Compensation Effect on the Interconnected Nigerian Electric Power Grid

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***Abstract---* The Nigerian power system is afflicted with continuous load shedding due to inadequate generation and transmission capacities. The power transmission capability available from transmission line design is limited by technological and economic constraints. To maximize the amount of real power that can be transferred over a network, reactive power flow must be minimized. Consequently, sufficient reactive power should be provided locally in the system to keep bus voltages within normal ranges to satisfy customers' equipment voltage ratings. Currently, less than 40% of the population is connected to the national grid and less than 50% of the available installed capacity is used in meeting demand. This paper presents an overview in reactive power compensation technologies which remains as research challenges in this area. Newton-Raphson's solution method was used to carry out the analysis because of its fast convergence, sparsity, and simplicity attributes when compared to other solution methods, with relevant data obtained from Power Holding Company of Nigeria (PHCN). MAT LAB/SIMULINK was used to carry out the simulation analysis. It is observed that the application of compensation on the interconnected system jointly has side effect on the other buses. This is confirmed by a step-by-step application of compensation at 5percent intervals. The effects were noticed in Bus (20) where voltage decreased from 0.9568p.u to 0.9329p.u about 2.39percent, bus (19) from 0.998p.u to 1.1035p.u and others. These results indicate undershoot and overshoot that will cause damage to the system, and may lead to system collapse if no contingency control is installed. It is also observed that compensation should be done on weak buses only for better results. The results also showed that control of active and reactive power greatly influence the Nigeria electricity grid, hence need adequate attention with the recent advent of renewable energy and its integration into the grid.**

KEYWORDS: Compensation Effects, Interconnected Network, Active and Reactive Power, Nigerian power system.

I. INTRODUCTION

Voltage ampere reactive (VAR) compensation is the management of reactive power to improve the performance of ac power systems. The concept of VAR compensation embraces a wide and diverse field of both system and customer problems, especially related with power quality issues since most power quality problems are attenuated or solved with an adequate control of reactive power [1]. In general, the problem of reactive power compensation is viewed from two aspects: load compensation and voltage support. In load compensation the objectives are to increase the value of the system voltage (power factor improvement), balance the real power drawn from the ac supply, compensate voltage regulation and eliminate current harmonics. In voltage support, the idea is for sustenance and to maintain stable voltage flow in the network. For power flow studies the frequency should remain nearly constant, because considerable drop in frequency could result in high magnetizing currents in induction motors and transformers [2]. The flows of active and reactive powers in a transmission network are fairly independent of each other and are influenced by different control actions. Active power control is closely related to frequency control, and reactive power control is closely related to voltage control [3]. Since constancy of frequency and voltage are important factors in determining the quality of power supply, then the control of active and reactive power is vital to the satisfactory performance of a power system [2, 4].

Since electrical energy is normally generated at the power stations far away from the urban areas where consumers are located and are delivered to the ultimate consumers through a network of transmission and distribution, the terminal voltage vary substantially. Wider variation in voltage may cause erratic operation or even malfunctioning of consumers' appliances. The main cause for voltage variation is the variation in load on the supply system. With the increase in load on the supply system the voltage at the consumer premises falls due to increase in voltage drop in: (I) Alternator synchronous impedance. (ii) Transmission lines (iii) Feeders and (iv) Distributors [5, 6, 7].

A power system is said to be well designed if it gives good quality and reliable supply. By good quality it meants the voltage levels being within reasonable limits. Naturally all the equipment on the power system are designed to operate satisfactorily only when the voltage levels in the system correspond to the rated voltage or at the most the variation are within ±5% of rated value [7]. Hence, compensation could be beneficial in in this aspect. The benefits of compensations are enormous and include the following: reactive power compensation in a transmission system improves the stability of the ac system by increasing the maximum active power that can be transmitted. It also helps to maintain a substantially flat voltage profile at all levels of power transmission if properly harnessed. It also increases transmission efficiency. It controls steady-state and temporary over-voltages and can avoid disastrous blackouts [8, 7 13]. Objectively, the study of the effect of joint compensation on an interconnected network is the main issue of this work and the result obtained showed the disparity.

II REAL AND REACTIVE POWER CONTROL

A synchronous machine that is connected to an infinite bus has fixed speed and terminal voltage. The control variables are the field current and the mechanical torque on the shaft. The variation of the field current (I_f), referred to as excitation system control is applied to either a generator or a motor to supply or absorb a variable amount of reactive power. Since the synchronous machine runs at a constant

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speed, the only means of varying the real power is through control of the torque imposed on the shaft by either the prime mover in the case of a generator or the mechanical load in the case of a motor. The complex power delivered to the system by the generator is given in per unit as in eqns. (1) and (2)

$$S = P + jQ = V_i I_a^* = |V_i||I_a|(\cos\theta + j\sin\theta) \qquad \textbf{(1)}$$

And for real and imaginary quantities we obtain

$$P = |V_i||I_a|\cos\theta \ ; \quad Q = |V_i||I_a|\sin\theta \qquad \textbf{(2)}$$

III SHUNT COMPENSATION – STATIC-VAR COMPENSATION

Shunt compensation is the use of shunt capacitor or and shunt reactors in the line to avoid or reduce voltage instability [2, 8] Shunt compensators are connected in shunt either directly to a bus bar or to the tertiary winding or to the main transformer and sometimes at mid-point of the lines (in some countries) to minimize the voltage drop and the losses. Shunt compensators are installed near the local terminals in factory substations, in the receiving substations, at switching substations etc to provide leading volt ampere-reactive (MVar) and thus to reduce the line current and total kVA loading of substation transformer [4, 6, 7, 9].

IV CONTROL OF VOLTAGE AND REACTIVE POWER

For a transmission line where X>>R and R is negligibly small, therefore

$$|\Delta V| = \frac{XQ_r}{X}, \qquad Q_r = \frac{V_r}{X}|\Delta V| \qquad (3)$$

This relationship shows that the reactive power Q_r is proportional to the magnitude of the voltage drop in the line. Thus voltage control and reactive power control are interrelated. The reactive power generated should be exactly equal to the reactive power consumed. Any mismatch in the reactive power balance affects the bus voltage magnitudes [6, 7].

V REACTIVE POWER COMPENSATION IN THE NIGERIA 330KV NETWORK

VAr compensation is the management of reactive power to improve the performance of ac power systems. The concept of VAr compensation encircles a wide and diverse field of both system and customer problems, especially related with power quality issues. Most of the power quality problems can be attenuated or solved with an adequate control of reactive power.

System voltage is highly dependent on the flow of reactive power. The long transmission lines in the National Grid generate considerable reactive MVars which constitute serious problems in maintaining system voltages within statutory limits especially during light loads, system disturbances and or major switching. The Nigerian PHCN has many reactors in various locations in the country, some of which are shown in Table I. Some of these reactors were incorporated in the system to carry out the compensation to control the effect of reactive Mar. The major cause of voltage variation or drop in the line is the flow of reactive power. More of over reactive currents causes I^2R losses in the system but produces no revenue.

VI REACTIVE POWER MANAGEMENT IN ELECTRIC POWER SYSTEM

An important factor in the control of voltage in a power system depends on the reactive power production or absorption. Reactive power is required to excite consumer's equipment and transmission network which consists of capacitive and inductive elements. It is important that a balance of reactive power be maintained in the operation of a system because control of voltage can be lost if this is not achieved [2, 10]. The reactive power flow is minimized so as to reduce I^2R and (I^2X) losses to a practical minimum. This ensures that the transmission system operates efficiently. The rating of capacitor can be calculated with the simplified equation as;

$$C = \frac{Q_C}{\omega V^2} \qquad (5)$$

Equation 5 shows that the capacitance required to improve the system efficiency is inversely proportional to V^2. Note that at high voltages power capacitors or capacitor bank values are rated in Kilo Volt-Ampere Reactive (kVAr or MVAr). For three phase system, the equation for the capacitor in delta connection, where ($V_P = V_L$)

Is given by Eq. 6. $C_\Delta = \frac{Q_C}{\omega V_P^2} = \frac{Q_C}{\omega V_L^2}$ (6)

Compensation added to the network is given by Eq. 7, [7, 19]

$$Q_C = \frac{P}{Pf_1} \times \sin(\cos^{-1}(pf_1)) - \frac{P}{Pf_2}\sin(\cos^{-1}(pf_2) \qquad \textbf{(7)}$$

Where P = real power specified at the buses, Pf$_1$ = 0.85 power factor, Pf$_2$ = 0.95 power factor, Q_C = value of shunt capacitance to be added to the network to boost the system voltage. Hence the capacitor required per three phase in star connection is equal to three times the capacitance required per phase when the capacitors are connected in delta. Also, the capacitors for the star-connected bank have a working voltage equal to $\frac{1}{\sqrt{3}}$ times that for the delta-connected bank For this reason, the capacitors are connected in delta in three-phase systems for improvement of the system stability. The installation of a capacitor bank can be used to avoid the need to change a transformer in the event of a load increase. System behavior is affected by the characteristics of every major element of the system. The representation of these elements by means of appropriate mathematical models is critical to the successful analysis of the system behavior [11, 12].

TABLE 1
STATUS OF REACTORS IN THE NIGERIA POWER SYSTEM PHCN 330KV SYSTEM

Station	Reactor Nomenclature	Rating		Remarks
		KV	MVAr	
Kaduna	3R3	330	75	Good
Jebba	2R1	„	75	Good
Kanu	R1	„	75	„
Gombe	R1 R2	„ „	50 50	„
Oshogbo	4R1	330	75	„
Benin	6R2	330	75	Good
Ikeja-West	R1	330	75	„
Makurdi	R1	„	75	„
Maiduguri	2R1	330	75	Good

VII METHODOLOGY

The existing 330kV, 30 bus system of Nigeria transmission network with Egbin power station as the slack bus was used, and an in-depth examination of the Nigeria Integrated Power Plant Network was carried out. The parameters of all the generators and other system components were obtained. Equations for the power flow analysis are then formulated incorporating these parameters. The algorithm for the Newton-Raphson's method was developed. The Newton-Raphson's solution method represented with Eqns. (8) and (9) was used to carry out the analysis because of its sparsity, fast convergence and simplicity attributes as compared to other solution methods using the relevant data as obtained from Power Holding Company of Nigeria (PHCN). MATLAB m-file program and SIMULINK model were developed and used for the simulation analysis.

$$\Delta \mathrm{P} = J_{11} \Delta \delta \qquad (8)$$

$$\Delta Q = J_{22} \Delta |V| \qquad (9)$$

VIII NETWORK DESCRIPTION

The Nigerian power network like many practical systems in developing countries consists of a few generating stations mostly sited in remote locations near the raw fuel sources which are usually connected to the load centers by long transmission lines.

The National Electric Power Authority (NEPA) now known as Power Holding Company of Nigeria (PHCN) has the sole statutory functions of generation, transmission, distribution and marketing of electricity, before the partial unbundling of the power sector. Nigeria national electricity grid at present consists of nine generating stations comprising of three (3) hydro and six (6) thermal plants with a total installed generating capacity of 6500MW. The thermal stations are mainly in the southern part of the country located at Afam, Okpai, Delta (Ughelli), Egbin and Sapele. The hydroelectric power stations are in the country's middle belt and are located at Kainji, Jebba and Shiroro. The transmission network is made up of 5000km of 330kV lines, 6000km of 132kV lines, 23 of 330/132kV sub-stations and 91 of 132/33KV substations [7, 14].

Although, the installed capacity of the existing power stations is 6500MW the maximum load ever recorded was 4,000MW. Presently, most of the generating units have broken down due to limited available resources to carry out the needed level of maintenance. The transmission lines are radial and overloaded. The switchgears are obsolete while power transformers have not been maintained for a long time. The present installed generating capacity in Nigeria is shown in Table II. The PHCN has only once been able to generate a maximum of 4700MW, for a country of more than 160 million people [15 – 17].

TABLE II
EXISTING POWER STATIONS

S/N	Power Station Name	Location /State	Status	Capacity (MW)
1	Egbin Thermal Power Station	Lagos	Operating	1320
2	Afam Thermal PS	Rivers	Operating	969.6
3	Sapele Thermal PS	Delta	Operating	1020
4	Ijora Thermal PS	Lagos	Operating	40
5	Delta Thermal PS	Delta	Operating	912
6	Kainji Hydro PS	Niger	Operating	760
7	Jebba Hydro PS	Niger	Operating	578
8	Shiroro Hydro PS	Niger	Operating	600
9	AES Thermal PS	Lagos	Operating	300
TOTAL INSTALLED CAPACITY =				6500

IX SKETCH OF NIGERIA 330KV TRANSMISSION NETWORK USED AS CASE STUDY

The single-line diagram of the existing 330KV Nigeria transmission network used as the case study is as shown in Fig.1. It has 30 buses with nine generating station. The Egbin power station was chosen as the slack bus because of its capacity and location in the network.

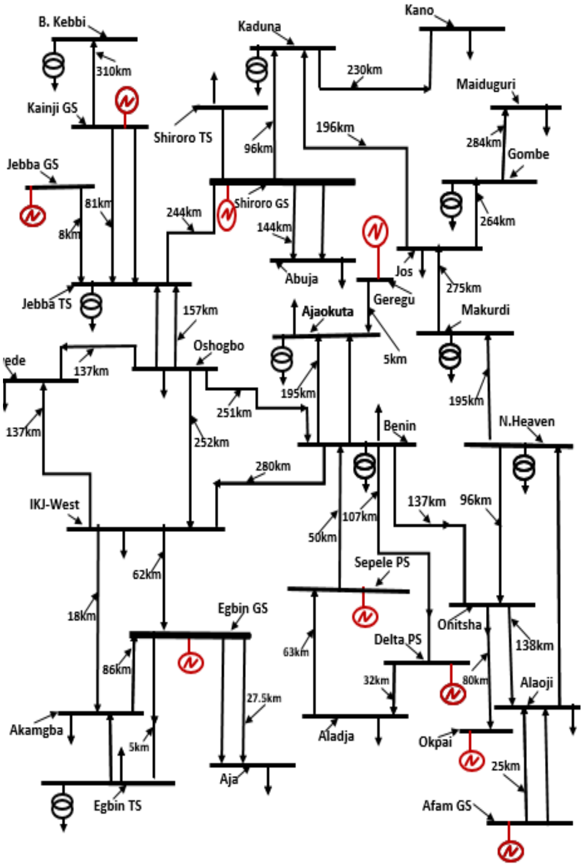

Fig.1 One Line Diagram of the PHCN 330KV

30 Bus Interconnected Network

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X DATA ASSEMBLY

The input data for the power flow analysis include the bus data, transmission line data (impedance of lines), voltages and transformer/load data obtained from Power Holding Company of Nigeria (PHCN) are as presented in Tables III to V.

XI LINE DATA

The load and generation data expressed in per unit values are given as $\frac{MW + jMVAr}{base.value}$. where the Slack Bus is Egbin Generating Station. As in Table IV

Base value = 100MVA

Base voltage = 330kV, Per Unit Value $= \frac{\text{MVA}}{\text{Base Valve}}$ as presented in Table V.

TABLE III
TRANSMISSION LINE DATA (OF BISON, TWO CONDUCTORS PER PHASE AND 2X350 MM^2 X-SECTION CONDUCTOR) FOR 330KV LINES

B/N	Bus Name		Length (km)	R_1(p.u.)	X_1(p,u.)	Shunt $\frac{y}{2}(p.u)$
	From	To				
1	Akamgbe	Ik-West	17	0.0006	0.0051	0.065
2	Ayede	Oshogbo	115	0.0041	0.0349	0.437
3	Ik-West	Egbin	62	0.0022	0.0172	0.257
4	Ik-West	Benin	280	0.0101	0.0799	1.162
5	Oshogbo	Jebba	249	0.0056	0.477	0.597
6	Oshogbo	Benin	251	0.0089	0.0763	0.954
7	Jebba Ts	Jebba Gs	8	0.003	0.0022	0.033
8	Jebba TS	Shiroro	244	0.0087	0.0742	0.927
9	Jebba TS	Kainji	81	0.0022	0.0246	0.308
10	Kainji	B.Kebbi	310	0.0111	0.942	1.178
11	Shiroro	Kaduna	96	0.0034	0.0292	0.364
12	Kaduna	Kano	320	0.0082	0.0899	0.874
13	Jos	Gombe	265	0.0095	0.081	1.01
14	Benin	Ajaokuta	195	0.007	0.056	0.745
15	Benin	Sapele	50	0.0018	0.0139	0.208
16	Benin	Onitsha	137	0.0049	0.0416	0.521
17	Onitsha	N .Heaven	96	0.0034	0.0292	0.0355
18	Onitsha	Alaoji	138	0.0049	0.0419	0.524
19	Alaoji	Afam	25	0.009	0.007	0.104
20	Sapele	Aladja	63	0.0023	0.019	0.239
21	Delta	Aladja	30	0.0011	0.0088	0.171
22	*Kainji GS	Jebba TS	81	0.0022	0.0246	0.308
23	Ayede	Ik West	137	0.0049	0.0416	0.521
24	Egbin TS	Aja	27.5	0.0022	0.0172	0.257
25	Egbin TS	Aja	27.5	0.0022	0.0172	0.257
26	Kaduna	Jos	197	0.007	0.0599	0.748
27	Jos	Makurdi	275	0.0029	0.0246	0
28	Oshogbo	Ik West	252	0.0049	0.0341	0.521
29	Benin	Delta	107	0.0022	0.019	0.239
30	Onitsha	Okpai	80	0.009	0.007	0.104
31	Geregu	Ajokuta	5	0.0022	0.0172	0.257
32	Shiroro	Kaduna	96	0.0034	0.0292	0.364

TABLE IV
BUS DATA IN PER UNIT

B/ N	Bus Name	Generation		Load	
		P (p.u)	Q (p.u)	P (p.u)	Q (p.u)
1	Egbin	-	-	0,0000	0.0000
2	Delta Ps	0.55	0.2816	-	-
3	Okpai	2.20	1.127	-	-
4	Sapele	0.75	0.3842	-	-
5	Afam	4.79	2.4539	-	-
6	Jebba	3.22	1.6496	-	-
7	Kainji	3.23	1.6549	-	-
8	Shiroro	2.80	1.4300	-	-
9	Geregu	2.00	1.0244	-	-
10	Oshogbo	-	-	1.2037	0.6165
11	Benin	-	-	1.6056	0.8224
12	Ikj-West	-	-	3.340	1.7111
13	Ayede	-	-	1.7665	0.9049
14	Jos	-	-	0.8223	0.42129
15	Onitsha	-	-	1.3051	0.6686
16	Akamgbe	-	-	2.33379	1.1956
17	Gomgbe	-	-	0.7448	0.3814
18	Abuja(katamkpe)	-	-	2.000	1.0244
19	Maiduguri	-	-	0.1000	0.0511
20	Egbin TS	-	-	0.000	0.000
21	Aladja	-	-	0.47997	0.24589
22	Kano	-	-	2.5245	1.2933
23	Aja	-	-	1.1999	0.61477
24	Ajaokuta	-	-	0.6322	0.3238
25	N.Heaven	-	-	1.1305	0.5791
26	Alaoji	-	-	1.6395	0.8398
27	Jebba TS	-	-	0.0744	0.0379
28	B.Kebbi	-	-	0.6999	0.3585
29	Kaduna	-	-	1.4977	0.7672
30	ShiroroTS	-	-	0.7307	0.3743

XII SHUNT CAPACITOR COMPENSATION ALGORITHM

The flow chart in Fig. 2 is the procedural method applied to achieve the desired compensation.

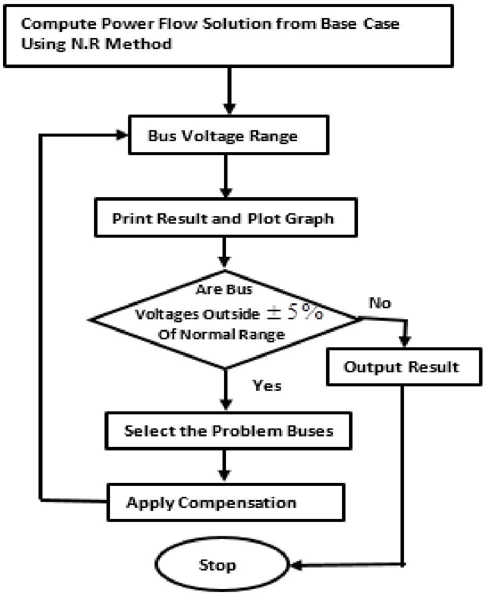


Fig. 2: Flow Chart for the Shunt Capacitor Compensation Analysis Algorithm

First, the base solution is obtained using Newton-Raphson's method. Check bus voltages range. Identify the problem buses by checking the bus voltages outside $\pm 5\%$ of the normal values (that is, 0.95 to 1.05) per unit. Calculate the capacitor values using this equation ($C = \frac{Q_C}{\omega V^2}$) and apply compensation using this

$$Q_C = \frac{P}{Pf_1} \times \sin(\cos^{-1}(pf_1)) - \frac{P}{Pf_2} \sin(\cos^{-1}(pf_2)).$$

Where P is real power specified at the buses, Pf_1 & Pf_2 are power factors, while Qc is value of shunt capacitance to be added to the network to boost the system voltage. Finally output result and stop. These procedures were simulated using MATLAB/SIMULINK. The results from the Newton-Raphson iterative method give the bus voltages, line flows, and power losses under normal (uncompensated) condition as shown in Table VI. The voltages at buses 14, 17, 18, 19, 22, 29 and 30 are outside the limit, and in order to ensure that they are within acceptable limits shunt capacitive compensation were injected into the buses. Based on Power Holding Company of Nigeria (PHCN) power factor of 0.85 and 0.95 for transmission lines are used. The MVAr capacities of the various capacitors required to carry out compensation of the network at the buses were determined using

$$Q_C = \frac{P}{Pf_1} \times \sin(\cos^{-1}(pf_1)) - \frac{P}{Pf_2} \sin(\cos^{-1}(pf_2))$$

The following capacitor sizes were selected for the various lines. Jos bus (30MVAr), Gombe bus (30MVAr), Abuja bus (60MVAr), Kano bus (40MVAr), Kaduna bus (40MVAr), and Makurdi bus (30MVAr). These were injected into the network to examine their effect on the system. The weak buses were identified as represented in Table VI, and the plots of the results are as shown in Figs. 3 and 4

TABLE V
BUS VOLTAGES FOR COMPENSATED & UNCOMPENSATED

		Bus Vtgs With Compensation	Without Compensation
B/N	Bus Name	Volts (p.u)	Volts (p.u)
1	Egbin-GS (Slack)	1.0000	1.0000
2	Delta-PS	1.0000	1.0000
3	Okpai-PS	1.0000	1.0000
4	SAP /PS	1.0000	1.0000
5	AFAM-GS	1.0000	1.0000
6	Jebba-GS	1.0000	1,0000
7	KAINJI-GS	1.0000	1,0000
8	Shiroro-PS	1.0000	1,0000
9	Geregu(PS)	1.0000	1,0000
10	Oshogbo	1.0035	0.9919
11	Benin	0.9998	0.9957
12	Ikeja-West	0.9969	0.993
13	Ayede	0.9967	0.9792
14	*Jos	0.9823	0.8171
15	Onitsha	0.9793	0.9748
16	Akangba	0.9931	0.9859
17	*Gombe	1.0242	0.8144
18	*Abuja (Katampe)	0.9667	0.9402
19	*Maiduguri	1.0455	0.8268
20	Egbin TS	0.9469	0.9816
21	Aladja	1.0006	0.9994
22	*Kano	0.9338	0.7609
23	Aja	0.9692	0.9838
24	Ajaokuta	0.9999	0.9997
25	N-Heaven	0.9721	0.9582
26	Alaoji	0.9598	0.9564
27	Jebba-TS	0.9993	0.9988
28	B.Kebbi	1.0075	0.9873
29	*Kaduna	0.9654	0.8738
30	*Makurdi	0.9943	0.8247

XIII RESULTS AND DISCUSSION

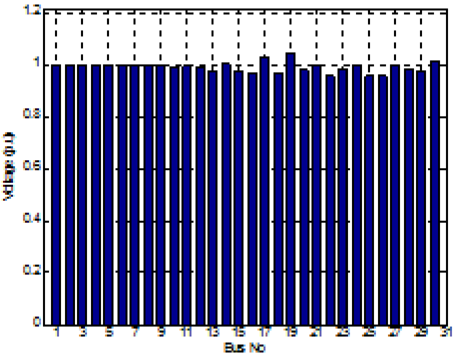


Fig. 3 Plot of Bus Voltages under Normal (Uncompensated) condition

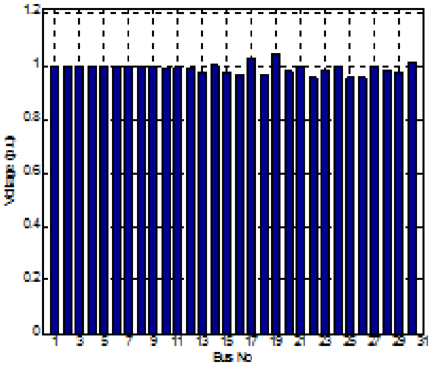


Fig. 4 Bar Plot of Bus Voltages with Compensation

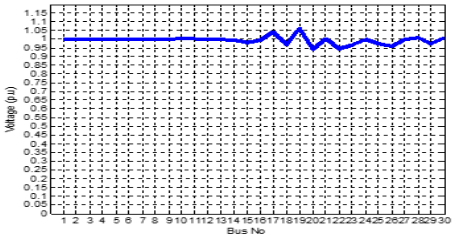
TABLE VI
BUS VOLTAGES AT DIFFERENT LEVELS OF PERCENTAGE COMPENSATION FOR THE PROBLEM BUSES ONLY

B/N	50percent	65percent	75percent	90percent
14	0.964547	0.976966	0.984707	0.995664
17	0.995396	1.009312	1.017975	1.030226
18	0.954925	0.954925	0.954925	0.954925
19	1.014868	1.029198	1.038118	1.05073
22	0.810757	0.834761	0.849712	0.945864
29	0.928746	0.93879	0.945069	0.953981
30	0.975601	0.98823	0.9961	1.007241

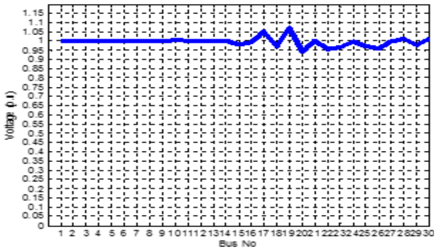
It is also recorded during the compensation of the entire system Jointly, that some buses that were normal are affected. Some buses values decreased from tolerable values while some over increased. Some of the pictorial graphs were as presented in Fig. 5 ((a) to (f)).

XIV DISCUSSION

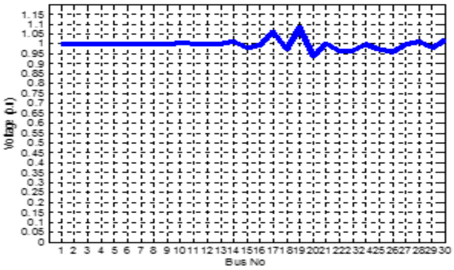
The analysis of Nigeria 330KV 30 bus network using Newton-Raphson's power flow solution algorithm with MATLAB/SIMULINK software was successfully completed. The results obtained revealed the weak buses with values outside the statutory limit of 0.95p.u. (313.5kV) and 1.05p.u. (346.kV).



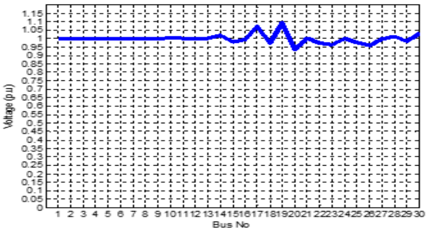
(a) 60%



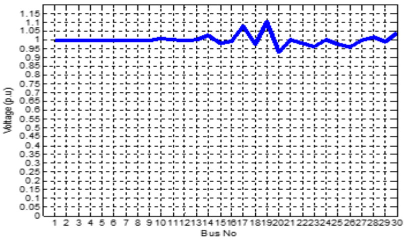
(b) 70%



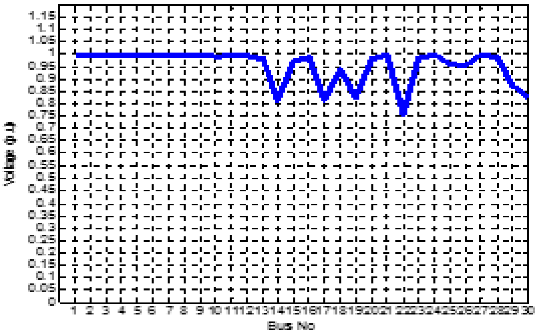
(c) 80%



(D) 90%



(e) 100%



(f) Uncompensated

Fig. 5(a) to (f) Graph of Voltage Vs Bus Nos. at Different levels of Percentage Compensation

They are recorded as, Bus 14(Jos) with value 0.8171pu, bus 17(Gombe) 0.8144p.u bus 18(Abuja) 0.9402pu, bus 19(Maiduguri) 0.8268pu, bus 22(Kano) 0.7609pu, bus 29(Kaduna) 0.8738pu, and bus 30(Makurdi) 0.8247pu under normal uncompensated condition as presented in Fig. 4.

The compensation technique discussed in this work was carried out on the weak buses. At 45 per cent capacitive shunt compensation on those buses showed improved performance and only Kano and Jos were still at the weak positions due to their distances in the national grid. With sixty (60) per cent compensation a better result was recorded as buses 14(Jos) improved to 0.9823 **and 22(Kano) 0.9338. The compensated results are** as shown in Fig. 5 ((a) to (f)). **It was observed that the application of compensation on the interconnected system jointly has side effect on the other buses** - which is the main aim of this work. This was proven by a step-by-step application of 5 percent intervals. **It was observed that compensating the whole network jointly affects some of the other buses that were within the tolerable range.** For instance, at Bus (20) the value decreased from 0.9568p.u to 0.9329p.u about 2.39 percent decrease. This can cause damage to the system if no proper security for contingency analysis control was installed. Also, bus (17) increased from 0.9786p.u to 1.0799p.u and bus (19) from 0.998p.u to **1.1035p.u** and so on, with some of the pictorial graphs as presented in Fig. 6 (the table is so large that we couldn't fix it in this text) which show undershoot and overshoot respectively which may lead to system collapse if not monitored. The results also showed that control of active and reactive power greatly influence the Nigeria electricity grid, hence need adequate attention with the recent advent of renewable energy and its integration into the grid.

XV CONCLUSION

Compensation techniques were reviewed. Shunt and series reactive compensation using capacitors has been widely recognized as one of the powerful methods to combat the problems of voltage drops, power losses, and voltage flicker in power system networks. Though each compensating technique has its area of proficiency and limit of application, but shunt capacitor compensation method was used because of its outstanding performance especially in long transmission lines and its control of reactive power flow. Though they have high cost implication but they control voltage *directly* and also control temporary over voltage rapidly. **It was observed also that application of compensation on the interconnected system jointly has side effect on the other buses**. The results showed that control of active and reactive power has greater influence on the Nigeria network, hence adequate attention must be placed on it. Also with innovation/advent of renewable energy integration into the grid, if adequate control measure of reactive power is not put in place there will be no much success. **Thus, it is advised that concentrating the compensation on the problem buses gives best result like buses** 14, 17, 18, 19, 22, 29, 30, at 65 percent recorded 0.976966, 1.009312, 0.954925. 1.029198, 0.834761, 0.93879, & 0.98823 and others as shown in Table VII. This reduces cost as well.

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