International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 6 ǁ 2022 ǁ PP. 122-129

Investigation of Voltage Stability of the Nigerian 330kv Transmission Network Using Newton Raphson Method

Christopher O. Ahiakwo[1]; Dikio C. Idoniboyeobu[2]; Sepiribo L. Braide[3]; Chukwuka L. Onita[4],
Electrical Engineering Department, Rivers State University

ABSTRACT
The Nigerian 330KV transmission network is characterized with voltage instability due to unplanned electrical energy demand as well as the use of obsolete transmission network. The system is often driven close to or even beyond voltage stability limits. This often leads to frequent fluctuations in the power flow, which in turn results in power losses and system collapse, especially in the congested networks. The study looked at the frequent occurrence of voltage instability in the system. Newton-Rapson load flow method was used to determine vunerable buses in close proximity to voltage collapse having operating voltages violating the statutory stability limit of 313.5kv-346.5kv. The system was modeled in NEPLAN Software. Buses in close proximity to voltage collapse having operating voltages less than 95% of the operating margin are; Maiduguri bus, Jalingo bus, Yola bus, Damaturu bus and Gombe bus, their corresponding bus operating voltages are; 87.14% 88.58% , 88.96%, 88.53% , 90.20% respectively. Hence, the Nigerian 330KV transmission network is currently experience instability because of these aforementioned buses operating below its statutory stability limit. Urgent placement of reactive power compensation is needed to stabilize the system operation and avoid fluctuation in the power flow or resultant collapse.

Date of Submission: 20-05-2022 Date of acceptance: 03-06-2022

I. INTRODUCTION

The 330KV voltage level is considered as high voltage in Nigeria and referred to as the grid system. The transmission company of Nigeria (TCN) is in charge of the management of the Nigerian grid system. Due to the high level of increased electrical power demand in the country and the transfer of energy between various locations, the transmission lines are often driven close to or even beyond voltage and stability limits which can cause fluctuations in power flows through the transmission line with resulting effects as increased power loss especially in congested lines that may trigger cascading outages thereby consequently resulting in system collapse.

The Nigeria's transmission network infrastructure in the power sector continues to be challenged as it still remains the weak link in the electricity supply chain which causes the 330KV network to be characterized with major problems such as voltage instability, in regards to this, it is imperative that the sector be improved with more sophisticated technology to foster continuity of the system and capable of withstanding disturbances, enhancement and monitoring and control actions (Ezekiel, *et al.*, 2019)

The Nigerian grid system is conventionally zoned into the Nigerian national four (4) geographical areas in conformity with operational structure of the electric utility. The Area 1 consists of three (3) hydro power stations, Area 2 consist of thermal power stations while Area 3 and Area 4 consist of gas power stations. The Nigerian national grid is characterized with so many inadequacies ranging from poor voltage profile in most part of the network especially the northern region, deteriorated radial and fragile grid network with inadequate dispatch and control infrastructure, in addition with frequent system collapse. (Aribi, *et al.*, 2015) These problems can be addressed with the application of automated smart grid technology with fast monitoring of voltage instability. The 330KV Nigerian transmission grid system is experiencing currently major social impacts and the continuous growths in environmental requirements which have called for expansion of the existing grid but required energy demand optimization technique for an automated system for reliable power system.

The Newton Raphson (NR) method is an iterative technique for solving a set of simultaneous nonlinear equations in an equal number of unknowns and can generally be formulated either in rectangular form or in polar form. The polar coordinate form is widely used in practice because it results in fewer equations than the total number of equations in rectangular form. The N-R method requires fewer iterations to achieve convergence, requires less computation time, therefore computation costs are lower and convergence is certain. It is more accurate and less sensitive to factors such as Slack bus selection, regulating transformers, etc. The number of iterations required with this method is independent of the network size of the power grid. The size of network determines the number of resulting iterations though both small and large system require up to two to three iterations for solution of higher accuracy.

II. REVIEW OF RELATED WORKS

Ngang and Aneke (2021) proposed enhanced voltage stability of the Nigerian 330kv transmission network using ANN controller. They modelled by running load flow in the network where the buses that fall short of the statutory minimum voltage stability range of 0.95 through 1.05. Designed a conventional SIMULINK model for the voltage stability enhancement using ANN controller. ANN controller was incorporated in the system which resulted to an increase in the system per unit volts to 1.047.

Swetha and Sudarshana (2014) proposed voltage stability assessment in power network using artificial neural network**.** 5 bus, IEEE 14 bus and 30 bus power system was tested for voltage stability using artificial neural network. The result from the testing showed feasibility of proposed network in predicting FVSI for the load buses in power system network as secure or insecure. The proposed method indicated a good agreement between targeted output and ANN output for different buses which were tested. Training process for the ANN took long time but testing process only required few seconds for the system. The proposed approach provided fast computation of voltage stability indicator FVSI and can analyze any unknown load patterns.

Ezekiel and Engala (2019) proposed enhancing the voltage stability of the Nigeria 330KV 48 bus power system network using modal/eigenvalue analysis. The study is based on the application of modal analysis on the 48 bus 330KV Nigerian network using PSAT MATLAB Toolbox. The Modal/Eigenvalue analysis technique was used to investigate the stability of the 48 bus Nigeria power network system. The modal method calculates the smallest eigenvalue and all the associated eigenvectors of the Jacobian matrix using the steady state mode. The magnitude of the smallest eigenvalue estimates the proximity of the system to the voltage instability. The participation factor can be employed to identify the bus that provides the highest contribution to the instability of the system. The 48 bus Nigerian network was simulated under static loads and changing loads and modal/eigenvalue analysis was performed on the system under each of these conditions. It was found that increase in loads at the three selected weakest buses reduced the stability of the system. Results obtained in the study proved that reactive power compensators were able to drastically improve the stability profile of the 48 bus Nigeria network and even rescue the system at the event of voltage instability especially the ones caused by change in loads.

Adepoju *et al.* (2017) proposed application of static synchronous series compensator (SSSC) to the 330KV Nigeria transmission network for voltage control. According to them, longitudinal power systems of Nigerian 330KV transmission network have steady state problems of congestion, voltage limit violation and high active power loss. That static synchronous series compensator (SSSC) currently in use for solving mesh problems has not been applied to Nigeria 330KV power network. He then propose it that the work involves the use of SSSC for solving problems associated with Nigeria 330KV longitudinal power network using voltage magnitude as performance metrics. Steady state modeling of power system and SSSC modeling produced two sets of non-linear algebraic equations that were solved simultaneously using Newton-Rapson algorithm (NR) method and was implemented using MATLAB. His results of power flow analysis of Nigeria 330KV transmission network without SSSC showed that, there was voltage limit violation of ± 10% at bus 16 Gombe (0.8973p.u.) however, the results with incorporation of SSSC showed that, the SSSC was effective in eliminating voltage limit violation, control bus voltage magnitude to specified value (bus 14 from 0.9462p.u. to 1.00p.u.) and reduced network active power loss by more than 5% of base case (93.87MW). Therefore, SSSC is effective in solving steady-state problems of longitudinal power systems.

Okakwu *et al.* (2018) proposed voltage profile improvement of the Nigerian 330KV transmission network using statcom. According to them, that the work is aimed at investigating the effect of statcom on the Nigerian 330KV transmission network. The Newton-Rapson iteration algorithm was used to solve the non-linear problem, which was modeled using MATLAB Software. The result shows that some of the buses fell outside the statutory limit of $0.95p.u \leq V \leq 1.05p.u$, which includes: 16 (Kano, 0.8721pu), 17 (Kaduna, 0.9046pu), 18 (Jos, 0.8731pu), 19 (Gombe, 0.8735pu), 20 (Yola, 0.8580) and 21 (Katampe, 0.9167pu). On incorporating STATCOM on these weak buses, the voltage magnitude was improved as follows: 16 (Kano, 1.0000pu), 17 (Kaduna, 0.9678), 18 (Jos, 1.0000pu), 19 (Gombe, 1.0188pu), 20 (Yola, 1.0106pu) and 21 (Katampe, 1.0000pu). The improvement of the bus voltage profiles, ranging from 7% at Kaduna (bus 17) to 17.8% at Yola (bus 20), with the proposed STATCOM enables the voltage profiles to fall within the acceptable statutory limits. The result of this simulation shows the effectiveness of the STATCOM in improving the bus voltage of the Nigerian 330KV transmission grid.

III. MATERIALS AND METHOD

The materials used include: Generating station data, transmission line data, transmission station load data, Nigerian 330kV grid network diagram and Neplan software. The data utilized in this rearch were collected from Transmission Company of Nigerian (TCN). The data comprises of 14 PV generators, 79 transmission lines, 34 load buses, bus rated voltage, impedance and susceptance of transmission line, load MW and Mvar. Egbin G/S is taken as the slack bus. These data are shown in Table 1.1 and 1.2 below.

Table 1.1: 330KV System Bus Data, 48-Bus Network

(Source: Transmission Company of Nigerian)

S/N	Bus Name	Volt. Magnit. (KV)	Volt. Magnit. (p.u.)	Angle(Deg)	Bus Type/Code	Bus Loads		Generation			
						P_{Li} (MW)	Q_{Li} (MVar)	P_{Gi} (MW)	Q_{Gi} (MVar)	Q_{min}	Q_{max}
1	Shiroro G/S	330	1.00	24.65	P-V (2)	207	95	450	220	-200	200
2	Afam G/S	330	1.00	28.34	P-V(2)	295	157.5	800	590	-210	222
3	Ikot Ekpene	324.72	0.984	26.56	P-Q (3)	321	160.5	0	0	0	0
4	Ayede	328.812	0.9964	36.84	P-Q (3)	275	206	0	0	0	0
5	Ikeja West	328.977	0.9969	36.74	P-Q	635	474	0	0	-150	0
6	Aja	329.967	0.9999	34.34	P-Q (3)	300	205	0	0	0	0
7	Egbin G/S	330	1.00	0	Slack (1)	0	0	0	0	-200	210
8	Ajaokuta	328.317	0.9949	26.56	P-Q (3)	230	115	0	0	0	0
9	Benin	329.868	0.9996	21.38	P-Q (3)	383	150	0	0	-150	0
10	Lokoja	328.218	0.9946	26.56	P-Q (3)	300	150	0	0	0	0
11	Akangba	328.944	0.9968	39.79	P-Q (3)	300	250	0	0	0	0
12	Sapele G/S	330	1.00	26.56	P-V (2)	50	25	120	90	-180	200
13	Aladja	329.934	0.9998	34.99	P-Q (3)	100	70	0	0	0	0
14	Delta G/S	330	1.00	26.98	P-V (2)	497	253	620	250	-100	120

Table 1.2: 330KV System Line Data, 48-Bus Network (February, 2021 Operational Data)

(Source: Transmission Company of Nigerian)

S/N	Code	From (Bus Name)	To (Bus Name)	Line Impedance		Susceptance B (Siemens)	Line Length (KM)
				R (Ω)	X (Ω)		
1	KIJ	Kainji	Jebba Line 1	3.159	26.811	0.0368	81
2	K2J	Kainji	Jebba Line 2	3.159	26.811	0.0368	81
3	K3R	Kainji	Birnin Kebbi	12.090	102.610	0.0096	310
4	B8J	Jebba G.S	Jebba T.S 1	0.315	2.424	0.4057	8
5	B9J	Jebba G.S	Jebba T.S 2	0.315	2.424	0.4057	8
6	J3R	Jebba	Shiroro Line 1	9.516	80.764	0.0122	244
7	J7R	Jebba	Shiroro Line 2	9.516	80.764	0.0122	244
8	J1H	Jebba	Osogbo Line 1	6.123	51.967	0.0189	157
9	J2H	Jebba	Osogbo Line 2	6.123	51.967	0.0189	157
10	J3G	Jebba	Ganmo Line	3.393	28.797	0.0342	87
11	H3G	Osogbo	Ganmo	2.730	23.170	0.0426	70
12	H2A	Osogbo	Ayede	4.485	38.065	0.0259	115
13	HIW	Osogbo	Ikeja West	9.828	83.412	0.0118	252

14	H7V	Osogbo	Ihovbor	8.814	74.806	0.0132	226

A. Method of Analyzing Voltage Stability

A typical power grid consists of a large number of interconnected buses. Electricity generated from the source is fed into a bus. There may be some buses with no generating facilities and some buses may be connected to VAR generators. The excess power on some buses is transported via transmission lines to the buses with poor performance. It is important to critically analyze voltage stability in the power grid, especially in a complex and large interconnected network.

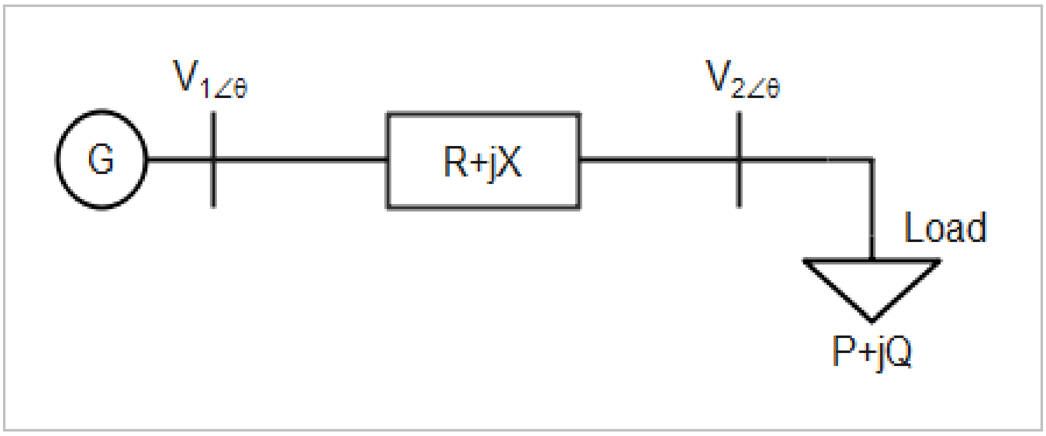


Figure 1.1: Single Line Diagram of a Two Bus System

Figure 1.1 shows a 2-bus system which consists of a load fed from a source via a transmission line. For any ith bus.

Let $V_i = V_{\mathrm{i}}\angle\delta_i$ and $V_i^* = V_{\mathrm{i}}\angle-\delta_i$, (1.1)

For kth bus,

$V_k = V_{\mathrm{k}}\angle\delta_k$ And $Y_{ik} = Y_{\mathrm{ik}}\angle\theta_{ik}$ (1.2)

The real and reactive power injected in the network is given by=

$S_i = V_i I_i^* = P_i + jQ_i$ (1.3)

Therefore, equation (3.3) becomes;

$I_i = \left(\frac{S_i}{V_i}\right)^* = \frac{P_i - jQ_i}{V_i^*}$ (1.4)

In general, injected current at any bus I take the form

$I_i = Y_{i1}V_1 + Y_{i2}V_2 + \dots\dots\dots + Y_{in}V_n$ For i = 1,2,……,n

$I_i = \sum_{k=1}^{n} Y_{ik}V_k$ For i = 1,2,……,n

Substituting sum of I_i into equation (3.4) yields equation (3.5)

$I_i = \frac{P_i - jQ_i}{V_i^*} = \sum_{k=1}^{n} Y_{ik}\, V_k$ (1.5)

$P_i - jQ_i = V_i^*(\sum_{k=1}^{n} Y_{ik}\, V_k)$ (1.6)

$P_i - jQ_i = V_i^*(\sum_{k=1}^{n} Y_{ik}\, V_k\angle\delta_k + \theta_{ik} - \delta_i)$ (1.7)

$P_i - jQ_i = \sum_{k=1}^{n}|Y_{ik}||V_{\mathrm{i}}||V_{\mathrm{k}}|\,[\cos(\delta_k + \theta_{ik} - \delta_i) + j\sin(\delta_k + \theta_{ik} - \delta_i)]$ (1.8)

Separating (3.8) into real and imaginary parts we have,

$P_i = \sum_{k=1}^{n}|Y_{ik}||V_{\mathrm{i}}||V_{\mathrm{k}}|\cos(\delta_k + \theta_{ik} - \delta_i)$ (1.9)

$Q_i = -\sum_{k=1}^{n}|Y_{ik}||V_{\mathrm{i}}||V_{\mathrm{k}}|\sin(\delta_k + \theta_{ik} - \delta_i)$ (1.10)

Where

Y_{ik} = the admittance matrix

P_i = the injected real power

Q_i= the injected reactive power

δ_i= phase angle

Expanding (3.9) and (3.10) in Taylors series neglecting higher order terms we have

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \frac{\Delta P_n^{(k)}}{\Delta Q_2^{(k)}} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \begin{bmatrix} \begin{vmatrix} \frac{\partial P_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_2^{(k)}}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_n^{(k)}}{\partial \delta_n} \end{vmatrix} & \begin{vmatrix} \frac{\partial P_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_n^{(k)}}{\partial |V_n|} \end{vmatrix} \\ \begin{vmatrix} \frac{\partial Q_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial Q_2^{(k)}}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial Q_n^{(k)}}{\partial \delta_n} \end{vmatrix} & \begin{vmatrix} \frac{\partial Q_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_n^{(k)}}{\partial |V_n|} \end{vmatrix} \end{bmatrix} \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \frac{\Delta \delta_n^{(k)}}{\Delta \left|V_2^{(k)}\right|} \\ \vdots \\ \Delta \left|V_n^{(k)}\right| \end{bmatrix} \tag{1.11}$$

The Jacobian matrix gives the linearized relationship between mall changes in voltage angle $\Delta\delta_i^{(k)}$ and magnitude $\Delta\left|V_i^{(k)}\right|$ with small change in real $\Delta P_i^{(k)}$ and reactive power $\Delta Q_i^{(k)}$ respectively.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_3 \\ J_2 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \tag{1.12}$$

Where

$J_1,\ J_2, J_3, J_4$ are the elements of the Jacobian matrix

The off-diagonal and diagonal elements of J_1 are

$$\frac{\partial P_i}{\partial \delta_k} = |Y_{ik}||V_{\mathrm{i}}||V_{\mathrm{k}}|\sin(\delta_i + \theta_{ik} - \delta_k) \tag{1.13}$$

$$\frac{\partial P_i}{\partial \delta_i} = -\sum_{\substack{k=1 \\ k\neq i}} |Y_{ik}||V_{\mathrm{i}}||V_{\mathrm{k}}| \sin(\delta_i + \theta_{ik} - \delta_k) \tag{1.14}$$

The off-diagonal and diagonal elements of J_2 are

$$\frac{\partial P_i}{\partial V_k} = |Y_{ik}||V_{\mathrm{i}}|\cos(\delta_i + \theta_{ik} - \delta_k) \tag{1.15}$$

$$\frac{\partial P_i}{\partial V_i} = 2|Y_{ii}||V_{\mathrm{i}}|cos\theta_{ii} + \sum_{\substack{k=1 \\ k\neq i}}^{n} |Y_{ik}||V_{\mathrm{k}}|\cos(\delta_i + \theta_{ik} - \delta_k) \tag{1.16}$$

The off-diagonal and diagonal elements of J_3 are

$$\frac{\partial Q_i}{\partial \delta_k} = -|Y_{ik}||V_{\mathrm{i}}||V_{\mathrm{k}}|\cos(\delta_i + \theta_{ik} - \delta_k) \tag{1.17}$$

$$\frac{\partial Q_i}{\partial \delta_i} = \sum_{\substack{k=1 \\ k\neq i}} |Y_{ik}||V_{\mathrm{i}}||V_{\mathrm{k}}| \cos(\delta_i + \theta_{ik} - \delta_k) \tag{1.18}$$

The off-diagonal and diagonal elements of J_2 are

$$\frac{\partial Q_i}{\partial V_k} = |Y_{ik}||V_{\mathrm{i}}|\sin(\delta_i + \theta_{ik} - \delta_k) \tag{1.19}$$

$$\frac{\partial Q_i}{\partial V_i} = 2|Y_{ii}||V_{\mathrm{i}}|sin\theta_{ii} + \sum_{\substack{k=1 \\ k\neq i}}^{n} |Y_{ik}||V_{\mathrm{k}}|\sin(\delta_i + \theta_{ik} - \delta_k) \tag{1.20}$$

Compute the scheduled error ΔP_i and ΔQ_i for each load

$$\Delta P_i^{(k)} = P_i^{sch} - P_i^{(k)} \tag{1.21}$$

$$\Delta Q_i^{(k)} = Q_i^{sch} - Q_i^{(k)} \tag{1.22}$$

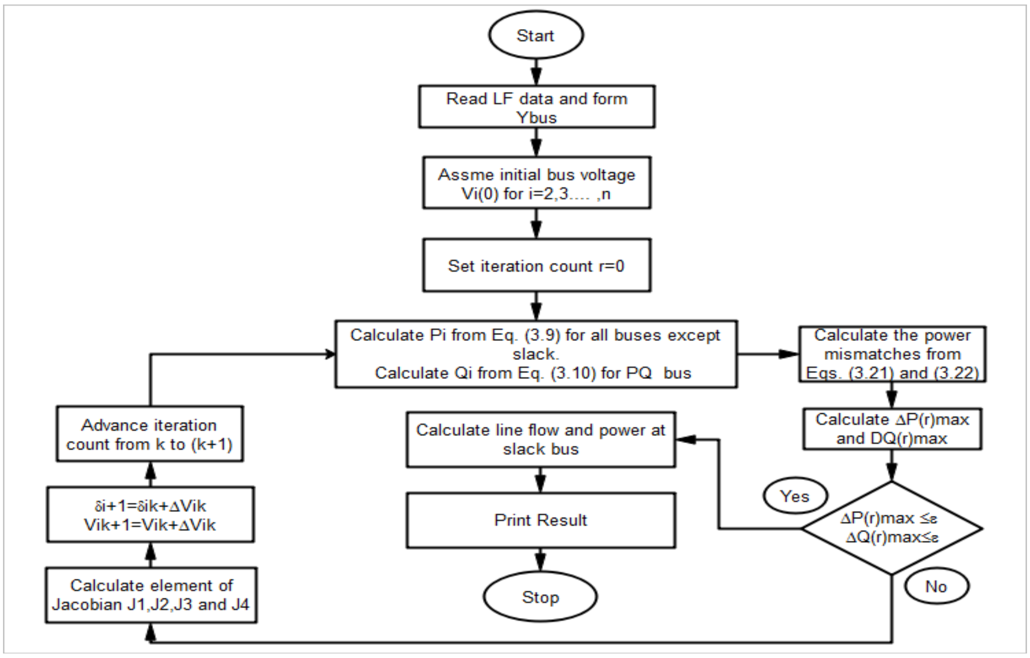


Figure 1.2: Flow-Chart for Load Flow Solution Using N-R Method

IV. RESULTS AND DISCUSSION

A. Pre-Upgrade Network Result

NEPLAN software simulation result of the modeled 330kv transmission network is presented in figure 4.1 below and refers to as Pre-upgrade network. The 5 buses with red color show the unstable state of the system.

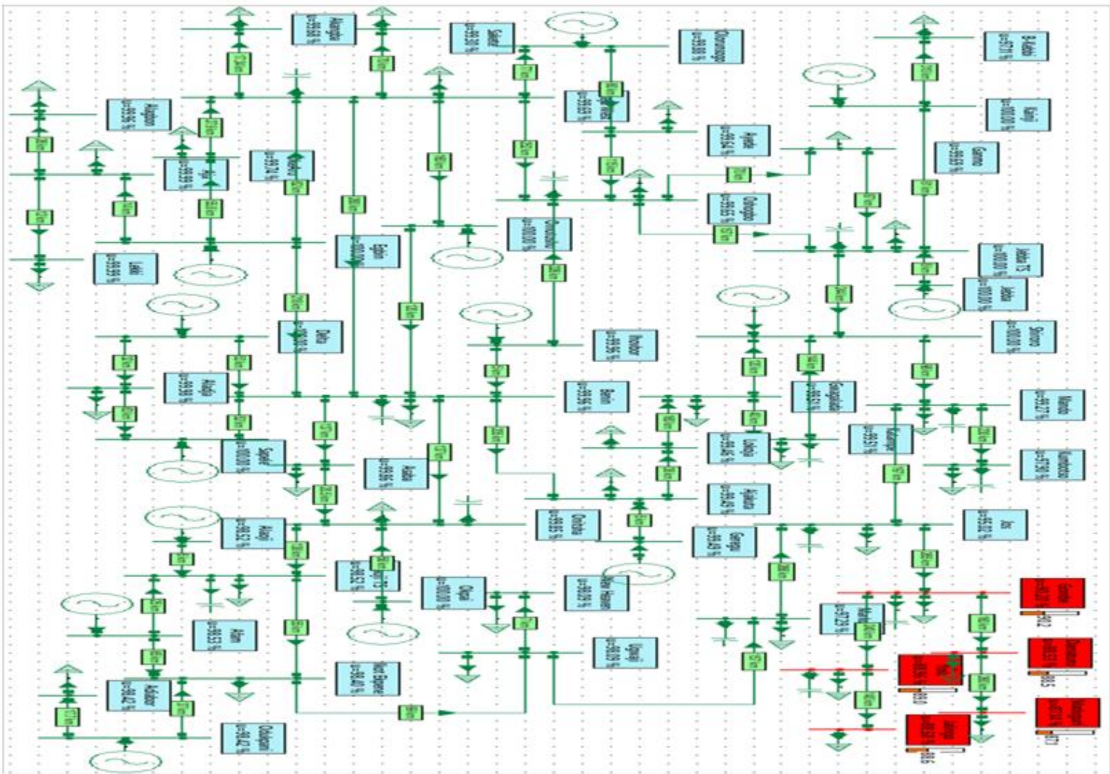


Figure 1.3: Pre-Upgrade Network Simulation in NEPLAN Software

B. Bus Operating Voltage for Pre-Upgrade Network Condition

Table 1.3 below shows the nominal and operating voltage of the system for pre-upgrade network condition.

Table 1.3: Bus Operating Voltage for Pre-Upgrade Network Condition

No	Bus Name	Nominal (kV)	Operating Voltage (KV)	Operating Voltage (P.U.)	Operating Voltage (%)
1	Adiabor	330	324.786	0.9842	98.42
2	Afam	330	325.149	0.9853	98.53
3	Aja	330	329.967	0.9999	99.99
4	Ajakuta	330	328.317	0.9949	99.49
5	Akangba	330	328.944	0.9968	99.68
6	Aladja	330	329.934	0.9998	99.98
7	Alagbon	330	329.868	0.9996	99.96
8	Alaoji	330	325.116	0.9852	98.52
9	Alaoji TS	330	325.116	0.9852	98.52
10	Asaba	330	329.538	0.9986	99.86
11	Ayede	330	328.812	0.9964	99.64
12	Benin	330	329.868	0.9996	99.96
13	B-Kebbi	330	320.463	0.9711	97.11

Table 1.3 above is the first NEPLAN simulation result of the operating voltage of the system represented as pre-upgrade network condition. The following buses (Maiduguru, Jalingo, Yola, Damaturu and Gombe), violates the bus voltage statutory limit condition of 0.95p.u - 1.05p.u (0.8714p.u, 0.8858p.u , 0.8896p.u, 0.8853p.u , 0.9020p.u) respectively.

C. Voltage Profile and Bus Number for Pre-Upgrade Network

Figure 4.2 below shows the voltage profile of the system for pre-upgrade network condition.

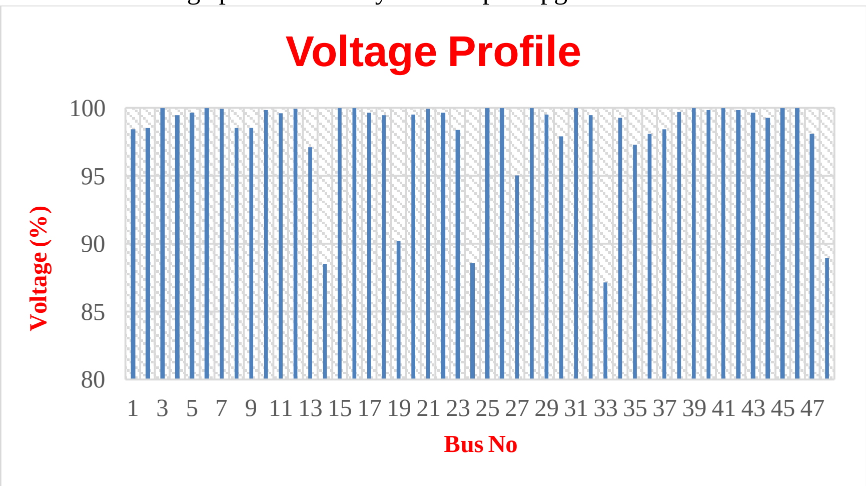
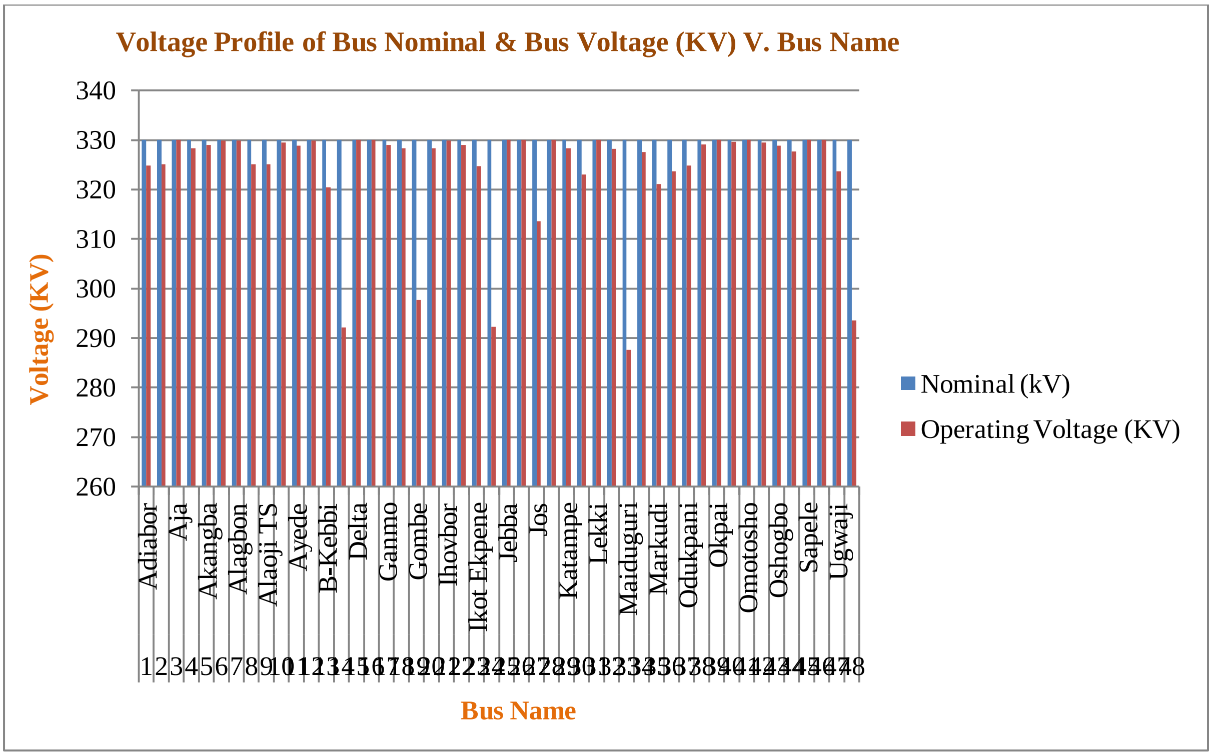


Figure 1.4: Voltage Profile for Pre-Upgrade Network Condition

Figure 1.4 above depicts the voltage maximum loadability of the pre-upgrade network. The variation of load is because of the different operating state of the bus voltages and the 5 vulnerable buses are seen to be below 90% showing that the buses are unstable. The 5 vulnerable buses IDs (14, 19, 24, 33, 48) violates the bus voltage statutory limit condition of 0.95 - 1.05p.u (88.53% 88.58%, 87.14% 88.96%, 90.20%) respectively.

D. Voltage Profile of Bus Nominal and Pre-Upgrade Voltages against Bus Name

Figure 4.3 below is the plot of voltage profile of bus nominal and voltage against bus name where the blue represent the nominal voltage (KV) while red represent bus operating voltages (KV).



The graph above depicts the maximum voltage loadability of the pre-upgrade network. The variation of load is because of the different operating state of the bus voltages and the 5 vulnerable buses are seen to be below 300KV showing that the buses are unstable.

V. Conclusion

The investigation carried out in the Nigerian 330KV transmission network showcased Buses in close proximity to voltage collapse having operating voltages less than 95% of the operating margin and they are; Maiduguri bus, Jalingo bus, Yola bus, Damaturu bus and Gombe bus, their corresponding bus operating voltages are; 87.14% 88.58% , 88.96%, 88.53% , 90.20% respectively. Hence, the Nigerian 330KV transmission network is currently experience instability because of these aforementioned buses operating below its statutory stability limit. Urgent placement of reactive power compensation is needed to stabilize the system operation before it result in a total collapse.

REFERENCES

[1]. Adepoju, G. A., Sanusi, M. A., & Tijani, M. A. (2017). Application of SSSC to the 330kv Nigerian transmission network for voltage control. Nigerian Journal of Technology (NIJOTECH), 36(4), 1258 – 1264.

[2]. Aribi, F., Mark, N. N., Ahmad, A. S., & James. G. S. (2015). Voltage Profile Enhancement of the Nigerian North-East 330kV Power Network Using STATCOM. International Journal of Advanced Research in Science, Engineering and Technology, 2(1). 8-12.

[3]. Ezekiel, N. A., & Engla, A. (2019). Enhancing the voltage stability of the Nigerian 330kv 48-bus power system network using modal/eigenvalue analysis. Journal of Information Engineering and Applications, 9(7), 2224-5782. www.iiste.org

[4]. Ngang, N. B., & Anke, N.E. (2021). Enhance voltage stability of the Nigerian 330kv transmission network using ANN controller. American Journal of Applied Science and Engineering, 2(3), 27-30. https://airjournal.org/ajase.

[5]. Okakwu, I., Emmanuel, A. O., & Patrick, A. O. (2017). Load flow assessment of the Nigeria 330-kv power system. American Journal of Electrical and Electronic Engineering, 5(4), 159-165.

[6]. Swetha, G. C., & Sudarshana, H. R. (2014) proposed voltage stability assessment in power network using artificial neural network. International journal of advanced research in electrical, electronics and instrumentation engineering, 3(3), 22-25.