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LOSS MITIGATION ON SULEJA 33KV NETWORK USING STATCOM DEVICE

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Abstract: : The load flow analysis was carried out to establish base voltage at various buses. The buses that have the voltages fall below the prescribed or nominal voltage range between 0.95 and 1.05 p.u. volt are considered as faulty buses. These include bus 1, bus 4 and bus 5 with per unit volts of 1.06, 1.057 and 0.8897p.u respectively. After the incorporation of STATCOM, the p.u. volts at buses 1, 4 and 5 improved to 1.025 p.u., 1.026 p.u. and 1.01 p.u. respectively. The total active power loss without STATCOM is 323.9891MW while that of the reactive power loss 50.07631MVar and the total active power loss with STATCOM is 275.6053MW while that of the reactive power loss is 18.79948MVar. The losses reduced when STATCOM was incorporated into the distribution network. Therefore, the percentage of power system improvement is 17.6% when STATCOM was incorporated

Keywords: Technical, Loss, STATCOM, Network

1. INTRODUCTION

Losses are among the major reasons for energy shortages and the inefficient operation of most power systems. This paper presents the analysis of technical losses in Suleja 33KV distribution feeders. The main purpose of the transmission and the distribution subsystems is to transfer economically and reliably the electrical energy produced by the generation subsystem over long distances to a point where the energy is available to the end-users, the consumers. About 40 % of total investments in the electricity sector goes into the distribution subsector [1], still, the distribution subsystem is more troublesome than either the generation subsystem or the transmission subsystem because a significant part of the energy produced is often lost in the distribution subsystem. Electrical energy losses are among the major factors responsible for power distribution systems inefficiency and unreliability. The higher the losses in the system, the more the outages signifying the inefficiency and unreliability of the power system [2]. losses that occur in power system networks are classifiable into technical and non-technical losses. Technical losses are natural being due to the material properties of the components that make up the system. These losses are due to the heat generated in transformers windings and iron cores, overhead lines and distribution lines. The non-technical losses, on the other hand, are as a result of factors external to the power system. For example, electricity theft arising from non-payment of electricity bills, billing errors, improper reading of meters, poor record-keeping, transformer overloading and defective meters, etc. [2].

According to the studies carried out by [3], using the ETAP software environment and the Newton Raphson method to model and analyze the technical power losses in the University of Benin Teaching Hospital electrical distribution network; the findings showed that replacing the existing network feeders with larger-size conductors and compensator can help reduce the level of losses in the

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network. [4] Worked on Electrical Energy losses reduction using power factor correction technique. The low power factors witnessed were less than 0.85. Low power factor result in higher reactive power (MVAR) usage in power consumption, leading to increase in electricity costs or increase in billed demand. Deployment of power factor correction (capacitance bank) can eliminate higher billing rate related to reactive power consumption. Balancing load across phases on the LV networks was employed by [5]. Their findings revealed that balancing load across phases can reduce losses in the network. [6] Studied the integration of shunt in the electrical Static Synchronous Compensator (STATCOM) network. The power flow and power loss before and after placing the STATCOM were compared. The result showed that there was a considerable power loss reduction in the three buses where the STATCOM was installed. Bus 03 gave the best result, meaning that it was optimally placed compared to other two buses.

[7] Integrated micro-grid system with STATCOM (static synchronous compensator) controller to ensure the higher power flow with enhanced voltage profile and reduced power loss using MATLAB/PSAT. The results showed that STATCOM raises the capacity of the distribution line and contributes to voltage profile improvements and power loss reduction.

2. MATERIALS AND METHODS

The data required for this project are the network bus data and line data. The determined power flow result is then analyzed and the faulty buses are identified, after which they are incorporated into STATCOM using the MATLAB 2015 Software.

A. Power Flow Equations

To enhance optimal power flow, STATCOM is incorporated into the power flow network. The device is attached to a suitable bus m, and the expression of the source voltage is given by:

$$E_{rs} = V_{rs}(cos\delta_{rs} + jsin\delta_{rs})$$

Where E_{rs} is the source voltage from STATCOM, $V_{rs}$is the terminal voltage of STATCOM, $\delta_{rs} isthephaseangle$

The complex power of STATCOM is a function of the terminal voltage and the conjugate of the current flowing through it. Equation (3.2) and (3.3) express the conjugate current and the complex power respectively.

$$I_{rs}^* = Y_{rs}^*(V_{rs}^* - V_m^*) \quad (2)$$

$$S_{rs} = V_{rs}I_{rs}^* \quad (3)$$

The power components of the converter are given by equations (4) and (5), while the power components at bus m, where it is attached is given by equations (6) and (7)

$$P_{rs} = V_{rs}^2 G + V_{rs}V_m[G\,\mathrm{Cos}(\delta_{rs} - \phi_m) + BSin(\delta_{rs} - \phi_m)] \quad (4)$$

$$Q_{rs} = -V_{rs}^2 B + V_{rs}V_m[GSin(\delta_{rs} - \phi_m) - B\,\mathrm{Cos}(\delta_{rs} - \phi_m)] \quad (5)$$

$$P_m = V_m^2 G + V_m V_{rs}[G\,\mathrm{Cos}(\phi_m - \delta_{rs}) + BSin(\phi_m - \delta_{rs})] \quad (6)$$

$$Q_m = -V_m^2 B + V_m V_{rs}[GSin(\phi_m - \delta_{rs}) - B\,\mathrm{Cos}(\phi_m - \delta_{rs})] \quad (7)$$

From the power equations derived, the linearized model of STATCOM is represented by a Jacobian matrix which is given by equation (8).

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$$\begin{bmatrix} \Delta P_m \\ \Delta Q_m \\ \Delta P_{rs} \\ \Delta Q_{rs} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_m}{\partial \phi_m} & \frac{\partial P_m}{\partial V_m} V_m & \frac{\partial P_m}{\partial \delta_{rs}} & \frac{\partial P_m}{\partial V_{rs}} V_{rs} \\ \frac{\partial Q_m}{\partial \phi_m} & \frac{\partial Q_m}{\partial V_m} V_m & \frac{\partial Q_m}{\partial \delta_{rs}} & \frac{\partial Q_m}{\partial V_{rs}} V_{rs} \\ \frac{\partial P_{rs}}{\partial \phi_m} & \frac{\partial P_{rs}}{\partial V_m} V_m & \frac{\partial P_{rs}}{\partial \delta_{rs}} & \frac{\partial P_{rs}}{\partial V_{rs}} V_{rs} \\ \frac{\partial Q_{rs}}{\partial \phi_m} & \frac{\partial Q_{rs}}{\partial V_m} V_m & \frac{\partial Q_{rs}}{\partial \delta_{rs}} & \frac{\partial Q_{rs}}{\partial V_{rs}} V_{rs} \end{bmatrix} \begin{bmatrix} \Delta \phi_m \\ \frac{\Delta V_m}{V_m} \\ \Delta \delta_{rs} \\ \frac{\Delta V_{rs}}{V_{rs}} \end{bmatrix} \quad (8)$$

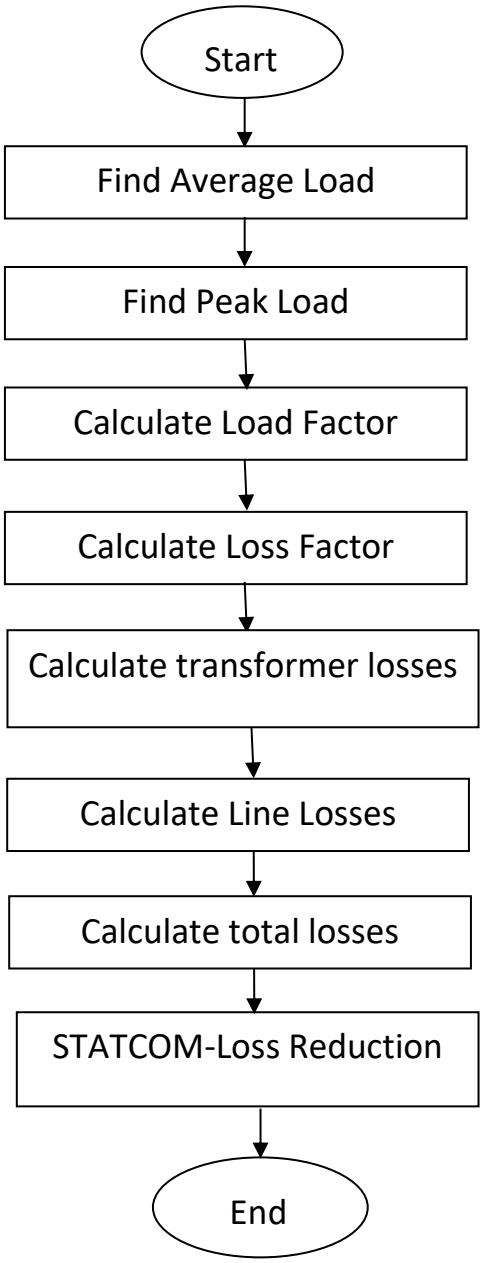
The STATCOM voltage magnitude V_{rs} and phase angle $\partial \delta_{rs}$ are used as the state variables with correction values $\Delta V_{rs}$and $\Delta \delta_{rs}$ respectively which are added for each iteration. The derivatives of active power P and reactive power Q form the Jacobian matrix's element. The initial estimates of the state variables are introduced at the beginning of iterations. The new voltage profile at bus m is given by equations (9) and (10)

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$$V_{rS}^{(i)} = V_{rS}^{(i-1)} + \Delta V_{rS}^{(i)} \quad (9)$$

$$\delta_{rS}^{(i)} = \delta_{rS}^{(i-1)} + \Delta\delta_{rS}^{(i)} \quad (10)$$

Where 'i' is the number of iteration



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Figure 1: Flow Chart for Calculating Technical losses and Reduction.

General mathematical equation of STATCOM for active or real power, reactive power and STATCOM output voltage can be expressed as follows:

$$P = \frac{(V_1 V_2) Sin\delta}{X_L} \quad (11)$$

The relationship between fundamental component of the converter AC output voltage and voltage across DC capacitor is given as:

$$Q = \frac{V_1(V_1 - V_2 Cos\delta)}{X_L} \quad (12)$$

Where K is coefficient which depends upon on the converter configuration, number of switching pulses and the converter controls.

$$V_{out} = KV_{dc} \quad (13)$$

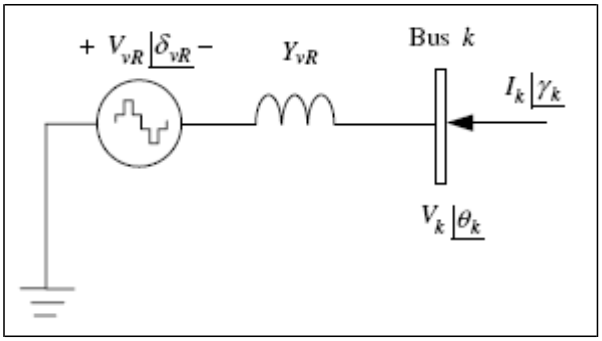


Figure 3.5: shunt solid state voltage source [8].

The shunt voltage source of the three-phase STATCOM may be represented by:

$$E_{VR}^{\ell} = V_{VR}^{\ell}\left(\cos\delta_{VR}^{\ell} + j\sin\delta_{VR}^{\ell}\right) \quad (14)$$

Where ℓ indicates phase quantities a, b and c. The voltage magnitude V_{VR}, produces maximum and minimum limits which depends on the function of STATCOM capacitor rating. Also δ_{VR} is between 0 and 2π radian.

$$[I_k] = [Y_{VR} - Y_{VR}]\begin{bmatrix} V_K \\ E_{VR} \end{bmatrix} \quad (15)$$

$$I_K = \left[I_k^a \angle\gamma_k^a \quad I_k^b \angle\gamma_k^b \quad I_k^c \angle\gamma_k^c\right]^t \quad (16)$$

$$V_K = \left[V_k^a \angle\theta_k^a \quad V_k^b \angle\theta_k^b \quad V_k^c \angle\theta_k^c\right]^t \quad (17)$$

$$E_{VR} = \left[V_{VRK}^a \angle\delta_{VRK}^a \quad V_{VRK}^b \angle\delta_{VRK}^b \quad V_{VRK}^c \angle\delta_{VRK}^c\right]^t \quad (18)$$

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$$Y_{VR} = \begin{bmatrix} Y_{VRK}^{a} & 0 & 0 \\ 0 & Y_{VRK}^{b} & 0 \\ 0 & 0 & Y_{VRK}^{c} \end{bmatrix}$$

3. RESULTS AND DISCUSSIONS

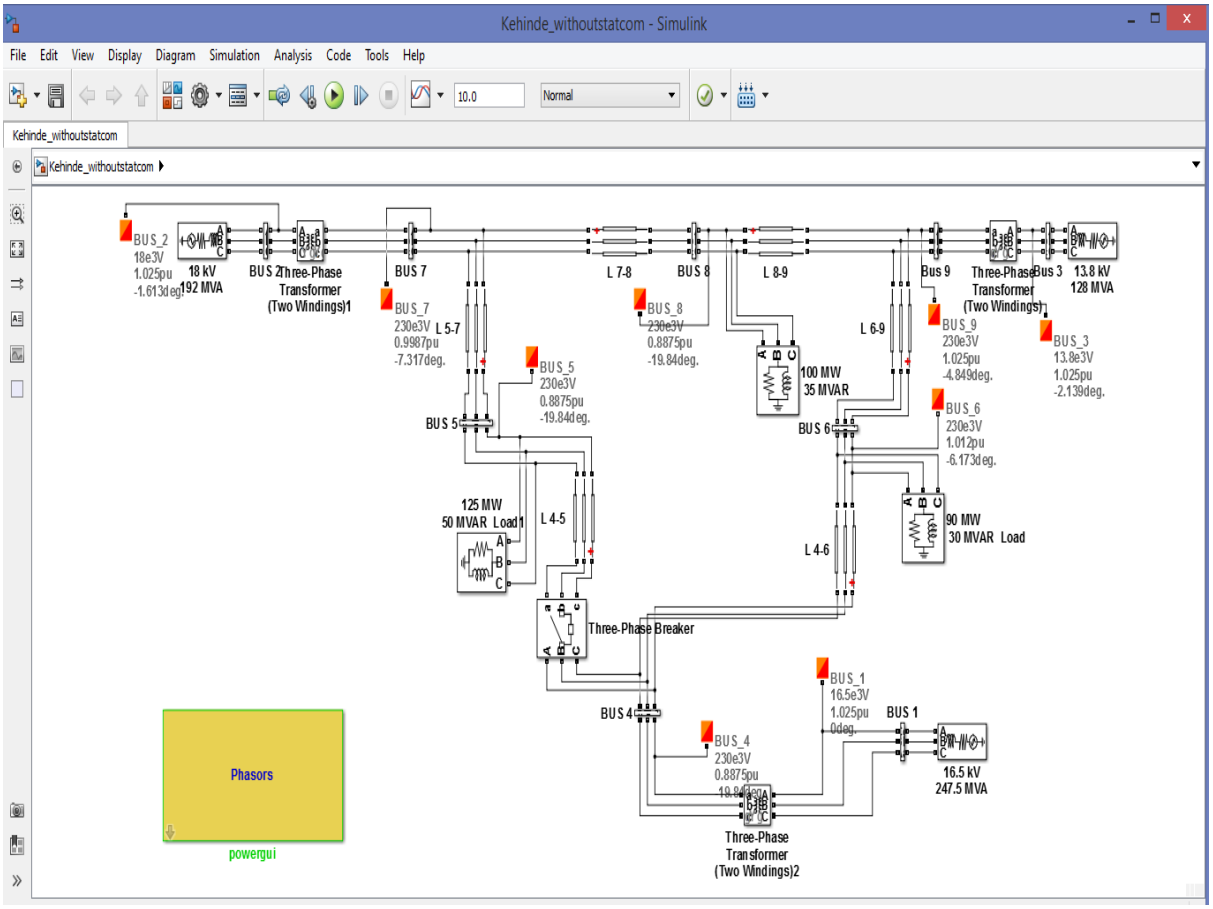
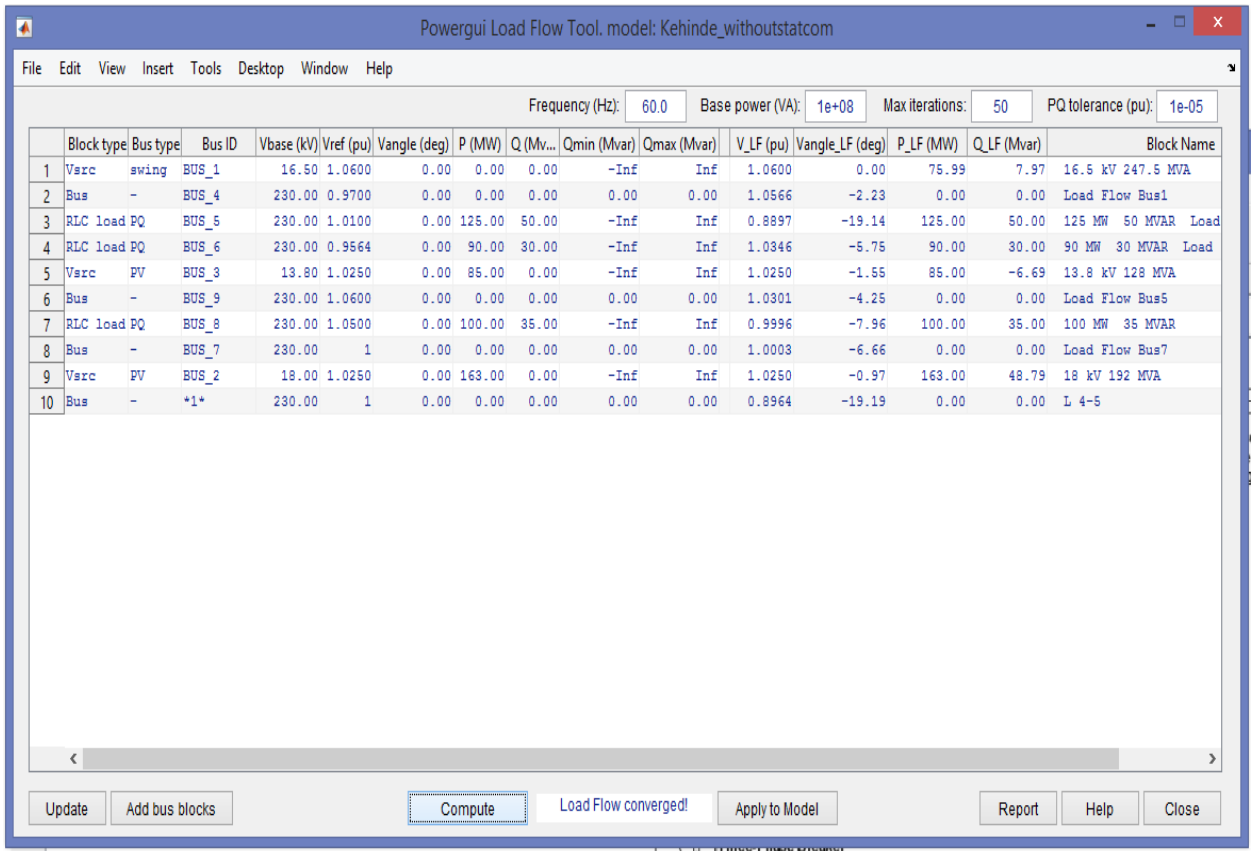


Figure 2: Simulink model of load flow on a Suleja distribution 9-Bus system

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	Block type	Bus type	Bus ID	Vbase (kV)	Vref (pu)	Vangle (deg)	P (MW)	Q (Mv...	Qmin (Mvar)	Qmax (Mvar)	V_LF (pu)	Vangle_LF (deg)	P_LF (MW)	Q_LF (Mvar)	Block Name
1	Vsrc	swing	BUS_1	16.50	1.0600	0.00	0.00	0.00	-Inf	Inf	1.0600	0.00	75.99	7.97	16.5 kV 247.5 MVA
2	Bus	-	BUS_4	230.00	0.9700	0.00	0.00	0.00	0.00	0.00	1.0566	-2.23	0.00	0.00	Load Flow Bus1
3	RLC load	PQ	BUS_5	230.00	1.0100	0.00	125.00	50.00	-Inf	Inf	0.8897	-19.14	125.00	50.00	125 MW 50 MVAR Load
4	RLC load	PQ	BUS_6	230.00	0.9564	0.00	90.00	30.00	-Inf	Inf	1.0346	-5.75	90.00	30.00	90 MW 30 MVAR Load
5	Vsrc	PV	BUS_3	13.80	1.0250	0.00	85.00	0.00	-Inf	Inf	1.0250	-1.55	85.00	-6.69	13.8 kV 128 MVA
6	Bus	-	BUS_9	230.00	1.0600	0.00	0.00	0.00	0.00	0.00	1.0301	-4.25	0.00	0.00	Load Flow Bus5
7	RLC load	PQ	BUS_8	230.00	1.0500	0.00	100.00	35.00	-Inf	Inf	0.9996	-7.96	100.00	35.00	100 MW 35 MVAR
8	Bus	-	BUS_7	230.00	1	0.00	0.00	0.00	0.00	0.00	1.0003	-6.66	0.00	0.00	Load Flow Bus7
9	Vsrc	PV	BUS_2	18.00	1.0250	0.00	163.00	0.00	-Inf	Inf	1.0250	-0.97	163.00	48.79	18 kV 192 MVA
10	Bus	-	*1*	230.00	1	0.00	0.00	0.00	0.00	0.00	0.8964	-19.19	0.00	0.00	L 4-5

Figure 3 Simulink Result of load flow on a Suleja distribution 9-Bus system

Table 1 L-oad flow result of a 9 bus system without STATCOM

BUS	Voltage (p.u.)	Voltage Angle (deg)	PGEN (MW)	QGEN (MVAR)	PLOAD (MW)	QLOAD (MVAR)
BUS_1	1.06	0	75.98907	7.9736	0	0
BUS_2	1.025	-0.97	163	48.79462	0	0
BUS_3	1.025	-1.55	85	-6.69192	0	0
BUS_4	1.057	-2.23	0	0	0	0
BUS_5	0.8897	-19.14	0	0	125	50
BUS_6	1.035	-5.75	0	0	90	30
BUS_7	1.0003	-6.66	0	0	0	0
BUS_8	0.9996	-7.96	0	0	100	35
BUS_9	1.0301	-4.25	0	0	0	0
			323.9891	50.07631	315	115

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The MATLAB load flow simulation result interface is presented in figure below. It shows the result of power flow SIMULINK of voltage profile of the distribution network. The optimal operational range of the voltage profile of the network is given to be $0.95 \leq v \leq 1.05$ p.u. The buses with voltage below 0.95p.u or above 1.05 p.u. were taken to be faulty. Voltage swell is detected in all the faulty buses. These are the buses in distribution network that cause over current, low power factor, short circuit, over voltage and instability in power supply from the distribution to the final consumers.

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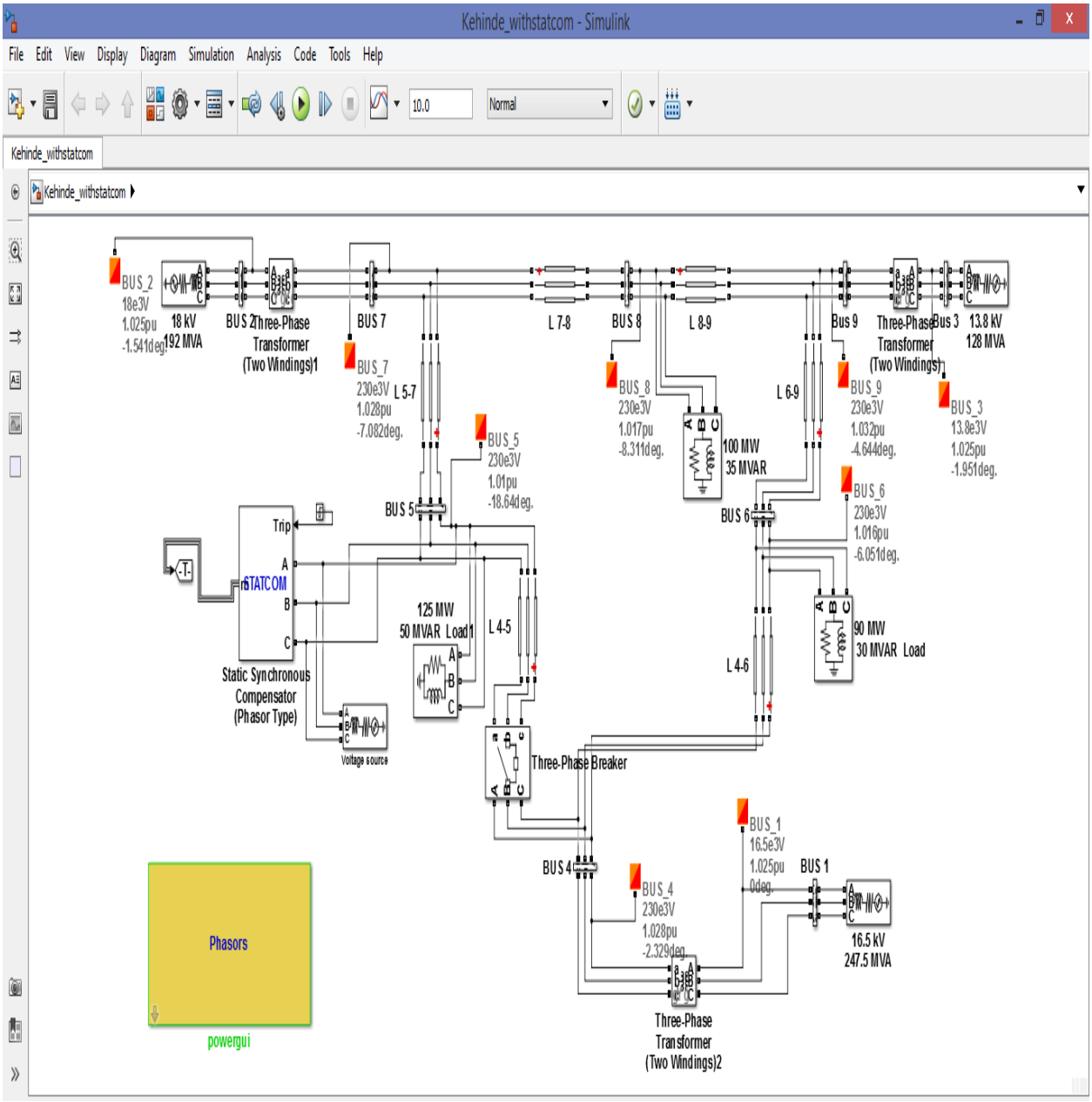
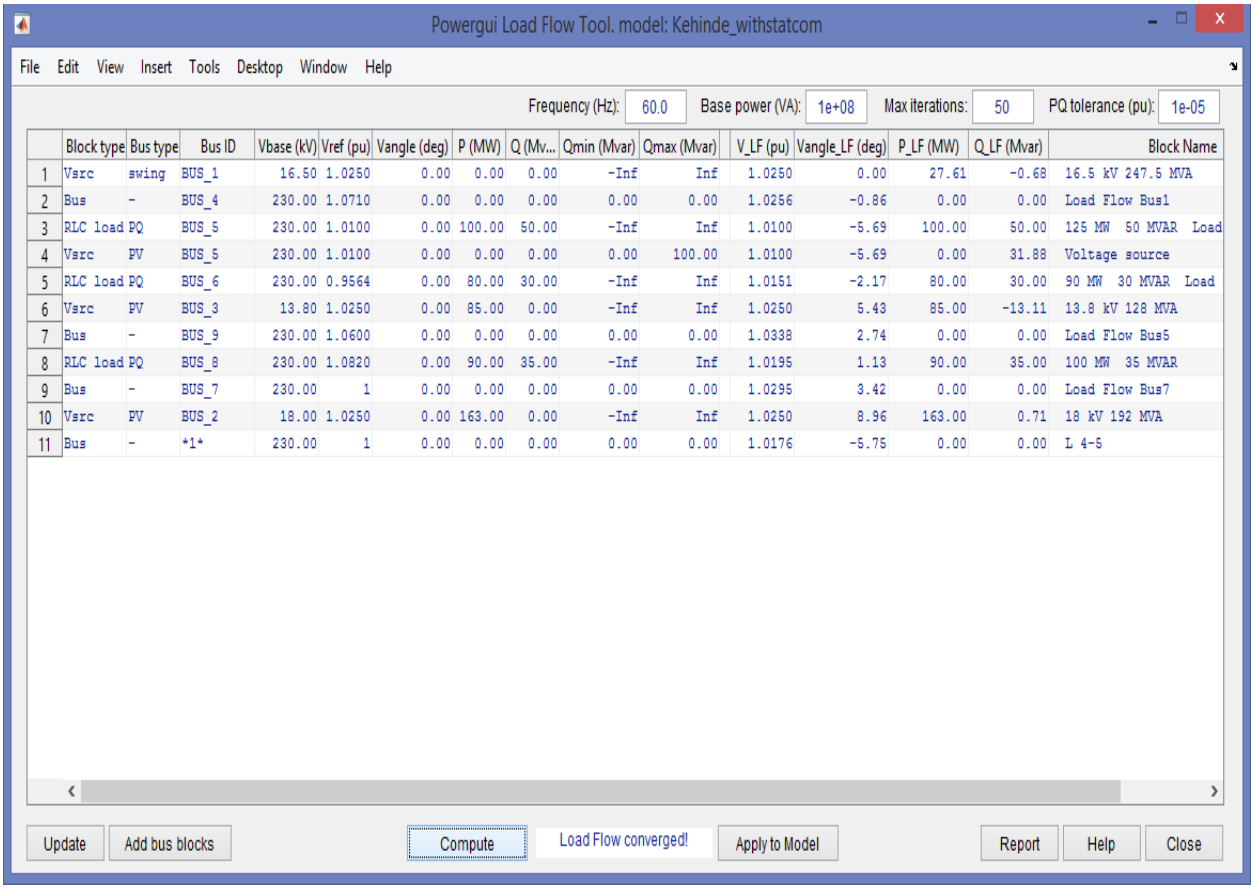


Figure 4:Simulink model of load flow on Suleja distribution 9-Bus system with incorporation of STATCOM

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	Block type	Bus type	Bus ID	Vbase (kV)	Vref (pu)	Vangle (deg)	P (MW)	Q (Mv...	Qmin (Mvar)	Qmax (Mvar)	V_LF (pu)	Vangle_LF (deg)	P_LF (MW)	Q_LF (Mvar)	Block Name
1	Vsrc	swing	BUS_1	16.50	1.0250	0.00	0.00	0.00	-Inf	Inf	1.0250	0.00	27.61	-0.68	16.5 kV 247.5 MVA
2	Bus	-	BUS_4	230.00	1.0710	0.00	0.00	0.00	0.00	0.00	1.0256	-0.86	0.00	0.00	Load Flow Bus1
3	RLC load	PQ	BUS_5	230.00	1.0100	0.00	100.00	50.00	-Inf	Inf	1.0100	-5.69	100.00	50.00	125 MW 50 MVAR Load
4	Vsrc	PV	BUS_5	230.00	1.0100	0.00	0.00	0.00	0.00	100.00	1.0100	-5.69	0.00	31.88	Voltage source
5	RLC load	PQ	BUS_6	230.00	0.9564	0.00	80.00	30.00	-Inf	Inf	1.0151	-2.17	80.00	30.00	90 MW 30 MVAR Load
6	Vsrc	PV	BUS_3	13.80	1.0250	0.00	85.00	0.00	-Inf	Inf	1.0250	5.43	85.00	-13.11	13.8 kV 128 MVA
7	Bus	-	BUS_9	230.00	1.0600	0.00	0.00	0.00	0.00	0.00	1.0338	2.74	0.00	0.00	Load Flow Bus5
8	RLC load	PQ	BUS_8	230.00	1.0820	0.00	90.00	35.00	-Inf	Inf	1.0195	1.13	90.00	35.00	100 MW 35 MVAR
9	Bus	-	BUS_7	230.00	1	0.00	0.00	0.00	0.00	0.00	1.0295	3.42	0.00	0.00	Load Flow Bus7
10	Vsrc	PV	BUS_2	18.00	1.0250	0.00	163.00	0.00	-Inf	Inf	1.0250	8.96	163.00	0.71	18 kV 192 MVA
11	Bus	-	*1*	230.00	1	0.00	0.00	0.00	0.00	0.00	1.0176	-5.75	0.00	0.00	L 4-5

Figure 5: Simulink Result of load flow on Suleja distribution 9 Bus systems with incorporation of STATCOM

Table 2 Load flow solution of 9 buses of Suleja distribution network with STATCOM

BUS	Voltage (p.u.)	Voltage Angle (deg)	PGEN (MW)	QGEN (MVAR)	PLOAD (MW)	QLOAD (MVAR)
BUS_1	1.025	0	27.6053	-0.67792	0	0
BUS_2	1.025	8.96	163	0.705351	0	0
BUS_3	1.025	5.43	85	-13.319	0	0
BUS_4	1.026	-0.86	0	0	0	0
BUS_5	1.01	-5.69	0	31.881	100	50
BUS_6	1.015	-2.17	0	0	80	30
BUS_7	1.029	3.42	0	0	0	0
BUS_8	1.02	1.13	0	0	90	35
BUS_9	1.034	2.74	0	0	0	0

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	275.6053	18.79948	270	115

With the insertion of STATCOM into the network, there is a considerable improvement in the voltage profile of the system. The voltage at bus 5 was regulated from 0.8875 p.u. to 1.01 p.u. other buses that experienced voltage improvement are buses 4, 6, 7, 8 and 9 with increase from 1.0264 p.u., 1.0122 p.u., 0.9987 p.u., and 0.9964 p.u. to 1.0276 p.u, 1.0156 p.u., 1.028 p.u., 1.017 p.u., and 1.032 p.u. respectively. It can also be seen that STATCOM injected more reactive power into the system in order to obtain improved voltage profile and stability at the buses.

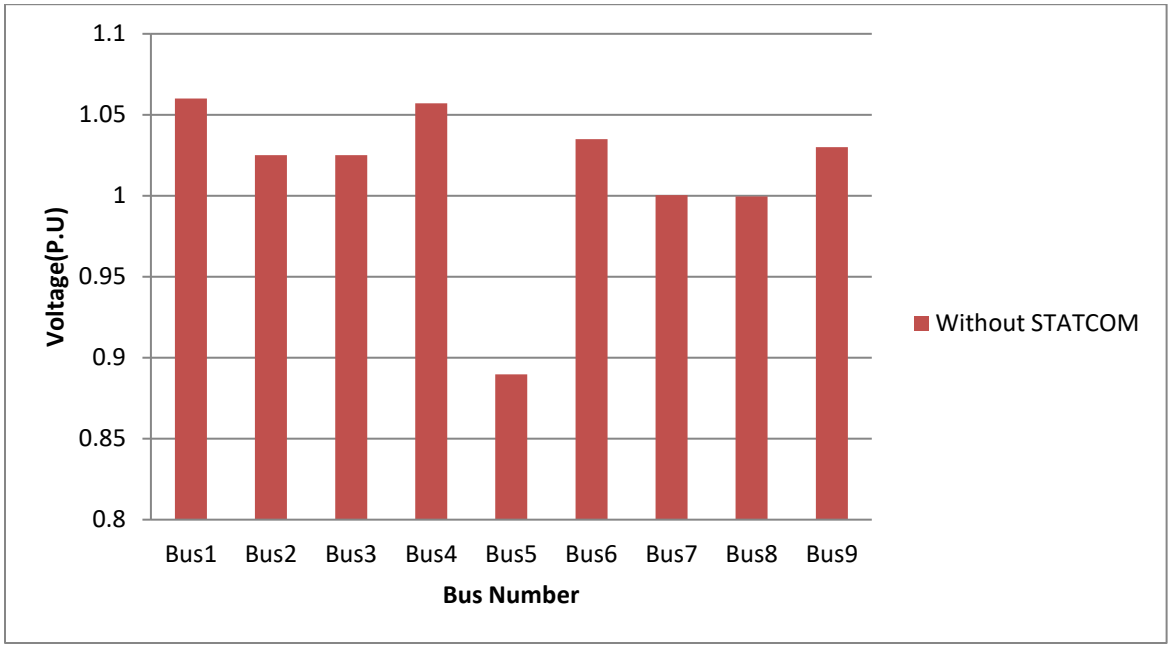


Figure 6: Per-Unit Voltage stability of power system without STATCOM

The load flows of nine buses without STATCOM showed that buses 1, 4 and 5 with per unit volts of 1.06, 1.057 and 0.8897p.u respectively violated the prescribed voltage limits and as such are regarded as faulty buses. These faulty buses cause, over current, over voltage, low power factor, increase in transformer losses, thereby, causing instability of power supply in the distribution network

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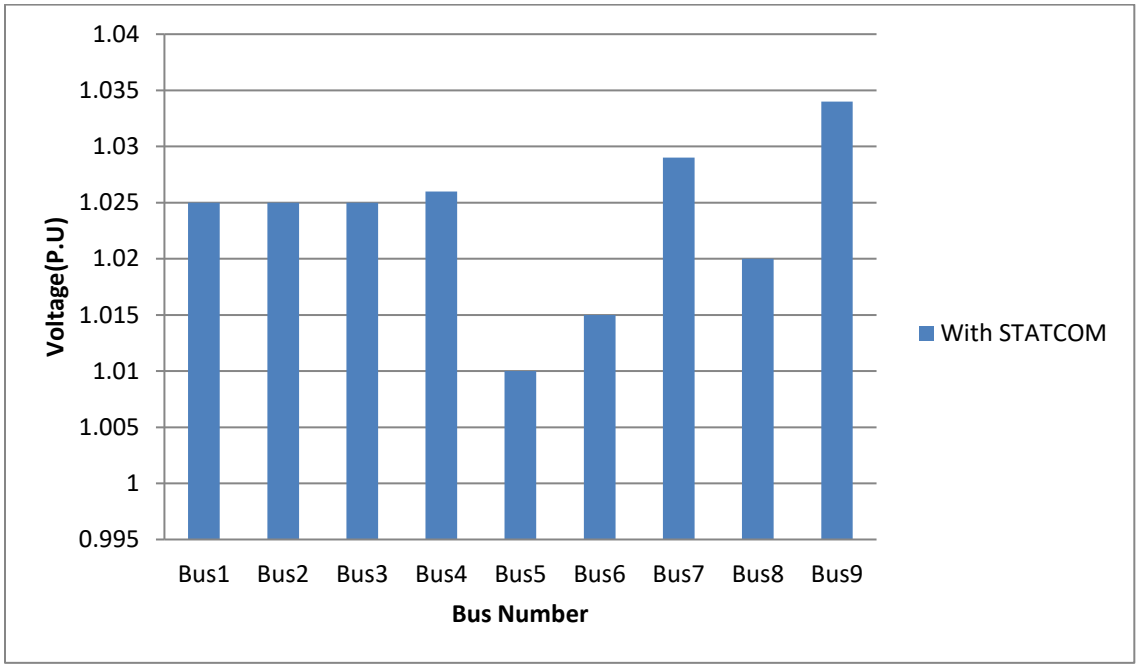


Figure 7: Per-Unit Voltage stability of power system with STATCOM

Figure 7 shows graphical results of the corrected faulty buses in power quality improvement of distribution networks using STATCOM.

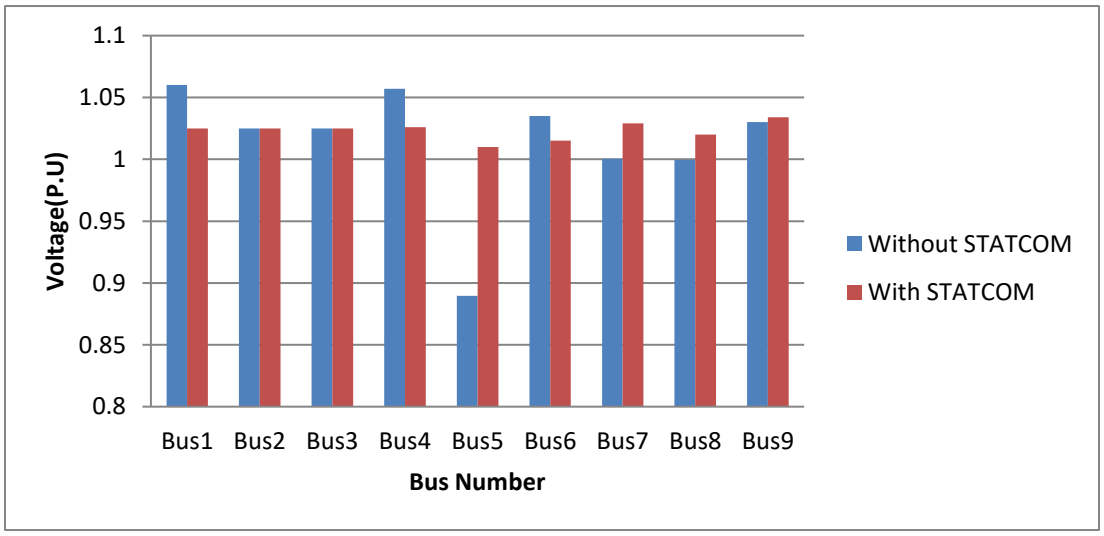


Figure 8: Graph showing the voltage profile at the buses without STATCOM and with STATCOM.

The graph in figure 8 shows the voltage magnitude of the power system without and with STATCOM. Bus1, Bus4 and Bus 5 are seen to have a voltage boost which allows it to fall within the voltage limit range. Thus, the application of STATCOM device helps to normalize the faulty faulty buses

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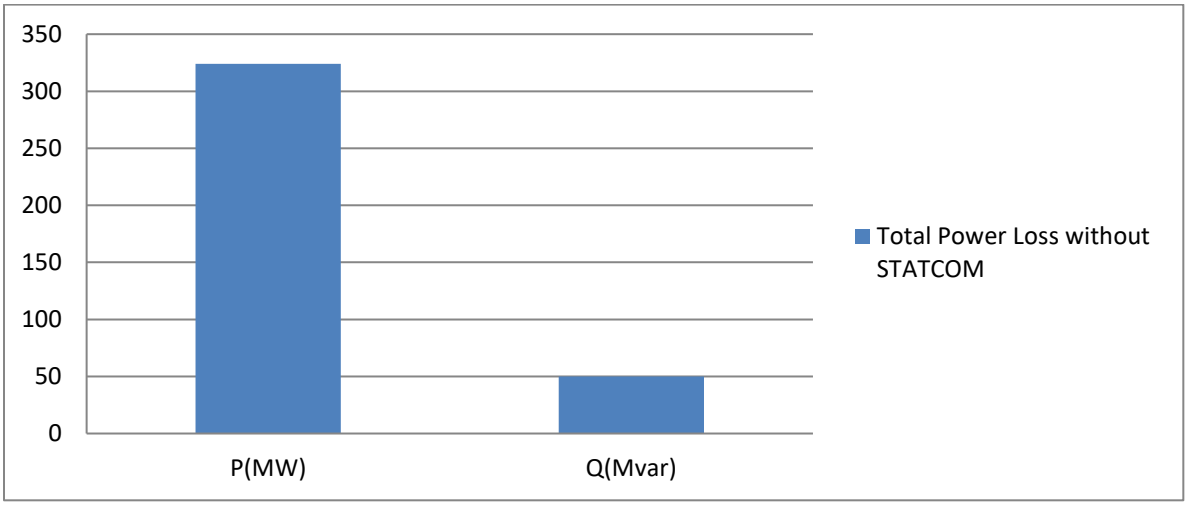


Figure 9: Result of Load flow Power Loss without STATCOM

The result of power flows and losses on the distribution network without the incorporation of STATCOM . The total active power loss all the lines is 323.9891MW and the total reactive power loss is 50.07631MVar.

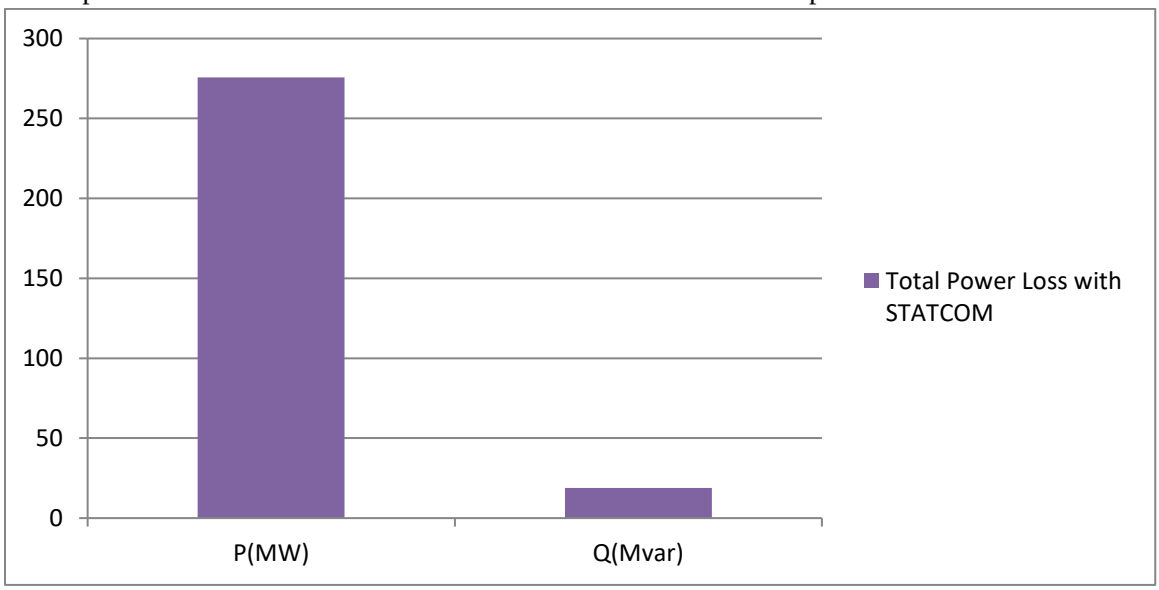


Figure 10: Result of Load flow Power Loss with STATCOM

The result of power flows and losses on the distribution network with STATCOM . The total active power loss all the lines is 275.6053MW and the total reactive power loss is 18.7995MVar.

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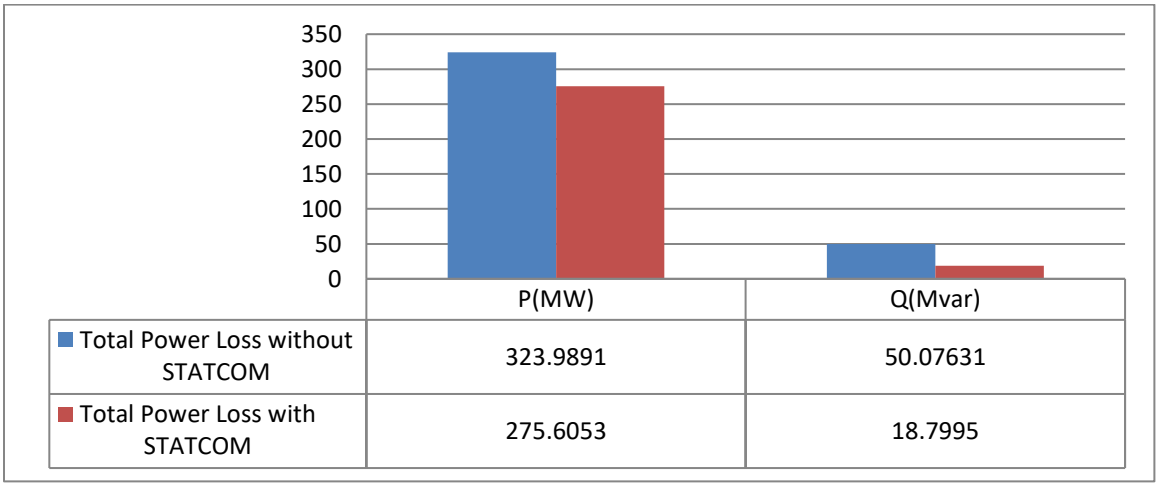


Figure 11: Result of Load flow Power Loss without and with STATCOM

The power flow solution after the insertion of STATCOM using the Newton-Raphson method converged at maximum of 50 iterations. Also, PQ tolerance of 1.000e-5 was used with base power (VA) of 1e-8. The STATCOM was incorporated in other to improve on the power quality and to stabilize voltages. The per unit voltage of the distribution network without STATCOM are 1.06pu, 1.025pu, 1.025pu, 1.057pu, 0.8897pu, 1.035pu, 1.0003pu, 0.9996pu and 1.03 with Bus1, Bus2, Bus3, Bus4, Bus5, Bus6, Bus7, Bus8 and Bus9 respectively. The per unit voltage of the distribution network with STATCOM are 1.025pu, 1.025pu, 1.025pu, 1.026pu, 1.01pu, 1.015pu, 1.029pu, 1.02pu and 1.034pu respectively. The total power loss without STATCOM is 323.9891MW and total power loss with STATCOM is 275.6053MW. Therefore the losses reduced when STATCOM was incorporated into the distribution network. The active power flow at each case for both sending and receiving end is presented alongside the steady state values. Therefore, the percentage of power system improvement:

$$\frac{323.9891 - 275.6053}{275.6053} * 100\% = 17.6\%$$

when STATCOM is incorporated. Finally, Power quality and voltage of system improves when STATCOM is applied.

$$\frac{323.9891 - 275.6053}{275.6053} * 100\% = 17.6\%$$

4. CONCLUSION

The results showed a tremendous reduction in both active and reactive power losses when a STATCOM device was connected. The results also revealed some buses that contributed to these losses. These include buses 1, 4 and 5 with p.u volts 1.06 p.u, 1.057p.u and 0.8897p.u respectively without STATCOM being connected. With the incorporation of STATCOM, the p.u. volts at buses 1, 4 and 5 improved to 1.025 p.u., 1.026 p.u. and 1.01 p.u. respectively.

5. REFERENCES

Mustafa, s., Yasen, M. Abdullahi, H (2011) Evaluation of Electrc Energy Losses in Kirkuk Distribution Electric System Area. *Iraq J. Electrical and Electronic Engineering, 7(2)*

Amadi H, Izuegbunam F. and Okafor E. (2016), Evaluation of Losses in Distribution Networks of Selected Industrial Cities in Nigeria Using ETAP. *British Journal of Applied Science and Technology 17(6): 1 – 12.*

Odiaesea O. and Agbonaye O. (2018),Technical Power Losses reduction on Distribution Network of University of Benin Teaching Hospital. *Int. J. Renew Energ anf Envir. 3, 12- 27*

Osahenwemwen O., Okhumeode M. and Omatahunde B. (2018) Electrical Energy Losses Reduction Using Power Factor Correction Technique. *Advance in Electrical and Telecommunication Engineering (AETE) 1, 2018, 9 – 16 ISSN 2636 – 7416.*

Groan S., Predrag D., Danny P., Loanni K., Roberto M. (2018) Strategic For Reducing Losses in Distribution Network. *Imperial College, London,*

Messaoud F., Tédjini H. and Boudia M. (2019) Power loss reduction in power system using optimal location of STATCOM. *International Journal of Scientific Research Engineering Technology (IJSET) 2019, vol. 8, pp 5 – 9.*

Mezigebu G. , Livingstone M., Dereje S. and Peterson H. (2020) Management of Voltage Profile and Power Loss Minimization in a Grid-Connected Microgrid System Using Fuzzy-Based STATCOM Controller. *Journal of Electrical and Computer Engineering* Vol. 2020, Article ID 2040139, 13 pages https://doi.org/10.1155/2020/2040139

Enrique A., Claudio R., Fuerte-Esquivel, Hugo A. and Cesar A. (2004 "*Modelling and Simulationin Power Networks*" John Wiley & Sons, Ltd,2004.