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Modeling 72 bus networks with high penetration of hybrid (Solar PV and Wind) renewable energy for Nigeria's future energy sustainability and Economic Development.

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ABSTRACT:
Constant network, system collapse, and inadequate energy supply to the user connected to the network lead to the increase in the cost of energy supply by utility companies. The aim of this paper is to model a 74-bus network using ETAP as a simulation tool for analyzing the impact of hybrid renewable energy on the network for the country's energy sustainability. The reliability of the energy on the network is the priority of the penetration of solar PV and wind energy. The hybrid gives a better improvement on the network by increasing, improving, and power optimization on the network thereby dispatching economically. The inclusion of the hybrid renewable energy to the network results to stable electrical power on the network, reliable and affordable. Due to the high penetration of renewable energy into the network, the energy supply has improved, affordable, reliable, and stable. There is an increase in bus voltages on the network and generally voltage increases. This will help improve the nation's economy and sustainable development in terms of business growth, production and manufacturing, and attraction of investors.

KEYWORDS: ***Renewable Energy, Penetration, power Stability, Economic Importance and Development.***

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I. Introduction

The electrical energy network in Nigeria has been upgraded from 12 bus network to 22 buses, 32 buses, and 72 buses network comprising 22 generators, and 68 connections with different load points, the network, [1,3] uses kanji swing buses in some cases, the total installed capacity of the network is about 14,280 MW with an increase in generator to 14 generators. [3,4, 5] The economic development deeply depends on the stability of electricity in the area. The increase in energy generation, the increase in economic and social development of the nation. [6] thereby, improving the welfare of the people. [7] high penetration of renewable(hybrid) into the network gives a better effect on the bus voltage, voltage drop, energy stability, and reliability of the energy on the network and its connections with the inclusion of renewable energy on the network, energy stability is certain, economic and social development will improve and a voltage profile also improved on the network. Thus, an increase in energy generation results in end-user satisfaction with usage from the utility company. There is an increase in investment in the network due to an increase in development [8, 11, 20]. According to [1, 11] the impact of renewable energy on the existing network is numerous, starting from energy improvement and energy sustainability. It enhances effective energy delivery and equips the network with future energy considerations. It maintains that the major drawback is the issue and challenges of integration. According to [3, 14], the economic advancement of a nation is a major advantage of improving the electrical power network. According to [17, 16], high penetration of energy (renewable) to the already built electrical network reduces the costs of energy to the whitening users although it might not be immediately that most of it affects release.

II. Modelling

Modeling an electricity network of 72 buses, 14 generators, and 69 line connections is done using ETAP19.0. The load flow simulations on the network is modeled using the fast decouple method as follows
The voltage equation for $(k+1)^{th}$ iteration is

$$A(x^1) = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix}; \text{ by choosing } A(x^1) = \begin{bmatrix} J_{11} & 0 \\ 0 & J_{22} \end{bmatrix} \quad 1$$

$$\Delta P = J_{11}\Delta\delta \quad 2$$

$$\Delta Q = J_{22}\Delta|V| \quad 3$$

The principle is based on the following.

${\partial P_i}/{\partial \delta_k}$ is much larger than ${\partial Q_i}/{\partial \delta_k}$ approximately zero and
${\partial Q_i}/{\partial |V_k|}$ is much larger than ${\partial P_i}/{|\partial V_k|}$ approximately zero.
By incorporating these approximations in the Jacobian equation we have

$$\begin{bmatrix} \frac{\partial P_2}{\partial \delta_2} & \cdots & \cdots & \frac{\partial P_2}{\partial \delta_4} \\ \vdots & J_{11} & & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ \frac{\partial P_4}{\partial P_4} & \cdots & \cdots & \frac{\partial P_4}{\partial \delta_4} \end{bmatrix} \begin{bmatrix} \Delta\delta_2 \\ \vdots \\ \vdots \\ \Delta\delta_4 \end{bmatrix} = \begin{bmatrix} \Delta P_2 \\ \vdots \\ \vdots \\ \Delta P_4 \end{bmatrix} \quad 4$$

$$\begin{bmatrix} |V_2|\frac{\partial Q_2}{\partial |V_2|} & \cdots & \cdots & |V_4|\frac{\partial Q_2}{\partial |V_4|} \\ \vdots & \vdots & J_{22} & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ |V_2|\frac{\partial Q_4}{\partial |V_2|} & \cdots & \cdots & |V_4|\frac{\partial Q_4}{\partial |V_4|} \end{bmatrix} \begin{bmatrix} \Delta\frac{|V_2|}{|V_2|} \\ \vdots \\ \vdots \\ \Delta\frac{|V_4|}{|V_4|} \end{bmatrix} = \begin{bmatrix} \Delta Q_2 \\ \vdots \\ \vdots \\ \Delta Q_4 \end{bmatrix} \quad 5$$

The equations are decoupled in nature
Thus

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & 0 \\ 0 & L \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \frac{|\Delta V|}{|V|} \end{bmatrix} \quad 6$$

This is the Decoupled Newton Method
It can be further factored out as;

$$[\Delta P] = [H][\Delta\delta] \quad 7$$

$$[\Delta Q] = [L]x\left[\frac{|\Delta V|}{|V|}\right] \quad 8$$

$$H_{ik} = L_{ik} = |V_i V_k|(G_{ik} sin\delta_{ik} - B_{ik}\, cos\delta_{ik}) \quad i \neq k$$

The elements of the Jacobian Equation 8 can be simplified as:

$$H_{ik} = \frac{\partial P_i}{\partial \delta_k} \quad \text{and} \quad L_{ik} = \partial Q_i \frac{|V_i|}{\partial ||V_i||}$$

From Eq. 9 & 10

$$\frac{\partial P_i}{\partial \delta_k} = P_i = |V_i V_k Y_{ii}| \cos\theta_{ii} + \sum_{K=1,K\neq i}^{N} |V_i V_k Y_{ik}|\, cos(\theta_{ik} + \delta_k - \delta_i) \quad 11$$

$$Q_i = |V_i V_k Y_{ii}| \sin\theta_{ii} + \sum_{K=1,K\neq i}^{N} |V_i V_k Y_{ik}|\, sin(\theta_{ik} + \delta_k - \delta_i) \quad 12$$

Off-diagonal elements of H (i.e. when i≠k) are:

$$H_{ik} = \frac{\partial P_i}{\partial \delta_k} = |V_i V_k Y_{ik}|\, sin(\theta_{ik} + \delta_k - \delta_i) \quad 13$$

Expanding by trigonometric function yields,

$$= |V_i V_k|(Y_{ik}) sin\theta_{ik} cos(\delta_k - \delta_i) + sin\,|Y_{ik}|\, cos\theta_{ik} sin(\delta_k - \delta_i) \quad 14$$

We know that $Y_{ik} sin\theta_{ik} = -B_{ik}$ 15
and $Y_{ik} cos\theta_{ik} = -G_{ik}$ 16
then $(Y_{ik} = G_{ik} - jB_{ik})$ 17

$$H_{iK} = |V_i V_K|[-B_{iK}\, cos(\delta_K - \delta_i) + G_{iK}\, sin(\delta_K - \delta_i)] \quad 18$$

Likewise, the off-diagonal element of L (i.e. normalized form) is

$$L_{ik} = \frac{\partial Q_i}{\partial |V_K|} V_K = |V_i V_K Y_{iK}| sin(\theta_{iK} + \delta_K - \delta_i) \quad 19$$

$$L_{ik} = V_i V_k[-B_{ik} cos(\delta_k - \delta_i) + G_{ik} sin(\delta_k - \delta_i)] \quad 20$$

From Eqs 3.63 and 3.64b we can see that

$$H_{iK} = L_{ik} = |V_i V_k[-G_{ik} sin(\delta_k - \delta_i) - B_{ik} cos(\delta_k - \delta_i)] \quad 21$$

The diagonal elements of H are given as:

$$H_i = \frac{\partial P_i}{\partial \delta_k} = \sum_{K=1,K\neq i}^{N} |V_i V_K Y_{iK}| sin(\theta_{iK} + \delta_K - \delta_i) \quad 22$$

$$= -\sum_{K=1,K\neq i}^{N} |V_i V_K Y_{iK}| sin(\theta_{iK} + \delta_K - \delta_i) - |V_i V_K Y_{iK}| sin\theta_{ik}$$

$$= -\left\{\theta_{ik} + |V_i V_K Y_{iK}| sin\theta_{ii}\right\} \quad 23$$

$$H_{ii} = -Q_i - V_i^2 B_{ii} \quad 24$$

Similarly, the diagonal element of L are given as:

$$L_{ii} = \frac{\partial P_i}{\partial V_i}\left|V_i\right| = \left|2V_i^2 Y_{ii}\right| sin\theta_{ii} + \sum_{K=1}^{N}\left|V_i V_K Y_{iK}\right| sin(\theta_{iK} + \delta_K - \delta_i) \quad 25$$

$$L_{ii} = \left|2V_i^2 Y_{ii}\right| \sin\theta_{ii} + \sum_{K=1}^{N}\left|V_i V_K Y_{iK}\right| sin(\theta_{iK} + \delta_K - \delta_i) - \left|V_i V_K Y_{iK}\right| sin\theta_{ii}$$

$$= \left|2V_i^2 Y_{ii}\right| \sin\theta_{ii} + Q_i - \left|V_i^2 Y_{ii}\right| \sin\theta_{ii} \quad 26$$

$$L_{ii} = \left|V_i^2 Y_{ii}\right| \sin\theta_{ii} + Q_i\,, \quad \text{but } \{Y_{ii} sin\,\theta_{ii} = -B_{ii} \quad 27$$

$$= -V_i^2 B_{ii} + Q_i$$

$$L_{ii} = Q_i - V_i^2 B_{ii} \quad 28$$

III. RESULT PRESENTATION

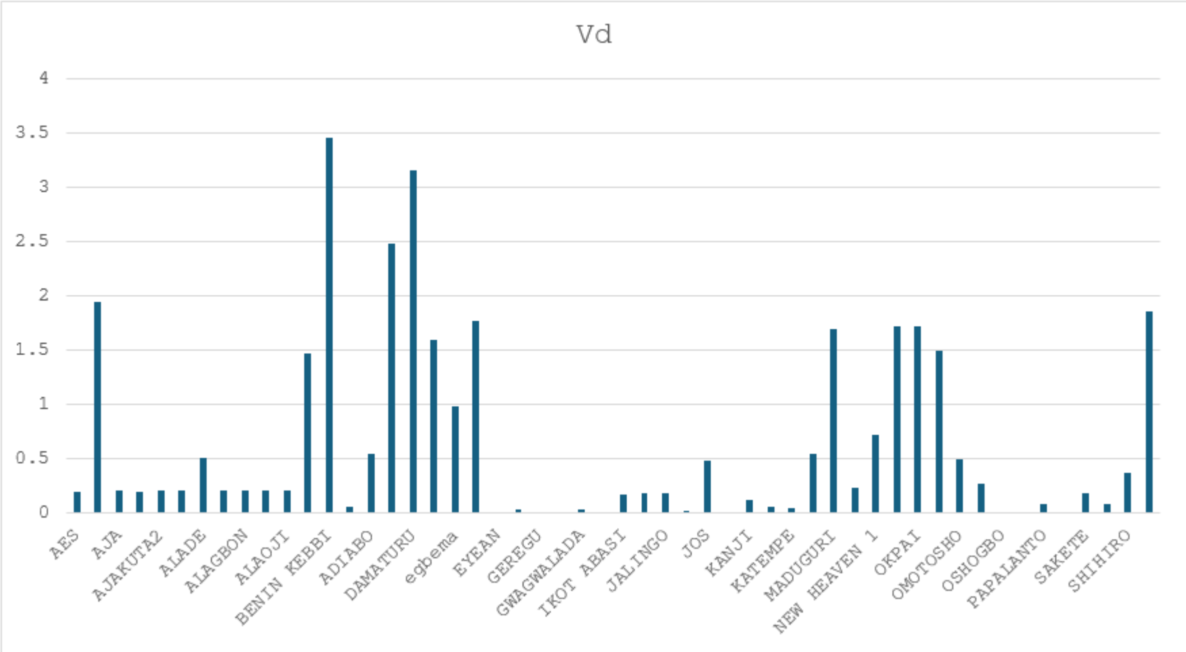

Fig. 1.0: graph of bus voltage drop (network with renewable energy)

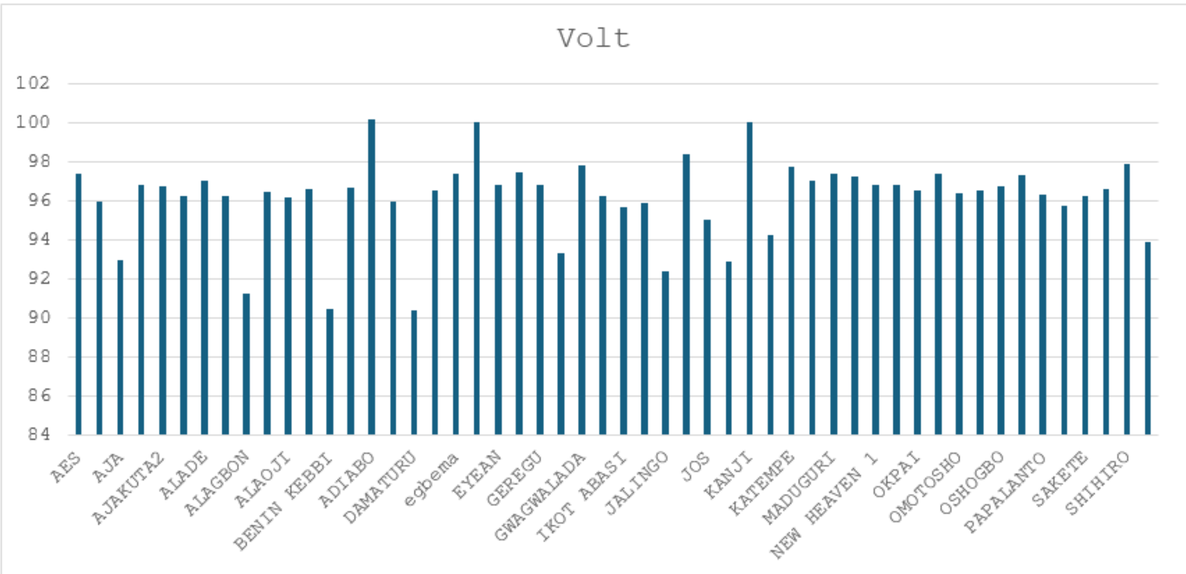

Fig. 2.0: graph of % bus voltage (network with renewable energy)

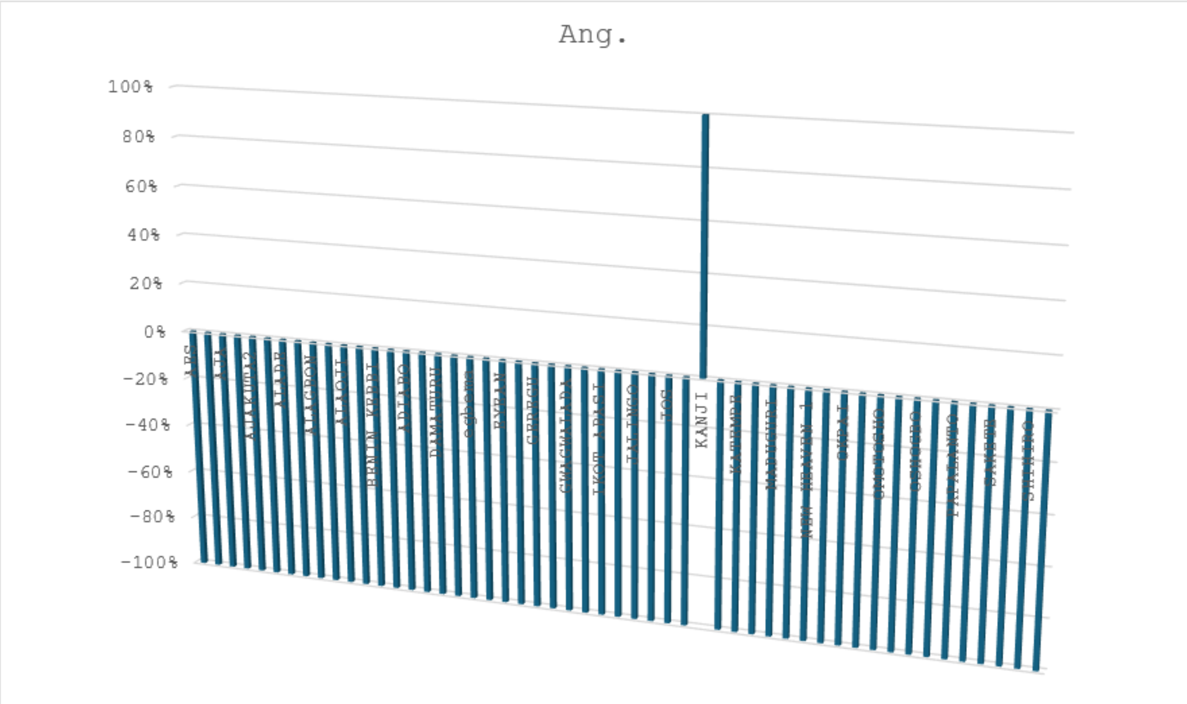

Fig. 3.0: graph of bus voltage against bus angle (network with renewable energy)

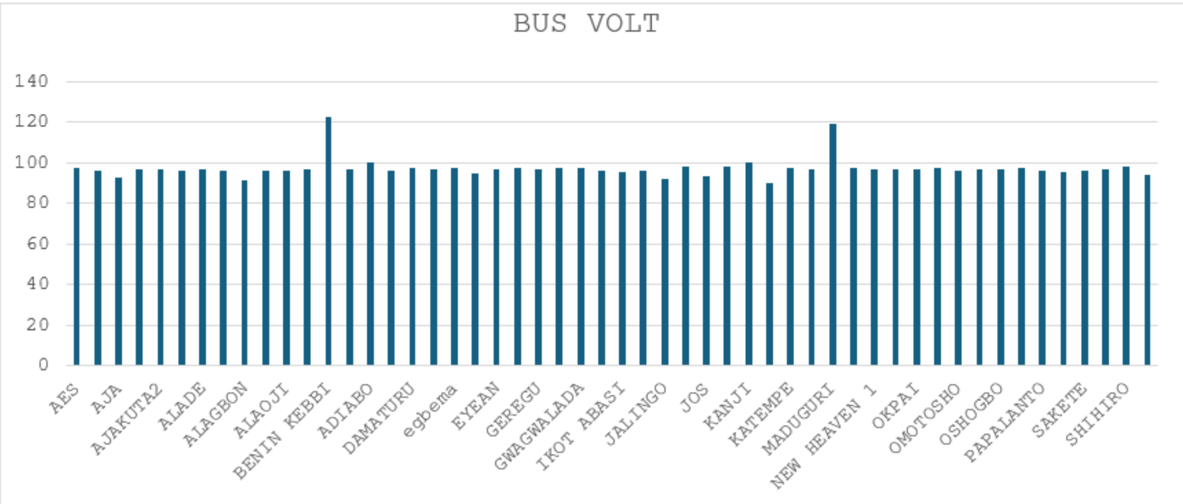

Fig. 4.0: graph of bus voltages (network without renewable energy)

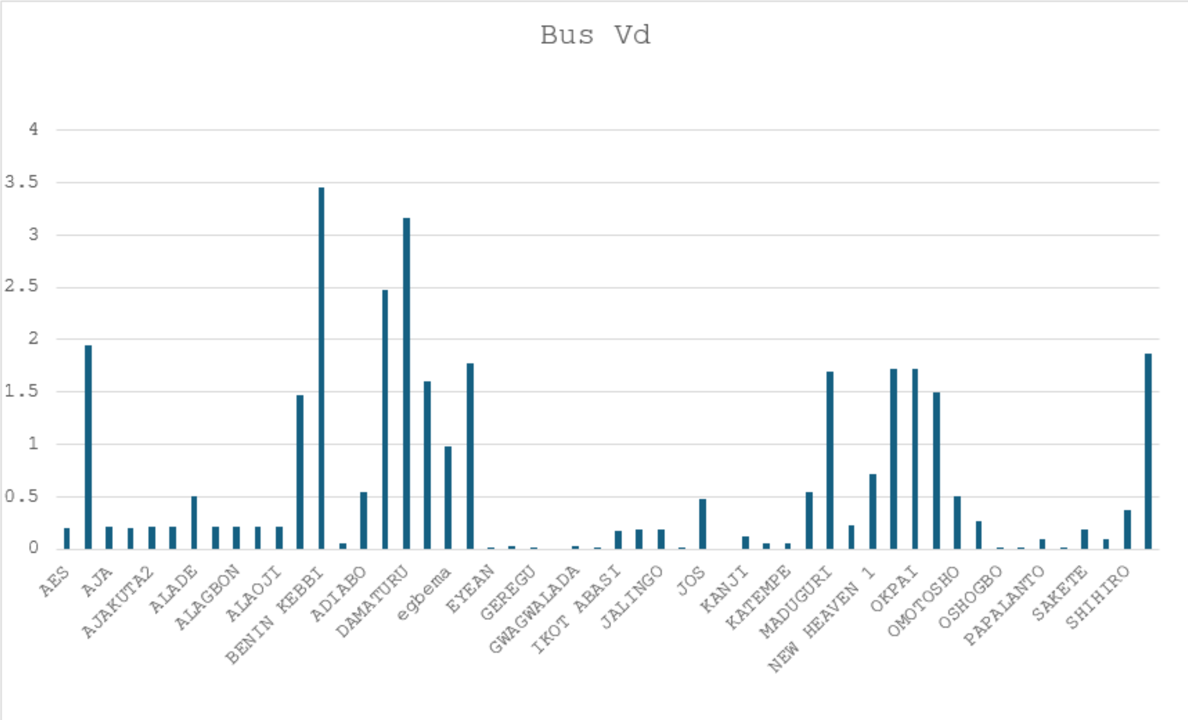

Fig. 5.0: graph of bus voltage drop (network without renewable energy)

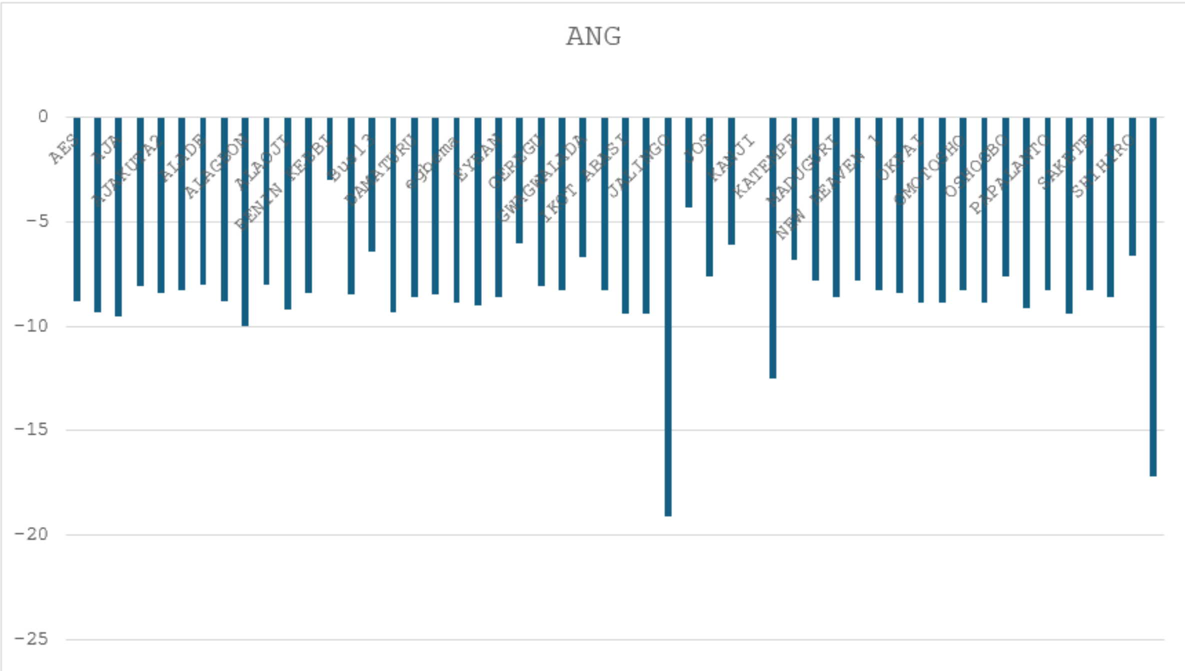

Fig. 6.0: graph of bus angle (network without renewable energy)

IV. DISCUSSION OF RESULT

Fig.1.0 is a graph of bus voltage drop on the network with a renewable hybrid system connected. It reveals that Benin Kebbi has a voltage drop of 3.5 volts. Figure 2.0 is the graph of % bus voltage, where Adiabo, Eyean, and Kanji have a 100% voltage level with hybrid energy connected, and figure 3.0 is a bus voltage angle where hybrid renewable is connected, Kanji has an angle of 0; being a reference bus. Figure 4.0 is a graph of bus voltage without a hybrid renewable energy connection, Benin Kebbi, and Maiduguri buses have voltage levels of 120%. Figure 5.0 voltages drop, Benin Kebbi and Damaturu has a highest of 3.45 and 3.1 volts drops respectively. Figure 6 has the least bus angle of -18 and 17. The level of penetration of the hybrid energy system helps in determining the level of economic developments of the area.

V. CONCLUSION

Reduced Carbon Emissions: Increasing the share of solar PV and wind energy in Nigeria's energy mix can cut carbon emissions dramatically. Nigeria may be able to fulfill its international climate pledges thanks to this shift to cleaner energy sources, which is consistent with efforts made worldwide to tackle climate change. Nigeria's dependence on fossil fuels, particularly oil and gas, can be reduced by utilizing the country's rich solar and wind resources. This energy security can protect the economy from erratic international energy markets and improve national security. The frequent power outages and blackouts that have afflicted Nigeria in the past can be lessened with the use of solar and wind energy sources. For economic expansion and development, this increased energy reliability is crucial. Employment opportunities in manufacture, installation, maintenance, and operations are brought about by the development of solar and wind energy infrastructure. This may help to reduce unemployment rates and advance the economy of the nation. Nigeria has a lot of isolated and underdeveloped regions. A decentralized energy system fueled by renewable energy sources can increase access to electricity in these communities, raising living standards and promoting business activity. Nigeria's economy can become more diverse by switching to renewable energy sources. It can boost investment in the field of renewable energy, advance R&D, and foster innovation, resulting in economic growth outside the oil industry. Although there are substantial potential advantages, switching to a high-penetration renewable energy system is not without difficulties. These include the requirement for large investments, grid infrastructure upgrades, regulatory and policy frameworks, as well as resolving logistical and technological difficulties. Solutions for effective energy storage are needed to manage the erratic nature of solar and wind resources. Building storage facilities will be essential for preserving a steady supply of electricity. Collaborations and public-private partnerships are necessary for the successful deployment of a hybrid renewable energy system. Government programs, incentives, and subsidies should encourage private-sector investment in the industry.

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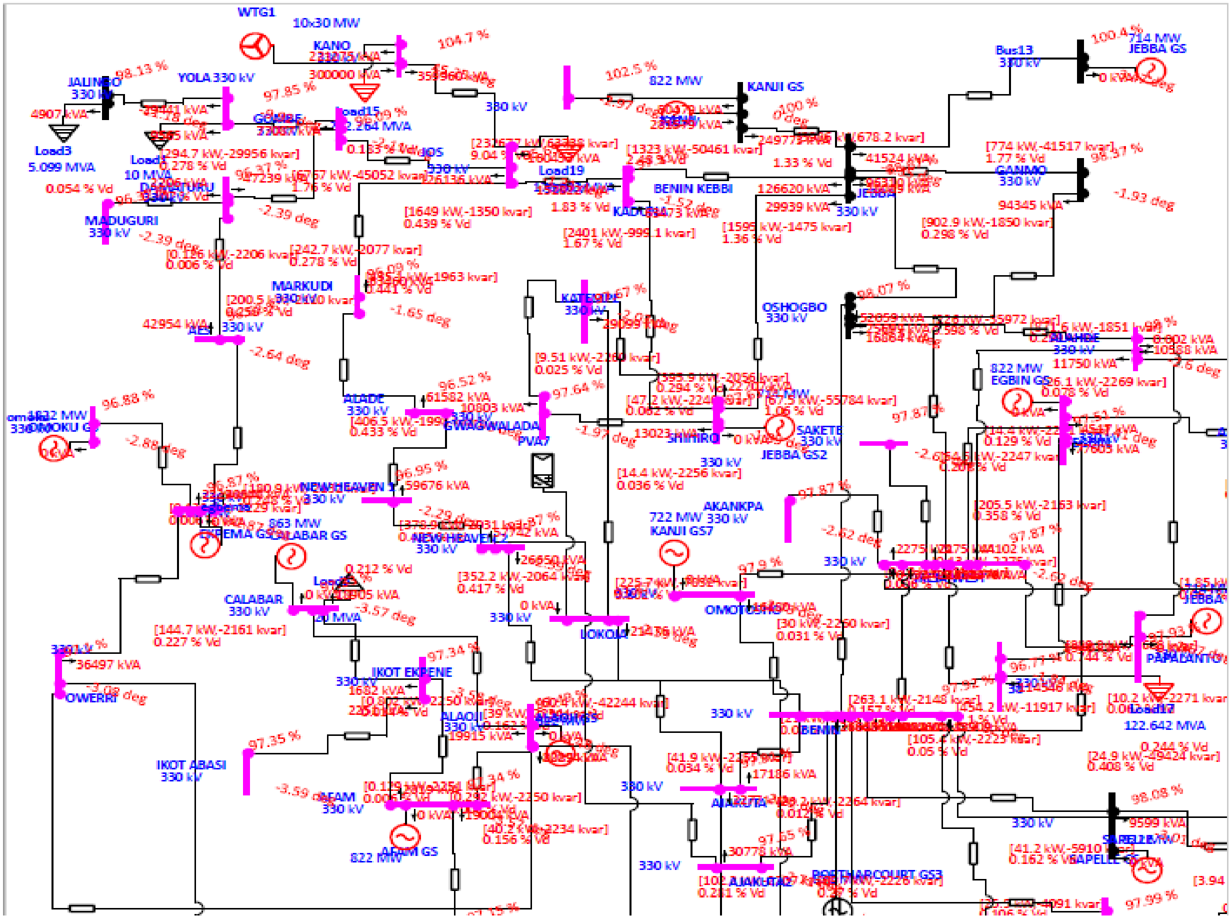

Fig. 7.0: Graph of Etap model of the network with hybrid PV solar and Wind power.