Reactive Power Compensation for Reduction of Losses in Nigeria 330kV Network Using Static Compensator (STATCOM)

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Abstract -- This work is focused on Reactive Power Compensation to reduce losses in Nigeria 330kV Power Transmission lines. Management of reactive power and voltage control constitute part of the major challenges in a power system. Adequate reactive power control solves power quality problems like voltage profile maintenance at all power transmission levels, transmission efficiency and system stability. Power demand increases steadily while the expansion of power generation and transmission has been severely limited due inadequate resources and environmental forces in Nigeria. A Flexible Alternating Current Transmission System (Facts) called Static Synchronous Compensator (Statcom) device was adopted. Using the relevant data obtained from Transmission Company of Nigeria (TCN) control centre Oshogbo, the system soft-model of 330kV 57 buses of the Nigeria transmission line was built with the help of Electrical Transient Analyzer Program software (Etap 12.6). The results show voltage magnitude where voltage drops were noticed at buses Damaturu (0.9992pu), Gombe (0.9880pu), Yola (0.9900pu), Jalingo (0.9904pu), Ikeja West (0.9892pu), and Maiduguri (0.0504pu) respectively. When Statcom was integrated into the network, the new voltage magnitudes of these buses improved to 1.2062, 1.0327, 1.0319, 1.1682, 1.1600, and 1.0374pu respectively; The simulation result obtained showed improvement of weak bus voltages and loss reduction to 85 percent.

Indexed Terms: Statcom, Etap, VSC, Matlab

I. INTRODUCTION

The engineer who works in the electrical power industry will encounter some challenges in designing future power systems to deliver increasing amounts of energy in a safe, clean and economical manner (Annual Energy Outlook 2006 with Projections to 2030, 2006). The origin of the Nigeria Electric power System can be traced back to the year 1898 (Acha, 2004) when a small generating plant was installed in Lagos. The first power interconnection was a 132kV link constructed in 1962 between Lagos and Ibadan. By 1968 the first National grid structure emerged with the construction of the kainji hydro station which supplied power via a 330kV, primarily radial type transmission network into the three members' 132kV subsystem then existing in the Western, Northern and Eastern parts of the country. The 330kV and 132kV systems were initially run by two separate bodies- "Nigeria Dams Authority (NDA)", and "Electricity Corporation of Nigeria (ECN)" respectively. Central control for the 330kV Network was coordinated from kainji power supply control room, while the 132kV Network was run by load dispatcher located at Ijora Power Supply Lagos. These two bodies were merged formally into single power utility known as National Electric Power Authority (NEPA) in 1972 thus ushering in centralized regulation and coordination of the entire rapidly growing 330KV and 132kV National network. These networks are characterized by many disturbances which cause various hindrances and outages [19].

II. 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. Generation, transmission, distribution and marketing of electricity in Nigeria are the statutory functions of the Power Holding Company of Nigeria (PHCN) which has now been privatized into three (3) constituents: Transmission Company of Nigeria (TCN), Generation Companies of Nigeria (GENCOS) and Distribution Companies of Nigeria (DISCOS). Presently, the national electricity grid consists of twenty nine (29) generating stations comprising three

(3) hydro and twenty six (26) thermal with a total installed generating capacity of 13,063MW. 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 5395km of 330kV lines, 6889km of 132kV lines. Although, the installed capacity of the existing power stations is about 13,063MW the maximum load ever recorded was 4,000MW (TCN Daily Operational Report Jan., 2018).

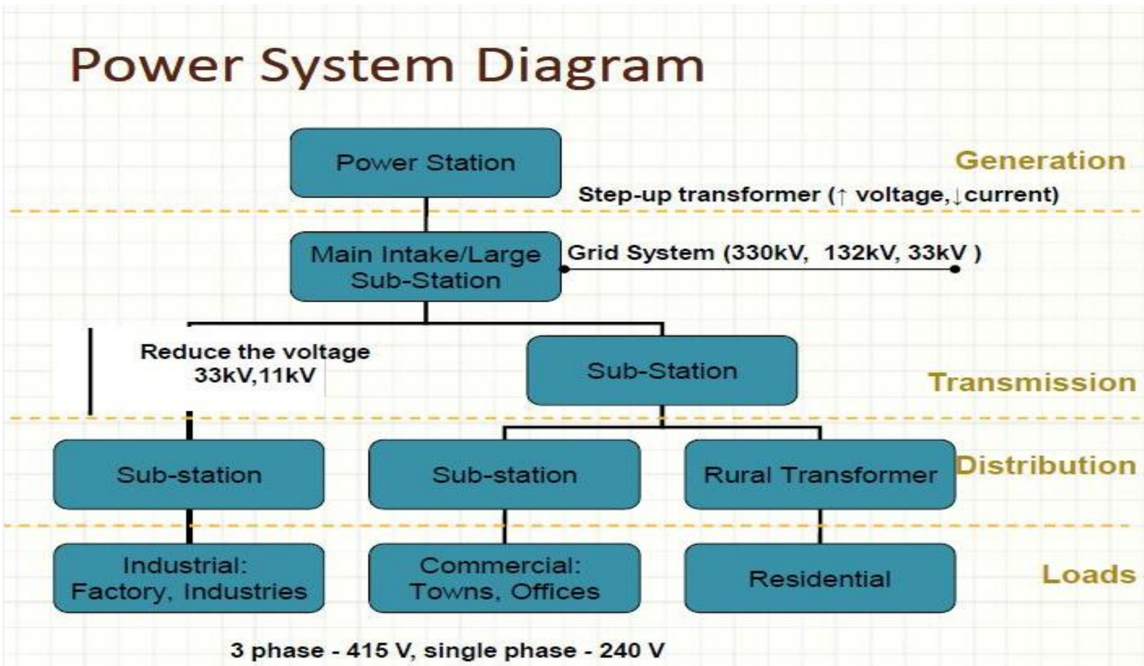

Fig. 1.1: Nigeria Grid Configuration

III. NETWORK CONSTRUCTION

An electrical network consists of various electrical elements such as generator, load, transmission line, transformer etc. Here we assume that all the data for generator, load, and transmission line parameters are given in per unit system and common MVA base**.** After data have been collected, suitable software called Electrical Transient Analyzer Program (Etap) was selected for the network design.

This software offers both graphical and tabular data entry modes, single-line diagram drawing options. This user-friendly software is implemented and practically used to determine not only the power flow in transmission lines but also to identify weak buses for installing the compensating device in order to minimize the unwanted losses on the 57 Bus power grid system. The simulated 57-bus 330kV Nigerian Transmission network used as the case study is shown in fig 3.8a below. The network consists of nine generating stations, fourteen loads stations and thirty one transmission Lines.

In the case of Nigeria, the power network is constructed to generate and wheel power to load centers at specific voltage and frequency levels with statutory limits. The nominal frequency is 50Hz ±2.5%. Even though there are possibilities for system stress; the power system variation, statutorily, could be 50Hz± 2.5%. (i.e. 48.75 Hz-51.25Hz). On the other hand, the nominal transmission system voltage levels are 330kV and 132kV; in the case of the latter, it has a statutory limit stated as 132kV ±5%. However, when the power system is under stress or during system faults, voltages can deviate outside the limits by a further 5% except under transient and sub-transient disturbances.

The grid is divided into three 3 sections: North, South – East and the South – West sections. The North is connected to the South through one triple circuit lines between Jebba and Oshogbo while the West is linked to the East through one transmission line from Oshogbo to Benin and one double circuit line from Ikeja to Benin [19].

Structurally Statcom is a voltage-source inverter (VSI) based device (Fig. 3.8a), which converts a direct current input voltage into an alternating current output voltage in order to compensate the reactive power needs of the system.
In case the system voltage drops sufficiently to force the Statcom output to its ceiling, still its reactive power output is not affected by the grid voltage magnitude. Therefore, it exhibits constant current characteristics when the voltage is low. Statcom can provide instantaneous and continuously variable reactive power in response to grid voltage transients, enhancing the grid voltage stability. The Statcom operates according to voltage source principles, which together with unique PWM (Pulsed Width Modulation) switching of power switches gives it unequalled performance in terms of effective rating and response speed [21]. This performance can be dedicated to active harmonic filtering (The Changing Structure of the Electric Power Industry 2000) and voltage flicker mitigation, but it also allows providing reactive power compensation of the load.

	STATIONS	NO OF UNITS INSTALLED	AVAILABLE UNITS	INSTALLED CAPACITY OF AVAILABLE UNITS(MW)	GENERATION CAPABILITY OF AVAILABLE UNITS(MW)	UNITS ON BAR	CAPABILITY OF UNITS ON BAR (MW)	GENERATION AT 06:00HRS (MW) AT 50.27Hz.
PRIVATISED COMPANIES	KAINJI HYDRO	8	1G6, 6 & 12 3	340	310	1G6, 6 & 12 3	310	238
	JEBBA HYDRO	6	2G1 - 4 4	385.6	360	2G1, 3 & 4 3	270	214
	SHIRORO HYDRO	4	411G1 - 4 4	600	540	411G1 & 2 2	270	118
	EGBIN STEAM	6	ST1 - 4 4	880	515	ST1 - 4 4	516	491
	SAPELE (STEAM)	6	ST3 1	120	60	ST3 1	60	60
	DELTA (GAS)	18	GT6, 7, 10, 12, 13, 16, 19 & 20 8	435	371	GT6, 7, 10, 12, 13, 12, 16, 19 & 20 8	371	371
	AFAM IV & V (GAS)	8	0 0	0	0	0 0	0	0
	GEREGU GAS	3	GT11 & 12 2	290	290	GT11 & 12 2	290	211
	OMOTOSHO GAS	8	GT2, 4,6 & 8 4	168	113.4	GT2, 4, 6 & 8 4	113.4	113.4
	OLORUNSOGO GAS	8	GT1, 3,5 - 7 5	210	162.9	GT1, 3,5 - 7 5	162.9	152.9
NIPP	GEREGU NIPP	3	GT21 & 22 2	290	290	GT21 & 22 2	290	209
	SAPELE NIPP	4	GT4 1	112.5	112.5	GT4 1	112.5	93.2
	ALAOJI NIPP	4	0 0	0	0	0 0	0	0
	OLORUNSOGO NIPP	6	0 0	0	0	0 0	0	0
	OMOTOSHO NIPP	4	GT2 1	120	84	GT2 1	84	84
	ODUKPANI NIPP	5	GT2 - 5 4	480	400	GT2 - 4 3	300	234
	IHOVBOR NIPP	4	GT1 1	112.5	112.5	GT1 1	112.5	100.7
	GBARAIN NIPP	1	0 0	0	0	0 0	0	0
IPP	OKPAI GAS/STEAM	3	GT11 1	160	140	GT11 1	140	118
	AZURA - EDO	3	GT11 - 13 3	461	461	GT11 - 13 3	461	343
	AFAM VI GAS/STEAM	4	GT11 - 13 3	450	450	GT11 & 13 2	300	278
	IBOM POWER GAS	3	GT3 1	115	115	GT3 1	115	87.7
	AES	9	0 0	0	0	0 0	0	0
	ASCO	2	0 0	0	0	0 0	0	0
	OMOKU GAS	6	GT1, 3 & 5 3	75	58.8	GT1, 3 & 5 3	58.8	58.8
	TRANS-AMADI	4	GT1, 2 & 4 3	75	65.5	GT1, 2 & 4 3	65.5	65.5
	RIVERS	1	GT1 1	180	160	GT1 1	160	113
	SUB TOTAL	141	59	6029.6	5151.4	54	4541.4	3740

Table 1.1: Daily Operational Report 26/06/2019 – Transmission Company of Nigeria NCC, Oshogbo

IV. STATCOM

Static Synchronous Compensator is a static synchronous generator operated as a parallel connection static reactive power compensator whose capacitive or inductive output current can be controlled independent of the ac system voltage. In addition to system voltage control, which typically is the main task of the Statcom, it may also be employed for additional tasks such as damping of power system oscillations, which results in improvement of the transmission capability.

The Statcom provides operating characteristics similar to a rotating synchronous compensator without the mechanical inertia, due to the Statcom employed solid state power switching devices it provides rapid controllability of the three phase voltages, both in magnitude and phase angle.

Statcom provide voltage support to buses by modulating bus voltages during dynamic disturbances in order to provide better transient characteristics, improve the transient stability margins and to damp out the system oscillations due to these disturbances.
The principle of Statcom operation is as follows. The VSC (Voltage Source Converter) generates a controllable alternating current voltage source behind the leakage reactance. This voltage is compared with the alternating current bus voltage system; when the alternating current bus voltage magnitude is above that of the VSC voltage magnitude, the alternating current system sees the Statcom as an inductance connected to its terminals. Otherwise, if the VSC voltage magnitude is above that of the alternating current bus voltage magnitude, the alternating current system sees the Statcom as a capacitance connected to its terminals. If the voltage magnitudes are equal, the reactive power exchange is zero. If the Statcom has a direct current source or energy storage device on its direct current side, it can supply real power to the power system. This can be achieved adjusting the phase angle of the Statcom terminals and the phase angle of the alternating current power system. When the phase angle of the alternating current power system leads the VSI phase angle, the Statcom absorbs real power from the alternating current system; if the phase angle of the alternating current power system lags the VSC phase angle, the Statcom supplies real power to alternating current system.

Statcom could have many topologies, but in most practical applications it employs the direct current to alternating current converter, which can also be called a Voltage Source convertor (VSC) in 3-phase configuration as the primary block. The basic theory of VSC is to produce a set of controllable 3-phase output voltages/ currents at the fundamental frequency of the alternating current bus voltage from a direct current input voltage source such as a charged capacitor or a direct current energy supply device. By varying the magnitude and phase angle of the output voltage and current, the system can exchange active/reactive power between the direct current and alternating current buses, and regulate the alternating current bus voltage.

Reactive power has been recognized as an important factor in the design and operation of alternating current electric power systems. Since the impedance of the network components are mainly reactive, the transmission of active power requires a difference in angular phase between the voltages at the sending end and the receiving end, while the transmission of reactive power requires a difference in magnitude of these same voltages. Reactive power is consumed not only by most of the network elements, but also by most of the consumer loads. The required reactive power must be supplied somewhere and if we cannot transmit it very easily then it must be generated at the point where it is needed. The reactive power must be supplied at the same voltage of the load that requires it.

The Statcom consists of a three phase inverter (generally a PWM inverter) using SCRs, MOSFETs or IGBTs, a direct current capacitor which provides the direct current voltage for the inverter, a link reactor which links the inverter output to the alternating current supply side, filter components to filter out the high frequency components due to the PWM inverter from the direct current side.

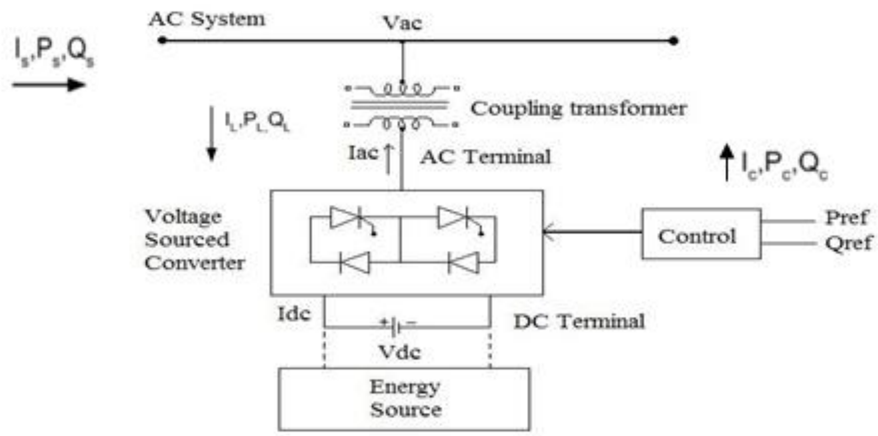

Figure 3.8a: Simplified Model of STATCOM

V. STATCOM CONTROL PRINCIPLE

The sets of equations given below are derived from the analysis of figure 3.8a, where: X = Coupling transformer reactance, V_s': rms line-to-neutral alternating current grid voltage with a phase angle of 0 referred to Statcom side.

V_C: RMS line-to-neutral Statcom fundamental voltage
Is: RMS source current
I_L: RMS load current
I_C: RMS Statcom current
Q_s: Source reactive power
Q_L: Load reactive power
Q_c: Statcom reactive power
δ: Phase angle between fundamental voltage of Statcom and AC grid.

If V_c is equal to Vs, reactive power generation is zero.

If $V_c < V_s$, a current is induced which lags V_X. This current also lags V_s since V_X is in phase with V_s. Therefore, Alternating Current grid sees this current as inductive and STATCOM is said to be operating in inductive mode.

If V_c > Vs, a current is induced which lags V_X. However, this current leads Vs since V_X is in opposite direction with Vs. Therefore, Alternating Current grid sees this current as capacitive and Statcom is said to be in operating capacitive mode.

$$P_c \cong \frac{V_s V_c}{X} \sin\delta \tag{3.57}$$

$$Q_c \cong V_s \frac{V_s - V_c \cos\delta}{X} \tag{3.58}$$

or

$$P_c \cong \frac{V_s V_c}{X} \delta \tag{3.59}$$

$$Q_c \cong V_s \frac{V_s - V_c}{X} \tag{3.60}$$

It can be deduced from (3.57) and (3.58) that Statcom absorbs active power even at zero reactive power because of converter losses.

Assuming the relationship between V_c and dc link voltage V_d is given in terms of a constant k, since $V_c \propto V_d$.

$$V_c = kV_d \tag{3.61}$$

By substituting (3.61) in (3.57) and (3.58), (3.62) and (3.63) are obtained.

$$P_c \cong \frac{V_s^{'}}{X} kV_d \sin\delta \tag{3.62}$$

$$Q_c \cong \frac{V_s^{'}}{X}(V_s^{'} - kV_d \cos\delta) \tag{3.63}$$

In order to approximate input voltage of VSC to a pure sinewave at fundamental frequency, Pulse Width Modulation (PWM) or Pulse Amplitude Modulation (PAM) technique can be applied.

For this case, peak value of fundamental component of VSC input voltage (line-to neutral) can be related to dc link voltage in terms of modulation index (ma) as given in (3.64) by assuming a two-level line-to-neutral ac voltage.

$$\hat{V}_c = m_a \frac{V_d}{2} \tag{3.64}$$

By using (3.61) and (3.64) one obtains:

$$k = \frac{m_a}{2\sqrt{2}} \cong 0.35m_a \tag{3.65}$$

$$V_c \cong 0.35 m_a V_d \tag{3.66}$$

Substituting of (3.65) in (3.62) and (3.63) gives:

$$P_c \cong \frac{0.35V_s^{'}}{X} m_a V_d \sin\delta \tag{3.67}$$

$$Q_c \cong \frac{V_s^{'}}{X}(V_s^{'} - 0.35 m_a V_d \cos\delta \tag{3.68}$$

This assumption simplifies the term which is going to be controlled to $0.35mV_d$. It can therefore be concluded that reactive power absorbed or delivered by Statcom can be controlled by one of the following techniques:

i) Varying modulation index (ma) while keeping direct current link voltage V_d constant

ii) Varying V_d while keeping (ma) constant, or

iii) A combination of i and ii [5].

VI. RESULTS

The Nigerian transmission network was used as a case study. The case study consists of 57 buses, 128 transmission lines and 22 generators. The proposed algorithm was developed in the Etap programming language using version Etap 12.6.0. The steady-state and dynamic performance of the Statcom, the behavior of the system with and without Statcom is studied, with objective of determining the best location of the Statcom to improve the voltage in the grid, and to observe the grid response to with and without Statcom.

For the system without Statcom, the voltage magnitude of load buses given by the load flow program, design that the losses and the percentage of the voltage drop magnitude at buses, most of the voltage drop are very significant up to 4.85%. When Statcom is connected at buses in figure 3.8c,

Initially the programmable voltage source in Matlab environment is set at 1.0491pu, resulting in a 1.0pu voltage at bus B1 when the Statcom is out of service. As the reference voltage V_{ref} is set to 1.0pu, the Statcom is initially floating (zero current). The direct current voltage is 19.3kV as shown in figure 3.8b below:

a. At t = 0.1s, voltage is suddenly decreased by 4.5% (0.955pu of nominal voltage). The Statcom reacts by generating reactive power (Q = +70Mvar) to keep voltage at 0.979pu. The 95% settling time is approximately 47ms. At this point the direct current voltage has increased to 20.4 kV.

b. Then, at t = 0.2s the source voltage is increased to1.045pu of its nominal value. The Statcom reacts by changing its operating point from capacitive to inductive to keep voltage at 1.021pu. At this point the Statcom absorbs 72Mvar and the direct current voltage has been lowered to 18.2kV. Observe on the first trace showing the Statcom primary voltage and current that the current is changing from capacitive to inductive in approximately one cycle.

c. Finally, at t = 0.3s the source voltage in set back to its nominal value and the Statcom operating point comes back to zero Mvar.

Similarly, Simulating the 57 bus in Etap environment it observed that the voltage magnitude at those buses improved. Table 4.1 and 4.2 respectively: Show the power flow result obtained which gives a typical scenario of how Nigeria Network is characterized.

VII. CONCLUSION

Statcom has number of advantages over conventional methods of compensation viz: quick response time, less space requirement, optimum voltage platform, higher operational flexibility and excellent dynamic characteristics under various operating conditions.

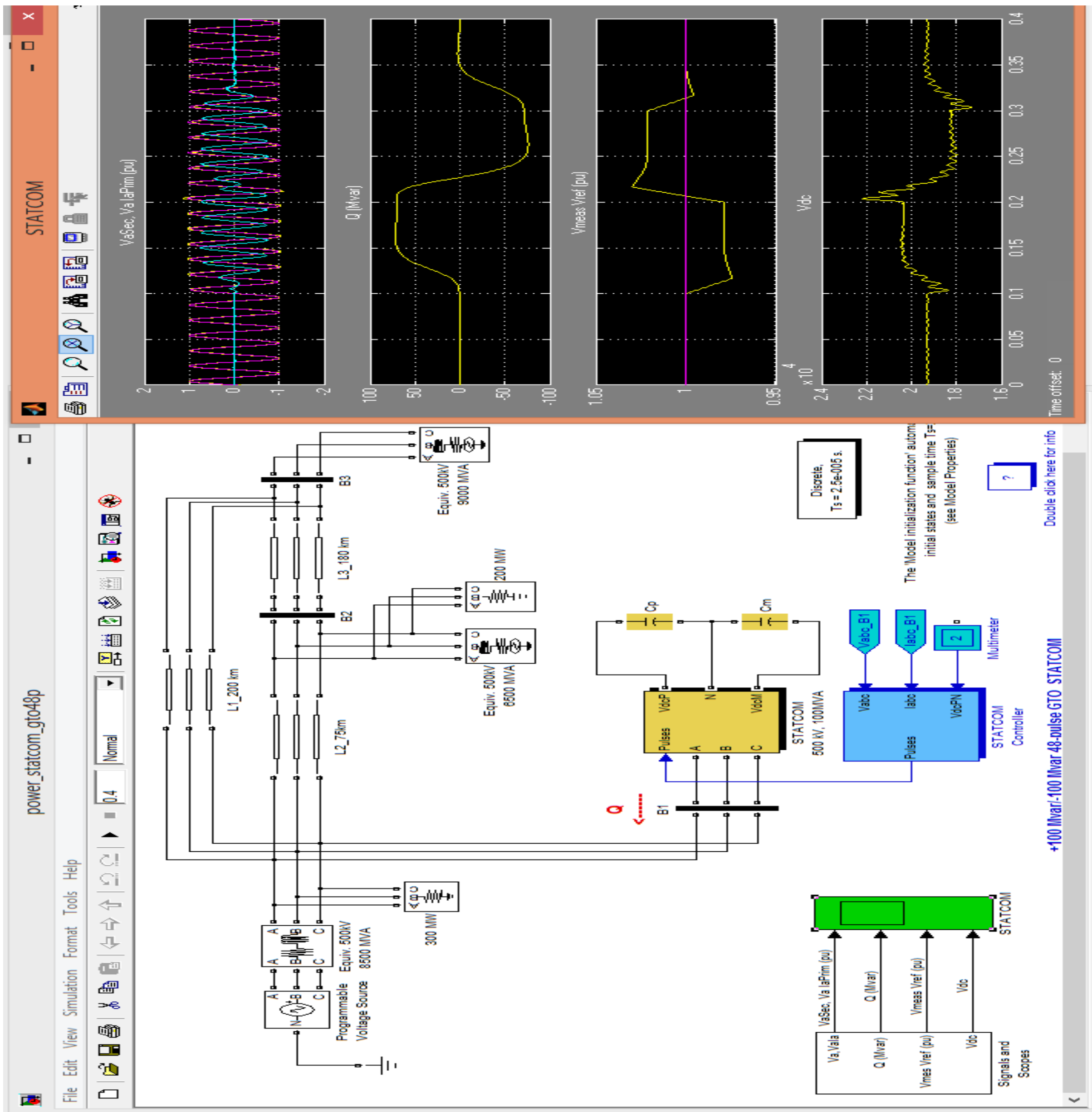

Figure 3.8b: 75Mvar 48 pulse GTO STATCOM

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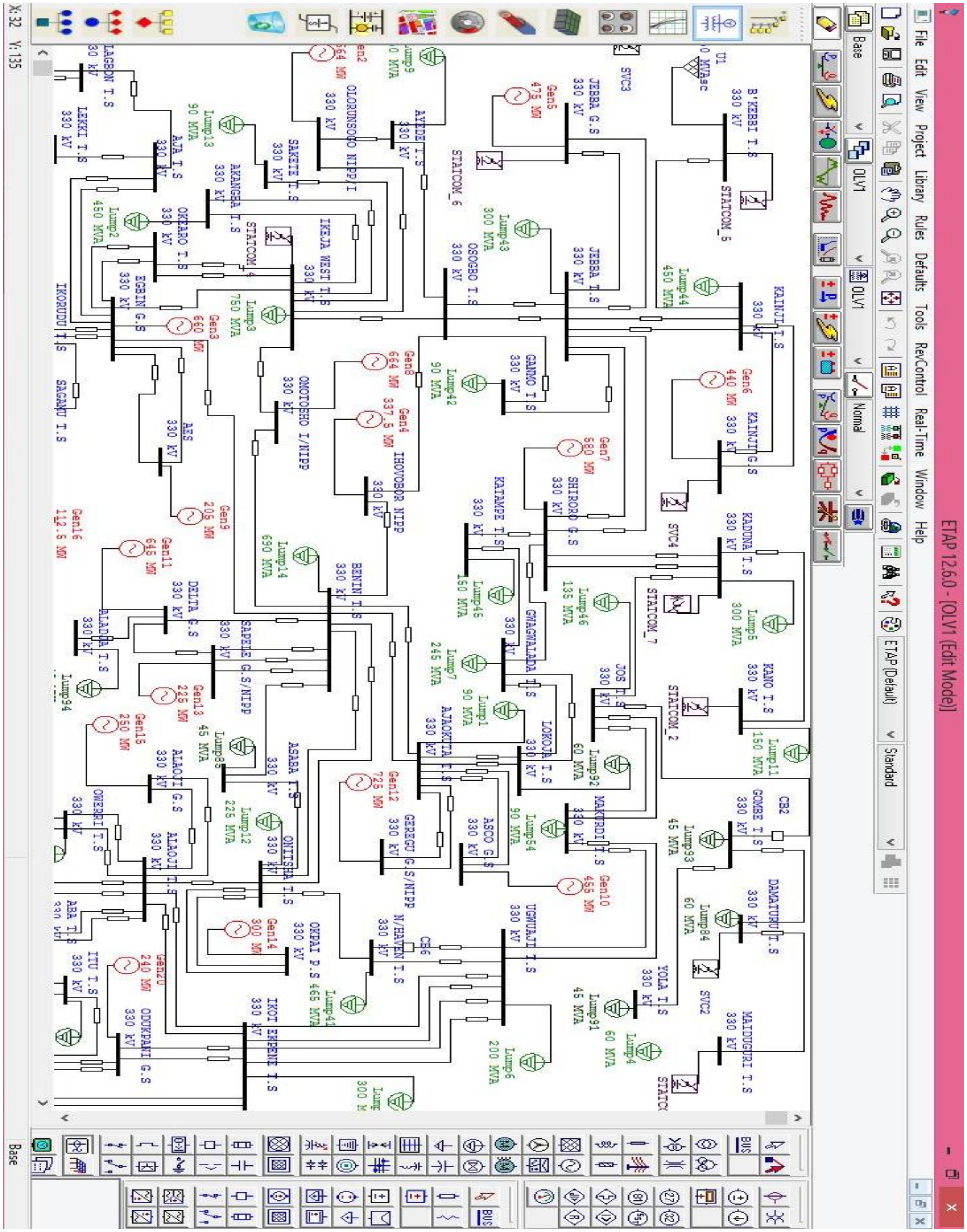

Figure 3.8c: 57 bus of Nigeria 330kV Grid simulated in Etap

Project: STATCOM on 330kV National Grid	ETAP	Page:	1
Location: National Control Centre Oshogbo	12.6.0H	Date:	12/05/2018
Contract: COOU M.Eng Project		SN:	2015112012
Engineer: Uzowulu Ifeanyi Nnanedu	Study Case: OPF	Revision:	Base
Filename: STATCOM-33OKv		Config:	Normal

Table 4.1 Results for the Losses and Percentage of Voltage drop before the STATCOM placement.

LOAD FLOW REPORT

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
ABA T.S	330.000	103.394	-10.3	0	0	0	0	ALAOJI T.S	-0.605	17.004	28.8	-3.6
								ALAOJI T.S	-0.605	17.004	28.8	-3.6
								ITU T.S	1.210	-34.008	57.6	-3.6
ADIABOR T.S	330.000	103.472	-10.3	0	0	0	0	ODUKPANI G.S	0.549	11.330	19.2	4.8
								ODUKPANI G.S	0.549	11.330	19.2	4.8
								ITU T.S	-1.098	-22.660	38.4	4.8
AES	330.000	50.000	0.0	0	0	0	0	EGBIN G.S	0.000	0.000	0.0	0.0
								EGBIN G.S	0.000	0.000	0.0	0.0
AFAM IV-V/VI	330.000	103.521	-10.3	0	0	0	0	ALAOJI T.S	-0.487	15.526	26.3	-3.1
								ALAOJI T.S	-0.487	15.526	26.3	-3.1
								PH MAIN T.S	0.000	-8.555	14.5	0.0
								PH MAIN T.S	0.000	-8.555	14.5	0.0
								IKOT EKPENE T.S	0.487	-6.971	11.8	-7.0
								IKOT EKPENE T.S	0.487	-6.971	11.8	-7.0
AHODA T.S	330.000	111.338	-10.9	0	0	0	0	OWERRI T.S	0.000	6.183	9.7	0.0
								OWERRI T.S	0.000	6.183	9.7	0.0
								GBARAIN G.S	0.000	-2.473	3.9	0.0
								GBARAIN G.S	0.000	-2.473	3.9	0.0
								YENEGOA T.S	0.000	-3.710	5.8	0.0
								YENEGOA T.S	0.000	-3.710	5.8	0.0
AJA T.S	330.000	50.027	0.0	0	0	0	0	EGBIN G.S	0.000	1.685	5.9	0.0
								EGBIN G.S	0.000	1.685	5.9	0.0
								ALAGBON T.S	0.000	-1.685	5.9	0.0
								LEKKI T.S	0.000	-1.686	5.9	0.0
AJAOKUTA T.S	330.000	60.724	-5.3	0	0	0	0	LOKOJA T.S	-3.557	127.334	367.0	-2.8
								LOKOJA T.S	-3.557	127.334	367.0	-2.8
								ASCO G.S	0.000	-0.460	1.3	0.0
								ASCO G.S	0.000	-0.460	1.3	0.0
								GEREGU G.S/NIPP	0.000	-0.460	1.3	0.0
								GEREGU G.S/NIPP	0.000	-0.460	1.3	0.0
								BENIN T.S	3.557	-126.414	364.4	-2.8
								BENIN T.S	3.557	-126.414	364.4	-2.8
AKANGBA T.S	330.000	51.601	-0.6	0	0	0	0	IKEJA WEST T.S	0.000	0.000	0.0	0.0
								IKEJA WEST T.S	0.000	0.000	0.0	0.0
ALADJA T.S	330.000	78.693	-7.5	0	0	0	0	DELTA G.S	0.000	0.000	0.0	0.0
ALAGBON T.S	330.000	50.048	0.0	0	0	0	0	AJA T.S	0.000	0.062	0.2	0.0

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
								LEKKI T.S	0.000	-0.062	0.2	0.0
ALAOJI G.S	330.000	103.313	-10.3	0	0	0	0	ALAOJI T.S	0.000	0.000	0.0	0.0
								ALAOJI T.S	0.000	0.000	0.0	0.0
ALAOJI T.S	330.000	103.313	-10.3	0	0	0	0	ONITSHA T.S	-6.335	292.554	495.5	-2.2
								ALAOJI G.S	0.000	-0.125	0.2	0.0
								ALAOJI G.S	0.000	-0.125	0.2	0.0
								OWERRI T.S	0.596	-98.847	167.4	-0.6
								OWERRI T.S	0.596	-98.847	167.4	-0.6
								AFAM IV-V/VI	0.493	-22.155	37.5	-2.2
								AFAM IV-V/VI	0.493	-22.155	37.5	-2.2
								IKOT EKPENE T.S	1.472	-5.496	9.6	-25.9
								IKOT EKPENE T.S	1.472	-5.496	9.6	-25.9
								ABA T.S	0.607	-19.653	33.3	-3.1
								ABA T.S	0.607	-19.653	33.3	-3.1
ASABA T.S	330.000	82.613	-8.0	0	0	0	0	BENIN T.S	-26.993	515.218	1092.6	-5.2
								ONITSHA T.S	26.993	-515.218	1092.6	-5.2
ASCO G.S	330.000	60.724	-5.3	0	0	0	0	AJAOKUTA T.S	0.000	0.000	0.0	0.0
								AJAOKUTA T.S	0.000	0.000	0.0	0.0
AYEDE T.S	330.000	59.491	-3.3	0	0	0	0	OSOGBO T.S	4.686	-11.816	37.4	-36.9
								OLORUNSOGO NIPP/I	-4.686	11.816	37.4	-36.9
B'KEBBI T.S	330.000	61.152	-4.0	0	0	0	0	KAINJI T.S	0.000	0.000	0.0	0.0
BENIN T.S	330.000	78.049	-7.4	0	0	0	0	IHOVOBOR NIPP	-8.215	96.296	216.6	-8.5
								EGBIN G.S	-19.618	207.730	467.7	-9.4
								OMOTOSHO I/NIPP	-15.055	144.980	326.7	-10.3
								AJAOKUTA T.S	1.009	136.215	305.3	0.7
								AJAOKUTA T.S	1.009	136.215	305.3	0.7
								DELTA G.S	0.010	-18.233	40.9	-0.1
								SAPELE G.S/NIPP	0.006	-12.319	27.6	0.0
								SAPELE G.S/NIPP	0.006	-12.319	27.6	0.0
								SAPELE G.S/NIPP	0.006	-12.319	27.6	0.0
								ASABA T.S	30.915	-488.947	1098.2	-6.3
								ONITSHA T.S	4.964	-88.650	199.0	-5.6
								ONITSHA T.S	4.964	-88.650	199.0	-5.6
DAMATURU T.S	330.000	131.741	-13.6	0	0	0	0	GOMBE T.S	-0.321	114.794	152.4	-0.3
								MAIDUGURI T.S	0.321	-114.794	152.4	-0.3
DELTA G.S	330.000	78.686	-7.5	0	0	0	0	BENIN T.S	0.001	1.928	4.3	0.0
								SAPELE G.S/NIPP	-0.001	-0.076	0.2	1.3
								ALADJA T.S	0.000	-1.853	4.1	0.0

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
* EGBIN G.S	330.000	50.000	0.0	71.574	-408.644	0	0	IKEJA WEST T.S	28.461	-148.181	528.0	-18.9
								OKEARO T.S	5.514	-30.556	108.6	-17.8
								OKEARO T.S	5.514	-30.556	108.6	-17.8
								AJA T.S	0.000	-2.558	8.9	0.0
								AJA T.S	0.000	-2.558	8.9	0.0
								IKORUDU T.S	0.562	-23.160	81.1	-2.4
								IKORUDU T.S	0.562	-23.160	81.1	-2.4
								BENIN T.S	30.961	-147.665	527.9	-20.5
								AES	0.000	-0.125	0.4	0.0
								AES	0.000	-0.125	0.4	0.0
EKET T.S	330.000	104.541	-10.4	0	0	0	0	ITU T.S	-0.090	-35.469	59.4	0.3
								IBOM G.S	0.045	17.734	29.7	0.3
								IBOM G.S	0.045	17.734	29.7	0.3
GANMO T.S	330.000	58.397	-3.6	0	0	0	0	JEBBA T.S	0.602	27.573	82.6	2.2
								OSOGBO T.S	-0.602	-27.573	82.6	2.2
GBARAIN G.S	330.000	111.342	-10.9	0	0	0	0	AHODA T.S	0.000	0.000	0.0	0.0
								AHODA T.S	0.000	0.000	0.0	0.0
GEREGU G.S/NIPP	330.000	60.724	-5.3	0	0	0	0	AJAOKUTA T.S	0.000	0.000	0.0	0.0
								AJAOKUTA T.S	0.000	0.000	0.0	0.0
GOMBE T.S	330.000	123.404	-13.1	0	0	0	0	JOS T.S	-1.827	263.028	372.9	-0.7
								YOLA T.S	0.219	-92.695	131.4	-0.2
								DAMATURU T.S	1.608	-170.332	241.5	-0.9
GWAGWALADA T.S	330.000	56.288	-4.5	0	0	0	0	KATAMPE T.S	-4.065	98.651	306.9	-4.1
								SHIRORO G.S	-5.634	144.779	450.3	-3.9
								LOKOJA T.S	4.849	-121.715	378.6	-4.0
								LOKOJA T.S	4.849	-121.715	378.6	-4.0
IBOM G.S	330.000	104.439	-10.4	0	0	0	0	EKET T.S	-0.042	-20.983	35.1	0.2
								EKET T.S	-0.042	-20.983	35.1	0.2
								IKOT EKPENE T.S	0.042	20.983	35.1	0.2
								IKOT EKPENE T.S	0.042	20.983	35.1	0.2
IHOVOBOR NIPP	330.000	77.141	-7.2	0	0	0	0	OSOGBO T.S	-8.373	97.542	222.0	-8.6
								BENIN T.S	8.373	-97.542	222.0	-8.6
IKEJA WEST T.S	330.000	51.591	-0.6	0	0	0	0	OSOGBO T.S	10.376	-49.092	170.2	-20.7
								OLORUNSOGO NIPP/I	5.244	-36.972	126.6	-14.0
								SAKETE T.S	0.000	-1.660	5.6	0.0
								AKANGBA T.S	0.000	-1.195	4.1	0.0
								AKANGBA T.S	0.000	-1.195	4.1	0.0
								OKEARO T.S	-5.382	27.533	95.1	-19.2

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
								OKEARO T.S	-5.382	27.533	95.1	-19.2
								EGBIN G.S	-27.781	152.410	525.4	-17.9
								OMOTOSHO I/NIPP	22.925	-117.363	405.5	-19.2
IKORUDU T.S	330.000	50.168	0.0	0	0	0	0	EGBIN G.S	-0.552	22.737	79.3	-2.4
								EGBIN G.S	-0.552	22.737	79.3	-2.4
								SAGAMU T.S	1.103	-45.475	158.6	-2.4
IKOT EKPENE T.S	330.000	103.317	-10.3	0	0	0	0	UGWUAJI T.S	1.250	40.758	69.1	3.1
								UGWUAJI T.S	1.250	40.758	69.1	3.1
								UGWUAJI T.S	1.250	40.758	69.1	3.1
								UGWUAJI T.S	1.250	40.758	69.1	3.1
								ODUKPANI G.S	-0.546	-17.707	30.0	3.1
								ODUKPANI G.S	-0.546	-17.707	30.0	3.1
								ALAOJI T.S	-1.471	-4.618	8.2	30.4
								ALAOJI T.S	-1.471	-4.618	8.2	30.4
								AFAM IV-V/VI	-0.486	-17.023	28.8	2.9
								AFAM IV-V/VI	-0.486	-17.023	28.8	2.9
								IBOM G.S	0.004	-42.168	71.4	0.0
								IBOM G.S	0.004	-42.168	71.4	0.0
ITU T.S	330.000	103.619	-10.3	0	0	0	0	ABA T.S	-1.200	29.803	50.4	-4.0
								ADIABOR T.S	1.102	18.411	31.1	6.0
								EKET T.S	0.098	-48.215	81.4	-0.2
JEBBA G.S	330.000	56.790	-3.4	0	0	0	0	JEBBA T.S	0.000	12.144	37.4	0.0
								JEBBA T.S	0.000	-12.144	37.4	0.0
JEBBA T.S	330.000	56.709	-3.4	0	0	0	0	JEBBA G.S	0.002	-12.769	39.4	0.0
								JEBBA G.S	0.000	-12.751	39.3	0.0
								KAINJI T.S	0.096	-19.630	60.6	-0.5
								KAINJI T.S	0.096	-19.630	60.6	-0.5
								SHIRORO G.S	0.638	81.000	249.9	0.8
								SHIRORO G.S	0.638	81.000	249.9	0.8
								GANMO T.S	-0.482	-32.475	100.2	1.5
								OSOGBO T.S	-0.495	-32.372	99.9	1.5
								OSOGBO T.S	-0.495	-32.372	99.9	1.5
JOS T.S	330.000	92.589	-10.3	0	0	0	0	KADUNA T.S	2.490	417.084	788.1	0.6
								GOMBE T.S	12.511	-263.097	497.7	-4.8
								MAKURDI T.S	-7.501	-76.993	146.2	9.7
								MAKURDI T.S	-7.501	-76.993	146.2	9.7
KADUNA T.S	330.000	50.000	-3.9	0	0	0	0	KANO T.S	0.031	-14.563	51.0	-0.2
								SHIRORO G.S	-12.564	127.989	450.0	-9.8

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
								SHIRORO G.S	-12.564	127.989	450.0	-9.8
								JOS T.S	25.096	-241.415	849.3	-10.3
KAINJI G.S	330.000	57.785	-3.6	0	0	0	0	KAINJI T.S	0.000	0.000	0.0	0.0
								KAINJI T.S	0.000	0.000	0.0	0.0
KAINJI T.S	330.000	57.784	-3.6	0	0	0	0	B'KEBBI T.S	0.108	-26.564	80.4	-0.4
								KAINJI G.S	0.000	-0.039	0.1	0.0
								KAINJI G.S	0.000	-0.039	0.1	0.0
								JEBBA T.S	-0.054	13.321	40.3	-0.4
								JEBBA T.S	-0.054	13.321	40.3	-0.4
KANO T.S	330.000	51.564	-4.2	0	0	0	0	KADUNA T.S	0.000	0.000	0.0	0.0
KATAMPE T.S	330.000	51.371	-3.6	0	0	0	0	SHIRORO G.S	-5.275	94.094	321.0	-5.6
								GWAGWALADA T.S	5.275	-94.094	321.0	-5.6
LEKKI T.S	330.000	50.043	0.0	0	0	0	0	AJA T.S	0.000	0.812	2.8	0.0
								ALAGBON T.S	0.000	-0.812	2.8	0.0
LOKOJA T.S	330.000	60.678	-5.3	0	0	0	0	GWAGWALADA T.S	-3.570	127.282	367.1	-2.8
								GWAGWALADA T.S	-3.570	127.282	367.1	-2.8
								AJAOKUTA T.S	3.570	-127.282	367.1	-2.8
								AJAOKUTA T.S	3.570	-127.282	367.1	-2.8
MAIDUGURI T.S	330.000	137.051	-13.9	0	0	0	0	DAMATURU T.S	0.000	0.000	0.0	0.0
MAKURDI T.S	330.000	99.320	-10.2	0	0	0	0	JOS T.S	7.962	14.873	29.7	47.2
								JOS T.S	7.962	14.873	29.7	47.2
								UGWUAJI T.S	-7.962	-14.873	29.7	47.2
								UGWUAJI T.S	-7.962	-14.873	29.7	47.2
N/HAVEN T.S	330.000	99.022	-10.0	0	0	0	0	UGWUAJI T.S	6.173	-160.298	283.4	-3.8
								UGWUAJI T.S	6.173	-160.298	283.4	-3.8
								ONITSHA T.S	-12.345	320.596	566.9	-3.8
ODUKPANI G.S	330.000	103.403	-10.3	0	0	0	0	IKOT EKPENE T.S	0.548	14.523	24.6	3.8
								IKOT EKPENE T.S	0.548	14.523	24.6	3.8
								ADIABOR T.S	-0.548	-14.523	24.6	3.8
								ADIABOR T.S	-0.548	-14.523	24.6	3.8
OKEARO T.S	330.000	50.797	-0.3	0	0	0	0	IKEJA WEST T.S	5.446	-29.157	102.2	-18.4
								IKEJA WEST T.S	5.446	-29.157	102.2	-18.4
								EGBIN G.S	-5.446	29.157	102.2	-18.4
								EGBIN G.S	-5.446	29.157	102.2	-18.4
OKPAI P.S	330.000	89.234	-8.7	0	0	0	0	ONITSHA T.S	0.000	0.000	0.0	0.0
								ONITSHA T.S	0.000	0.000	0.0	0.0
OLORUNSOGO NIPP/I	330.000	53.570	-1.2	0	0	0	0	AYEDE T.S	5.055	-33.882	111.9	-14.8
								IKEJA WEST T.S	-5.055	33.882	111.9	-14.8

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
OMOKU G.S	330.000	103.567	-10.3	0	0	0	0	PH MAIN T.S	0.000	0.000	0.0	0.0
OMOTOSHO I/NIPP	330.000	67.347	-5.2	0	0	0	0	IKEJA WEST T.S	-18.008	139.166	364.5	-12.8
								BENIN T.S	18.008	-139.166	364.5	-12.8
ONITSHA T.S	330.000	84.320	-8.3	0	0	0	0	BENIN T.S	-4.099	72.457	150.6	-5.6
								BENIN T.S	-4.099	72.457	150.6	-5.6
								ASABA T.S	-25.532	524.915	1090.4	-4.9
								N/HAVEN T.S	19.116	-291.049	605.2	-6.6
								ALAOJI T.S	14.153	-265.652	552.0	-5.3
								OKPAI P.S	0.231	-56.563	117.4	-0.4
								OKPAI P.S	0.231	-56.563	117.4	-0.4
OSOGBO T.S	330.000	60.039	-3.8	0	0	0	0	GANMO T.S	0.693	20.633	60.2	3.4
								JEBBA T.S	0.702	20.547	59.9	3.4
								JEBBA T.S	0.702	20.547	59.9	3.4
								IHOVOBOR NIPP	11.950	-101.136	296.8	-11.7
								IKEJA WEST T.S	-9.375	38.091	114.3	-23.9
								AYEDE T.S	-4.673	1.317	14.1	-96.2
OWERRI T.S	330.000	104.416	-10.4	0	0	0	0	ALAOJI T.S	-0.458	92.872	155.6	-0.5
								ALAOJI T.S	-0.458	92.872	155.6	-0.5
								AHODA T.S	0.458	-92.872	155.6	-0.5
								AHODA T.S	0.458	-92.872	155.6	-0.5
PARAS ENERGY G.S	330.000	63.821	-2.1	0	0	0	0	SAGAMU T.S	0.000	0.000	0.0	0.0
PH MAIN T.S	330.000	103.563	-10.3	0	0	0	0	AFAM IV-V/VI	0.000	4.814	8.1	0.0
								AFAM IV-V/VI	0.000	4.814	8.1	0.0
								TRANS-AMADI G.S	0.000	-3.745	6.3	0.0
								TRANS-AMADI G.S	0.000	-3.745	6.3	0.0
								OMOKU G.S	0.000	-2.140	3.6	0.0
RIVERS IPP	330.000	103.575	-10.3	0	0	0	0	TRANS-AMADI G.S	0.000	0.000	0.0	0.0
								TRANS-AMADI G.S	0.000	0.000	0.0	0.0
SAGAMU T.S	330.000	60.307	-1.6	0	0	0	0	IKORUDU T.S	-0.118	28.934	83.9	-0.4
								PARAS ENERGY G.S	0.118	-28.934	83.9	-0.4
SAKETE T.S	330.000	51.610	-0.6	0	0	0	0	IKEJA WEST T.S	0.000	0.000	0.0	0.0
SAPELE G.S/NIPP	330.000	78.300	-7.4	0	0	0	0	BENIN T.S	-0.002	4.726	10.6	0.0
								BENIN T.S	-0.002	4.726	10.6	0.0
								BENIN T.S	-0.002	4.726	10.6	0.0
								DELTA G.S	0.006	-14.178	31.7	0.0
* SHIRORO G.S	330.000	38.799	0.0	60.592	-520.937	0	0	JEBBA T.S	3.272	-66.606	300.7	-4.9
								JEBBA T.S	3.272	-66.606	300.7	-4.9
								KADUNA T.S	16.676	-102.492	468.2	-16.1

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
								KADUNA T.S	16.676	-102.492	468.2	-16.1
								KATAMPE T.S	8.618	-76.955	349.2	-11.1
								GWAGWALADA T.S	12.077	-105.785	480.1	-11.3
TRANS-AMADI G.S	330.000	103.572	-10.3	0	0	0	0	PH MAIN T.S	0.000	1.605	2.7	0.0
								PH MAIN T.S	0.000	1.605	2.7	0.0
								RIVERS IPP	0.000	-1.605	2.7	0.0
								RIVERS IPP	0.000	-1.605	2.7	0.0
UGWUAJI T.S	330.000	99.501	-10.0	0	0	0	0	MAKURDI T.S	7.967	-8.999	21.1	-66.3
								MAKURDI T.S	7.967	-8.999	21.1	-66.3
								N/HAVEN T.S	-6.067	159.477	280.6	-3.8
								N/HAVEN T.S	-6.067	159.477	280.6	-3.8
								IKOT EKPENE T.S	-0.950	-75.239	132.3	1.3
								IKOT EKPENE T.S	-0.950	-75.239	132.3	1.3
								IKOT EKPENE T.S	-0.950	-75.239	132.3	1.3
								IKOT EKPENE T.S	-0.950	-75.239	132.3	1.3
YENEGOA T.S	330.000	111.347	-10.9	0	0	0	0	AHODA T.S	0.000	0.000	0.0	0.0
								AHODA T.S	0.000	0.000	0.0	0.0
YOLA T.S	330.000	127.617	-13.3	0	0	0	0	GOMBE T.S	0.000	0.000	0.0	0.0

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

\# Indicates a bus with a load mismatch of more than 0.1 MVA

Project: STATCOM on 330kV National Grid	ETAP	Page: 1
Location: Nigeria Nation Grid - NCC	12.6.0H	Date: 14-05-2018
Contract: COOU- M.Eng Project		SN: 2015112012
Engineer: Uzowulu Ifeanyi Nnanedu	Study Case: OPF	Revision: Base
Filename: STATCOM-330kV		Config.: Normal

Table 4.2 Results for the Load Flow, Ampacity & the Voltage with STATCOM placement.

LOAD FLOW REPORT

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
ABA T.S	330.000	107.803	-3.5	0	0	39.490	13.454	ALAOJI T.S	-123.095	-17.873	201.9	99.0
								ALAOJI T.S	-123.095	-17.873	201.9	99.0
								ITU T.S	206.700	11.272	336.0	99.9
ADIABOR T.S	330.000	107.153	-4.8	0	0	17.504	6.009	ODUKPANI G.S	64.018	12.790	106.6	98.1
								ODUKPANI G.S	64.018	12.790	106.6	98.1
								ITU T.S	-145.540	-36.428	245.0	97.0
AES	330.000	111.967	0.0	0	0	0	0	EGBIN G.S	0.000	0.000	0.0	0.0
								EGBIN G.S	0.000	0.000	0.0	0.0
* AFAM IV-V/VI	330.000	109.124	0.0	1708.994	141.894	0	0	ALAOJI T.S	585.610	44.938	941.6	99.7
								ALAOJI T.S	585.610	44.938	941.6	99.7
								PH MAIN T.S	12.833	4.255	21.7	94.9
								PH MAIN T.S	12.833	4.255	21.7	94.9
								IKOT EKPENE T.S	256.054	21.753	412.0	99.6
								IKOT EKPENE T.S	256.054	21.753	412.0	99.6
AHODA T.S	330.000	111.849	-6.4	0	0	40.170	13.033	OWERRI T.S	-33.474	-14.516	57.1	91.7
								OWERRI T.S	-33.474	-14.516	57.1	91.7
								GBARAIN G.S	0.000	-2.496	3.9	0.0
								GBARAIN G.S	0.000	-2.496	3.9	0.0
								YENEGOA T.S	13.389	4.565	22.1	94.7
								YENEGOA T.S	13.389	4.565	22.1	94.7
AJA T.S	330.000	111.754	-0.2	0	0	0	0	EGBIN G.S	-62.422	-30.635	108.9	89.8
								EGBIN G.S	-62.422	-30.635	108.9	89.8
								ALAGBON T.S	50.861	23.415	87.7	90.8
								LEKKI T.S	73.983	37.855	130.1	89.0
AJAOKUTA T.S	330.000	101.308	-10.6	0	0	76.903	28.197	LOKOJA T.S	-64.054	31.648	123.4	-89.7
								LOKOJA T.S	-64.054	31.648	123.4	-89.7
								ASCO G.S	0.000	-1.280	2.2	0.0
								ASCO G.S	0.000	-1.280	2.2	0.0
								GEREGU G.S/NIPP	0.000	-1.280	2.2	0.0
								GEREGU G.S/NIPP	0.000	-1.280	2.2	0.0
								BENIN T.S	25.603	-52.919	101.5	-43.6
								BENIN T.S	25.603	-52.919	101.5	-43.6
AKANGBA T.S	330.000	108.227	-2.8	0	0	395.605	134.110	IKEJA WEST T.S	-197.802	-122.587	376.2	85.0
								IKEJA WEST T.S	-197.802	-122.587	376.2	85.0
ALADJA T.S	330.000	103.488	-12.7	0	0	38.793	13.887	DELTA G.S	-38.793	-24.042	77.2	85.0
ALAGBON T.S	330.000	111.387	-0.4	0	0	71.274	23.257	AJA T.S	-50.818	-31.166	93.6	85.2

Project: STATCOM on 330kV National Grid	ETAP	Page: 1
Location: Nigeria Nation Grid - NCC	12.6.0H	Date: 14-05-2018
Contract: COOU- M.Eng Project		SN: 2015112012
Engineer: Uzowulu Ifeanyi Nnanedu	Study Case: OPF	Revision: Base
Filename: STATCOM-330kV		Config.: Normal

Table 4.2 Results for the Load Flow, Ampacity & the Voltage with STATCOM placement.

LOAD FLOW REPORT

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
ABA T.S	330.000	107.803	-3.5	0	0	39.490	13.454	ALAOJI T.S	-123.095	-17.873	201.9	99.0
								ALAOJI T.S	-123.095	-17.873	201.9	99.0
								ITU T.S	206.700	11.272	336.0	99.9
ADIABOR T.S	330.000	107.153	-4.8	0	0	17.504	6.009	ODUKPANI G.S	64.018	12.790	106.6	98.1
								ODUKPANI G.S	64.018	12.790	106.6	98.1
								ITU T.S	-145.540	-36.428	245.0	97.0
AES	330.000	111.967	0.0	0	0	0	0	EGBIN G.S	0.000	0.000	0.0	0.0
								EGBIN G.S	0.000	0.000	0.0	0.0
* AFAM IV-V/VI	330.000	109.124	0.0	1708.994	141.894	0	0	ALAOJI T.S	585.610	44.938	941.6	99.7
								ALAOJI T.S	585.610	44.938	941.6	99.7
								PH MAIN T.S	12.833	4.255	21.7	94.9
								PH MAIN T.S	12.833	4.255	21.7	94.9
								IKOT EKPENE T.S	256.054	21.753	412.0	99.6
								IKOT EKPENE T.S	256.054	21.753	412.0	99.6
AHODA T.S	330.000	111.849	-6.4	0	0	40.170	13.033	OWERRI T.S	-33.474	-14.516	57.1	91.7
								OWERRI T.S	-33.474	-14.516	57.1	91.7
								GBARAIN G.S	0.000	-2.496	3.9	0.0
								GBARAIN G.S	0.000	-2.496	3.9	0.0
								YENEGOA T.S	13.389	4.565	22.1	94.7
								YENEGOA T.S	13.389	4.565	22.1	94.7
AJA T.S	330.000	111.754	-0.2	0	0	0	0	EGBIN G.S	-62.422	-30.635	108.9	89.8
								EGBIN G.S	-62.422	-30.635	108.9	89.8
								ALAGBON T.S	50.861	23.415	87.7	90.8
								LEKKI T.S	73.983	37.855	130.1	89.0
AJAOKUTA T.S	330.000	101.308	-10.6	0	0	76.903	28.197	LOKOJA T.S	-64.054	31.648	123.4	-89.7
								LOKOJA T.S	-64.054	31.648	123.4	-89.7
								ASCO G.S	0.000	-1.280	2.2	0.0
								ASCO G.S	0.000	-1.280	2.2	0.0
								GEREGU G.S/NIPP	0.000	-1.280	2.2	0.0
								GEREGU G.S/NIPP	0.000	-1.280	2.2	0.0
								BENIN T.S	25.603	-52.919	101.5	-43.6
								BENIN T.S	25.603	-52.919	101.5	-43.6
AKANGBA T.S	330.000	108.227	-2.8	0	0	395.605	134.110	IKEJA WEST T.S	-197.802	-122.587	376.2	85.0
								IKEJA WEST T.S	-197.802	-122.587	376.2	85.0
ALADJA T.S	330.000	103.488	-12.7	0	0	38.793	13.887	DELTA G.S	-38.793	-24.042	77.2	85.0
ALAGBON T.S	330.000	111.387	-0.4	0	0	71.274	23.257	AJA T.S	-50.818	-31.166	93.6	85.2

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
*EGBIN G.S	330.000	111.967	0.0	1700.266	537.286	0	0	IKEJA WEST T.S	850.585	425.873	1486.4	89.4
								OKEARO T.S	164.714	73.154	281.6	91.4
								OKEARO T.S	164.714	73.154	281.6	91.4
								AJA T.S	62.455	26.509	106.0	92.1
								AJA T.S	62.455	26.509	106.0	92.1
								IKORUDU T.S	71.067	-69.081	154.9	-71.7
								IKORUDU T.S	71.067	-69.081	154.9	-71.7
								BENIN T.S	253.210	51.500	403.8	98.0
								AES	0.000	-0.625	1.0	0.0
								AES	0.000	-0.625	1.0	0.0
EKET T.S	330.000	107.161	-5.8	0	0	78.770	27.040	ITU T.S	-21.075	-43.996	79.6	43.2
								IBOM G.S	-28.847	-2.411	47.3	99.7
								IBOM G.S	-28.847	-2.411	47.3	99.7
GANMO T.S	330.000	109.832	-3.0	0	0	79.656	26.490	JEBBA T.S	-112.053	-7.193	178.9	99.8
								OSOGBO T.S	32.397	-42.174	84.7	-60.9
GBARAIN G.S	330.000	111.853	-6.4	0	0	0	0	AHODA T.S	0.000	0.000	0.0	0.0
								AHODA T.S	0.000	0.000	0.0	0.0
GEREGU G.S/NIPP	330.000	101.309	-10.6	0	0	0	0	AJAOKUTA T.S	0.000	0.000	0.0	0.0
								AJAOKUTA T.S	0.000	0.000	0.0	0.0
GOMBE T.S	330.000	137.512	-25.1	0	0	45.066	9.999	JOS T.S	-154.275	226.813	349.0	-56.2
								YOLA T.S	45.681	-84.830	122.6	-47.4
								DAMATURU T.S	63.529	-169.913	230.8	-35.0
GWAGWALADA T.S	330.000	101.128	-9.5	0	0	209.195	76.852	KATAMPE T.S	-107.520	-8.899	186.7	99.7
								SHIRORO G.S	-281.520	-69.447	501.6	97.1
								LOKOJA T.S	89.923	-25.651	161.8	-96.2
								LOKOJA T.S	89.923	-25.651	161.8	-96.2
IBOM G.S	330.000	107.185	-5.7	0	0	0	0	EKET T.S	28.853	-0.986	47.1	-99.9
								EKET T.S	28.853	-0.986	47.1	-99.9
								IKOT EKPENE T.S	-28.853	0.986	47.1	-99.9
								IKOT EKPENE T.S	-28.853	0.986	47.1	-99.9
IHOVOBOR NIPP	330.000	104.115	-11.5	0	0	0	0	OSOGBO T.S	-140.356	-65.275	260.1	90.7
								BENIN T.S	140.356	65.275	260.1	90.7
IKEJA WEST T.S	330.000	109.359	-2.0	0	0	662.481	221.570	OSOGBO T.S	30.286	-52.650	97.2	-49.9
								OLORUNSOGO NIPP/I	-156.580	-84.486	284.6	88.0
								SAKETE T.S	79.409	42.542	144.1	88.1
								AKANGBA T.S	198.317	121.056	371.7	85.4
								AKANGBA T.S	198.317	121.056	371.7	85.4
								OKEARO T.S	-163.663	-84.369	294.6	88.9

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
								OKEARO T.S	-163.663	-84.369	294.6	88.9
								EGBIN G.S	-845.159	-389.638	1488.9	90.8
								OMOTOSHO I/NIPP	160.257	0.289	256.4	100.0
IKORUDU T.S	330.000	112.159	-0.1	0	0	80.447	26.000	EGBIN G.S	-71.028	66.859	152.2	-72.8
								EGBIN G.S	-71.028	66.859	152.2	-72.8
								SAGAMU T.S	61.610	-183.574	302.1	-31.8
IKOT EKPENE T.S	330.000	106.898	-5.1	0	0	262.278	90.310	UGWUAJI T.S	188.545	11.111	309.1	99.8
								UGWUAJI T.S	188.545	11.111	309.1	99.8
								UGWUAJI T.S	188.545	11.111	309.1	99.8
								UGWUAJI T.S	188.545	11.111	309.1	99.8
								ODUKPANI G.S	-63.961	-19.227	109.3	95.8
								ODUKPANI G.S	-63.961	-19.227	109.3	95.8
								ALAOJI T.S	-220.266	-36.017	365.3	98.7
								ALAOJI T.S	-220.266	-36.017	365.3	98.7
								AFAM IV-V/VI	-252.897	-24.724	415.9	99.5
								AFAM IV-V/VI	-252.897	-24.724	415.9	99.5
								IBOM G.S	28.896	-23.528	61.0	-77.5
								IBOM G.S	28.896	-23.528	61.0	-77.5
ITU T.S	330.000	107.527	-4.3	0	0	39.445	13.483	ABA T.S	-206.330	-13.180	336.4	99.8
								ADIABOR T.S	145.735	33.263	243.2	97.5
								EKET T.S	21.150	-44.529	80.2	-42.9
* JEBBA G.S	330.000	111.078	0.0	807.531	113.028	0	0	JEBBA T.S	787.216	156.644	1264.2	98.1
								JEBBA T.S	20.315	-43.616	75.8	-42.2
JEBBA T.S	330.000	110.230	-1.3	0	0	265.968	88.023	JEBBA G.S	-784.603	-139.866	1264.9	98.4
								JEBBA G.S	-20.248	-50.543	86.4	37.2
								KAINJI T.S	166.270	74.024	288.9	91.4
								KAINJI T.S	166.270	74.024	288.9	91.4
								SHIRORO G.S	-21.741	-16.533	43.4	79.6
								SHIRORO G.S	-21.741	-16.533	43.4	79.6
								GANMO T.S	112.509	-10.587	179.4	-99.6
								OSOGBO T.S	68.657	-39.408	125.6	-86.7
								OSOGBO T.S	68.657	-39.408	125.6	-86.7
JOS T.S	330.000	115.021	-16.5	0	0	122.162	38.076	KADUNA T.S	-207.354	136.610	377.7	-83.5
								GOMBE T.S	163.695	-263.733	472.1	-52.7
								MAKURDI T.S	-39.252	25.707	71.4	-83.7
								MAKURDI T.S	-39.252	25.707	71.4	-83.7
KADUNA T.S	330.000	105.494	-6.6	0	0	260.758	91.252	KANO T.S	128.946	39.805	223.8	95.6
								SHIRORO G.S	-301.862	-26.995	502.6	99.6

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
								OKEARO T.S	-163.663	-84.369	294.6	88.9
								EGBIN G.S	-845.159	-389.638	1488.9	90.8
								OMOTOSHO I/NIPP	160.257	0.289	256.4	100.0
IKORUDU T.S	330.000	112.159	-0.1	0	0	80.447	26.000	EGBIN G.S	-71.028	66.859	152.2	-72.8
								EGBIN G.S	-71.028	66.859	152.2	-72.8
								SAGAMU T.S	61.610	-183.574	302.1	-31.8
IKOT EKPENE T.S	330.000	106.898	-5.1	0	0	262.278	90.310	UGWUAJI T.S	188.545	11.111	309.1	99.8
								UGWUAJI T.S	188.545	11.111	309.1	99.8
								UGWUAJI T.S	188.545	11.111	309.1	99.8
								UGWUAJI T.S	188.545	11.111	309.1	99.8
								ODUKPANI G.S	-63.961	-19.227	109.3	95.8
								ODUKPANI G.S	-63.961	-19.227	109.3	95.8
								ALAOJI T.S	-220.266	-36.017	365.3	98.7
								ALAOJI T.S	-220.266	-36.017	365.3	98.7
								AFAM IV-V/VI	-252.897	-24.724	415.9	99.5
								AFAM IV-V/VI	-252.897	-24.724	415.9	99.5
								IBOM G.S	28.896	-23.528	61.0	-77.5
								IBOM G.S	28.896	-23.528	61.0	-77.5
ITU T.S	330.000	107.527	-4.3	0	0	39.445	13.483	ABA T.S	-206.330	-13.180	336.4	99.8
								ADIABOR T.S	145.735	33.263	243.2	97.5
								EKET T.S	21.150	-44.529	80.2	-42.9
* JEBBA G.S	330.000	111.078	0.0	807.531	113.028	0	0	JEBBA T.S	787.216	156.644	1264.2	98.1
								JEBBA T.S	20.315	-43.616	75.8	-42.2
JEBBA T.S	330.000	110.230	-1.3	0	0	265.968	88.023	JEBBA G.S	-784.603	-139.866	1264.9	98.4
								JEBBA G.S	-20.248	-50.543	86.4	37.2
								KAINJI T.S	166.270	74.024	288.9	91.4
								KAINJI T.S	166.270	74.024	288.9	91.4
								SHIRORO G.S	-21.741	-16.533	43.4	79.6
								SHIRORO G.S	-21.741	-16.533	43.4	79.6
								GANMO T.S	112.509	-10.587	179.4	-99.6
								OSOGBO T.S	68.657	-39.408	125.6	-86.7
								OSOGBO T.S	68.657	-39.408	125.6	-86.7
JOS T.S	330.000	115.021	-16.5	0	0	122.162	38.076	KADUNA T.S	-207.354	136.610	377.7	-83.5
								GOMBE T.S	163.695	-263.733	472.1	-52.7
								MAKURDI T.S	-39.252	25.707	71.4	-83.7
								MAKURDI T.S	-39.252	25.707	71.4	-83.7
KADUNA T.S	330.000	105.494	-6.6	0	0	260.758	91.252	KANO T.S	128.946	39.805	223.8	95.6
								SHIRORO G.S	-301.862	-26.995	502.6	99.6

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
OMOKU G.S	330.000	109.081	0.0	0	0	0	0	PH MAIN T.S	0.000	0.000	0.0	0.0
OMOTOSHO I/NIPP	330.000	106.791	-7.7	0	0	0	0	IKEJA WEST T.S	-158.060	-30.739	263.8	98.2
								BENIN T.S	158.060	30.739	263.8	98.2
ONITSHA T.S	330.000	104.251	-11.9	0	0	194.572	69.057	BENIN T.S	6.285	-7.099	15.9	-66.3
								BENIN T.S	6.285	-7.099	15.9	-66.3
								ASABA T.S	67.456	86.028	183.5	61.7
								N/HAVEN T.S	-7.621	3.261	13.9	-91.9
								ALAOJI T.S	-267.681	-22.747	450.8	99.6
								OKPAI P.S	0.353	-86.464	145.1	-0.4
								OKPAI P.S	0.353	-86.464	145.1	-0.4
OSOGBO T.S	330.000	110.739	-3.7	0	0	0	0	GANMO T.S	-32.312	16.414	57.3	-89.2
								JEBBA T.S	-68.256	-5.437	108.2	99.7
								JEBBA T.S	-68.256	-5.437	108.2	99.7
								IHOVOBOR NIPP	143.351	14.995	227.7	99.5
								IKEJA WEST T.S	-30.135	-17.215	54.8	86.8
								AYEDE T.S	55.608	-3.322	88.0	-99.8
OWERRI T.S	330.000	108.225	-3.9	0	0	131.867	44.704	ALAOJI T.S	-99.759	35.667	171.3	-94.2
								ALAOJI T.S	-99.759	35.667	171.3	-94.2
								AHODA T.S	33.825	-76.529	135.3	-40.4
								AHODA T.S	33.825	-76.529	135.3	-40.4
PARAS ENERGY G.S	330.000	136.146	-5.1	0	0	0	0	SAGAMU T.S	0.000	0.000	0.0	0.0
PH MAIN T.S	330.000	109.077	0.0	0	0	70.581	23.686	AFAM IV-V/VI	-12.831	-8.400	24.6	83.7
								AFAM IV-V/VI	-12.831	-8.400	24.6	83.7
								TRANS-AMADI G.S	-22.459	-12.285	41.1	87.7
								TRANS-AMADI G.S	-22.459	-12.285	41.1	87.7
								OMOKU G.S	0.000	-2.374	3.8	0.0
RIVERS IPP	330.000	109.127	0.0	0	0	0	0	TRANS-AMADI G.S	0.000	0.000	0.0	0.0
								TRANS-AMADI G.S	0.000	0.000	0.0	0.0
SAGAMU T.S	330.000	128.648	-4.7	0	0	57.681	14.823	IKORUDU T.S	-58.218	95.920	152.6	-51.9
								PARAS ENERGY G.S	0.537	-131.668	179.1	-0.4
SAKETE T.S	330.000	108.761	-2.5	0	0	79.298	26.712	IKEJA WEST T.S	-79.298	-49.145	150.1	85.0
SAPELE G.S/NIPP	330.000	103.730	-12.2	0	0	0	0	BENIN T.S	-6.401	4.238	12.9	-83.4
								BENIN T.S	-6.401	4.238	12.9	-83.4
								BENIN T.S	-6.401	4.238	12.9	-83.4
								DELTA G.S	19.204	-12.713	38.8	-83.4
* SHIRORO G.S	330.000	108.480	0.0	1187.333	118.024	0	0	JEBBA T.S	21.853	-55.412	96.1	-36.7
								JEBBA T.S	21.853	-55.412	96.1	-36.7
								KADUNA T.S	306.736	35.717	498.0	99.3

Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF
								KADUNA T.S	306.736	35.717	498.0	99.3
								KATAMPE T.S	241.428	74.449	407.5	95.6
								GWAGWALADA T.S	288.728	82.964	484.5	96.1
* TRANS-AMADI G.S	330.000	109.124	0.0	44.924	16.295	0	0	PH MAIN T.S	22.462	9.929	39.4	91.5
								PH MAIN T.S	22.462	9.929	39.4	91.5
								RIVERS IPP	0.000	-1.782	2.9	0.0
								RIVERS IPP	0.000	-1.782	2.9	0.0
UGWUAJI T.S	330.000	104.003	-11.4	0	0	172.777	61.493	MAKURDI T.S	80.433	-103.580	220.6	-61.3
								MAKURDI T.S	80.433	-103.580	220.6	-61.3
								N/HAVEN T.S	204.550	109.528	390.3	88.2
								N/HAVEN T.S	204.550	109.528	390.3	88.2
								IKOT EKPENE T.S	-185.686	-29.744	316.3	98.7
								IKOT EKPENE T.S	-185.686	-29.744	316.3	98.7
								IKOT EKPENE T.S	-185.686	-29.744	316.3	98.7
								IKOT EKPENE T.S	-185.686	-29.744	316.3	98.7
YENEGOA T.S	330.000	111.808	-6.5	0	0	26.776	8.692	AHODA T.S	-13.388	-8.297	24.6	85.0
								AHODA T.S	-13.388	-8.297	24.6	85.0
YOLA T.S	330.000	139.337	-26.7	0	0	45.452	9.760	GOMBE T.S	-45.452	-28.169	67.1	85.0

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

\# Indicates a bus with a load mismatch of more than 0.1 MVA

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