QUALITATIVE ANALYSIS OF LOAD LOSSES ON NIGERIAN 330 kV TRANSMISSION LINES

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ABSTRACT

This work aimed at providing a qualitative analysis of technical losses in transmission lines using Nigerian 330 kV lines as a case study. The specific objectives of this study include mathematical modeling of the Nigeria transmission network, incorporating long transmission lines effects on a 52-bus network. The system is modeled in DIgSILENT PowerFactory and advanced Newton-Raphson's load flow algorithm is employed to determine systems parameters of each of the 330 kV buses, hence, qualifying the evaluation of voltage profile, voltage drop, and transmission line losses. This analysis reveals variations in power generation at different locations, contributing to increased line power losses and significant voltage drops in certain bus bars. The frailest buses are identified in the northern part of the country, in areas such as Kano, Yola, Damaturu, Maiduguri, and Gombe, with voltage deviations exceeding the ±5 % of the nominal voltage level, while the strongest bus exists in the west - Egbin and Olorunsogo. The total power loss is found to correlate with the percentage line loading, with the heaviest loaded line experiencing the highest total loss such as, the Egbin-Benin line with a loading of 103.81 % experiences the highest total loss of 51.70 MW. The least efficient line in terms of power loss is Alaoji-Terminal II, which loses 34.62 % of the transmitted power. This inefficiency can be attributed to its operating conditions as it connects both the south-eastern and south-southern zones of the network but has variable power supply from both Afam, Alaoji GENCOs and Onitsha TCN.

Keywords: Buses, DIgSILENT, line losses, load flow, national grid, transmission lines.

1.0 INTRODUCTION

The rate at which power supply fails in Nigeria has reached an unprecedented level that the public is almost demanding for a state of emergency in electricity supply sector (Ogbuefi and Madueme, 2015). Nigeria faces severe electricity-related issues that are impeding its development, despite the nation's abundance of natural resources (Emeasoba *et al*., 2023). The various efforts made to rescue the power shortfall has not yielded the expected outcome (Obi *et al*., 2021). It has been found out that excessive power losses and low bus voltages militate against the operation of power system in Nigeria (Obi *et al*., 2022). These aforementioned issues were the major contributing factor in the Nigerian electric power system's ongoing power outages, volatility, and unreliability (Anumaka, 2018).

There are currently 52 buses and 64 lines on the 330 kV lines. Numerous unfinished transmission line projects, power industry reinforcement and expansion initiatives, a poor voltage profile in the majority of the grid's northern regions, the inability of the current transmission lines to move more than 5300 MW of power, as well as operational issues with voltage and frequency controls are just a few of the issues the national grid is currently grappling with. Additionally, some of the transmission lines which are fragile and radial in nature, are prone to frequent system collapse (Nwachi *et al*., 2022; Oputa *et al*., 2023). Several issues have been raised in recent years, including inadequate network arrangements in some regional work centers, control over the parameters of the transmission lines, an excessive number of overload transformers in the grid system, frequent destruction of 330 kV transmission lines across the nation, and using the transmission lines beyond their limit. (Onohaebi and Omodamwen, 2010). 40 % of Nigerians, or about 77 million people, lacked access to affordable, dependable, and sustainable electricity in 2017. Plans were made over the long term to enhance the Nigerian electricity industry in response to these problems. Three major objectives are included in these: a capacity expansion target of 30 GW of installed on-grid capacity by 2030, of which 13.8 GW will come from grid-connected renewables (corresponding to 45 % of total capacity and 30 % of generation, respectively); a universal electrification target of 2040; and a 90 % electrification target of 2030 (Roche *et al.*, 2020).

The specific objectives of this study were to model Nigeria transmission network for long transmission lines and the fifty-two (52) bus network using DIgSILENT PowerFactory; to perform advanced Newton – Raphson's load flow algorithm to find the parameters of each 330 kV bus; and to evaluate the voltage profile, voltage drop and each transmission line losses, quantifying the frailest and strongest buses of the network.

2.0 SUMMARY OF LITERATURE REVIEW

Okakwu *et al*. (2017) conducted a load-flow assessment on the Nigerian 330 kV system, which includes 36 transmission lines, 11 generating stations, and 32 buses. Information obtained from the defunct Power Holding Company of Nigeria (PHCN) was analyzed using the Newton-Raphson iteration approach. MATLAB/SIMULINK software was used to run the simulations. The results showed that in order to achieve optimal line usage, the current 330 kV grid network in Nigeria must be compensated for its significant line losses using reactive power sources, such as Flexible Alternating Current Transmission Systems (FACTS) devices. Matthew *et al.* (2018), which examined Nigeria's 330 kV national grid losses both with and without the use of a static variable compensator (SVC) and suggested using the SVC to address power quality problems, particularly transmission loss. He modeled the Nigerian 28-bus power system using MATLAB/SIMULINK and data from the PHCN power control center in Oshogbo, along with two Static VAR compensators. The active power losses for both cases were estimated from the simulation results and contrasted using a graph and bar chart. The comparison revealed that SVC significantly reduced the real power loss in the power system. Ofoma and Okonkwo (2021) employed the Newton-Raphson iterative algorithm to perform load flow analysis on the existing 58 bus in order to calculate the real and reactive power flow, bus voltages, and line power losses in the 330 kV network. Six buses out of the 58 that were simulated failed to meet the required voltage range of 0.95 pu to 1.05 pu.

The losses on a transmission line are one of the determining factors of the line's capacity. The line loss factor is required to determine the cost of electrical energy as the line itself acts as a load to the power system. Hence study like this is required to determine the nature of the losses in the line and identify the causes of the losses which is a step towards line losses reduction, increase in lines efficiency and availability of electrical energy at the consumer end. To this end, this research employed DIgSILENT PowerFactory which combines reliable and flexible system modeling capabilities with cutting-edge algorithms and a novel database concept for qualitative analysis of load losses on Nigeria 330 kV transmission lines. It was carried out by utilizing Unified Power Flow Controller (UPFC) FACTS device and the continuation power flow method to clear the violated buses along the transmission lines.

3.0 METHODOLOGY

The materials used for this work are DIgSILENT PowerFactory, line data from National Control Center, Osogbo, and HP Windows 10 laptop.

3.1 Mathematical Model of Nigerian 330 kV Long Transmission Line.

For a long transmission line, the constants cannot be lumped as it will introduce lots of error; hence they are assumed to be distributed. It is convenient to make the ABCD constants which are called generalized circuit constants of a transmission line to be approximately equal to the following expressions as stated in (Kothari and Nagrath, 2009; Bansal, 2019);

$$\mathrm{A} = \mathrm{D} \approx \left(1 + \frac{1}{2}YZ\right) \tag{1}$$

$$\mathrm{B} \approx Z\left(1 + \frac{1}{6}YZ\right) \tag{2}$$

$$\mathrm{C} \approx Y\left(1 + \frac{1}{6}YZ\right) \tag{3}$$

Where *ABCD* are generalized circuit constants of a transmission line, *Z* is line impedance, *Y* is line shunt admittance.

Substituting Equations (1) to (3) into equation of a two-bus model;

$$P_R = \frac{|V_S||V_R|}{|Z|\left|1+\frac{1}{6}YZ\right|}\angle\cos(\beta-\delta) - \frac{\left|1+\frac{1}{2}YZ\right|}{|Z|\left|1+\frac{1}{6}YZ\right|}|V_R|^2\angle\cos(\beta-\alpha) \quad (4)$$

$$Q_R = \frac{|V_S||V_R|}{|Z|\left|1+\frac{1}{6}YZ\right|}\angle\sin(\beta-\delta) - \frac{\left|1+\frac{1}{2}YZ\right|}{|Z|\left|1+\frac{1}{6}YZ\right|}|V_R|^2\angle\sin(\beta-\alpha) \quad (5)$$

Where R_R is the receiving-end real power, Q_R is the receiving-end reactive power, V_S is the sending-end voltage per phase, V_R is the receiving-end voltage per phase, β/α is the phase shift and δ is the phase angle between V_S and V_R.

3.2 Adaptive Newton-Raphson's Load Flow Model

The general expression for power as stated in (Gupta, 2015; Obi *et al*., 2021; Obi *et al*., 2022) is given as;

$$P_i - jQ_i = V_i^* I_i = V_i^* \sum_{k=1}^{n} Y_{ik} V_k \quad (6)$$

Let i and k denote the sending-end and receiving-end bus respectively.

For any i-th bus;

$$V_i = V_i e^{j\delta i}, \text{then } V'_i = V_i e^{-j\delta i}, and\ V_k = V_k e^{j\delta k}, and\ Y_{ik} = Y_{ik} e^{-j\theta ik} \quad (7)$$

where, V_i is the voltage at the i-th bus, V_k is the voltage at the k-th bus, Y_{ik} is the mutual admittance between i-th and k-th bus, δ is the phase angle of the bus voltage and θ is an admittance angle.

Substituting, V'_i, V_k and Y_{ik} into Equation (6);

$$P_i - jQ_i = V'_i \sum_{k=1}^{n} V_i V_k Y_{ik} e^{-j(\theta_{ik}+\delta_i-\delta_k)} \quad (8)$$

$$Thus\ P_i = Real\ V'_i \sum_{k=1}^{n} V_k Y_{ik} = \sum_{k=1}^{n} V_i V_k Y_{ik} \cos(\theta_{ik}+\delta_i-\delta_k) = V_i V_i Y_{ii}\cos\theta_{ii} + \sum_{k=1}^{n} V_i V_k Y_{ik} \cos(\theta_{ik}+\delta_i-\delta_k) \quad (9)$$

$$and\ Q_i = imaginary\ V'_i \sum_{k=1}^{n} V_k Y_{ik} = \sum_{k=1}^{n} V_i V_k Y_{ik} \sin(\theta_{ik}+\delta_i-\delta_k) = V_i V_i Y_{ii}\sin\theta_{ii} + \sum_{k=1}^{n} V_i V_k Y_{ik} \sin(\theta_{ik}+\delta_i-\delta_k) \quad (10)$$

For i = 2, 3, 4, n because bus 1 is slack bus.

The equation in polar form becomes;

$$\begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \vdots \\ \Delta P_n \\ \Delta Q_2 \\ \Delta Q_3 \\ \vdots \\ \Delta Q_n \end{bmatrix} = \left[\begin{array}{cccc:cccc} \frac{\partial P_2}{\partial \delta_2} & \frac{\partial P_2}{\partial \delta_3} & \cdots & \frac{\partial P_2}{\partial \delta_n} & \frac{\partial P_2}{\partial V_2} & \frac{\partial P_2}{\partial V_3} & \cdots & \frac{\partial P_2}{\partial V_n} \\ \frac{\partial P_3}{\partial \delta_2} & \frac{\partial P_3}{\partial \delta_3} & \cdots & \frac{\partial P_3}{\partial \delta_n} & \frac{\partial P_3}{\partial V_2} & \frac{\partial P_3}{\partial V_3} & \cdots & \frac{\partial P_3}{\partial V_n} \\ \vdots & \vdots & & \vdots & \vdots & \vdots & & \vdots \\ \frac{\partial P_n}{\partial \delta_2} & \frac{\partial P_n}{\partial \delta_3} & \cdots & \frac{\partial P_n}{\partial \delta_n} & \frac{\partial P_n}{\partial V_2} & \frac{\partial P_n}{\partial V_3} & \cdots & \frac{\partial P_n}{\partial V_n} \\ \hdashline \frac{\partial Q_2}{\partial \delta_2} & \frac{\partial Q_2}{\partial \delta_3} & \cdots & \frac{\partial Q_2}{\partial \delta_n} & \frac{\partial Q_2}{\partial V_2} & \frac{\partial Q_2}{\partial V_3} & \cdots & \frac{\partial Q_2}{\partial V_n} \\ \frac{\partial Q_3}{\partial \delta_2} & \frac{\partial Q_3}{\partial \delta_3} & \cdots & \frac{\partial Q_3}{\partial \delta_n} & \frac{\partial Q_3}{\partial V_2} & \frac{\partial Q_3}{\partial V_3} & \cdots & \frac{\partial Q_3}{\partial V_n} \\ \vdots & \vdots & & \vdots & \vdots & \vdots & & \vdots \\ \frac{\partial Q_n}{\partial \delta_2} & \frac{\partial Q_n}{\partial \delta_3} & \cdots & \frac{\partial Q_n}{\partial \delta_n} & \frac{\partial Q_n}{\partial V_2} & \frac{\partial Q_n}{\partial V_3} & \cdots & \frac{\partial Q_n}{\partial V_n} \end{array}\right] \begin{bmatrix} \Delta \delta_2 \\ \Delta \delta_3 \\ \vdots \\ \Delta \delta_n \\ \Delta V_2 \\ \Delta V_3 \\ \vdots \\ \Delta V_n \end{bmatrix} \quad (11)$$

Putting Equation (11) in compacted form as stated in (Chukwulobe *et al*., 2022);

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix} = \begin{bmatrix}J_1 & J_2\\ J_3 & J_4\end{bmatrix}\begin{bmatrix}\Delta\delta\\ \Delta V\end{bmatrix} \tag{12}$$

Where J_1, J_2, J_3, and J_4 are elements of Jacobian matrix and can be determined from power Equations (13) to (19) as follows;

The off - diagonal and diagonal element of J_1 are;

$$\frac{\partial P_i}{\partial \delta_k} = V_i V_k Y_{ik}\sin(\theta_{ik} + \delta_i - \delta_k) \;\; for\ k \neq i \tag{13}$$

$$and\ \frac{\partial P_i}{\partial \delta_i} = -\sum_{\substack{k=1\\k\neq 1}}^{n} V_i V_k Y_{ik}\sin(\theta_{ik} + \delta_i - \delta_k) \tag{14}$$

The off - diagonal and diagonal element of J_2 are;

$$\frac{\partial P_i}{\partial V_k} = V_i Y_{ik}\cos(\theta_{ik} + \delta_i - \delta_k) \;\; for\ k \neq i \tag{15}$$

$$\frac{\partial P_i}{\partial V_k} = 2V_i Y_{ii}\cos\theta_{ii} + \sum_{k=1}^{n} V_k Y_{ik}\cos(\theta_{ik} + \delta_i - \delta_k) \tag{16}$$

The off - diagonal and diagonal element of J_3 are;

$$\frac{\partial Q_i}{\partial \delta_k} = -V_i V_k Y_{ik}\cos(\theta_{ik} + \delta_i - \delta_k) \quad for\ k \neq i \tag{17}$$

$$and\ \frac{\partial Q_i}{\partial \delta_i} = \sum_{\substack{k=1\\k\neq 1}}^{n} V_i V_k Y_{ik}\cos(\theta_{ik} + \delta_i - \delta_k) \tag{18}$$

The off - diagonal and diagonal element of J_4 are;

$$\frac{\partial Q_i}{\partial V_k} = V_i Y_{ik}\sin(\theta_{ik} + \delta_i - \delta_k) \;\; for\ k \neq i \tag{19}$$

$$\frac{\partial Q_i}{\partial V_k} = 2V_i Y_{ii}\sin\theta_{ii} + \sum_{k=1}^{n} V_k Y_{ik}\sin(\theta_{ik} + \delta_i - \delta_k) \tag{20}$$

The elements of the Jacobian matrix are computed with the latest voltage estimate and computed power.

3.3 Calculation of Line Flows and Line Losses

Figure 1 shows a nominal л model of lines connecting *i*-th and *k*-th buses.

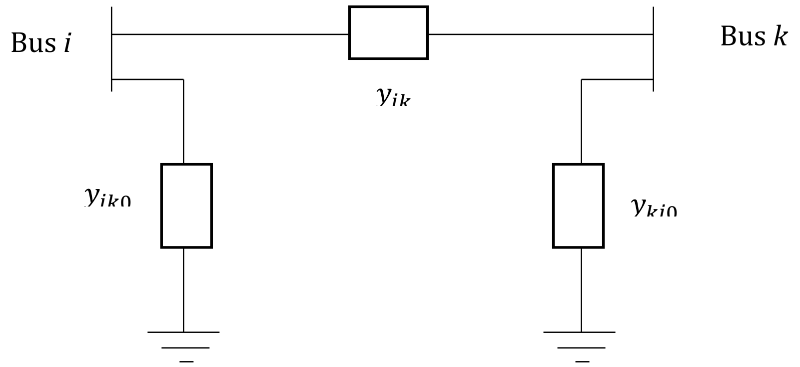

Figure 1: л - Representation of a line between two buses.

Current flowing from bus *i* towards bus *k*.

$$I_{ik} = [V_i - V_k]y_{ik} + V_i y_{ik0} \tag{21}$$

Where V_i and V_k are the bus voltages at the buses i and k respectively which are already calculated from the power flow studies.

The power flow in the line i- k at the bus i is given as;

$$S_{ik} = P_{ik} + jQ_{ik} = V_i I'_{ik} = V_i (V'_k - V'_i) y'_{ik} + V_i V'_i y_{ik0} \quad (22)$$

Similarly, the power flow in the line i- k at bus k is given as;

$$S_{ki} = V_k (V'_k - V'_i) y_{ik0} + V_k V'_k y'_{ik} \quad (23)$$

The power losses in the $(i$- $k)$th line are given by the sum of the power flow determined from Equations (22) and (23), the power losses in the $(i$- $k)$th line $= S_{ik} + S_{ki}$. The total transmission losses can be computed by summing all the line flows (Gupta, 2015).

3.4 Nigeria 330-kV 52 Bus Transmission Network

The Nigeria 330kV has expanded from 16 power stations, 45 transmission lines; 41-bus system to 24 generating power stations, 64 transmission lines and 52-bus power system, hence it requires re-evaluation of its power evacuation capabilities and assessment of the impact of adding more power infrastructures to the new grid.

According to (Igbinovia, 2014), the national grid's voltage control policy is 330 kV (+5 %/-15 %), 132 kV (+10 %/-15 %) for sub-transmission, and 50 Hz (4 %) for the equivalent frequency control. The 9,454.8 km of 330 kV and the 8,985.28 km of 132 kV transmission lines that make up Nigeria's national grid are interconnected with 24 power plants. The grid connects these stations with 52 buses, 64 transmission lines—either dual or single circuit lines—and 4 control centers, including a National Control Center (NCC) at Osogbo and three supplemental control centers at Benin, Shiroro, and Egbin.

The single-line diagram of the existing 330 kV Nigeria transmission network used as the case study is as shown in Figure 2, while Figure 3 shows the network model in DIgSILENT PowerFactory. Among other power generating stations, the Egbin bus was selected as the reference bus because it produces the lowest power disparity in the network; as a result, the generator with the highest power should be utilized as the reference bus.

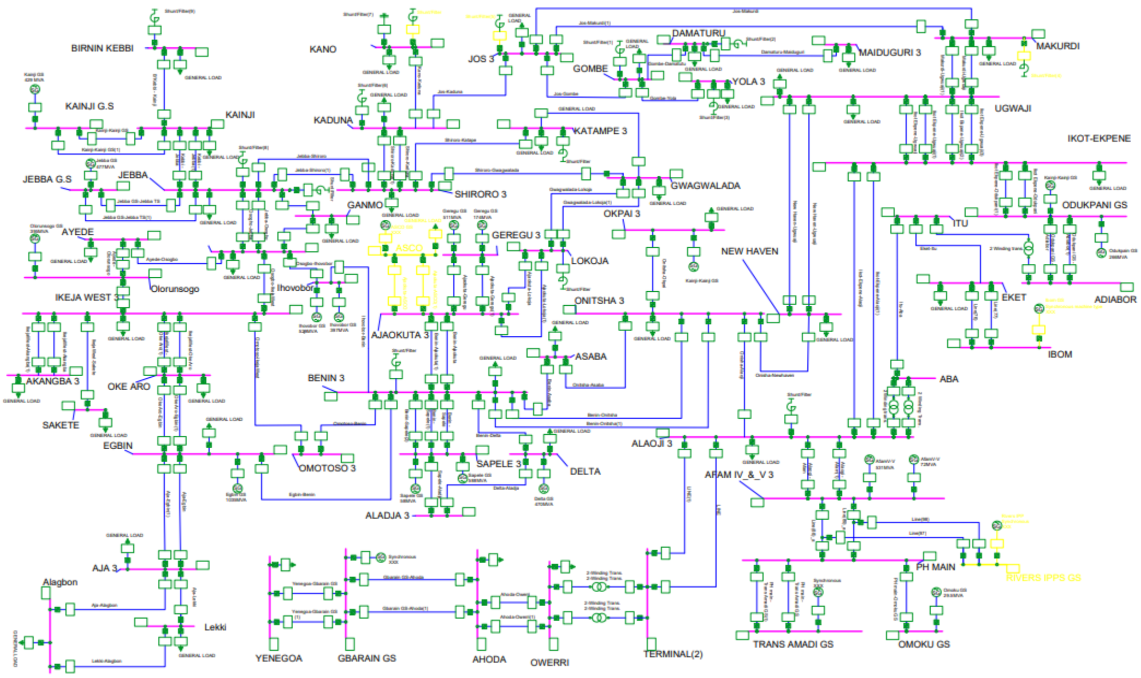

Figure 2: One-line diagram of 52 - bus system

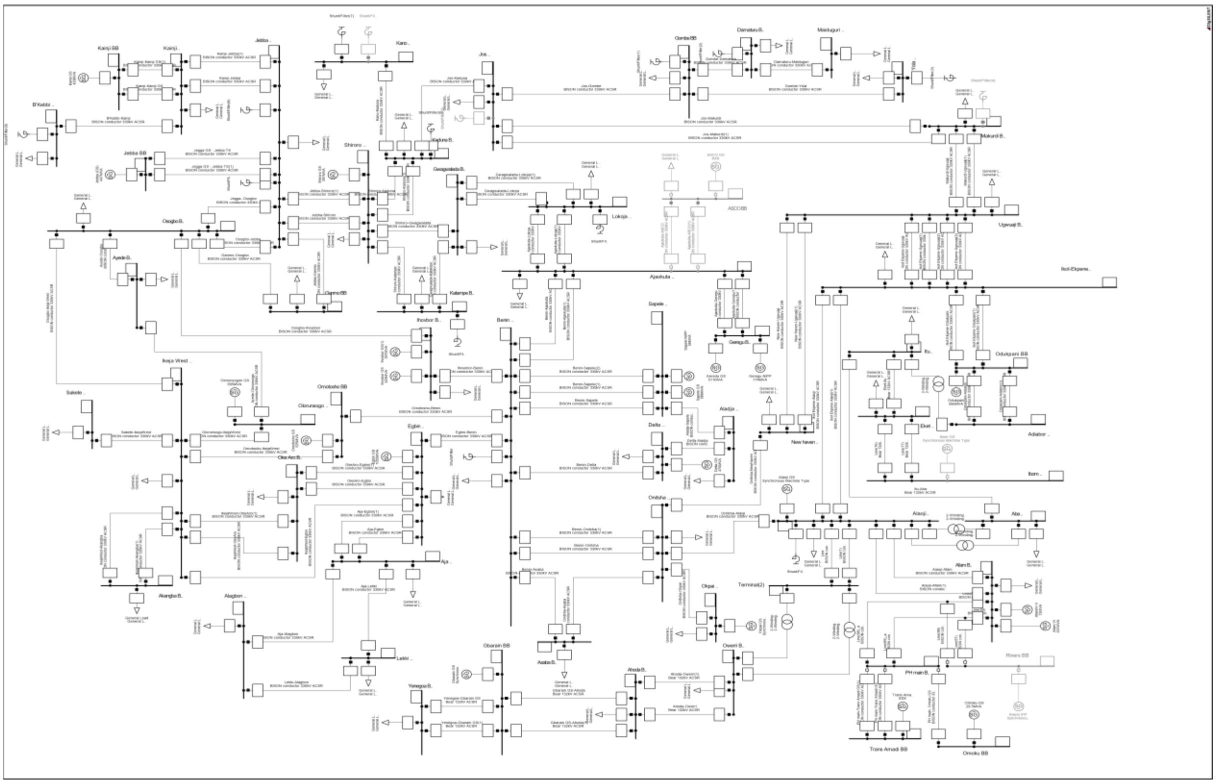

Figure 3: DIgSILENT PowerFactory network model of Nigeria transmission lines

With the pertinent data acquired from the National Control Center (NCC) Osogbo (NERC, 2022), the algorithm was created and the analysis was performed using Newton Raphson's power-flow based approach.

4.0 RESULTS AND DISCUSSION

The result of Figure 4 illustrates the load flow results of the network. Attached to it, is the Key to understand the colour codes of each element. Key 1 shows the colour code representing the voltage level at each bus, while Key 2 shows the colour code for the loading level of the equipment in the grid. Egbin thermal power plant which in this case is acting as the reference power station compensated for the excess load impressed on the grid and as a result became overloaded.

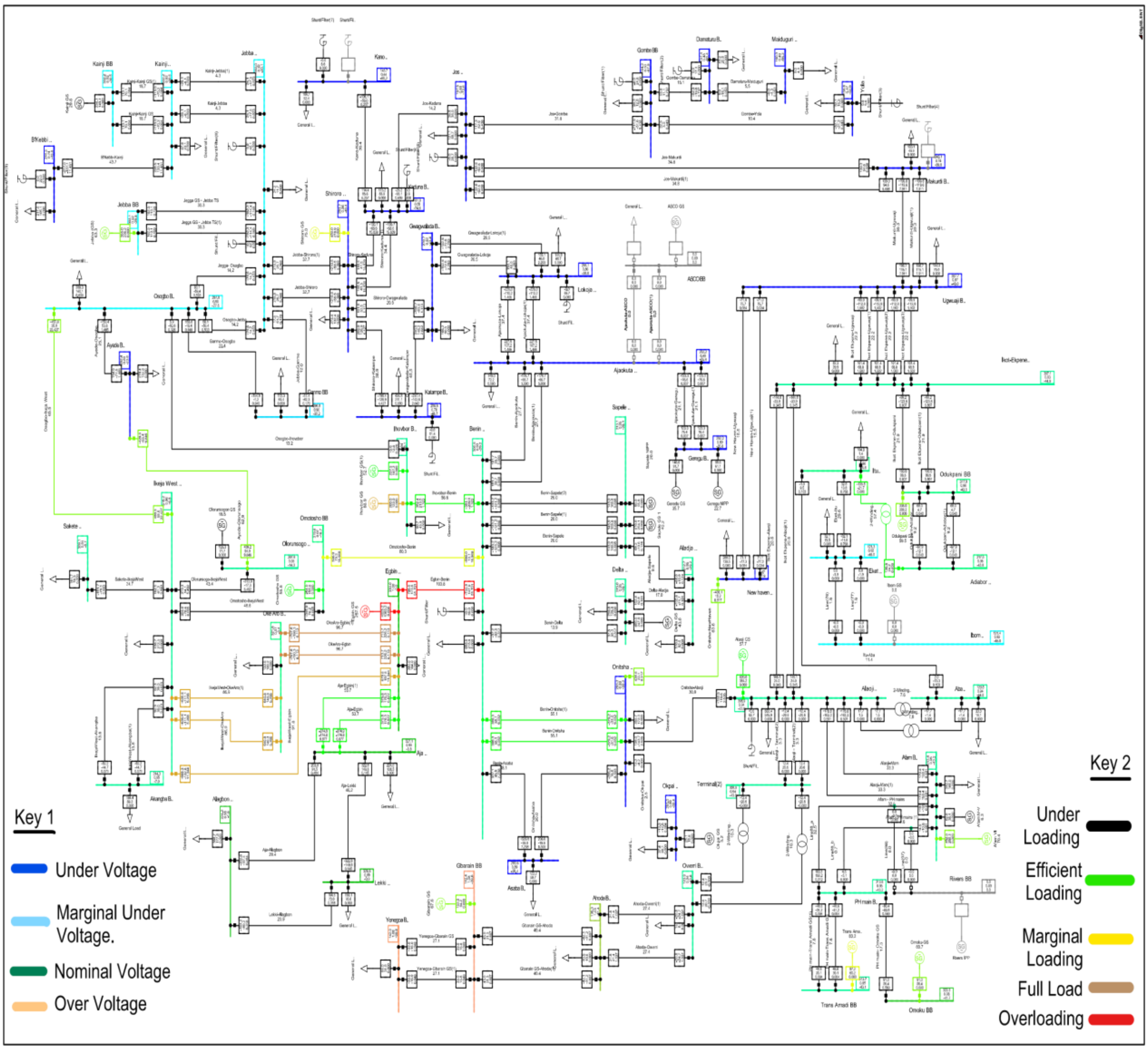

Figure 4: Grid view of load flow result obtained from DIgSILENT PowerFactory

A summarized result of active power, reactive power and complex power flow at each bus and the line flow is presented in Figure 5. The total active power loss from the power flow program solutions by Newton Raphson method is 203.620 MW and that of the reactive power loss is - 1556.448 Mvar.

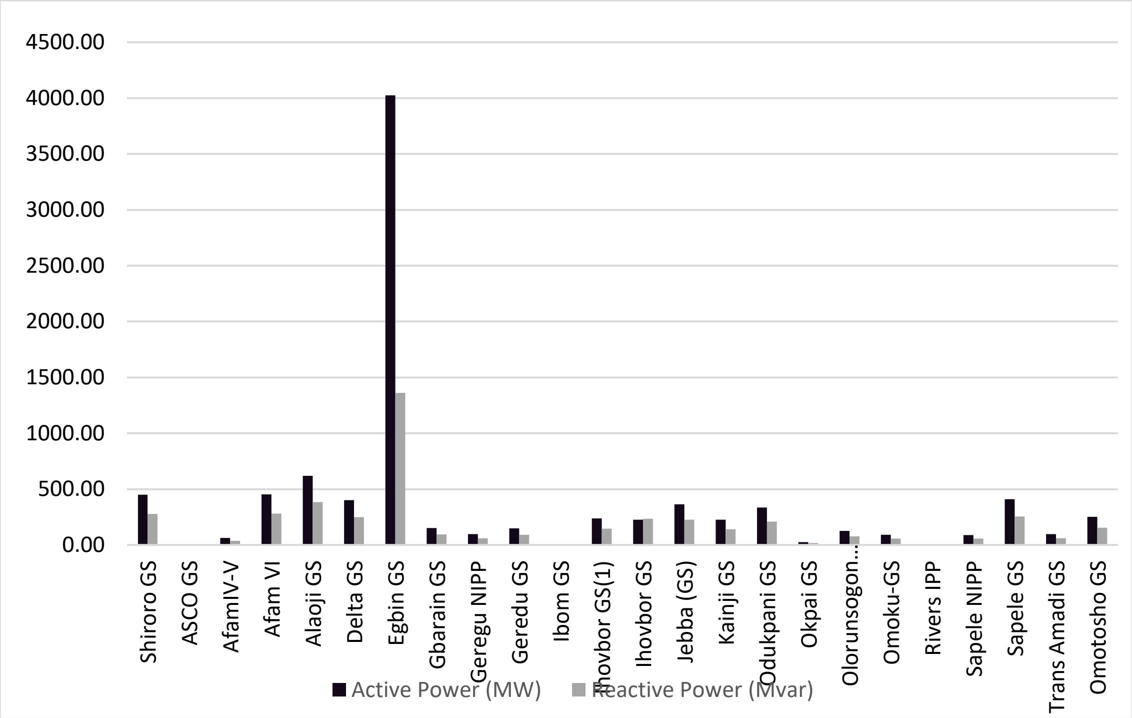

Figure 5: Power generation

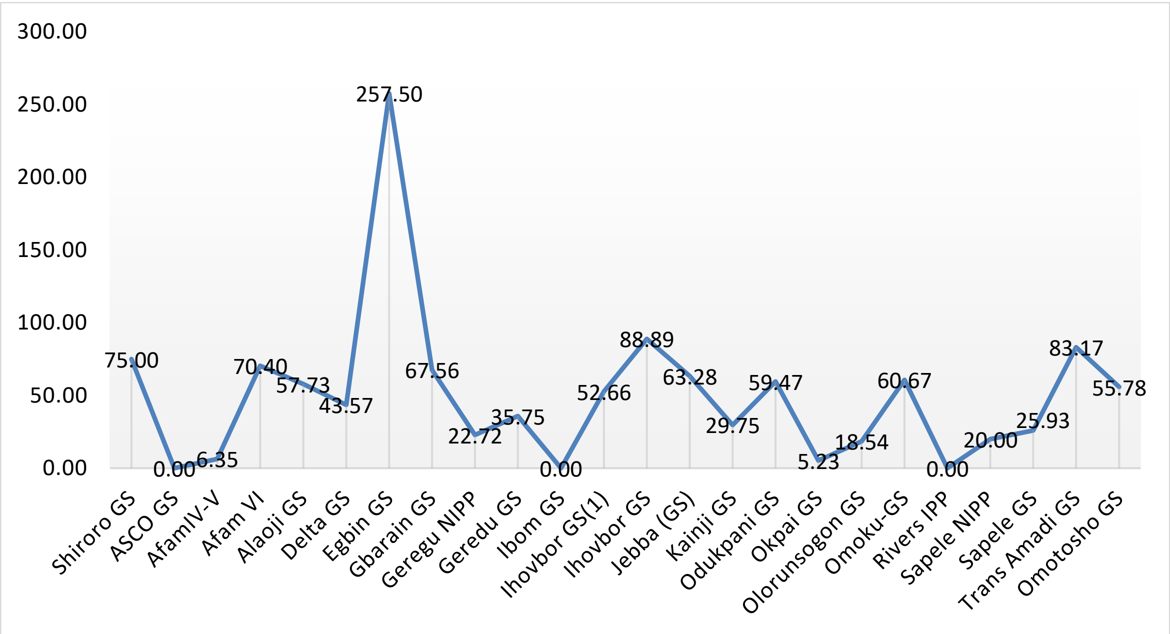

Figure 6: Loading (%)

Egbin power station as represented in Figure 5 bears greater burden in the grid, generating at a level of (4025.17 + j1360.19) MVA which overloads the station to 257.50 % of its rated value. This excessive overloading as shown in Figure 6 can be attributed to its place on the grid as the reference generator hence compensating for the excessive loading placed on the grid. Following Egbin power station is Alaoji power station supplying power at a value of (620.00 + j384.24) MVA, and at 57.73 % loading, Afam VI at (452.00 + j280.12) MVA with loading of 70.40 %. The grid voltage profile violations are shown in Figure 7.

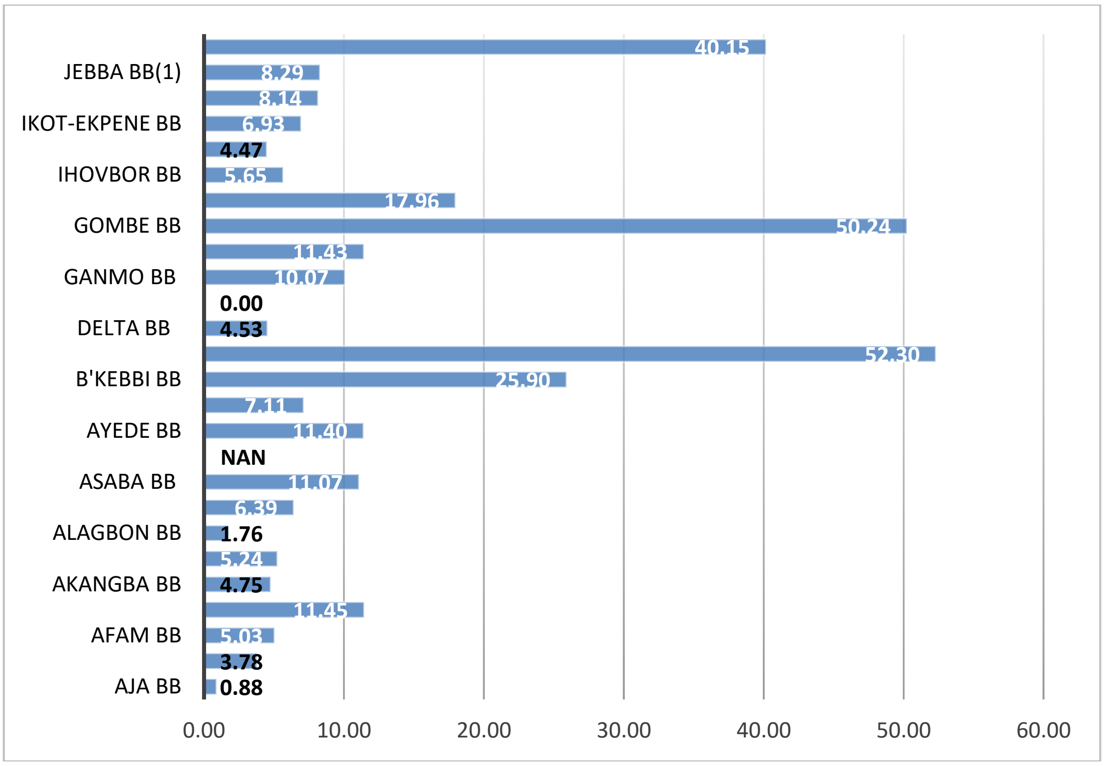

Figure 7a Voltage violation (%)

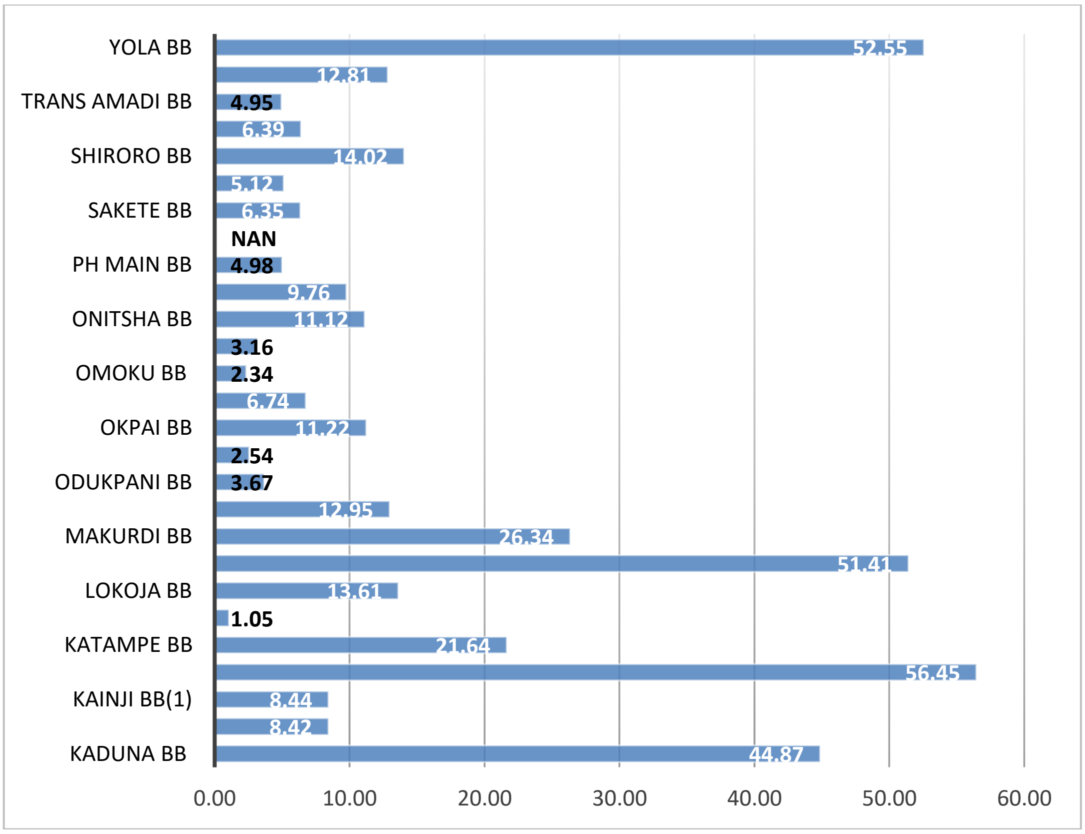

Figure 7b Voltage violation (%)

Results as represented in Figure 7 revealed that some buses witnessed an unacceptable voltage drop of below

15 % nominal value especially those in the north. The voltage violations are majorly due to the fact already established that all major generating stations are located far away down-country, leaving the north to depend on very long transmission lines for power supply and hence, suffers from extreme voltage drop. Those buses crossing the 10 % mark but not passing 15 % violations when studied closely, were observed to serve as primary or secondary terminals connecting the Power station populated areas (western and southern parts) and the North. Hence this voltage drops are as a result of the large load and long lines connected to these buses. Voltage deviations on other busbars were below the 10 % mark which is acceptable. Egbin BB has 0.00 % voltage violation excited at the nominal voltage of 330kV, followed by Ajah BB with violation of 0.88 % at 327.10 kV. This is as expected, Egbin hosts the largest powers source and Ajah BB is directly connected to Egbin BB. The charts for line losses and loading are shown in Figure 8.

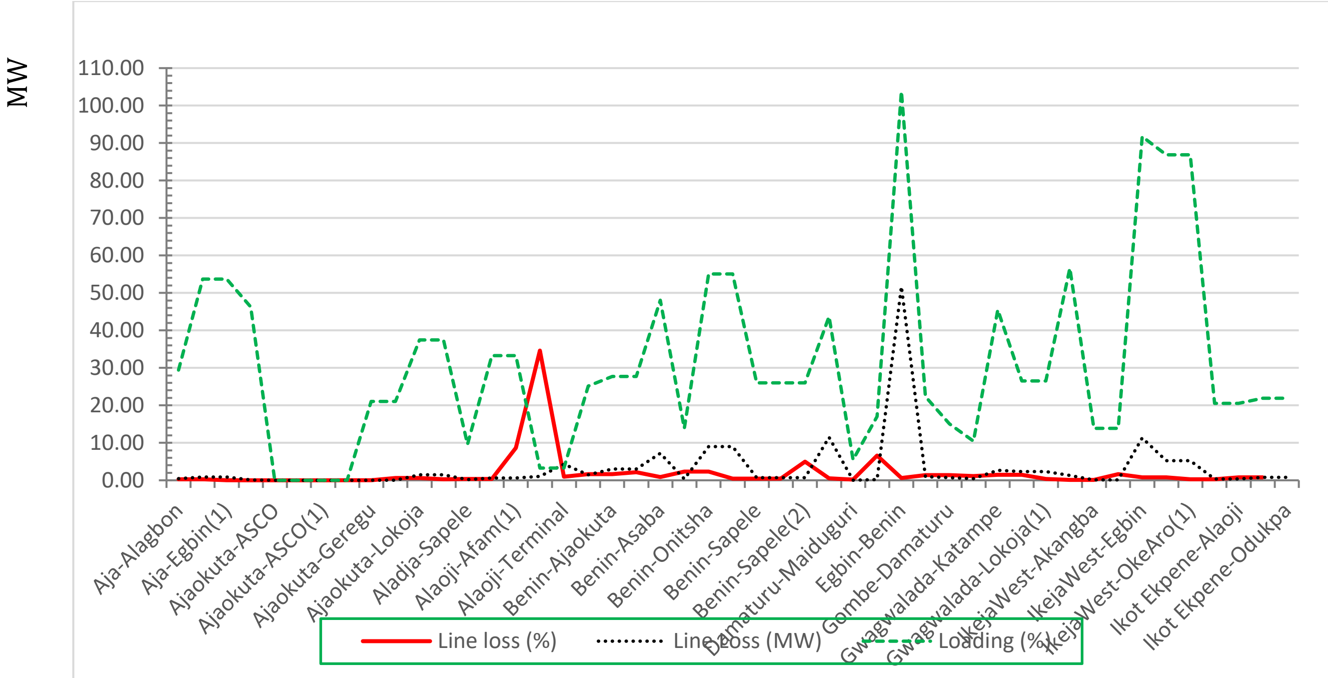

Figure 8a Line power loss and loading

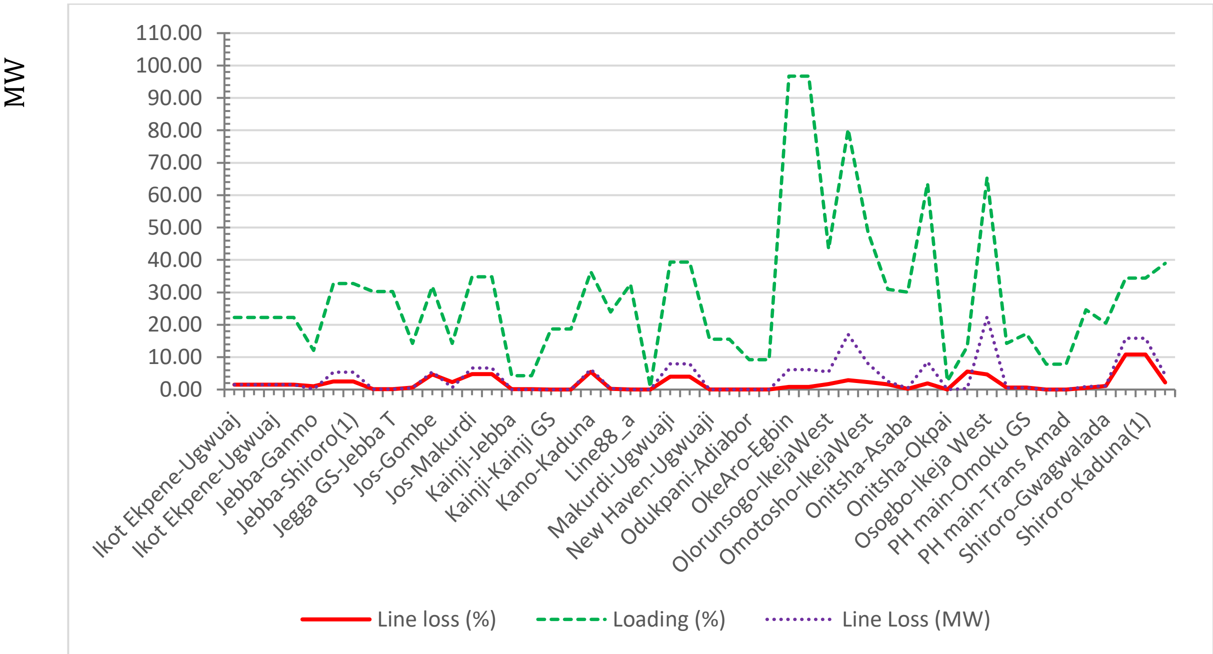

Figure 8b Line power loss and loading

Figures 8a and 8b show the lines' power loss and at the same time explain how the power loss relate to the loading impressed on the lines. The percentage power loss is of great priority here because it gives a measure of how efficient the transmission lines are. Egbin-Benin transmission line experienced the highest total Power loss of value 51.70 MW which is 6.57 % of the transmitted power and at a loading of 96.72 %. Though the power loss is the highest, the percentage of power loss is below average and hence the line can be considered to be efficient. But placing the spotlight on the loading condition, this line is marginally overloaded. Next is Oshogbo-Ikeja west line which is at 22.43 MW, 4.67 % Power loss and 65.45 % loading. This Line is another efficient line considering the percentage power loss. The least efficient line with respect to power loss is Alaoji-Terminal (2)1 line, connecting Alaoji GS 330 kV bus bar with the Alaoji 330/132 kV Transformer Substations which is supplying Owerri 132 kV substation. This line has a total Power loss of 4.30 MW, though with relatively small power loss, this value is at 34.62 % of the total Power transmitted on this line and is undesirable. The loading of this line is quite low; at a value of 3.31 %.

In summary, lines worth mentioning are those above 5 % power loss and these include; Alaoji-Terminal (2)1, Shiroro-Kaduna twin lines, Alaoji-Terminal (2), Egbin-Benin, Osogbo-Ihovobor, Kano-Kaduna, and B'Kebbi-Kainji lines with percentage power loss values of 34.62 %, 10.81 %, 8.62 %, 6.57 %, 5.60 %, 5.47 %, and 5.01 % respectively. The total power loss on the other hand did not follow this array with Egbin-Benin and Osogbo-Ikeja West lines topping the list with values of 51.70 MW and 22.43 MW respectively as mentioned earlier, followed by Omotosho-Benin, Shiroro-Kaduna twin lines, B'Kebbi-Kainji, Ikeja West-Egbin, Benin-Onitsha twin lines, Onitsha-New Haven, Omotosho-Ikeja West lines with power loss figures of 16.97 MW, 15.84 MW, 11.45 MW, 9.03 MW, 8.52 MW, and 8.07 MW respectively. For line loading, apart from Egbin-Benin line which was overloaded to 103.81%, Oke Aro-Egbin twin power line, Ikeja West-Egbin line, Ikeja West-Oke Aro twin lines and Omotosho-Benin line are all loaded inefficiently at 96.72 %, 91.75 %, 86.88 % and 80.33 % of their rated capacity. While Osogbo-Ikeja West, Onitsha-New Haven, Ihovbor-Benin lines, Benin-Onitsha twin lines and Ajah-Egbin twin lines are all loaded to an efficient level. The rest of the lines are all under loaded.

5.0 CONCLUSION

Majority of the generating stations and lines are efficiently loaded (within 50 % to 80 %), and the bus bars are at nominal voltages (less than 5 % voltage deviation). Because of the load compensating function of Egbin power plant it became overloaded over 200 % with 2 other generating stations marginally loaded, 9 generating stations efficiently loaded and 9 generating station under loaded. The locations of the power generating stations in this grid is not even, this among other factors are the major causes of line power loss and the serious voltage drop most of the buses are experiencing. This excessive voltage drop can be seen in buses in the northern part of the country. With respect to this, it was observed that Kano bus is the frailest bus terminal followed by Yola, Damaturu, Maiduguri and Gombe buses respectively. Voltage deviation in these buses were above 50 % of the nominal voltage level of 330 kV. On the other hand, the strongest bus exists in the west which is the Egbin bus with voltage deviation of 0 %. The total power loss tends to follow side by side with the percentage line loading, hence the line with the heaviest loading attainted the highest total loss also; bringing Egbin-Benin line (51.70 MW and 103.81 % respectively) to the top of the list. But the same cannot be said about the percentage power loss, as this value tends to behave independently with respect to the loading on the lines but shows the ability for the lines to transfer power with minimum loss. Alaoji-terminal (2)1 is the least efficient line loosing 34.62 % of the power transmitted and could be due to the line's design factors or the operating conditions. The research work therefore recommends that; another line to ease the loading and power loss on Egbin-Benin, Oke Aro-Egbin twin and Ikeja West-Egbin transmission lines are needed; renewable power stations such as wind and solar power plant should be sited in the North in order to create an even spread of power source in the grid, reduce the power loss due to long lines and create a better voltage profile on the buses; optimal placement capacitor banks should be encouraged in order to reduce the excessive voltage drop in the northern part of the grid; power stations working far below capacity in the Nigerian national grid should have their generators overhauled and brought online to ease the load concentration on Egbin power plant.

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