

Determination of Bus Voltages, Real and Reactive Power Losses in the Northern Nigeria 330Kv Network Using Power System Analysis Tool (PSAT)

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Abstract: The power system analysis and design is generally done by using Load flow studies. The essence of power flow analysis is to find the magnitude and phase angle of voltage at each bus and the real and reactive power flows in each transmission lines. Therefore, load flow analysis is an important tool involving numerical analysis applied to a power system. This analysis is being executed at the stage of planning, operation, control and economic scheduling. Load flow analysis is performed on a symmetrical steady state operating condition of a power system under normal operating condition. This information is essential for the continuous monitoring of the current state of the system and for analyzing the effectiveness of alternative plans for future system expansion to meet increased load demand. For power flow analysis, this research considered the 330KV of northern Nigeria transmission network with a view of estimating the real and reactive power flows, power losses in the entire network and phase angle using Power System Analysis Toolbox (PSAT).

Keywords: Load Flow Analysis, Transmission Network, PSAT, Bus Voltages, Power Losses

1. Introduction

Nigeria is a vast country with a total of 356, 667 square miles (923,768 km²), of which 351, 649 sq. miles (910,771 square km or 98.6% of total area) is land. The nation is made up of six geo-political zones subdivided into 36 states and the Federal Capital Territory (F. C. T.). Furthermore, the vegetation cover, physical features and land terrain in the nation vary from flat open savannah in the North to thick rain forests in the south, with numerous rivers, lakes and mountains scattered all over the country with population of 162,470,737 Million people. The total installed capacity of the currently generating plants is 9, 065 MW, but the available capacity is around 3,885 MW with peak value of 4,477.7 MW as at on 15th August 2014. Seven of the fourteen generation stations are over 20 years old and the average daily power generation is below 4,000 MW, which is far below the peak load forecast of 8,900MW for the currently existing

infrastructure. As a result, the nation experiences massive load shedding [1]. Currently, only about 40 percent of Nigeria's total population has access to public electricity supply due to inadequate transmission and distribution networks. Also ageing infrastructure, weak and radial network configuration, and overloaded transformers result in frequent system collapse, with high transmission and distribution losses and poor voltage profile. Currently, with some of the completed integrated power projects, the Nigeria 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. 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). The current projection of power generation by PHCN is to generate 26,561MW as envisioned in the vision 20: 2020

target. Presently, of the seventeen (17) active power generating stations, eleven of these are owned by the Federal Government of Nigeria (FGN), with installed capacity of 6,904.6MW and 2,271MW. The remaining six (6) is from National Integrated Power Project (NIPP) with total designed capacity of 4,775MW, of which 1,483MW is available. These generating stations are sometimes connected to load centers through either very long or inadequate transmission lines. The transmission network is overloaded with a wheeling capacity of 4,000MW. It has poor voltage profile, inadequate dispatch and control infrastructure, radial and fragile grid network, frequent system collapse, exceedingly high transmission losses which is as high as 25 percent compared with 3 percent in the US, 0.5 percent in Japan and 0.4 percent in South Korea due to low transmission grid voltages and long distances over which electrical energy is distributed in the country. The northern part of Nigeria is mainly dominated by hydro power plant located in Jebba, Shiroro and Kainji all in Niger state. The three hydro power plants have a total installed capacity of 1864MW but the total available capacity is 1013MW [2]. 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 [3].

Due to the above, new strategies, new methods of analysis and design are being sought to improve performance of power system.

According to [4]: in their work on power flow analysis of the Nigerian transmission system, concluded that incorporating FACTS devices are adequately enough to improve the power demand of the country.

Also in [5]: they identify poor power magnitude at Gombe, Kano, Jos, Kaduna and Katampe transmission station. Voltage violations were also improved by adding shunt capacitor compensators to the affected buses. The northern Nigeria is expanding with increase in agriculture output as a result more industries are coming up, adding shunt capacitor compensators can be a lasting solution to this problem.

In [6]: they study the steady state voltage stability enhancement using SSSC, upon running load flow, they discover that some buses recorded voltage drop, but upon incorporating SSSC device there was significant improvement.

According to [7]: he run a load flow analysis of 230/110kv substation using ETAP, he end up by recommending only capacitor bank for the correction of under voltage.

According to [8]: they look at the behavior of the national

grid before and after reform (unbundling of the power sector and the recent concluded/abandon project), the system has great improvement with the addition more generating power plant and more 330kv transmission network. The work depends heavily on assume data because up to now most of the generating plant and the transmission lines are under construction.

Much research is still ongoing in the determination of bus voltages, real and reactive power losses. It is the aim of this paper to investigate bus voltages, real and reactive power losses and flows on the northern Nigeria 330kv network using PSAT.

In [9] a simple and efficient computer algorithm has been presented to solve unbalanced radial distribution networks. The proposed method has good convergence property for any practical distribution networks with practical R/X ratio. Computationally, this method is extremely efficient.

2. Review of Current Nigeria Integrated Power System

Currently, only about 40 percent of Nigeria's total population has access to public electricity supply due to inadequate transmission and distribution networks. Also ageing infrastructure, weak and radial network configuration, and overloaded transformers result in frequent system collapse, with high transmission and distribution losses and poor voltage profile. Currently, with some of the completed integrated power projects, the Nigeria 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. 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). The current projection of power generation by PHCN is to generate 26,561MW as envisioned in the vision 20: 2020 target. Presently, of the seventeen (17) active power generating stations, eleven of these are owned by the Federal Government of Nigeria (FGN), with installed capacity of 6,904.6MW and 2,271MW is available. The remaining six (6) is from NIPP with total designed capacity of 4,775MW, of which 1,483MW is available. These generating stations are sometimes connected to load centers through either very long or inadequate transmission lines. The transmission network is overloaded with a wheeling capacity of less than 4,000MW. It has poor voltage profile, inadequate dispatch and control infrastructure, radial and fragile grid network, frequent system collapse, exceedingly high transmission losses which is as high as 25 percent compared with 3 percent in the US, 0.5 in Japan and 0.4 in South Korea due to low transmission grid voltages and long distances over which electrical energy is distributed in the country. Nigeria Power industry deregulation (and re-regulation) has started the dismantling of the traditional utility business structure so

that generation, transmission and distribution are becoming owned and operated by different entities.

2.1. Nigerian Electric Power Transmission System

The Nigerian electric power transmission network, operated by the Transmission Company of Nigeria (TCN), operates at a high pressure of 330kV while its lower transmission pressure is 132kV. The grid is an integrated network consisting of seventeen generating stations and fifty two 330kV bus; two of the generating stations (Trans Amadi G. S. and Omoku G. S.) are run on island operation. Only three generating stations (Jebba, Kainji and Shiroro Hydro power stations) and eleven transmitting stations were cited in the northern part of the country as at data collection time. Three of these transmitting stations (Damaturu T.S., Maiduguri T.S., and Yola T.S.) had no record of operation as at data collection time [5].

2.2. The Northern Nigeria Grid System

The northern Nigerian power system of 330kV transmission lines is the study area in the context of this work. It consists of 3 generator and 13 bus networks. All the three (3) generators are hydro units.

2.3. Power Balance Equations

As shown in equation (1) and (2), the total generation of real and reactive power must be equals to the total load demand plus losses, [4, 10].

$$\sum_{i=1}^n P_{Gi} = \sum_{i=1}^n P_{Di} + P_{Loss} \quad (1)$$

$$\sum_{i=1}^n Q_{Gi} = \sum_{i=1}^n Q_{Di} + Q_{Loss} \quad (2)$$

2.4. Power Flow Equations

Consider a typical bus of a power system network as shown in Figure 1.0. Transmission lines are represented by their equivalent π models where impedances have been converted to per – unit admittances on a common MVA base.

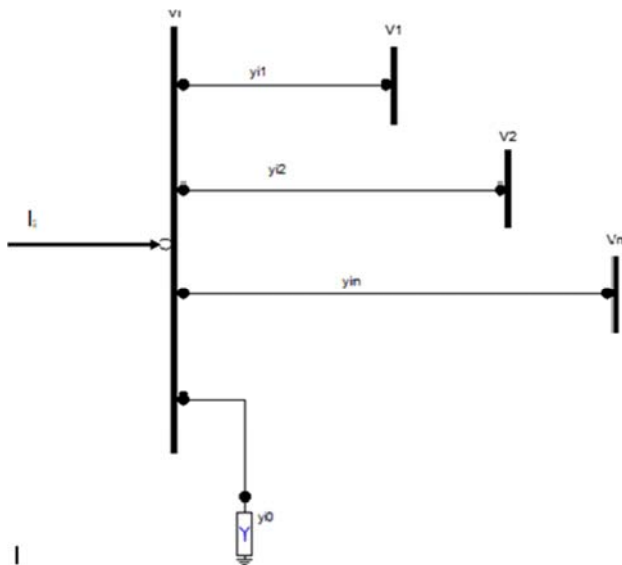


Figure 1. Typical bus of the power system.

Application of Kirchhoff's current Law (KCL) to this bus results in

$$I_i = y_{i0} V_i + y_{i1} (V_i - V_1) + y_{i2} (V_i - V_2) + \dots y_{in} (V_i - V_n) \\ = (y_{i0} + y_{i1} + y_{i2} + \dots + y_{in}) V_i - y_{i1} V_1 - y_{i2} V_2 - \dots - y_{in} V_n \quad (3)$$

$$I_i = V_i \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j, \quad j \neq i \quad (4)$$

The apparent power at bus i is

$$S_i = P_i + jQ_i = V_i I_i^* \quad (5)$$

Or

$$I_i = \frac{P_i - jQ_i}{V_i^*} \quad (6)$$

Using equation (6) in equation (5) gives

$$I_i = \frac{P_i - jQ_i}{V_i^*} = V_i \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j, \quad j \neq i \quad (7)$$

From equation (8), the mathematical formulation of the power flow problem results in a system of algebraic non-linear equations which must be solved by iterative techniques.

2.4.1. Gauss - Seidel Power Flow Solution

In the power flow study, it is necessary to solve the set of non – linear equations represented by equation (8). In the Gauss – Seidel method equation (8) is solved for V_i and the iterative sequence becomes,

$$V_i^{(k+1)} = \frac{\frac{P_i^{sch} - jQ_i^{sch}}{V_i^{*(k)}} + \sum y_{ij} V_j^{(k)}}{\sum y_{ij}} \quad j \neq i \quad (8)$$

In writing the KCL, current entering bus i was assumed positive. Thus, for buses where real and reactive powers are injected into the bus, such as generator buses, P^{sch} and Q^{sch} have positive values. For load buses where real and reactive powers are flowing away from the bus, P^{sch} and Q^{sch} have negative values. If equation (5) is solved for P_i and Q_i , we have

$$P_i^{(k+1)} = \text{Real}[V_i^{*(k)} \{ V_i^{(k)} \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j^{(k)} \}] \quad j \neq i \quad (9)$$

$$Q_i^{(k+1)} = \text{Imaginary}[V_i^{*(k)} \{ V_i^{(k)} \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j^{(k)} \}] \quad j \neq i \quad (10)$$

The bus admittance matrix Y_{bus} is an important network description of the interconnected power system and the power flow equation is usually expressed in terms of the elements of the bus admittance matrix, Y_{bus} . Since the off diagonal elements of the bus admittance matrix Y_{bus} are $Y_{ij} = -y_{ij}$ and the diagonal elements are $Y_{ii} = \sum y_{ij}$ then equation (6) above becomes

$$V_i^{(k+1)} = \frac{\frac{P_i^{sch} - jQ_i^{sch}}{V_i^{*(k)}} + \sum y_{ij} V_j^{(k)}}{Y_{ij}} \quad (11)$$

And equation (10) and (11) becomes

$$P_i^{(k+1)} = \text{Real} (V_i^{*(k)} \{ V_i^{(k)} Y_{ii} + \sum_{j=1, j \neq i}^n y_{ij} V_j^{(k)} \}) \quad j \neq i \quad (12)$$

$$Q_i(k+1) = \text{Imaginary}(V_i^{*(k)} \{V_i^{(k)} Y_{ii} + \sum_{j=1, j \neq i}^n Y_{ij} V_j^k\}) \quad j \neq i \quad (13)$$

Y_{ii} includes the admittance to ground of line charging susceptance and any other fixed admittance to ground.

2.4.2. Newton - Raphson Method

The load flow problem can also be solved by using Newton Raphson method. For the typical bus of the power system shown in Fig. 1.0 the current entering bus written in terms of the bus admittance matrix as.

$$I_i = \sum_{j=1}^n Y_{ij} V_j \quad (14)$$

Expressing equation (15) in polar form, we have

$$I_i = \sum_{j=1}^n |Y_{ij}| |V_j| < \theta_{ij} + \delta_j \quad (15)$$

The complex power at bus i is

$$P_i - jQ_i = V_i^* I_i \quad (16)$$

Substituting equation (16) into equation (17)

$$P_i - jQ_i = |V_i| < -\delta_i \sum_{j=1}^n |Y_{ij}| |V_j| < \delta_{ij} + \delta_j \quad (17)$$

Separating the real and imaginary parts

$$P_i = \sum_{j=1}^n |V_i| |V_j| |Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad (18)$$

$$\frac{\partial P_i}{\partial |V_i|} = 2|V_i| |Y_{ii}| \cos \theta_{ii} + \sum_{j=1}^n |V_j| |Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad (23)$$

$$\frac{\partial P_i}{\partial |V_j|} = |V_i| |Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i \quad (24)$$

The diagonal and off diagonal elements of J_3 are:

$$\frac{\partial Q_i}{\partial \delta_j} = \sum_{j \neq i}^n |V_i| |V_j| |Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad (25)$$

$$\frac{\partial Q_i}{\partial \delta_j} = -|V_i| |V_j| |Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i \quad (26)$$

The diagonal and off diagonal element of J_4 are:

$$\frac{\partial Q_i}{\partial |V_i|} = -2|V_i| |Y_{ii}| \sin \theta_{ii} + \sum_{j \neq i}^n |V_j| |Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \quad (27)$$

$$\frac{\partial Q_i}{\partial |V_j|} = -|V_i| |Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i \quad (28)$$

The terms $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ are the differences between the scheduled and calculated values, known as the power residuals given by:

$$\Delta P_i^{(k)} = P_{sch} - P_i^{(k)} \quad (29)$$

$$\Delta Q_i^{(k)} = Q_{sch} - Q_i^{(k)} \quad (30)$$

The new estimates for bus voltages are:

$$\delta_i^{(k+1)} = \delta_i^{(k)} + \Delta \delta_i^{(k)} \quad (31)$$

$$|V_i^{(k+1)}| = |V_i^k| + \Delta |V_i^k| \quad (32)$$

$$Q_i = -\sum_{j=1}^n |V_i| |V_j| |Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \quad (19)$$

Equation (19) and (20) constitute a set of non – linear algebraic equations in terms of the independent variables, voltage magnitude in per – unit and phase angle in radians. We have two equations for each load bus given by (19) and (20), and one equation for each voltage controlled bus, given by (19). Expanding (19) and (20) in Taylor's series about the initial estimate and neglecting all higher order terms results in a set of linear equations. These equations after linearization can be written in matrix form as.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \quad (20)$$

Where element J_1, J_2, J_3, J_4 are elements of Jacobian matrix. In obtaining the power flow solution by Newton - Raphson method, we have to consider equation (21).

The diagonal and off diagonal element of J_1 are:

$$\frac{\partial P_i}{\partial Q_i} = \sum_{j \neq i}^n |V_i| |V_j| |Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \quad (21)$$

$$\frac{\partial P_i}{\partial \delta_j} = -|V_i| |V_j| |Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i \quad (22)$$

The diagonal and off diagonal element of J_2 are:

2.4.3. Fast Decouple Newton- Raphson Power Flow Solution

This is an extension of Newton – Raphson method formulated in polar coordinates with certain approximation which results in fast algorithm for load flow solution. Because power system transmission lines have a very high X/R ratio thus it is reasonably assumed that real power changes (ΔP) are less sensitive to changes in voltage magnitude and are mainly sensitive to changes in phase angle ($\Delta \delta$). Similarly, the reactive power is less sensitive to changes in phase angle $\Delta \delta$ but mainly sensitive to changes in voltage magnitude. With these assumptions, recall equation (21)

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \quad (33)$$

Or

$$\Delta P = J_1 \Delta \delta = \frac{\partial P}{\partial \delta} \Delta \delta \quad (34)$$

$$\Delta Q = J_4 \Delta |V| = \frac{\partial Q}{\partial |V|} \Delta |V| \quad (35)$$

Equations (31) and (32) show that the matrix equation is separated into two decoupled equations requiring considerably less time to solve compared to the time required for the solution of (19). Furthermore, considerable simplification can be made to eliminate the need for re-computing J_1 and J_4 during each iteration. This procedure however, results in Fast Decoupled power flow equations [10].

3. Methodology

The design in the context of this paper will be limited to the northern Nigeria 330Kv network using PSAT, in order to achieve the following aim;

- To determine bus voltages, real and reactive power losses and flows on the northern Nigeria 330kv network using PSAT
- To design a model that can be used to determine the actual calculation of active and reactive power.
- To carry out an in-depth studies on load flow analysis.
- To evaluate the performance of the model on the collected data.
- To design a model that can be used to plan ahead the load demand by consumers.

3.1. Data Collection

The data used in this analysis and assessment were collected from Transmission company of Nigeria (TCN). These was modeled and simulated in PSAT 2.1.9 using N-R power flow algorithm. The network for this study consist of Three (3) generating stations, Thirteen (13) buses, Nine (9) loads and Twelve(12) transmission lines using N-R and modeled with Power System Analysis Toolbox (PSAT). Simulation of the designed model was carried out in order to determine the 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 Northern Nigeria 330KV Network using N-R Method

The Newton-Raphson method formulates and solves iteratively the following load flow equation (15-33).

Recall equation (21)

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \quad (21)$$

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 J_1 through J_4 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 Northern Nigeria 330KV Network.

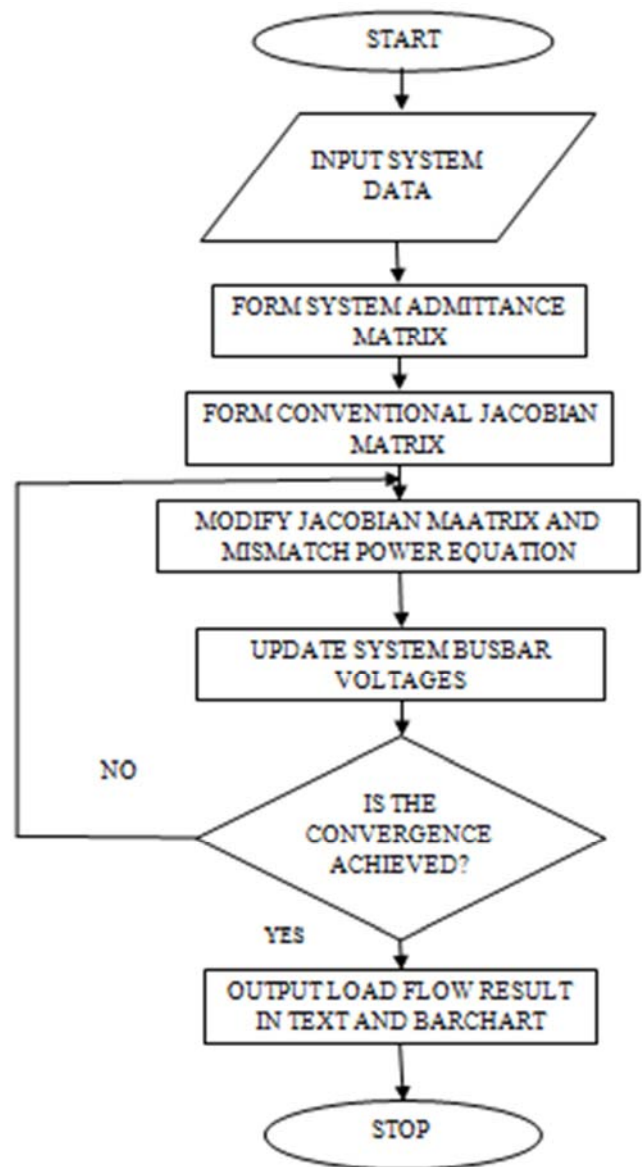


Figure 2. Flow chart for Newton-Raphson Algorithm.

3.3. IEEE 14 Bus Test Network

Test network system is widely used in power system research and education. It is imperative to understand the importance of using the standard test network. This is very

vital because; Practical power systems data are partially confidential, also the dynamic and static data of the system are not well documented, more so, Calculations of numerous scenarios are difficult due to large set of data and the lack of software capabilities for handling large set of data less generic results from practical power system.

The 14 bus system consists of five synchronous machines with IEEE type; 1 exciter, four of which are synchronous compensators used only for reactive power support. There are nine load buses in the system totaling to 259MW and 81.3 MVAR. The dynamic and static data of the system can be found. The system is widely used for voltage stability as well as low frequency oscillatory stability analysis. The 14 bus test case does not have line limits compared to other systems. It has also a low base voltage and an overabundance of voltage control capability.

4. Results and Discussion

The result obtained in this section shows the power flows in the transmission lines and losses from both generators and lines. The bus voltages were also obtained to know the weak ones among them. Comparism was made between the Northern Nigeria grid and the IEEE 14 bus test system.

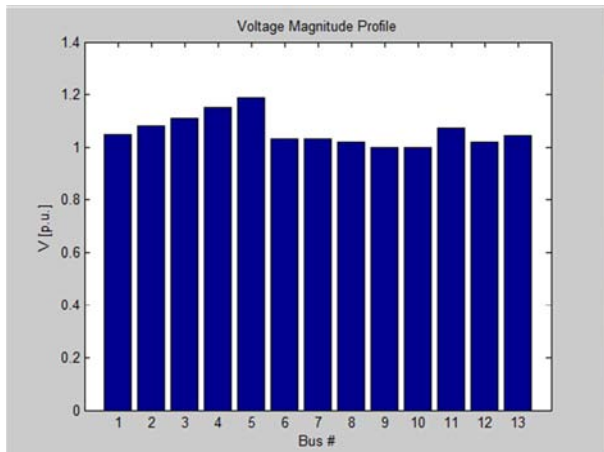


Figure 3. Voltage magnitude profile of Northern Nigeria.

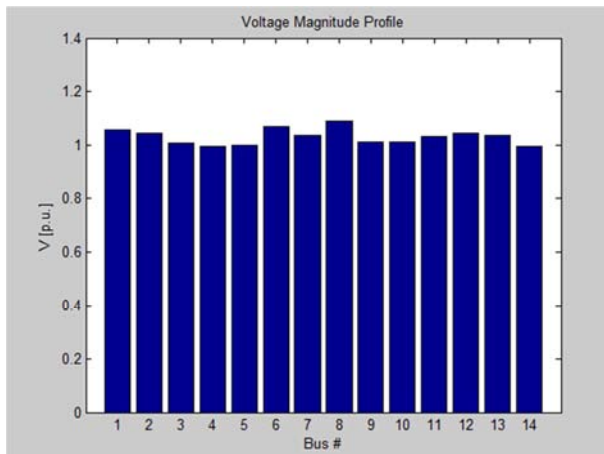


Figure 4. Voltage magnitude profile of IEEE 14 bus test.

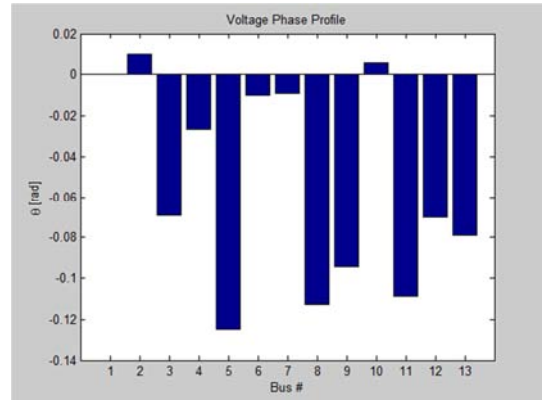


Figure 5. Voltage phase Profile of Northern Nigeria.

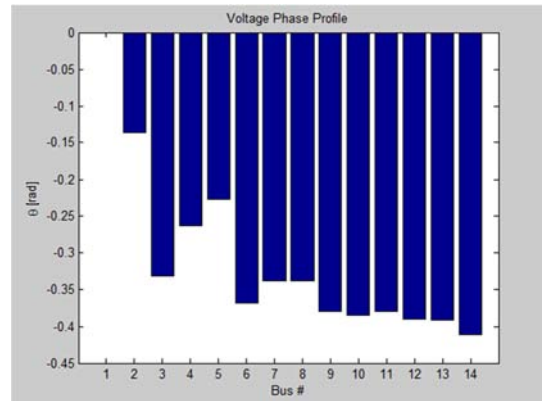


Figure 6. Voltage Phase Profile of IEEE 14 bus test.

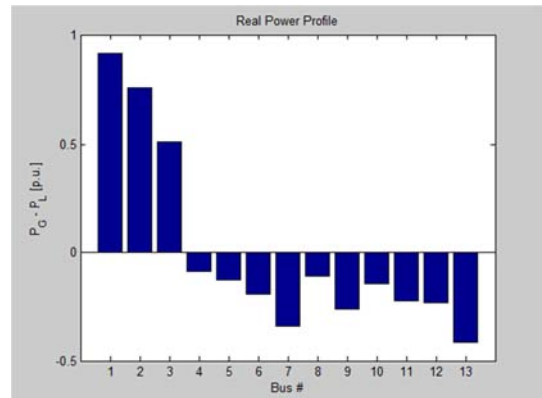


Figure 7. Real Power Profile of Northern Nigeria.

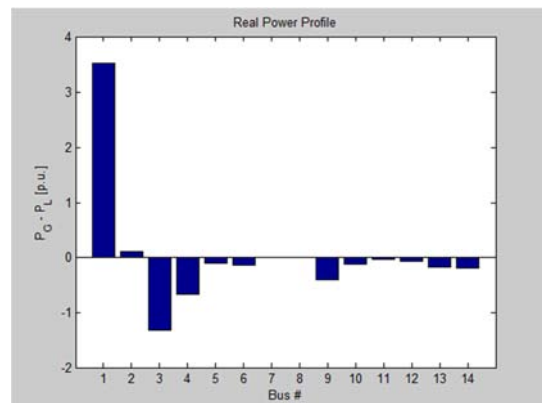


Figure 8. Real power profile of IEEE 14 bus test.

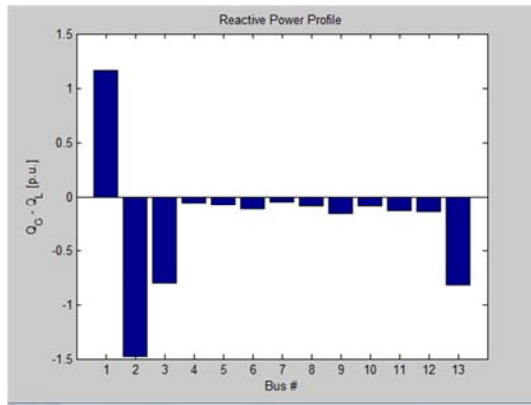


Figure 9. Reactive power profile of Northern Nigeria.

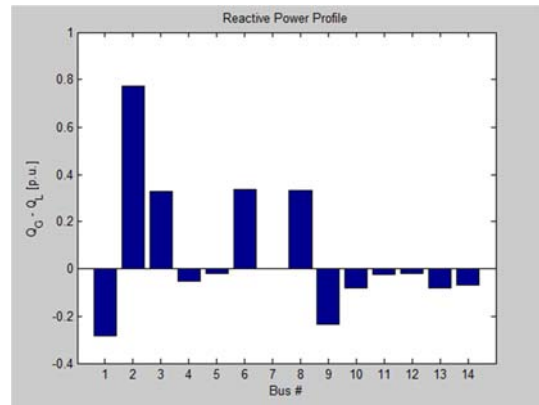


Figure 10. Reactive power profile of IEEE 14 bus test.

Table 1. Solution Statistics.

DESCRIPTION OF ITEM	IEEE 14 BUS	NORTHERN NIGERIA
Number of Iterations	9	4
Maximum P Mismatch [p.u]	0	0
Maximum Q Mismatch [p.u]	0	0
Power rate [MVA]	100	100

Table 2. Power Flow Result of Northern Nigeria.

Bus	V [P.u]	Phase [rad]	P _{Gen} [P.u]	Q _{Gen} [P.u]	P _{Load} [P.u]	Q _{Load} [P.u]
Bus 01	1.05000	0.00000	0.91476	1.1616	0.00000	0.00000
Bus 02	1.00100	0.00994	0.75600	-1.4766	0.00000	0.00000
Bus 03	1.02100	-0.06914	0.51300	-0.8082	0.00000	0.00000
Bus 04	1.03400	-0.02651	0.00000	0.00000	0.08900	0.05500
Bus 05	1.11480	-0.12489	0.00000	0.00000	0.13000	0.08000
Bus 06	1.03280	-0.01000	0.00000	0.00000	0.19400	0.12000
Bus 07	1.03510	-0.00915	0.00000	0.00000	0.33900	0.04900
Bus 08	1.09950	-0.11266	0.00000	0.00000	0.11400	0.09000
Bus 09	1.05290	-0.09417	0.00000	0.00000	0.26000	1.16100
Bus 10	1.00470	0.00575	0.00000	0.00000	0.14600	0.09000
Bus 11	1.05710	-0.10890	0.00000	0.00000	0.22600	0.14000
Bus 12	1.02040	-0.07080	0.00000	0.00000	0.23600	0.14600
Bus 13	0.99807	-0.07898	0.00000	0.00000	0.41300	0.82300

Table 3. Power Flow Result IEEE 14-Bus Test System.

Bus	V [P.u]	Phase [rad]	P _{Gen} [P.u]	Q _{Gen} [P.u]	P _{Load} [P.u]	Q _{Load} [P.u]
Bus 01	1.06000	0.00000	3.35730	0.78985	0.00000	0.00000
Bus 02	1.00090	-0.11932	0.57784	0.30000	0.30380	0.17780
Bus 03	0.93206	-0.33419	0.00000	0.40000	1.31880	0.26600
Bus 04	0.93066	-0.25988	0.00000	0.00000	0.66920	0.05600
Bus 05	0.94205	-0.22069	0.00000	0.00000	0.10640	0.02240
Bus 06	0.96224	-0.39544	0.00000	0.24000	0.15680	0.10500
Bus 07	0.94209	-0.36556	0.00000	0.00000	0.00000	0.00000
Bus 08	0.98501	-0.35556	0.00000	0.24000	0.00000	0.00000
Bus 09	0.91460	-0.42345	0.00000	0.00000	0.41300	0.02324
Bus 10	0.91087	-0.42733	0.00000	0.00000	0.12600	0.08120
Bus 11	0.93046	-0.41503	0.00000	0.00000	0.04900	0.02520
Bus 12	0.93675	-0.42244	0.00000	0.00000	0.08540	0.02240
Bus 13	0.92694	-0.42495	0.00000	0.00000	0.18900	0.08120
Bus 14	0.89044	-0.45658	0.00000	0.00000	0.20860	0.07000

Table 4. Line Flows of Northern Nigeria.

From Bus	To Bus	Line	P _{Flow} [P.u]	Q _{Flow} [P.u]	P _{Loss} [P.u]	Q _{Loss} [P.u]
Bus 06	Bus 07	1	-0.57320	-1.15370	0.00031	-0.00739
Bus 06	Bus 10	2	-0.51126	1.20420	0.00577	-0.12186
Bus 10	Bus 04	3	0.08968	-0.24788	0.00068	-0.30288
Bus 06	Bus 12	4	0.89046	-0.17058	0.0072	-0.45108
Bus 12	Bus 13	5	0.41568	0.65089	0.000268	-0.17211
Bus 09	Bus 12	6	-0.073601	1.17010	0.00744	-0.14694
Bus 09	Bus 11	7	0.22651	-0.35827	0.00051	-0.49827
Bus 08	Bus 09	8	-0.24494	0.54136	0.00456	-0.43144
Bus 05	Bus 08	9	-0.13000	-0.08000	0.000094	-0.71136
Bus 01	Bus 07	10	0.91476	1.16160	0.00225	-0.03363
Bus 02	Bus 10	11	0.75600	-1.47660	0.00329	-0.0074
Bus 03	Bus 12	12	0.51300	-0.80282	0.00113	-0.00221

Table 5. Line Flows of IEEE 14 Bus Network Systems.

From Bus	To Bus	Line	P _{Flow} [P.u]	Q _{Flow} [P.u]	P _{Loss} [P.u]	Q _{Loss} [P.u]
Bus 02	Bus 05	1	0.604090	0.15190	0.022370	0.036170
Bus 06	Bus 12	2	0.115200	0.04181	0.000199	0.004150
Bus 12	Bus 13	3	0.027800	0.01526	0.000125	0.000230
Bus 06	Bus 13	4	0.267080	0.12811	0.006270	0.012340
Bus 06	Bus 11	5	0.131930	0.09165	0.002650	0.005540
Bus 11	Bus 10	6	0.080280	0.06090	0.000960	0.002250
Bus 09	Bus 10	7	0.046790	0.02282	0.000100	0.000270
Bus 09	Bus 14	8	0.113800	0.02987	0.002100	0.004470
Bus 14	Bus 13	9	-0.096900	-0.04460	0.002450	0.004990
Bus 07	Bus 09	10	0.452560	0.24844	0.000000	0.033040
Bus 01	Bus 02	11	2.278400	0.40970	0.092870	0.227430
Bus 03	Bus 02	12	-0.999710	0.00238	0.054080	0.186890
Bus 03	Bus 04	13	-0.319090	0.13162	0.009510	-0.005700
Bus 01	Bus 05	14	1.078800	0.38014	0.063960	0.214570
Bus 05	Bus 04	15	0.819200	0.00542	0.010100	0.020630
Bus 02	Bus 04	16	0.801700	0.16807	0.039300	0.084320
Bus 04	Bus 09	17	0.121150	0.08266	0.000120	0.012970
Bus 05	Bus 06	18	0.671000	0.25348	0.000000	0.126910
Bus 04	Bus 07	19	0.452560	0.06724	0.000000	0.048340
Bus 08	Bus 07	20	0.000000	0.24000	0.000000	0.010460

4.1. Discussion of Result

It can be seen that from figure 3 Bus 05, Bus 09, and Bus 11 have exceed the voltage limit of 1.05 p.u and the reactive power generated by generator 2 at Bus 02 and generator 3 at Bus 03 are high. Base on the global summary, Real power generated was 218.38MW (2.1838 p.u) and total reactive power of -111.78Mvar (-1.1178 p.u) and total Load demand was Real power 214.7MW (2.147 p.u) and Reactive power 175.4 Mvar (1.754 p.u) and total losses due to transmission line was Real power 3.678 MW (0.003676 p.u), Reactive power -287.18 Mvar (-2.8718 p.u). The reactive power loss is higher than the reactive power generated. From table 4 it can be seen that between Bus 05 to Bus 08 i.e. Line 9 the reactive power loss is high and between Bus 09 to Bus 12 i.e. Line 6 has the highest real power loss of 0.744 MW.

4.2. Conclusion

From the result discussed, one can say that the power generated in Northern Nigeria is not adequate to meet the increasing demand. However, the available power generated also suffers losses due to ageing transmission lines and other power equipment.

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