DETERMINATION OF BUS VOLTAGES, POWER LOSSES AND FLOWS IN THE NIGERIA 330KV INTEGRATED POWER SYSTEM

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ABSTRACT

This paper involves power flow analysis of the Nigeria 330KV integrated power system. The test system involves the integrated network consisting of 52 buses, 17 generating stations, 64 transmission lines and 4 control centers. Newton-Raphson (N-R) power flow algorithm was carried out on this network using the relevant data as obtained from power holding company of Nigeria [PHCN], in ETAP 4.0 Transient Analyzer Environment, to determine bus voltages, real and reactive power flows and losses of the transmission lines and generators. The results obtained showed that the bus voltages outside the statutory limit of (0.95pu, 313.5KV) to (1.05pu, 346.5KV) include: (Makurdi, 0.931pu), (Damaturu, 0.934pu), Gombe, 0.941pu), (Maiduguri, 0.943pu), (Yola, 0.921pu), (Jos, 0.937pu) and (Jalingo, 0.929pu). The total losses emanating from both generators and transmission lines are 2.331MW+j32.644MVar and 90.3MW+j53.300Mvar respectively, and 39% of the reactive power losses are from the generating stations but the real power losses are about 2.58%. The result concludes that Nigeria still have a very long way to go in order to have a sustainable, efficient and reliable power system which, both the integrated power projects (IPP) and the Nigeria integrated power projects (NIPP) cannot effectively guarantee. It is recommended that, the generators require reactive compensation while the transmission lines require both real and reactive power compensation using Flexible Alternating Current Transmission Systems (FACTS) devices for effective utilization.

KEYWORDS: *ETAP 4.0, PHCN, N-R, IPP, NIPP, NIGERIA*

I. INTRODUCTION

Before the unbundling of the Nigeria existing power network, it comprises 11,000KM transmission lines (330KV) [1]. it is faced with so many problems such as; Inability to effectively dispatch generated energy to meet the load demand, large number of uncompleted transmission line projects, reinforcement and expansion projects in the power industry,Poor Voltage profile in most northern parts of the grid, Inability of the existing transmission lines to wheel more than 4000MW of power at present operational problems, voltage and frequency controls[2, 3, 12].Some of the transmission lines are also Fragile and radial nature, which is prone to frequent system collapse. Poor network configuration in some regional work centres, controlling the transmission line parameters, large numbers of overloaded transformers in the grid system, frequent vandalism of 330KV transmission lines in various parts of the country and using the transmission lines beyond their limit [3,4]. Also before the unbundling, the Nigeria existing 330KV network consist of nine generating stations, twenty eight buses and thirty two transmission lines [1].Most researchers that worked on the existing network [1,2, 3, 4, 9, 11] recommended that the network be transformed from radial to ring, because of the high losses inherent in it and the violation of allowable voltage drop of + or – 5% of nominal value.

Power Holding Company of Nigeria (PHCN) in an attempt to solve these problems resulted in its unbundling. Thus, the Nigeria 330KV integrated network intends to improve the grid stability and creates an effective interconnection. It is anticipated to increase transmission strength because of the very high demand on the existing and aging infrastructure by building more power stations and transmission lines, through the Independent Power Projects(IPP)[1].Considering the fact that most of the existing Nigeria generating stations are located far from the load centers with partial longitudinal network, there is possibility of experiencing low bus voltages, lines overload, frequency fluctuations and poor system damping in the network, thus making the stability of the network to be weak when subjected to fault conditions. In other to ascertain the impact of the integrated power projects on the existing network, a power or load flow program needs to be carried out.

Power flow analysis is one of the most important aspects of power system planning and operation. The load flow provides us the sinusoidal steady state of the entire system- voltages, real, reactive powers and line losses. It provides solution of the network under steady state condition subjected to certain inequality constraints such as nodal voltages, reactive power generation of the generators and gives the voltage magnitudes and angles at each bus in the steady state. This is rather important as the magnitudes of the bus voltages are required to be held within a specified limit. The following parameters can be determined in power flow study: Power flows in all branches in a network, power contributed by each generator, power losses in each component in the network and nodal voltages magnitudes and angles throughout the network[10].Section 2.0 is an overview of the current status of the Nigeria 330KV integrated power network. Data used and the methodology adopted for this work including the modeling and simulation in ETAP 4.0 environment as well as the flow chart are shown are section 3.0.Load flow result showing power losses from both generators and transmission lines and bus voltages are shown in section 4.0.discussion of results obtained and the conclusion of the work are shown in section 5.0 and 6.0 respectively.

II. OVERVIEW OF NIGERIA INTEGRATED POWER SYSTEM AND ITS CURRENT STATUS

The increasing demand for electricity in Nigeria is far more than what is available, thus resulting in the interconnected transmission systems being heavily loaded and stressed beyond their allowable tolerable limit. This constraint affects the quality of power delivered.

Currently, with some of the completed integrated power projects, the Nigerian national grid is an interconnection of 9,454.8KM length of 330KV and 8,985.28km length of 132KV transmission lines with seventeen power stations with the completion of some of the integrated power projects. The grid interconnects these stations with fifty two buses and sixty four transmission lines of either dual or single circuit lines and has four control centers (one national control center at Oshogbo and three supplementary control centers at Benin, Shiroro and Egbin) [1].

The current projection of power generation by PHCN is to generate 26,561MW as envisioned in the vision 20:2020 target [14]. Presently, of the seventeen (17) active power generating stations, eight of these are owned by the Federal Government (existing) with installed capacity of 6,256MW and 2,484MW is available. The remaining nine (9) are from both the National Independent Power Project (NIPP) and the Independent Power Project (IPP) with total designed capacity of 2,809MW, of which 1,336.5MW is available. These generating stations are sometimes connected to load centers through very long, fragile and radial transmission lines. On completion of all the power projects in Nigeria, its total installed capacity will become 12,054MW.Table 1.0 shows the completed power generating and existing stations currently in use with their available and installed capacities [8, 14]. Table 2.0 shows the generating stations with their supposed installed capacities that are still under construction, while Table3.0 and 4.0 shows all the buses in both existing and the integrated network and the features of the integrated 330KV power network respectively. The transmission line parameter used for this study is shown in appendix A.

Table 1.0 Generating stations that are currently in operation in Nigeria

S/N	STATION	STATE	TURBINE	INSTALLED CAPACITY(MW)	AVAILABLE CAPACITY(MW)
1	Kainji	Niger	Hydro	760	259

2	Jebba	Niger	Hydro	504	352
3	Shiroro	Niger	Hydro	600	402
4	Egbin	Lagos	Steam	1320	900
5*	Trans-Amadi	Rivers	Gas	100	57.3
6*	A.E.S (Egbin)	Lagos	Gas	250	211.8
7	Sapele	Delta	Gas	1020	170
8*	Ibom	Akwa-Ibom	Gas	155	25.3
9*	Okpai (Agip)	Delta	Gas	900	221
10	Afam I-V	Rivers	Gas	726	60
11*	Afam VI (Shell)	Rivers	Gas	650	520
12	Delta	Delta	Gas	912	281
13	Geregu	Kogi	Gas	414	120
14*	Omoku	Rivers	Gas	150	53
15*	Omotosho	Ondo	Gas	304	88.3
16*	Olorunshogo phase I	Ogun	Gas	100	54.3
17*	Olorunshogo phase II	Ogun	Gas	200	105.5
Total Power				**9,065**	**3,855.5**

Note: Generating stations marked* are the completed and functional independent power generation already in the Grid

Table 2.0 Ongoing national independent power projects on power generation

S/N	STATION	STATE	TURBINE	INSTALLED CAPACITY(MW)	AVAILABLE CAPACITY(MW)
1	Calabar	Cross River	Gas	563	Nil
2	Ihorvbor	Edo	Gas	451	Nil
3	Sapele	Delta	Gas	451	Nil
4	Gbaran	Bayelsa	Gas	225	Nil
5	Alaoji	Abia	Hydro	961	Nil
6	Egbema	Imo	Gas	338	Nil
7	Omoku	Rivers	Gas	252	Nil
Total Power				**2,989**	**Nil**

Table 3.0 Buses for both existing and integrated 330kv power project

S/NO	BUSES	S/NO	BUSES	S/NO	BUSES
1	Shiroro	21	New haven south	41	Yola
2	Afam	22	Makurdi	42	Gwagwalada
3	Ikot-Ekpene	23	B-kebbi	43	Sakete
4	Port-Harcourt	24	Kainji	44	Ikot-Abasi
5	Aiyede	25	Oshogbo	45	Jalingo
6	Ikeja west	26	Onitsha	46	Kaduna
7	Papalanto	27	Benin north	47	Jebba GS
8	Aja	28	Omotosho	48	Kano
9	Egbin PS	29	Eyaen	49	Katampe
10	Ajaokuta	30	Calabar	50	Okpai
11	Benin	31	Alagbon	51	Jebba
12	Geregu	32	Damaturu	52	AES
13	Lokoja	33	Gombe		
14	Akangba	34	Maiduguri		
15	Sapele	35	Egbema		
16	Aladja	36	Omoku		
17	Delta PS	37	Owerri		
18	Alaoji	38	Erunkan		
19	Aliade	39	Ganmo		
20	New haven	40	Jos		

Table 4.0 Basic description of Nigeria 330kv integrated 330kv transmission line

Capacity of 330/132KV (MVA)	10,894
Number of 330KV substation	28
Total number of 330KV circuits	62
Length of 330KV lines(KM)	9,454.8
Number of control centers	4
Number of transmission lines	64
Number of buses	52
Number of generating stations	17

III. METHODOLOGY ADOPTED FOR THE WORK

Newton-Raphson (N-R) power flow algorithm was used for this study. This was modeled in ETAP 4.0 Transient Analyzer Environment.

3.1 Data Collection:

The data used in this analysis and assessment were collected from Power Holding Company of Nigeria (PHCN).These was modeled and simulated in ETAP 4.0 Transient Analyzer environment using N-R power flow algorithm. The network for this study consist of Seventeen (17) generating stations, Fifty two (52) buses and Sixty four (64) transmission lines using N-R and modeled with ETAP 4.0 was carried out in other to determine the following: active and reactive power flows in all branches in a network, active and reactive power contributed by each generator, active and reactive power losses in each component in the network, bus voltages magnitudes and angles throughout the network.

3.2 Design and Simulation of Nigeria 330KV Existing Network using N-R Method

The Newton Raphson method formulates and solves iteratively the following load flow equation[5,8]:

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix}\begin{bmatrix}J_1 J_2\\ J_3 J_4\end{bmatrix}=\begin{bmatrix}\Delta\delta\\ \Delta V\end{bmatrix}$$

Where ΔP and ΔQ are bus real power and reactive power mismatch vectors between specified value and calculated value, respectively; ΔV and $\Delta\delta$ represents bus voltage angle and magnitude vectors in an incremental form; and J1 through J4 are called jacobian matrices. The Newton Raphson method possesses a unique quadratic convergence characteristic. It usually has a very fast convergence speed compared to other load flow calculation methods. It also has the advantage that the convergence criteria are specified to ensure convergence for bus real power and reactive power mismatches. This criterion gives the direct control of the accuracy method of Newton-Raphson. The convergence criteria for the Newton-Raphson method are typically set to 0.001MW and MVar. The Newton-Raphson method is highly dependent on the voltage initial values.

Flow Chart for Newton-Raphson Algorithm used for the Modified Nigeria 330KV Network

The following steps were used in computing the N-R algorithm in ETAP 4.0 and the flow chart is shown in Figure 1.0.

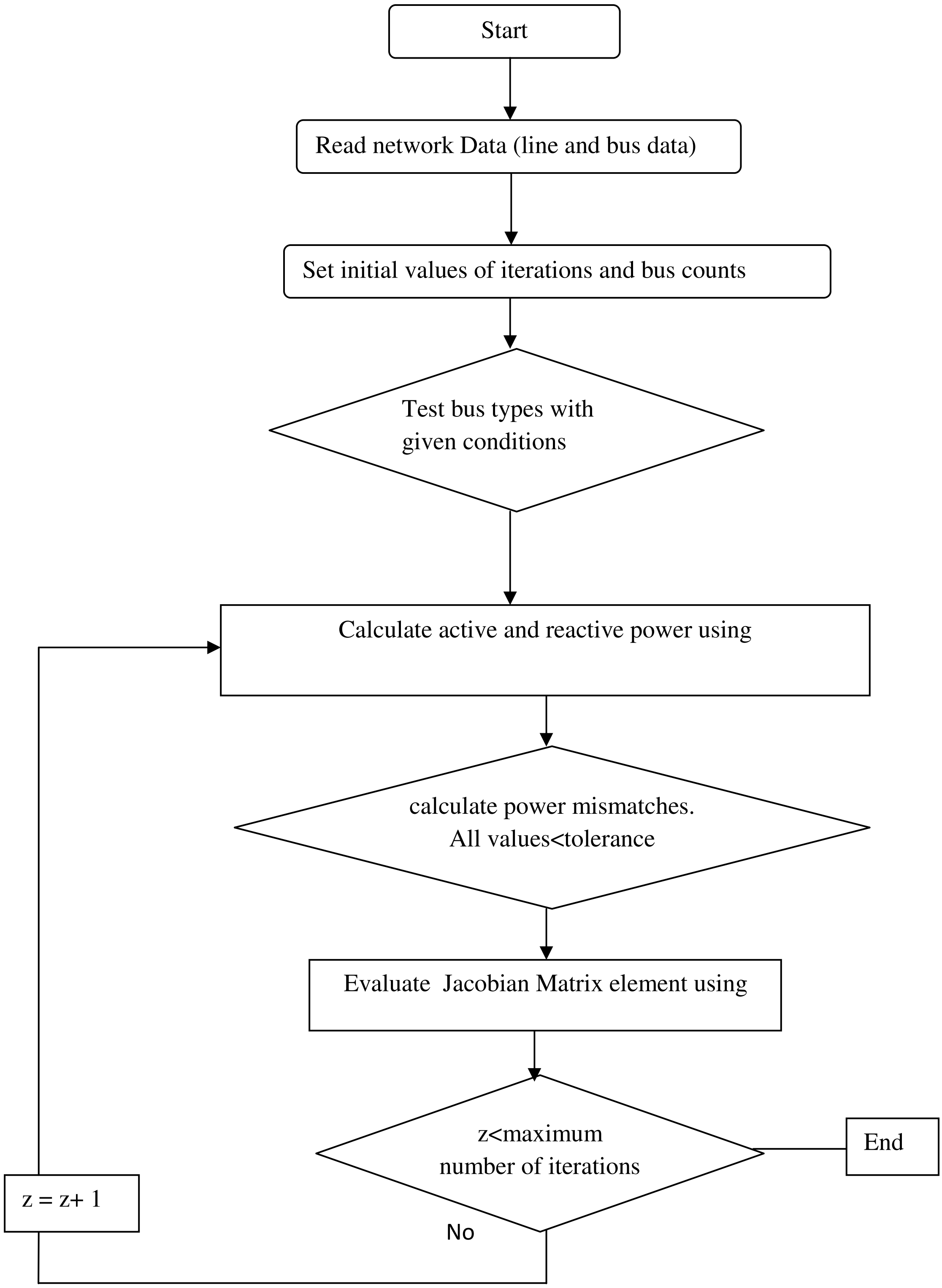

Figure 1.0 Flowchart for Newton-Raphson Load Flow Algorithm

Step 1**:** Enter the Nigeria 330KV system data(line data, bus data, active and reactive power limit)
Step 2: Set initial values of iterations and bus counts.
Step 3: Test bus then specify types with given conditions
Step4: Set the tolerance limit (convergence criterion)
Step 5: Form Y-Bus matrix
Step 6: Compute the active and reactive power of the network using equations respectively.
Step 7: Evaluate the jacobian matrix and solve the linearized equation

Step 8: Compute power mismatches using equations
Step 9: Update nodal voltages using equations

3.4 ETAP Power Station 2001

ETAP power station is a fully graphical electrical transient analyzer program that can run under the Microsoft, window 98, NT,4.0, 2000,Me,and XP environments. ETAP provides a very high level of reliability, protection and security of critical applications. It resembles real electrical system operation as closely as possible. It combines the electrical, logical, mechanical and physical attributes of system elements in the same database. Power station supports a number of features that assist in constructing networks of varying complexities. It is a foremost integrated database for electrical systems, allowing for multiple presentations of a system for different analysis or design purposes. ETAP power station can be used to run analysis such as short circuit analysis, load flow analysis, motor starting, harmonic transient stability, generator start-up, optimal power flow, DC load flow DC short circuit analysis, DC battery discharge analysis and reliability analysis[6].

3.5 Input Data Used For Power Flow Analysis of 330KVIntegrated Network

The input data for the power/load flow analysis includes; Generators output power, maximum and minimum reactive power limit of the generator, MW and MVAR peak loads, Impedance of the lines, transmission line sizes, voltage and power ratings of the lines and transformer data, and the nominal and critical voltages of each of the buses.

Figure 2.0 shows the load flow modeling of the Nigeria 330KV integrated power network using ETAP 4.0.while Figure 3.0 shows the result obtained after simulation in ETAP environment.

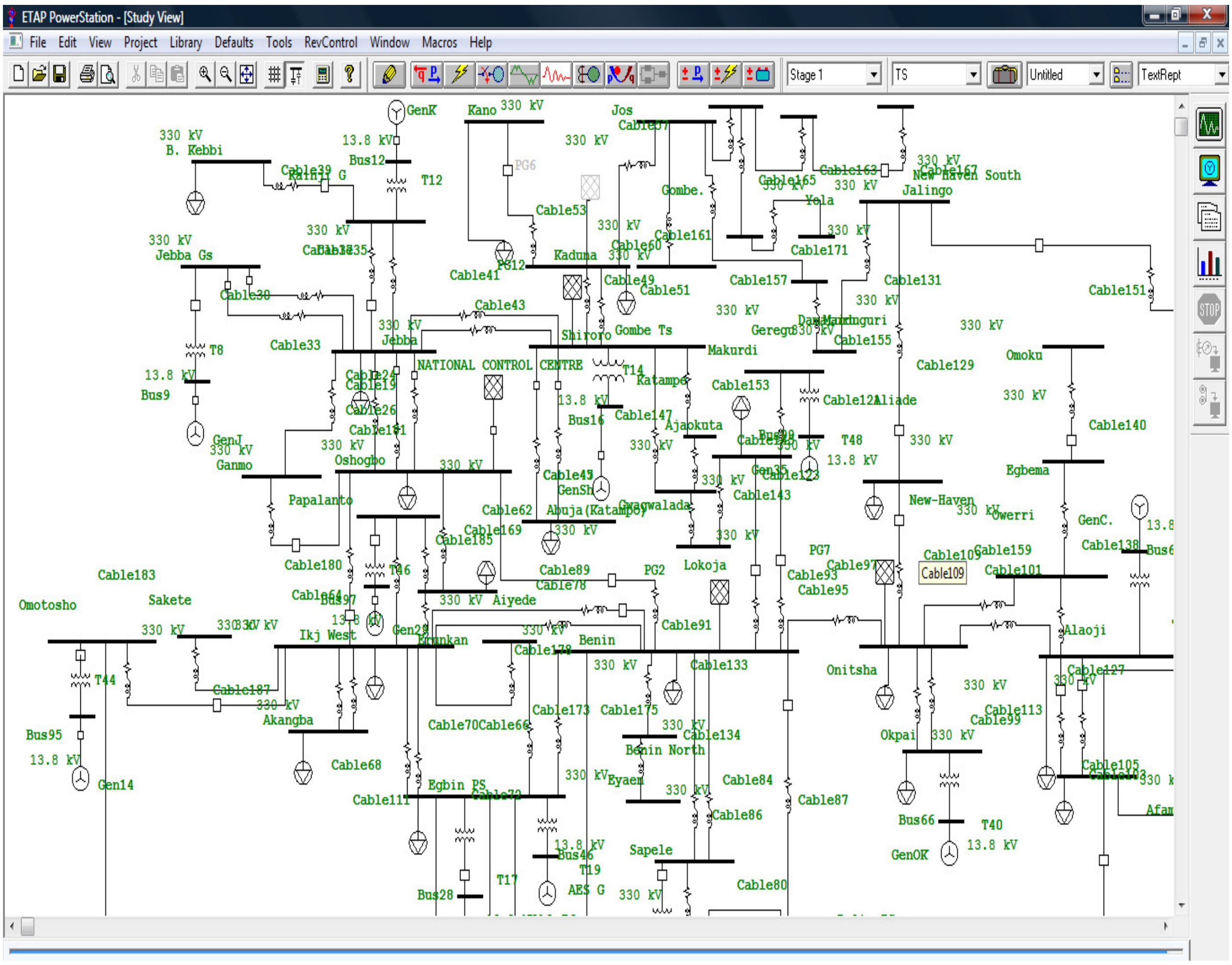

Figure 2.0: Modeling of the Integrated 330KV Network Using N-R algorithm

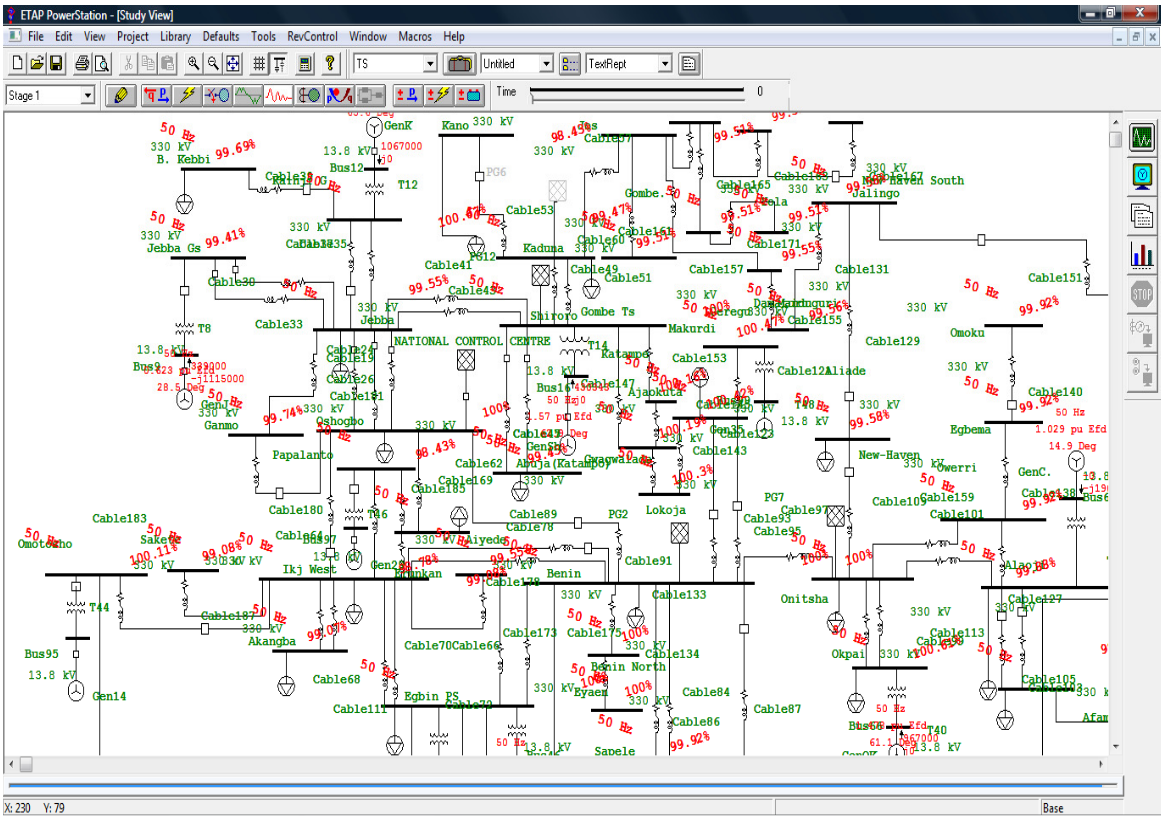

Figure 3.0 Load flow result of the integrated 330KV network using N-R algorithm

IV. Results

The result obtained in this section shows the power flows in the transmission lines and the losses from both generators and lines. The bus voltages were also obtained to know the weak ones among them.

4.1 Load flow results for the integrated power system after simulation

Table 5.0 gives the bus voltages and angles of the integrated network using N-R algorithm and table 6.0is the power flow and line losses.

Table 5.0 Buses voltages and phase angles for the integrated 330kvnetwork.

Bus number	Bus name	Voltage	Angle (Degrees)
1	Shiroro	**1.041**	-26.02
2	Afam	**1.038**	-34.59
3	Ikot-Ekpene	**1.042**	-21.41
4	Port-Harcourt	**1.023**	-12.44
5	Aiyede	**1.038**	-14.47
6	Ikeja west	**1.002**	-27.61
7	Papalanto	**1.043**	-18.67
8	Aja	**1.023**	-33.82
9	Egbin PS	**1.04**	-13.68
10	Ajaokuta	**0.986**	-8.95
11	Benin	**1.032**	-8.45
12	Geregu	**1.043**	-9.54
13	Lokoja	**1.022**	-9.56
14	Akangba	**1.021**	12.45
15	Sapele	**1.029**	-11.31
16	Aladja	**1.001**	-11.69
17	Delta PS	**1.045**	-10.69
18	Alaoji	**1.034**	-6.53
19	Aliade	**1.037**	-28.91

20	New haven	**1.052**	-23.38
21	New haven south	**0.964**	-12.11
22	Makurdi	**0.931**	-14.76
23	B-kebbi	**0.985**	7.32
24	Kainji	**1.012**	-9.62
25	Oshogbo	**1.044**	-12.66
26	Onitsha	**1.021**	-9.72
27	Benin north	**1.042**	-11.09
28	Omotosho	**1.051**	-13.57
29	Eyaen	**1.023**	-6.56
30	Calabar	**1.035**	0.00
31	Alagbon	**0.9925**	-12.31
32	Damaturu	**0.934**	-19.69
33	Gombe	**0.941**	-25.65
34	Maiduguri	**0.943**	-8.03
35	Egbema	**1.032**	-18.11
36	Omoku	**1.045**	-33.38
37	Owerri	**1.023**	-9.11
38	Erunkan	**0.932**	-34.76
39	Ganmo	**0.983**	-14.22
40	Jos	**0.937**	-11.44
41	Yola	**0.921**	-6.86
42	Gwagwalada	**0.998**	-24.32
43	Sakete	**0.983**	-8.29
44	Ikot-Abasi	**1.024**	-13.47
45	Jalingo	**0.929**	-4.45
46	Kaduna	**0.9922**	-8.61
47	Jebba GS	**1.023**	-15.43
48	Kano	**0.994**	-9.05
49	Katampe	**1.001**	-8.48
50	Okpai	**1.034**	-12.45
51	Jebba	**1.045**	-7.97
52	AES	**1.023**	-12.21

Table 6.0 Power flows for the integrated 330kvnetwork.

CONNECTED BUS		**Sending End**		**Receiving End**		**LOSSES**	
From	**To**	**P_{send}(pu)**	**Q_{send}(pu)**	**$P_{received}$(pu)**	**$Q_{received}$(pu)**	**Real power loss (pu)**	**Reactive power loss(pu)**
49	1	0.1775	-0.0727	-0.1179	0.0734	0.0596	0.0007
14	6	-0.1939	-0.1200	0.1935	0.1201	0.0001	0.0004
2	18	-0.0556	-0.0383	0.0556	0.0384	0.0000	0.0001
2	3	0.0038	0.0017	-0.0039	-0.0018	-0.0001	-0.0001
2	4	-0.0063	0.0003	0.0066	-0.0003	0.0003	0.0000
16	17	0.0512	-0.0566	-0.0516	0.0563	-0.0004	-0.0003
5	25	-0.1621	-0.099	0.1627	0.1005	0.0006	0.0015
5	6	-0.0186	-0.0119	0.0193	0.0121	0.0007	0.0002
5	7	-0.0283	-0.0182	0.0287	0.0188	0.0004	0.0006
8	9	-0.0999	-0.0619	0.0997	0.0624	-0.0002	0.0005
8	31	-0.0187	-0.0119	0.0185	0.0121	-0.0002	0.0002
10	11	-0.0215	-0.0134	0.0211	0.0136	-0.0004	0.0002
10	12	0.0239	0.0166	-0.0236	-0.0162	0.0003	0.0004
10	13	-0.0289	-0.0180	0.0291	0.0189	0.0002	0.0009
16	15	-0.1315	0.0163	0.1319	-0.0161	0.0004	0.0002
18	26	-0.2461	-0.1781	0.2463	0.1784	0.0002	0.0003
18	3	0.0457	0.0294	-0.0459	-0.0291	-0.0002	0.0003
18	37	-0.0153	-0.0116	0.0152	0.0117	-0.0001	0.0001

19	21	-0.0026	-0.0050	0.0029	0.0021	0.0003	-0.0029
19	22	0.0031	0.0024	-0.0026	-0.0045	0.0005	-0.0021
23	24	-0.0885	-0.0543	0.0884	0.0548	-0.0001	0.0005
11	6	0.0159	0.0114	-0.0154	-0.0113	0.0004	0.0001
11	15	-0.0257	0.0595	0.0261	-0.0593	0.0003	0.0002
11	17	-0.0611	0.0549	0.0612	-0.0546	0.0001	0.0003
11	25	0.0108	0.0843	-0.0109	0.0843	-0.0001	0.0001
11	26	0.0250	0.0194	-0.0255	-0.0190	0.0005	0.0004
11	27	0.0393	-0.0294	-0.0389	0.0300	0.0004	0.0006
11	9	0.0921	0.0779	-0.0925	-0.0779	-0.0004	0.0000
11	28	0.0476	0.0343	-0.0475	-0.0341	0.0001	0.0002
27	29	0.0308	0.0192	-0.0308	-0.0198	0.0002	-0.0006
30	3	0.0283	0.0182	-0.0286	-0.0182	-0.0003	0.0000
32	33	0.0367	0.0240	-0.0364	-0.0239	0.0003	0.0001
32	34	0.0485	0.0349	-0.0489	-0.0347	0.0004	0.0002
35	37	0.0181	0.0132	-0.0179	-0.0135	0.0002	-0.0003
35	36	0.0112	0.0088	-0.0111	-0.0089	0.0001	-0.0001
9	6	0.2148	0.1549	-0.2142	-0.1535	0.0006	0.0014
9	38	0.2605	0.1596	-0.2601	-0.1589	0.0004	0.0007
38	6	0.2601	0.1589	-0.2596	-0.1581	0.0005	0.0008
39	25	0.2668	-0.4055	-0.2636	0.4111	0.0032	0.0056
39	51	-0.2668	0.4055	0.2694	-0.4010	0.0026	0.0045
33	40	0.0674	0.1201	-0.0673	-0.1203	0.0001	-0.0002
33	41	0.0790	0.1002	-0.0789	0.1003	0.0067	-0.0001
42	49	-0.0115	-0.0072	0.0118	0.0071	0.0003	-0.0001
42	13	0.0292	0.0181	-0.0289	-0.0182	0.0003	-0.0001
42	1	-0.0175	-0.0109	0.0177	0.0110	0.0002	0.0001
6	25	-0.0180	-0.0247	0.0181	0.0249	0.0000	0.0002
6	28	-0.0474	-0.0340	0.0475	0.0342	0.0001	0.0002
6	7	0.0283	0.0185	-0.0283	-0.0182	0.0003	0.0000
6	43	0.0364	0.0202	-0.0366	-0.0205	-0.0002	-0.0003
44	3	0.0464	0.0332	-0.0461	-0.0332	0.0000	0.0003
3	21	0.0496	0.0316	-0.0494	-0.0310	0.0006	0.0001
45	41	0.0879	-0.1138	-0.0865	0.1149	0.0014	0.0411
51	25	0.2638	-0.3355	-0.2594	0.3448	0.0044	0.0093
47	51	-0.1669	0.6067	0.1674	-0.6055	0.0005	0.0012
51	24	-0.4846	0.0717	0.4877	-0.0653	0.0031	0.0064
51	1	-0.1733	-0.2580	0.1740	0.2644	0.0007	0.0064
40	46	-0.0029	-0.0054	0.0033	-0.0060	0.0004	0.0114
40	22	-0.0027	-0.0050	0.0026	0.0055	-0.0001	0.0005
46	1	-0.1509	-0.1180	0.1512	0.1189	0.0030	0.0009
46	48	-0.1252	0.0886	0.1244	-0.0790	-0.0008	-0.0096
20	26	-0.13468	-0.0855	0.1351	0.0862	0.0004	0.0007
20	21	-0.0468	-0.0260	0.0466	0.0259	-0.0002	-0.0001
50	26	0.4219	-0.0682	-0.4177	0.0769	0.0042	0.0087
26	37	0.0156	0.0120	-0.0152	-0.0116	0.0004	0.0004
Total Power Loss						**0.0903**	**0.0533**

Tables 7.0 shows the active and reactive power losses from individual generators while table 8.0 give a summary of total power losses from both generators and transmission lines. Figure 4.0 shows a plot of bus voltages versus bus numbers for the Nigeria 330KV integrated network.

Table 7.0 Power losses (active and reactive) from generators

S/N	GENERATORS	**MW**	**MVar**
1	Kainji	0.3989	4.299
2	Jebba	0.3761	5.0533
3	Shiroro	0.3794	1.8690

4	Egbin	0.4137	6.4565
5	Trans-Amadi	0.0268	0.6833
6	A.E.S	0.0548	1.3207
7	Sapele	0.255	0.1258
8	Ibom	0.0035	0.235
9	Okpai	0.2699	3.089
10	Afam i-v	0.0051	0.107
11	Afam vi	0.0016	0.293
12	Delta	0.0358	5.381
13	Geregu	0.0747	2.198
14	Omoku	0.0012	0.3031
15	Omotosho	0.0326	0.4518
16	Olorunsogo phase 1	0.0024	0.4329
17	Olorunsogo phase 2	0.0016	0.3439
TOTAL POWER LOSSES		**2.3331**	**32.6423**

Table 8.0 Summary of total losses from generations and transmission lines

	Real (MW)	Reactive(Mvar)
Generation	**2.3331**	**32.6423**
Lines	**90.300**	**53.300**
Total loss	**92.6331**	**85.9423**

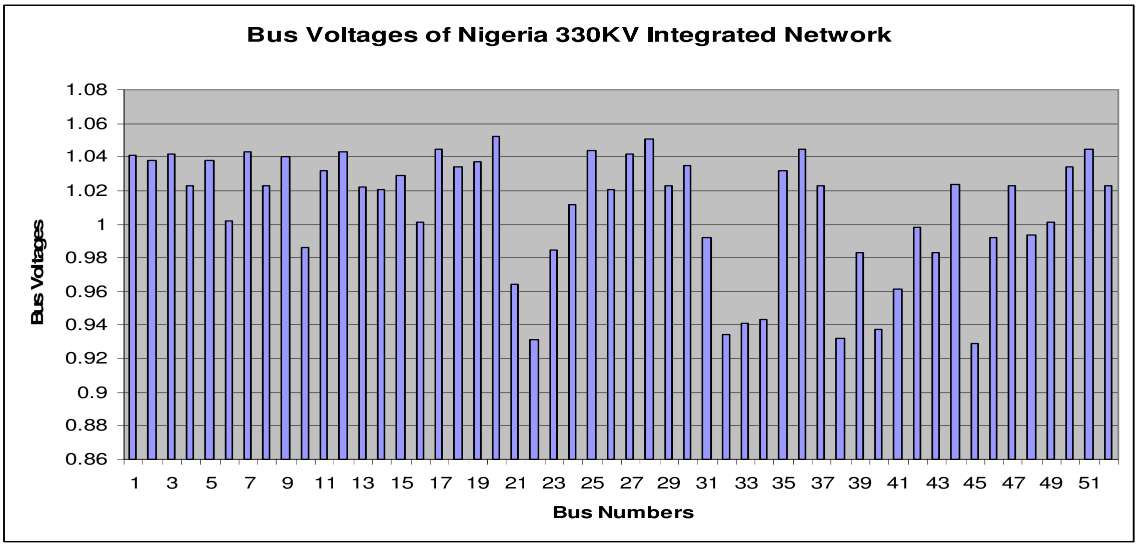

Figure 4.0 plot of bus voltages versus bus numbers for the Nigeria 330KV integrated network.

V. DISCUSSION

Power flow results of 330KVintegrated network was carried out using the records obtained from Power Holding Company of Nigeria (PHCN) logbooks and the Newton-Raphson power flow algorithm. It was found that of the total real power losses of 92.63331MW emanating from the network, the transmission lines constitute about 90.300MW and the generating stations gave 2.3331MW.Also, of the total reactive power losses of 85.9423MVar generated in the network, the transmission lines constitute 53.300MVar and the generating stations constitute 32.6423 MVar. Egbin had the highest reactive power losses in the network of about 6.4565Mvar while the highest active power loss is from Kanji of value 0.3989MW. The results obtained also showed that the bus voltages outside the statutory limit, of (0.95pu, 313.5KV) to (1.05pu, 346.5KV) include: (Makurdi, 0.931pu), (Damaturu, 0.934pu), (Gombe, 0.941pu), (Maiduguri, 0.943pu), (Yola, 0.921pu), (Jos, 0.937pu) and

(Jalingo, 0.929pu). On further investigation, it was found out that all these buses are all in the northern part of the country and some are still very far from the generating stations even in the NIPP and IPP stations. More so , the integrated network is still not a perfect ring arrangement, and the losses are still very high, hence, the benefits of ring connection is still lacking.

VI. CONCLUSION

The Nigeria 330KV integrated network has a relatively low voltage drop in the transmission lines compared to results obtained when the network consisted of 9 generating stations and 28 buses [1] Though, there was an obvious improvement over the existing case, some buses and generators of high reactive power values need to be compensated using either the conventional compensators such as reactors, capacitor banks, and tap changing transformers or the use of FACTS devices. This however will enable the Nigeria 330KV integrated transmission network to be used very close to its thermal limit, yet still remain very stable, reduce transmission line congestion and maintain grid stability and effective interconnectivity.

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APPENDIX A

S/N	TRANSMISSION LINE		LENGTH (KM)	CIRCUIT TYPE	LINE IMPEDANCE (PU)		
	From	To			Z	B	ADMITTANCE
1	Katampe	Shiroro	144	Double	0.0029 + j 0.0205	0.308	8-j4.808
2	Afam GS	Alaoji	25	Double	0.009 + j0.007	0.104	9.615-j16.129
3	Afam GS	Ikot-Ekpene	90	Double	0.0155 + j0.0172	0.104	9.615-j16.129
4	Afam GS	Port-Harcourt	45	Double	0.006 + j0.007	0.104	9.615-j16.129
5	Aiyede	Oshogbo	115	Single	0.0291 + j0.0349	0.437	3.205-j2.288
6	Aiyede	Ikeja west	137	Single	0.0341 + j0.0416	0.521	2.695-j19.919
7	Aiyede	Papalanto	60	Single	0.0291 + j0.0349	0.437	3.205-j2.288
8	Aja	Egbin PS	14	Double	0.0155 + j0.0172	0.257	16.129-j9.615
9	Aja	Alagbon	26	Double	0.006+j0.007	0.257	6.494-j3.891
10	Ajaokuta	Benin	195	Single	0.0126+j0.0139	0.208	1.429-j12.180
11	Ajaokuta	Geregu	5	Double	0.0155+j0.0172	0.257	6.494-j3.891
12	Ajaokuta	Lokoja	38	Double	0.0155+j0.0172	0.257	8-j4.808
13	Akangba	Ikeja west	18	Single	0.0155+j0.0172	0.065	32+j19.32
14	Aladja	Sapele	63	Single	0.016+j0.019	0.239	5.284-j51.913
15	Alaoji	Owerri	60	Double	0.006+j0.007	0.308	6.494-j3.891
16	Aladja	Delta PS	32	Single	0.016+j0.019	0.239	5.848-j4.184
17	Alaoji	Onitsha	138	Single	0.035+j0.0419	0.524	2.754-j33.553
18	Alaoji	Ikot-Ekpene	38	Double	0.0155+j0.0172	0.257	6.494-j3.891
19	Aliade	New Haven South	150	Double	0.006+j0.007	0.308	16.129-j9.615
20	Aliade	Makurdi	50	Double	0.0205+j0.0246	0.308	4.545-j3.247
21	B-kebbi	Kainji	310	Single	0.0786+j0.0942	1.178	1.235-j0.478
22	Benin	Ikeja west	280	Double	0.0705+j0.0779	1.162	1.637-j12.626
23	Benin	Sapele	50	Double	0.0126+j0.0139	0.208	3.194-j17.555
24	Benin	Delta PS	107	Single	0.016+j0.019	0.239	5.848-j4.184
25	Benin	Oshogbo	251	Single	0.0636+j0.0763	0.954	1.508-j12.932
26	Benin	Onitsha	137	Single	0.0347+j0.0416	0.521	2.8-j33.771
27	Benin	Benin north	20	Single	0.049+j0.056	0.208	8-j4.808
28	Benin	Egbin PS	218	Single	0.016+j0.019	0.239	5.848-j4.184
29	Benin	Omotosho	120	Single	0.016+j0.019	0.365	3.846-j2.739
30	Benin North	Eyaen	5	Double	0.0126+j0.0139	0.208	8-j4.808
31	Calabar	Ikot-Ekpene	72	Double	0.0126+j0.0139	0.208	6.494-j3.891
32	Damaturu	Gombe	135	Single	0.0786+j0.0942	1.178	1.19-j0.848
33	Damaturu	Maiduguri	140	Single	0.0786+j0.0942	1.178	1.19-j0.848
34	Egbema	Omoku	30	Double	0.0126+j0.0139	0.208	8-j4.808
35	Egbema	Owerri	30	Double	0.0126+j0.0139	0.208	8-j4.808
36	Egbin PS	Ikeja west	62	Single	0.0155+j0.0172	0.257	7.308+j57.14
37	Egbin PS	Erunkan	30	Single	0.016+j0.019	0.239	5.848-j4.184
38	Erunkan	Ikeja west	32	Single	0.016+j0.019	0.239	5.848-j4.184
39	Ganmo	Oshogbo	87	Single	0.016+j0.019	0.239	5.848-j4.184
40	Ganmo	Jebba	70	Single	0.0341+j0.0416	0.239	2.615-j1.919
41	Gombe	Jos	265	Single	0.067+j0.081	1.01	1.923-j16.456
42	Gombe	Yola	217	Single	0.0245+j0.0292	1.01	1.391-j2.999
43	Gwagwalada	Lokoja	140	Double	0.0156+j0.0172	0.257	6.494-j3.891
44	Gwagwalada	Shiroro	114	Double	0.0155+j0.0172	0.257	6.494-j3.891
45	Ikeja west	Oshogbo	252	Single	0.0341+j0.0416	0.521	2.695-j1.919
46	Ikeja west	Omotosho	160	Single	0.024+j0.0292	0.365	2.695-j1.919
47	Ikeja west	Papalanto	30	Single	0.0398+0.0477	0.597	2.695-j1.919
48	Ikeja west	Sakete	70	Single	0.0398+j0.0477	0.521	2.695-j1.919
49	Ikot-Abasi	IkotEkpene	75	Double	0.0155+j0.0172	0.257	6.494-j3.891
50	Jebba	Oshogbo	157	Single	0.0398+j0.0477	0.597	0.246-j3.092
51	Jalingo	Yola	132	Single	0.0126+j0.0139	0.208	8-j4.808
52	Jebba	Jebba GS	8	Double	0.002+j0.0022	0.033	3.174-j1.594

53	Jebba	Kainji	81	Double	0.0205+j0.0246	0.308	3.607-j40.328
54	Jebba	Shiroro	244	Single	0.062+j0.0702	0.927	1.559-j13.297
55	Jos	Kaduna	197	Single	0.049+j0.0599	0.927	1.873-J1.337
56	Jos	Makurdi	230	Double	0.002+j0.0022	0.308	4.545-J3.247
57	Kaduna	Kano	230	Single	0.058+j0.0699	0.874	1.657-j14.12
58	Kaduna	Shiroro	96	Single	0.0249+j0.0292	0.364	3.935-j3.379
59	Katampe	Shiroro	144	Double	0.0205+j0.0246	0.308	8-j4.808
60	New Haven	Onitsha	96	Single	0.024+j0.0292	0.365	3.935-j33.79
61	New Haven	New Haven South	5	Double	0.0205+j0.0246	0.308	4.545-J3.247
62	okpai	Onitsha	80	Double	0.006+j0.007	0.104	16.13-J9.615
63	Onitsha	Owerri	137	Double	0.006+j0.007	0.104	16.13-J9.615
64	IkotEkpene	New Haven South	143	Double	0.0205+j0.0246	0.257	6.494-j3.891

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