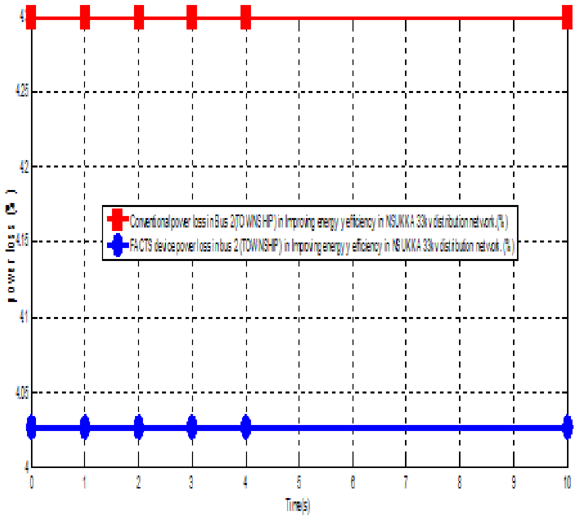

Fig 8. Comparing conventional and facts device power loss in bus 2(Township) in Improving energy efficiency in NSUKKA 33kv distribution network

4. CONCLUSION

In certain states and the nation as a whole, business operations are in danger due to the frequent power outages in the distribution network. The core causes of power failure in the distribution network is power losses that is anchored by per unit volts of some faulty buses not attaining voltage stability of 0.95 through 1.05. The power losses observed by the in the distribution network is over come by introducing minimization of power losses in distribution network using particle SWARP optimization. In order to accomplish this, the 33kV power distribution network is characterized to determine power losses, and a load flow analysis of the network is conducted to determine the sources of power loss and malfunctioning buses. utilizing particle swarm optimization to minimize power losses in the 33kV power distribution network, creating a SIMULINK model for particle swarm optimization, creating an algorithm to carry out the procedure, creating a SIMULINK model for particle SWARP optimization to minimize power losses in the distribution network, and verifying and defending the application of particle swarm optimization to 33kV power loss reduction. According to the results, bus 2's conventional voltage, which causes power supply instability in the distribution network, is between 0 and 940 P. U. V. In contrast, the percentage of power loss in faulty bus 2 feeder 2 is 3.2 percent when particle swarm optimization is implemented in the system. This is because the voltage reaches the stability of 1.03 per unit volts, improving the distribution network's steady power supply. However, it significantly decreased to 3.057 percent when particle swarm optimization was added to the system. The conventional per unit volts that consistently cause power failure in the defective bus 8 is 0.941, while the percentage improvement in the reduction of power loss in bus

3 feeder 3 of the distribution network is 0.187 percent. However, when particle swarm optimization is included, the voltage threshold stability is achieved between 0 and 1 point 95. Additionally, the conventional power loss in a distribution network's faulty bus 8 feeder 8 is 1 point 1 percent, whereas when particle swarm optimization is included, the power loss is 1 point 051 percent.

4.1 Recommendations

Future work should focus on the use of more sophisticated intelligent system that is capable of detecting and reducing power losses in a distribution networks to boost the efficiency of distributed power to the consumers.

4.2 Contribution to Knowledge

This study makes significant contributions to the field of power distribution systems, particularly in the context of power loss reduction and efficiency improvement. Some of the key contributions to knowledge include:

1. Identification of Power Loss Sources: This study provides a comprehensive analysis of power loss sources in the Nsukka 33kV power distribution network, highlighting the specific buses and lines that are most affected by power losses. This information can be used to inform strategies for power loss reduction and efficiency improvement.
2. Effectiveness of FACTS Devices: The study demonstrates the effectiveness of FACTS devices in reducing power losses and improving voltage profiles in the Nsukka 33kV power distribution network. This finding has significant implications for power distribution system operators, who can use FACTS devices to improve the efficiency and reliability of their networks.

5. REFERENCE

Alhejji, Ayman, Mohamed Ebeed Hussein, Salah Kamel, and Saeed Alyami. "Optimal power flow solution with an embedded center-node unified power flow controller using an adaptive grasshopper optimization algorithm." IEEE Access 8 (2020): 119020-119037..

Ambriz – Perez H. Acha, E. and Fuerte-Esquivel C.R. “Advanced SVC models For NewtonRaphson Load Flow and Newton Optimal Power flow studies”. IEEE Trans Power Systems 15(1) 129-136, Nov. 2000.

Bilbro G. Zhu J. and Chow M. “Phase balancing Using simulated annealing”, IEEE Trans power systems, Vol.14, no4, pp1508-1513, Nov 1999.

Biswas, Partha P., Parul Arora, R. Mallipeddi, P. N. Suganthan, and B. K. Panigrahi. "Optimal placement and sizing of FACTS devices for optimal power flow in a wind power integrated electrical network." Neural Computing and Applications (2020): 1-22.

Dileck M. Broadwater R.P. Thompson J.C. and Sequin R. “Simultaneous Phase balancing at substations and switches with time-varying load patterns”, IEEE Trans power systems, vol. 16, no4, pp922-928, Nov 2001

E.Hope, L. Rud, and B. Singh, “Electricity future Markets”, Models for energy policy. Studies in the History of Economic modeling. J.B Lesound and J.V Francis, Eds. New York: Routledge, 1996, vol1, pp238-249.

E.S Amundsen and B. Singh. “Developing future markets for electricity in Europe”, Energy J, Vol 13 pp 95- 112, 1999

Enrique Acha, Claudio Fuerte-Esquivel, Hugo Ambriz-Perez and Cesar Angeles-Camacho, “FACTS Modeling and Simulation in Power Networks”. 2004 John Wiley and sons.

FACTS Application Task Force, FACTS Application: IEEE Power Engineering Society 1996. pp1-4.

Fuerte-Esquivel, C.R, Acha, E. ‘Newton- Raphson Algorithm for the reliable solution of Large Power Networks with Embedded FACTS DEVICES’. IEEE Proceedings: Generation, Transmission and Distribution 143(5) 447-454, Sept. 1996.

Fuerte-Esquivel, C.R. Acha, E. “The Unified Power Flow Controller: A Critical Comparison of Newton-Raphson UPFC Algorithms in Power Flow studies” IEEE Proceedings: Generation, Transmission and Distribution 144(5), 437- 444, Nov.1997.

Gupta, B.R., “Reliability of Electric Power Systems”, Workshop organized by Central Board of Irrigation and Power (India), Nov., 1995.

Gyugyi, “Flexible Ac Transmission Systems (FACTS)”. In inst Elect. Eng. Power and Energy Series 30, Y.H. Song and A.T. Johns, Eds. London, U.K. 1991, Ch1.

IEEE/CIGRE (Institute of Electrical and Electronic Engineers/Conseil International des Grands Reseaux Electriques), 1995, FACTS Overview, Special issue, 95TP108, IEEE service Centre, Piscata-way, NJ.

K.H Knivsfla and I. Rud, “Markets for electricity structure, pricing and performance”, Pacific Asian Journal on Energy, Vol5, pp 261-284, Dec. 1995.

Kimbark, E.W., Improvement of Power System Stability, IEEE Trans., 1969, Vol. Power Apparatus and Systems, PAS-88, pp773-782.

Nadeem, Muhammad, Kashif Imran, Abraiz Khattak, Abasin Ulasyar, Anamitra Pal, Muhammad Zulqarnain Zeb, Atif Naveed Khan, and Malhar Padhee. "Optimal Placement, Sizing and Coordination of FACTS Devices in Transmission Network Using Whale Optimization Algorithm." Energies 13, no. 3 (2020): 753.

Onyegbula Henry, James Eke, and Emetu Chukwuma Kalu. “Improving Energy Y Efficiency Using Facts Device Technique in Nsukka 33KV Distribution Network” Iconic Research And Engineering Journals (IRE Journals) Vol5, Pp 131-140, Issue 10, 2022

Pable A.S. Electric Power Distribution, Fifth Edition, Tata Mc. Graw-Hill, New Delhi, 2003, Pg 1.

Paola Pezzini, Oriol Gomis-Bellmunt, Carles Gonzalez-de- Miguel, Adria Junyent-Ferre and Antoni Sudria-Andreu. “FACTS location using Genetic Algorithm to increase energy efficiency in distribution networks”. Department d’Enginyeria Electrica, Universitat Politecnica de Catalunya, ETS d’Enginyeria Industrial de Barcelonia, Av Diagonal, 647, Pl2.08028 barcelonia, Spain.

R.Green, “The British electricity spot market”, Pacific Asian J. Energy, Vol.6, pp39-52, June 1996.

Song Y.H, John A.T, Flexible AC Transmission Systems (FACTS), Institute of Electrical Engineers London 1999.

The Nation Newspaper, “Federal Government to adopt (PPP) model for power firms privatization”. Page 31, August 12, 2010.

The Nation Newspaper, “Government approves strategy for privatizing PHCN”. Page 60, August 24, 2010.

The Nation newspaper, “Manufacturers Spend 60% running cost on power, says Aganga” page 31, August 12, 2010. [3] J.M.E Pennings and W.J.M. Heijman, “Prospects for an electricity future market: A comment”, Res. Policy, Vol 21, pp 283-284, Dec.1995.

This day Newspaper, “Engineers want professional as power Minister”. Page 30, June 28, 2011.Hingorani, N.G. Gyugyi L. Understanding FACTS: concepts and Technology of flexible AC Transmission System, Institute of Electrical and Electronic Engineers, New York, 2000.

Tinney W.F. Hart C.E. “Power Flow Solution by Newton’s method”, IEEE Trans Power Apparatus and Systems, 1967, PAS-96 (11).1449-1460.

Vijayakumar, B., G. Rajendar, and Veerlapati Ramaiah. "Optimal location and capacity of Unified Power Flow Controller based on chaotic krill herd blended runner root algorithm for dynamic stability improvement in power system." International Journal of Numerical Modelling: Electronic Networks, Devices and Fields (2020): e2828.

Zhu J. Chow M.Y. and Zhang F. “Phase balancing using mixed integer programming”, IEEE Trans Power Systems, Vol. 13, no 4, PP1487-1492, Nov. 1998