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The Impact of Static Synchronous Compensator (STATCOM) on Power System Performance: A Case Study of the Nigeria 330 kV Power System Network

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--ABSTRACT--

The Static Synchronous Compensator (STATCOM) is one of the second generation of Flexible Alternating Current Transmission System (FACTS), which is widely utilized to enhance power system performance due to its several advantages such as compact, high response speed and no harmonic pollution. This paper investigates the effects of STATCOM on the performance of the Nigeria 330 kV, 34-bus power system network. The power flow equations describing the steady-state conditions of the system network before and after compensation were modeled and simulated in the NEPLAN software environment. The results from the analysis revealed that before the application of STATCOM, seven (7) buses of the thirty four (34) buses of the case study have their voltage magnitude below acceptable value limit of $0.95 \leq V \leq 1.05$ p.u., which were enhanced to 1.0 p.u. each at the application of STATCOM. Also, the real and reactive power losses were reduced by 9.4% and 2.4% respectively. Thus, the application of STATCOM on the Nigeria 330 kV power system network stabilizes the system's voltage and causes a reduction in the total power loss, which is an improvement in the power system performance.

Keywords *- STATCOM, FACTS, Power flow, Steady-state, Power loss, Power compensation.*

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I. INTRODUCTION

With the development and complexity of modern power system, it becomes highly imperative to control the power flow along the transmission corridor. The normal evolutionary process in late 1970s by introducing power electronics based control for reactive power has been greatly accelerated by more recent developments in the electric power industry, which have aggravated the early problems and highlighted the structural limitations of power systems in a greatly changed socio-economic environment. The desire to find solutions to these problems and limitations led to focus on technological developments under the Flexible AC Transmission System (FACTS). The basic transmission challenge of the evolving deregulated power system (comparative power market), whatever final form it may take, is to provide a network capable of delivering contracted power from any supplier to any consumer over a large geographic area under market forces-controlled, and thus continuously varying pattern of contractual arrangements. Due to cost, right-of-way and environmental problems, the network expansion is restricted [1 - 3].

The FACTS initiative was originally intended to solve the emerging power system problems in the late 1980s [1] due to restrictions on the construction of transmission line and to facilitate the growing power of export and import and wheeling transactions among utilities, with two main objectives to increase the power transfer capability of transmission systems and keep power flow over designed routes. The power electronic based FACTS devices are added to power transmission and distribution systems at strategic locations to improve system performance. FACTS are a family of devices, which can be inserted into power grids in series, shunt and in some cases, both in shunt and series. Recently, a number of control devices under the term FACTS technology have been proposed and implemented. Application of FACTS devices in power systems, leads to better performance of system in many aspects. Voltage stability, voltage regulation and power system stability, and damping can be improved by using these devices and their proper control [4 - 7].

In general, the voltage sourced converters are considered as superior in performance to the thyristor based types [8-10]. The thyristor switched capacitor (TSC) and the static Var compensator (SVC) are examples of thyristor based shunt FACTS controllers while the static synchronous compensator (STATCOM) is an example of voltage-sourced converter based shunt FACTS controller. Although SVC fulfills the same task as STATCOM, but due to its advanced technology and better performance, STATCOM has been found to be more effective than SVC in ensuring voltage stability. Under distorted main voltage conditions, STATCOM can provide more reactive power for keeping the voltage near referenced value. The ability to provide more reactive power during fault situations is one of the most important advantages of the STATCOM over the SVC, which helps for faster recovery of the system during faults situations. STATCOM normally exhibit a faster response than SVC, because of the voltage source converter technology, that has no delays associated with the firing of its thyristors [11-14]

Fundamentally, for planning, operation and control of a power system installed with a STATCOM, an appropriate power flow model of a STATCOM is a necessity. [15-17] present some research works on the power flow modeling of a STATCOM. In this paper, the goal is to study the impact of the application of STATCOM on Power System Performance considering Nigeria 330 kV, 34-bus power system network as a case study.

II. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

2.1 The Structure of STATCOM

STATCOM is a static synchronous generator operated as a shunt-connected static VAr compensator (SVC) whose capacitive or inductive output current can be controlled independently of the AC system voltage. Also, STATCOM is a solid-state switching converter capable of generating or absorbing independently controllable real and reactive power at its output terminals, when it is fed from an energy source or an energy storage device of appropriate rating [16]. Fig. 1 depicts a functional model of a STATCOM, which is the voltage-sourced inverter that converts an input dc voltage into a three phase output voltage at fundamental frequency. The steady-state characteristics of the STATCOM are similar to those of a rotating synchronous compensator but with no inertia, so that its response is basically instantaneous and it does not significantly alter the existing system impedance; the latter is an advantage over Static Var Compensators (SVCs) [15].

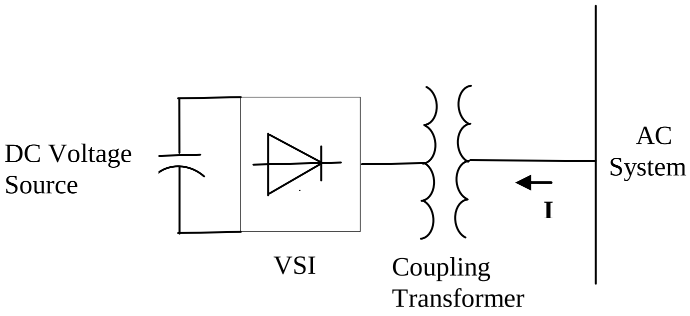


Fig. 1: Basic Structure of STATCOM [15]

2.2 Description of STATCOM Operation

The simplified electronic block of the STATCOM as presented in Fig.1, is a voltage-sourced inverter capable of converting an input dc voltage into a three-phase output voltage at fundamental frequency. It consists of a coupling transformer, a voltage-sourced inverter and a dc capacitor. In this arrangement, the control of the reactive power exchange between the STATCOM and the AC system can be accomplished either by regulating the amplitude of the STATCOM output voltage or by controlling the inverter output voltage with respect to the AC system voltage [15, 17]. An increase in the amplitude of the STATCOM output voltage above the amplitude of the AC system voltage will result in the current flow through the transformer reactance from the STATCOM to the AC system causing the device to generate reactive power. On the other hand, if the output voltage of the STATCOM is lower than that of the AC system voltage, the current flows from the AC system to the STATCOM, resulting in the device absorbing reactive power. However, if the output voltage of the STATCOM equals the AC system voltage, the reactive current is zero and the STATCOM does not generate/absorb reactive power.

The significance of a capacitor in the circuit is to maintain dc voltage to the inverter as the inverter keeps the capacitor charged to the required levels. Therefore, by controlling the inverter output voltage lead or lag with respect to the ac system voltage, the capacitor voltage can be decreased or increased, respectively, to control the reactive power output of the device. When the inverter voltage leads the bus voltage, the capacitor supplies active power to the system, reducing its voltage; on the other hand, when the inverter voltage lags the bus voltage, the capacitor is charged by consuming active power from the system. In steady-state, the output voltage of the inverter slightly lags the ac system voltage, so that the inverter absorbs a small amount of real power from the ac system to replenish its internal losses and, thus, keep the capacitor voltage constant [15].

III. PROBLEM FORMULATION

3.1 Power Flow Equations

A simplified bus of a power system network is as shown in Fig. 2. The transmission lines are represented by their equivalent π model where impedances have been converted to per unit admittances on common MVA base. [18-19]. For an optimized performance of the interconnected system as Fig. 2, information such as bus voltage levels, reactive power compensation requirements etc. are highly imperative and can be obtained from power flow analysis [18].

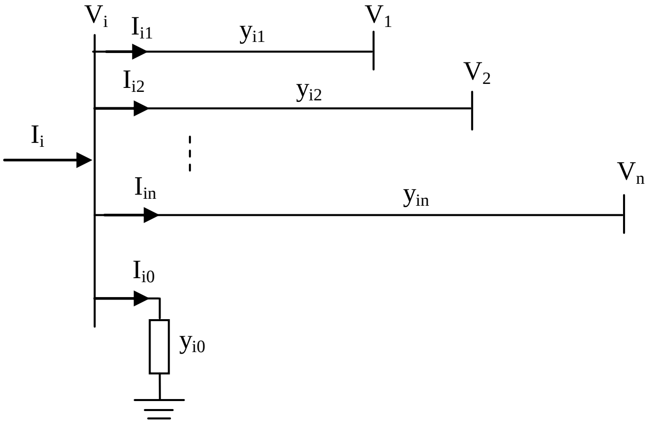


Fig. 2: A simplified Bus of a Power System Network

Application of Kirchhoff's Current Law (KCL) to ith bus of Fig. 2 gives the expression for the injected current I_i into the bus as equation (1).

$$I_i = y_{io}V_i + y_{i1}(V_i - V_1) + y_{i2}(V_i - V_2) + ... + y_{in}(V_i - V_n) \qquad (1)$$

$$I_i = y_{io}V_i + y_{i1}V_i - y_{i1}V_i + y_{i2}V_i - y_{i2}V_2 + \cdots + y_{in}V_i - y_{in}V_n \qquad (2)$$

$$I_i = (y_{io} + y_{i1} + y_{i2} + \cdots + y_{in})V_i - y_{i1}V_1 - y_{i2}V_2 - y_{in}V_n \qquad (3)$$

Equation (3) is a simplified expression of equation (2)., where I_i is the current injected into bus i, V_i is the voltage at bus i, V_1 is the voltage at bus 1, V_2 is the voltage at bus 2, V_n is the voltage at bus n, y_{i0} is the admittance of transmission line between bus i and ground, y_{i1} is the admittance of transmission line between bus i and bus 1, y_{i2} is the admittance of transmission line between bus i and bus 2, and y_{in} is the admittance of transmission line between bus i and bus n. Further simplification can be obtained from equation (3) by defining the expressions in equation (4):

$$\left.\begin{array}{l} Y_{ii} = y_{i0} + y_{i1} + y_{i2} + \cdots + y_{in} \\ Y_{i1} = -y_{i1} \\ Y_{i2} = -y_{i2} \\ . \\ . \\ . \\ Y_{in} = -y_{in} \end{array}\right\} \qquad (4)$$

$$I_i = Y_{ii}V_i + Y_{i1}V_i + Y_{i2}V_2 + \cdots + Y_{in}V_n$$

or $$I_i = Y_{ii}V_i + \sum_{\substack{j=1 \\ j \neq i}}^{n} Y_{ij}V_j \qquad (5)$$

A solution is required for all the voltages, but the injected currents I_i are also unknown; however, each current may be defined in terms of its corresponding complex power and voltage as expressed in equation (6).

$$S_i = P_i - jQ_i = V_i^* I_i \tag{6}$$

where* indicates a complex conjugate value, P_i and Q_i are the active and reactive power at bus I respectively. From equation (6), the injected currents I_i can be obtained as equation (7).

$$I_i = \frac{P_i - jQ_i}{V_i^*} \tag{7}$$

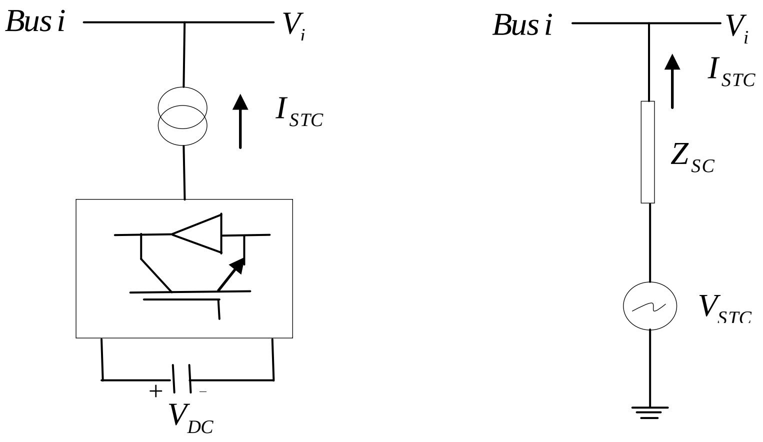
From equations (5) and (7), the expression in equation (8) is obtained.

$$\frac{P_i - jQ_i}{V_i^*} = Y_{ii} V_i + \sum_{\substack{j=1 \\ j \neq i}}^{n} Y_{ij} V_j \tag{8}$$

$$V_i = \frac{1}{Y_{ii}} \left[\frac{P_i - jQ_i}{V_i^*} - \sum_{\substack{j=1 \\ j \neq i}}^{n} Y_{ij} V_j \right] \tag{9}$$

3.2 Modeling of Power System with STATCOM

The power flow equations as developed in equation (9) can be obtained for a specific bus i, as shown in Fig. 3, which shows when the STATCOM is connected.



(a) (b)

Fig. 3: Thevenin Equivalent Circuit Diagram of STATCOM: (a) STATCOM Schematic Diagram (b) STTCOM Equivalent Circuit

The real and reactive powers for the STATCOM are given by equations (10) and (11) respectively, while that of bus i, are given by equations (12) and (13).

$$P_{STC} = G_{SC}\left\{\left(e_{STC}^2 + f_{STC}^2\right) - \left(e_{STC}e_i + f_{STC}f_i\right)\right\} + B_{SC}\left(e_{STC}f_i - f_{STC}e_i\right) \tag{10}$$

$$Q_{STC} = G_{SC}\left(e_{STC}e_i - f_{STC}e_i\right) + B_{SC}\left(-e_{STC}^2 - f_{STC}^2 + e_{STC}e_i + f_{STC}f_i\right) \tag{11}$$

$$P_i = G_{SC}\left\{\left(e_i^2 + f_i^2\right) - \left(e_i e_{STC} + f_i f_{STC}\right)\right\} + B_{SC}\left(e_i f_{STC} - f_i e_{STC}\right) \tag{12}$$

$$Q_i = G_{SC}\left(e_i f_{STC} - f_i e_{STC}\right) + B_{SC}\left\{\left(e_i f_{STC} + f_i e_{STC}\right) - \left(e_i^2 + f_i^2\right)\right\} \tag{13}$$

To find the solution of the combined system of non-linear equations through iterative method, the full Newton-Raphson method of load flow is utilized. The use of Jacobian in conventional power flow is appropriately extended to accommodate the new element contributed by the STATCOM. Thus, the set of linearized power flow equations for the complete system with STATCOM incorporated is given by equation (14).

$$\begin{bmatrix} \Delta P_i \\ \Delta |V_i|^2 \\ \Delta P_{STC} \\ \Delta Q_{STC} \end{bmatrix} = \begin{bmatrix} \dfrac{\partial P_i}{\partial e_i} & \dfrac{\partial P_i}{\partial f_i} & \dfrac{\partial P_i}{\partial e_{STC}} & \dfrac{\partial P_i}{\partial f_{STC}} \\ \dfrac{\partial |V_i|^2}{\partial e_i} & \dfrac{\partial |V_i|^2}{\partial f_i} & 0 & 0 \\ \dfrac{\partial P_{STC}}{\partial e_i} & \dfrac{\partial P_{STC}}{\partial f_i} & \dfrac{\partial P_{STC}}{\partial e_{STC}} & \dfrac{\partial P_{STC}}{\partial f_{STC}} \\ \dfrac{\partial Q_{STC}}{\partial e_i} & \dfrac{\partial Q_{STC}}{\partial f_i} & \dfrac{\partial Q_{STC}}{\partial e_{STC}} & \dfrac{\partial Q_{STC}}{\partial f_{STC}} \end{bmatrix} \begin{bmatrix} \Delta e_i \\ \Delta f_i \\ \Delta e_{STC} \\ \Delta f_{STC} \end{bmatrix} \tag{14}$$

IV. RESULTS AND DISCUSSION

This section presents the results of the power flow simulation carried out for Nigeria 330 kV, 34-bus power system in both steady-state and during the introduction of STATCOM. The bus and transmission line data of the Nigeria 330 kV, 34-bus power system network used as a case study were obtained from the Transmission Company of Nigeria Control Centre, Osogbo [20]. The 34-bus network shown in Fig. 4 consists of thirty-four (34) buses, nine (9) generation stations, and fifty-two (52) transmission lines. The transmission line data and the bus data are shown in Tables 1 and 2 respectively. While Table 2 represents steady-state power flow results of the Nigeria 330 kV 34-Bus power system.

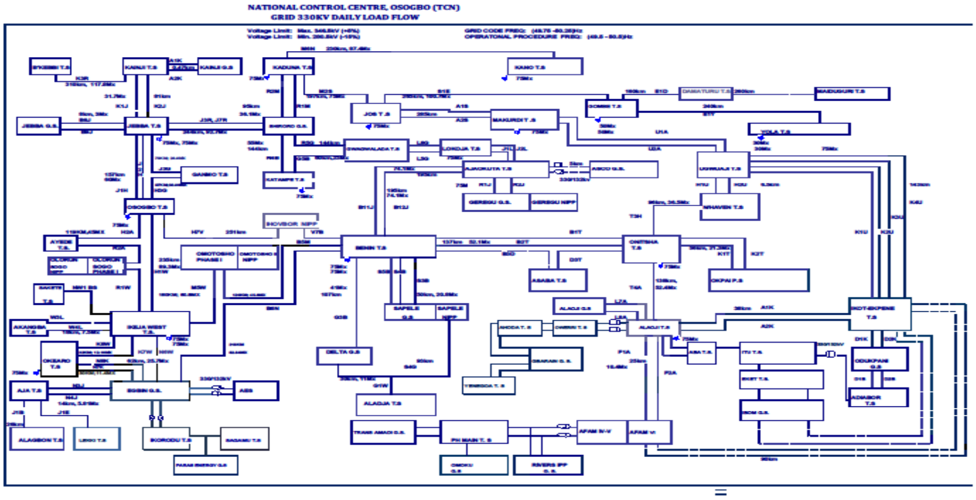


Fig. 4: NEPLAN Modeled Diagram of the Nigeria 330 kV, 34-Bus Power System

Table 1: Transmission Line Parameters of the Nigeria 330 kV, 34-Bus Power System [20]

S/N	**Bus Interconnectivity**		**Length (KM)**		**Resistance**	**Reactance**	**Shunt**
	FROM	**TO**		**No of line(s)**	**(P.U)**	**(P.U)**	**(y/2) P.U**
1	B. KEBBI T.S	KAINJI T.S	310	1	0.011102	0.094224	1.17723
3	KAINJI T.S	JEBBA T.S	81	2	0.002901	0.02462	0.3076
4	JEBBA G.S	JEBBA T.S	8	2	0.000289	0.00223	0.03312
5	JEBBA T.S	SHIRORO G.S	244	2	0.008738	0.074163	0.9266
6	JEBBA T.S	GANMO T.S	70	1	0.003939	0.013343	0.41842
7	GANMO T.S	OSOGBO T.S	87	1	0.001683	0.014286	0.17848
8	JEBBA T.S	OSOGBO T.S	157	2	0.005623	0.04772	0.59621
9	KADUNA T.S	KANO T.S	230	1	0.008237	0.069908	0.87343
10	KADUNA T.S	SHIRORO G. S	95	2	0.003438	0.074163	0.36456
11	KADUNA T.S	JOS T.S	197	1	0.007019	0.059574	0.74432
12	SHIRORO	KATAMPE	144	1	0.007887	0.060656	0.90244
13	JOS T.S	MAKURDI T.S	285	2	0.002876	0.024557	0.00323
14	JOS T.S	GOMBE T.S	265	1	0.009455	0.080242	1.00255
15	GOMBE T.S	YOLA T.S	240	1	0.008595	0.072948	0.91141
16	AJAOKUTA T.S	GEREGU G.S	75	2	0.000036	0.000278	0.00414
17	AJAOKUTA T.S	BENIN T.S	195	2	0.007055	0.054256	0.80723
18	N/HAVEN T.S	ONITSHA T.S	96	1	0.003438	0.029179	0.36456
19	ONITSHA T.S	OKPAI P.S	56	2	0.002171	0.016674	0.24838
20	ONITSHA	ALAOJI T.S	138	1	0.004942	0.041945	0.52406
21	ALAOJI T.S	AFAM	25	2	0.000905	0.006956	0.10349
22	BENIN T.S	ONITSHA T.S	137	2	0.004906	0.041641	0.52026
23	BENIN T.S	SAPELE G.S	50	3	0.001809	0.013912	0.20698
24	SAPELE	ALAOJI	93	1	0.002256	0.019149	0.23924
25	BENIN	DELTA G.S	107	1	0.001468	0.012462	0.1577
26	DELTA G.S	ALADJA	30	1	0.001146	0.009726	o.12152
27	OSOGBO T.S	AYEDE T.S	119	1	0.004118	0.034954	0.43672
28	AYEDE T.S	OLORUNSOGO	60	1	0.002149	0.018237	0.22785
29	OLORUNSOGO	IKEJA WEST T.S	77	1	0.002757	0.023403	0.29239
30	BENIN T.S	EGBIN G.S	218	1	0.007163	0.06079	0.75951
31	BENIN T.S	OMOTOSHO	120	1	0.00286	0.024336	0.41842
32	OMOTOSHO	IKEJA WEST	160	1	0.00716	0.060787	0.75947
33	SAKETE	IKEJA WEST	70	1	0.002507	0.021276	0.26583
34	AKANGBA	IKEJA WEST	18	2	0.000615	0.00437	0.07037
35	IKEJA WEST	EGBIN G.S	15.2	1	0.000645	0.005471	0.06836
36	AJA T.S	EGBIN G.S	14	2	0.000501	0.004255	0.05317
37	OSOGBO T.S	BENIN T.S	251	1	0.008989	0.076291	0.95318
38	IKEJA WEST	OSOGBO	250	1	0.008953	0.075987	0.94938

Table 2: Load Data of the Nigeria 330 kV, 34-Bus Power System [20]

S/N	Bus Name	P(MW)	Q(MVAR)	Voltage (kV)
1	IKEJA WEST	420	85	315
2	KADUNA	300	45	315
3	KANO	300	45	300
4	YOLA	120	20	317
5	JOS	100	20	324
6	GOMBE	80	20	305
7	SHIRORO	160	17	328
8	AIYEDE	120	33	335
9	OSOGBO	180	40	334
10	GANMO	80	45	335
11	BENIN	160	38	333
12	ONITSHA	160	40	329
13	ALAOJI	180	36	323
14	NEW HAVEN	120	38	331
15	JEBBA	60	20	338
16	BIRNIN KEBBI	110	40	329
17	SAKATE	180	53	311
18	KATAMPE	200	55	323
19	AKANGBA	120	45	331
20	MAKURDI	50	16	327
21	GWAGWALADA			327
22	AJA	100	25	313
23	ADIABOR			
24	IKOT EKPENE			327
25	UGWUAJI			336
26	LOKOJA			332
27	LEKKI TS			N/R
28	ALAGBON T.S			N/R
29	AJAOKUTA	40	20	340
30	OKEARO			N/R

The simulation of the Nigeria 330 kV, 34-bus of the power system was successfully performed using NEPLAN software under the conditions of steady-state and the introduction of STATCOM. Under the steady-state conditions as shown in Table 3, the total real power loss was found to be 49,335 MW, while the total reactive power loss was 410.226 MVAr. Seven buses were found to have their bus voltages below acceptable values and these include Kano 305.097 kV, New Haven 313.249 kV, Kaduna 309.721 kV, Jos 305.563 kV, Makurdi 304.787 kV, Gombe 304.443 kV and Yola 300.375 kV. Consequently, STATCOM was introduced at these seven buses and the effect is presented in Table 4, Fig. 5 and Fig. 6.

Fig. 5 depicts the voltage magnitude of the power system network before and after the introduction of STATCOM, which revealed that there was an improvement in the voltage profile of the buses 22 (Kano), 27 (New Haven), 30 (Kaduna), 31 (Jos), 32 (Makurdi), 33 (Gombe) and 34 (Yola) due to the introduction of STATCOM. Fig. 6 shows the total real power loss before and after the compensation. The result shows a reduction of 9.4% in total real power loss from 49.335 MW to 44.710 MW, which signifies improvement in the active power transmission capacity of the transmission lines. These results of analysis indicate that STATCOM is capable of improving the voltage at buses and also reducing real power loss on the power system network.

Table 3: Steady-state Power Flow Results of the Nigeria 330 kV 34-Bus Power System

	Node	**U**	**U**	**Angle U**	**P Load**	**Q Load**
	Name	kV	%	°	MW	MVar
1	KAINJI GS	329.785	99.93	-0.1	0	0
2	KATAMPE TS	313.286	94.94	-6.6	200	55
3	KAINJI TS	329.785	99.93	-0.1	0	0
4	AJA TS	316.22	95.82	-5.3	100	25
5	BIRNIN KEBBI TS	324.887	98.45	-1.7	110	40
6	AYEDE TS	319.804	96.91	-3.7	120	33
7	JEBBA TS	329.957	99.99	0	60	20
8	OLORUNSOGO TS	318.431	96.49	-4.3	0	0
9	BENIN TS	314.509	95.31	-6.1	160	38
10	SAPELE GS	314.414	95.28	-6.1	0	0
11	ALAOJI TS	314.179	95.21	-6.2	180	36
12	JEBBA GS	330	100	0	0	0
13	AFAM GS	314.179	95.21	-6.2	0	0
14	ONITSHA TS	313.717	95.07	-6.4	160	40
15	OKPAI GS	313.717	95.07	-6.4	0	0
16	OSOGBO TS	326.003	98.79	-1.3	180	40
17	AJAOKUTA TS	314.084	95.18	-6.2	40	20
18	GEREGU GS	314.084	95.18	-6.2	0	0
19	GANMO TS	327.802	99.33	-0.6	80	45
20	DELTA GS	314.509	95.31	-6.1	0	0
21	ALADJA TS	314.509	95.31	-6.1	0	0
22	**KANO TS**	**305.097**	**92.45**	-12.4	300	45
23	OMOTOSHO TS	314.905	95.43	-5.9	0	0
24	IKEJA WEST TS	316.244	95.83	-5.3	420	85
25	EGBIN GS	316.223	95.83	-5.3	0	0
26	AKANGBA TS	316.236	95.83	-5.3	120	45
27	**NEW HAVEN TS**	**313.249**	**94.92**	-6.6	120	38
28	SEKATE TS	315.893	95.73	-5.5	180	53
29	SHIRORO GS	315.59	95.63	-5.6	0	0
30	**KADUNA TS**	**309.721**	**93.85**	-9.5	300	45
31	**JOS TS**	**305.563**	**92.59**	-12	100	20
32	**MAKURDI TS**	**304.787**	**92.36**	-12.5	50	16
33	**GOMBE TS**	**302.443**	**91.65**	-13.3	80	20
34	**YOLA TS**	**300.375**	**91.02**	-14.6	120	20
	P Loss	Q Loss				
	MW	MVar				
	49.355	410.226				

Table 4: Power Flow Results of the Nigeria 330 kV 34-Bus power system with the Introduction of STATCOM

	.					
	Node	U	u	Angle U	P Load	Q Load
	Name	kV	%	°	MW	MVar
1	KATAMPE TS	324.884	98.45	-6.5	200	55
2	KAINJI GS	329.807	99.94	-0.1	0	0
3	AJA TS	322.833	97.83	-5.4	100	25
4	KAINJI TS	329.807	99.94	-0.1	0	0
5	AYEDE TS	324.378	98.3	-3.8	120	33
6	BIRNIN KEBBI TS	324.91	98.46	-1.7	110	40
7	OLORUNSOGO TS	323.765	98.11	-4.4	0	0
8	Jebba Ts	329.979	99.99	0	60	20
9	BENIN TS	325.607	98.67	-6.1	160	38
10	ALAOJI TS	325.704	98.7	-6.3	180	36
11	SAPELE GS	325.631	98.68	-6.2	0	0
12	ONITSHA TS	327.199	99.15	-6.5	160	40
13	AFAM GS	325.704	98.7	-6.3	0	0
14	JEBBA GS	330	100	0	0	0
15	OKPAI GS	327.199	99.15	-6.5	0	0
16	GEREGU GS	325.196	98.54	-6.2	0	0
17	AJAOKUTA TS	325.196	98.54	-6.2	40	20
18	OSOGBO TS	327.683	99.3	-1.3	180	40
19	**KANO TS**	**330**	**100**	**-11.8**	**300**	**45**
20	ALADJA TS	325.607	98.67	-6.1	0	0
21	DELTA GS	325.607	98.67	-6.1	0	0
22	GANMO TS	328.537	99.56	-0.6	80	45
23	OMOTOSHO TS	324.96	98.47	-5.9	0	0
24	EGBIN GS	322.836	97.83	-5.4	0	0
25	IKEJA WEST TS	322.829	97.83	-5.3	420	85
26	**NEW HAVEN TS**	**330**	**100**	**-6.7**	**120**	**38**
27	AKANGBA TS	322.821	97.82	-5.4	120	45
28	SHIRORO GS	327.103	99.12	-5.6	0	0
29	SEKATE TS	322.485	97.72	-5.5	180	53
30	**JOS TS**	**326.7**	**99**	**-11.4**	**100**	**20**
31	**KADUNA TS**	**330**	**100**	**-9.2**	**300**	**45**
32	**GOMBE TS**	**330**	**100**	**-13.8**	**80**	**20**
33	**MAKURDI TS**	**330**	**100**	**-11.6**	**50**	**16**
34	**YOLA TS**	**330**	**100**	**-14.9**	**120**	**20**

P Loss	Q Loss
MW	MVar
44.719	399.561

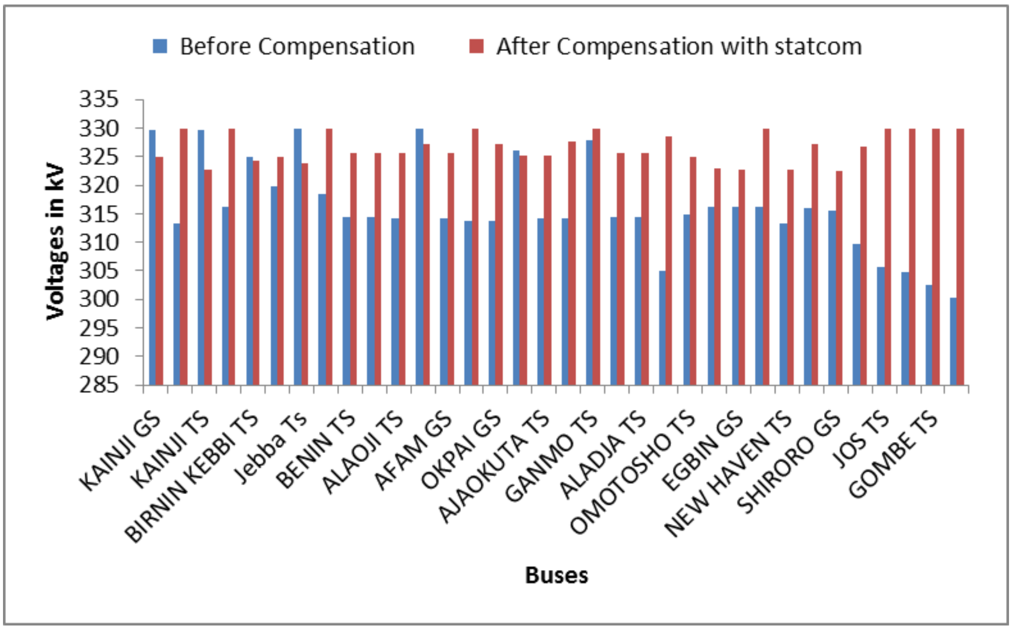


Fig. 5: Voltage Magnitude Nigeria 34-buses Power System Network before and after Application of STATCOM

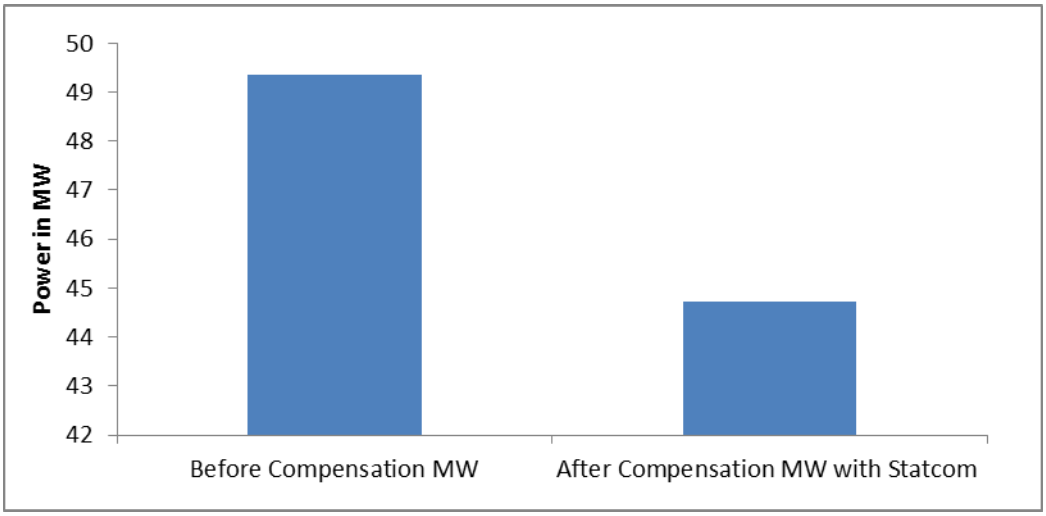


Fig. 6: Graph of loss reduction after compensation with STATCOM

V. CONCLUSION

In this study, a power flow analysis to determine the impact of STATCOM on the power system performance was carried out using Nigeria 330 kV, 34-bus power system as a case study. Simulation was successfully performed under the conditions of steady-state and under the introduction of STATCOM. Under the steady-state condition, the total real power loss was found to be 49,335 MW, while the total reactive power loss was 410.226 MVar.Seven buses were found to have their bus voltages below acceptable values, which include Kano 305.097 kV, New Haven 313.249 kV, Kaduna 309.721 kV, Jos 305.563 kV, Makurdi 304.787 kV, Gombe 304.443 kV and Yola 300.375 kV.

However, the introduction of STATCOM into the modeled power system and simulation in the NEPLAN software, revealed a compensated voltage at the affected buses of Kano 330 kV, New Haven 330 kV, Jos 326 kV, Kaduna 330 kV, Gombe 330 kV, Makurdi 330 kV and Yola 330 kV. The total system losses were reduced from 49.335 MW to 44.719 MW and 410.226 MVar to 399.561 MVar. This study has evidently established that the deployment of STATCOM has the capacity to positively impact the Nigeria power system network by improving the voltage profile and reducing the total power loss thereby enhancing the electric power transmission system.

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