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MINIMIZATION OF POWER LOSS AT ABA 33KV DISTRIBUTION SYSTEMS USING PHOTOVOLTAIC DISTRIBUTED GENERATOR

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Abstract - This study is aimed at addressing the challenges of power losses and unreliable power supply in the Aba 33 KV power distribution system in Nigeria. Given the need to balance increased power generation with environmental sustainability, this study proposes the integration of photovoltaic distributed generations (PVDG) to minimize power losses in the system. The objective is to characterize and model the system to identify weak buses and power losses to minimize the losses and improve the voltage profile by integrating optimally sized PVDGs at adequate sites. The methodology involves computational modeling using MATLAB/Simulink and Power System Analysis Toolbox (PSAT) for load flow analysis, and modeling of the test network using bus and line data obtained from the Enugu Electricity Distribution Company (EEDC). By examining the bus and line data of the distribution system, the study determined the voltage magnitudes, power demand, and power losses. The findings revealed that five buses; bus 2 (Mobitra), bus 5 (Aba T1A), bus 6 (Omoba), bus 7 (Igi), and bus 8 (Ogbo) are below the IEEE acceptable benchmark of 1±5 % pu. The total real power loss on the distribution system was found to be 3.389 MW. Using the method of eigenvalue analysis and repeated load flow (RPF), optimal PVDG sites and the corresponding sizes were found respectively. The deployment of these PVDGs resulted in a 58.82 % reduction in losses and tremendous improvement of the voltage profiles. Against this backdrop, it was concluded that photovoltaic distributed generation (PVDG) is an effective tool in compensation of real power losses in Aba 33kV distribution network.

Key Words: Photovoltaic generators, Power distribution system, Voltage stability, Loss minimization

I. Introduction

There is currently a prevailing paradox in developing countries of the world like Nigeria where there is urgent demand for increased power generation, yet widespread worries about climate change. The reliance of traditional power systems on fossil fuels poses a serious challenge to the environment as evidence of climate change emerges stronger. On the other hand, the electric power supply is the fulcrum on which modern civilization revolves. It has been argued that the level of development of any state is directly proportional to the quantity of power on the infinite bus bar of such a state (Komolafe and Udofia, 2020). Given this, there is a need to strike a balance between environmental sustainability and power consumption. The imperativeness of this need necessitates the integration of renewable energy sources into the electrical power system, especially in the form of distributed generation in the existing infrastructures.

While it has been established that the distribution systems is inherently weaker than the transmission system globally, there is significantly more strain in the distribution systems of developing countries like Nigeria

(Komolafe and Udofia, 2020). For instance, the rapid population growth, urbanization and industrialization in Nigeria has resulted to connection of numerous residential and commercial buildings to the power distribution systems without corresponding improvement in the generation capacity. This has ultimately led to an increasing vulnerability of the distribution systems in Nigeria, marked by frequent outages and unreliable operations. Thus, the Nigerian power sector has been characterized by this unreliability to the extent that the electricity consumers have been categorized into different bands, from Band A to E, with Band A, the highest band, theoretically entitled to twenty (20) hours of power supply daily, and band E, the lowest, four (4) hours of supply daily (Nigeria Electricity Regulatory Commission, 2023).

To address the current problems, this study is focused on the Aba 33 KV power distribution system to characterize and model the system so that weak buses and power losses in the system can be identified for compensation using photovoltaic distributed generation. The recent unbundling of the Nigerian power system has made distributed generation attractive as a potent tool in addressing the myriads of challenges in the distribution sector. Technically, the distribution systems are now more accountable for meeting the power demands of the customers. The advent of distributed generation has brought increased attention to the performance of distribution systems. The distribution companies have no more excuses for excessive technical losses in the distribution systems. According to Adegboyega and Onime (2020), technical losses occur due to the inherent resistance of power lines and electrical equipment, resulting in energy dissipation. Jain and Kanwar, (2021) rightly observed that Power losses not only reduce the efficiency of the distribution system but also impose financial burdens on distribution companies and end consumers.

Considering the preeminent importance of Aba in Abia State Nigeria as one of the leading manufacturing hubs in Nigeria (Ogbulu, 2019), there is a need to focus attention on the electric power system within the area. Epileptic power supply is one of the most critical challenges affecting the progress of the manufacturing companies in Aba, especially the small-size and medium-scale enterprises (SMEs) (Ibecheozor et al., 2023). The characterization and modeling of the distribution system provide an opportunity to investigate the system and propose innovative solutions to enhance the system's reliability, efficiency, and sustainability.

II. Review of Related Literature

Power distribution systems form an integral part of the modern electrical grid, connecting power generation stations to residential, commercial, and industrial consumers. Despite advancements in power transmission technology, power losses in distribution systems remain a significant issue. Power losses reduce overall system efficiency, increase operational costs, and contribute to environmental concerns (Toirov et al. 2021). To address these challenges, understanding the different types of power losses and their causes is crucial.

As asserted by Onodugo *et al* (2021), power losses in distribution systems are the dissipation of electrical energy in the form of heat during the transmission and distribution of electricity. These losses occur due to various factors such as resistance of the conductor and reactance, each contributing to the overall inefficiency of the distribution network. Resistance losses, also known as I^2R losses, occur when electric current flows through the resistive elements in a power system, such as wires, transformers, and other electrical components. These losses result from the conversion of electrical energy into heat due to the inherent resistance of the conducting materials. To understand resistance losses, there is a need to review Ohm's law. This fundamental law in electricity states that the current (I) flowing through a conductor is directly proportional to the voltage (V) across it and inversely proportional to the resistance (R) of the conductor:

$$V = I \times R \quad (1)$$

Considering the power (P) dissipated as heat in a resistive element, power is the product of current and voltage:

$$P = V \times I \quad (2)$$

Substituting Ohm's law into the power equation:

$$P = (I \times R) \times I \quad (3)$$

$$P = I^2 \times R \quad (4)$$

From this equation, the power dissipation (or resistance losses) is directly proportional to the square of the current passing through the resistance and the resistance value itself. This is why these losses increase significantly with higher current levels or higher resistance values.

Moreover, losses are broadly classified as technical losses and non-technical losses. Technical losses also known as power losses, are the energy losses that occur in electrical power systems during the generation, transmission, and distribution of electricity (Mba et al, 2022). These losses result from various physical and electrical factors and are an inherent part of any power system operation. According to Mahmood et al., (2014), technical losses can be categorized into two main types: resistive losses and non-resistive losses.

The resistive losses are calculated using the I^2R formula, where I is the current flowing through the component and R is the resistance of the component. High resistive losses lead to reduced energy efficiency and wasted electricity. On the other hand, non-resistive losses are caused by various other factors in the power system. Transformers and other magnetic devices have losses associated with the magnetization and demagnetization of their cores. These losses are known as core losses or iron losses and are related to hysteresis and eddy currents in the magnetic materials (Mahmood et al, 2014). Besides this, capacitors and insulating materials in power equipment exhibit dielectric losses, where energy is lost as heat due to the charging and discharging of the dielectric materials. In contrast, non-technical losses, also known as commercial losses or revenue losses, refer to the energy losses in an electrical power system that are not caused by physical or technical factors but instead arise from non-technical reasons (Mahmood et al, 2014). These losses are primarily associated with billing, metering, and revenue collection processes. Non-technical losses are often a significant concern for utility companies and can impact their financial viability and overall efficiency.

Given the significant impact of losses in the power distribution system, it is important to devise a sustainable and economically viable means of compensating for the losses. Despite the imperativeness of the Aba 33 KV distribution systems, there has been no attempt to address the observed losses in that system. To this end, this study seeks to close this gap by modeling and simulating the system to quantify the losses and then to optimally deploy photovoltaic distributed generation into the system to compensate for the losses.

III. Materials and Method

3.1 Materials

Some basic materials were deployed to achieve the broad aim of this study. Specifically, Matlab/Simulink software was used as the instrument for modeling and simulation of the research variables. Simulink has vast arrays of tools that allow for modeling and simulations of complex systems such as power systems. It provides an interface for visualization of results using tools such as graphs, charts, trends, etc. More so, the Power Systems Analysis Tools Box (PSAT) was also used in the study. The line and bus data obtained from Enugu Electricity Distribution Company (EEDC) was used in the characterization of the test network.

3.2. Design Method

The research method adopted for this study is computational modeling otherwise known as simulation. To obtain the fundamental operating characteristics of the power distribution system under normal operating conditions, the system is characterized using load flow analysis. This requires the use of line and bus data of the test network to determine the voltage magnitude, voltage angle, changes in power generated and power demand, power losses in the lines, line flows, and other variables of interest. Thus, characterizing this test network is pertinent to determine the weak buses and the real power loss in the test system. The integration of the photovoltaic generator can only be properly done if the vulnerable buses and the total real power losses are determined. It is worth stressing that the bus and line data are the two principal inputs required for a load flow study. This set of data is important because the bus data stipulates the initial voltage magnitude of the buses, power generated, and power demand. The line data on the other hand specifies the line parameters (line resistance and line reactance). The determination of optimal sites for integration of the photovoltaic distributed generator was done using the method of modal analysis, while the optimal sizes were determined with the help of repeated load flow (RLF) analysis.

3.2.1Characterisation of the Test Distribution System

The load flow analysis was performed using Power System Analysis Toolbox (PSAT) in MATLAB. According to Gupta (2014), the Newton-Raphson method is considered to be the most sophisticated and important among the numerous solution methods available for power flow analysis. It is therefore imperative to x-ray the mathematical principles behind the Newton-Raphson method. The Newton-Raphson method is based on Taylor’s series and partial derivatives. The Newton-Raphson method is recent, needs less number of iteration to reach convergence, takes less computer time and hence computation cost is less and the convergence is certain. The N-R method is more accurate and less sensitive to factors like slack bus selection, regulating transformers etc. and the number of iterations in this techniques is almost independent of the system size.

Convergence can be considerably speeded up by performing the first iteration through the G-S method and using the value of voltages so obtained for starting the N-R iteration. These voltages are used to compute active power at every bus except the swing bus and also reactive power Q where reactive power is specified. The process of iteration is continued till the difference in the specified and calculated values of P, Q and V are within the given permissible limit (Gupta, 2014).

For any i^th bus, we have

$V_{\boldsymbol{i}} = V_i e^{j\delta i}$, then $V_i^* = V_i e^{-j\delta i}$

and $V_k = V_k e^{j\delta k}$ (5)

and $Y_{ik} = Y_{ik} e^{-j\theta ik}$

where δ is the phase angle of the bus voltages and θ_{ik} is an admittance angle.

For any ith bus

$$S^* = P_i - jQ_i = V_i^* \sum_{k=1}^{n} Y_{ik} V_k ; i = 1,2,3,..n \quad (6)$$

Substituting the values of V_i^*, V_k *and* Y_{ik} from Equation (5) in equation (6) we have

$$p_i - jQ_i = \sum_{k=1}^{n} V_i V_k Y_{ik} e^{-j(\theta_{ik}+\delta_i-\delta_k)} \quad (7)$$

Thus $P_i =$ Real $\mathrm{V_i^* \sum_{k=1}^{n} Y_{ik} V_{ik}} =$
$\mathrm{\sum_{k=1}^{n} V_i V_k Y_{ik} \cos(\theta_{ik} + \delta_i - \delta_i)}$

$$= V_i V_i Y_{ii} \cos\theta_{ii} + \sum_{\substack{k=1\\k\neq i}}^{n} V_i V_k Y_{ik} \cos(\theta_{ik} + \delta_i - \delta_k) \quad (8)$$

and $Q_i = I$maginary $V_i^* \sum_{k=1}^{n} Y_{ik} Y_k$

$$= \sum_{k=1}^{n} V_i V_k Y_k \sin(\theta_{ik} + \delta_i - \delta_k)$$

$$= V_i V_i Y_{ii} sin\theta_{ii} + \sum_{\substack{k=1\\k\neq i}}^{n} V_i V_k Y_{ik} \sin(\theta_{ik} + \delta_i - \delta_k) \quad (9)$$

for $i = 2,3,3,4, \dots n$ because bus 1 is slack bus

Now the linear equation in polar form becomes

$$\begin{bmatrix} \Delta\boldsymbol{P} \\ \Delta\boldsymbol{Q} \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\boldsymbol{\delta} \\ \Delta\boldsymbol{V} \end{bmatrix} \quad (10)$$

where $J_1, J_2, J_3 and\, J_4$ are the elements of Jacobian matrix and can be determined from power equations (8) and (9).

The following procedure was used to conduct the lead flow analysis on the test distribution network using PSAT on MATLAB. First, the PSAT was launched on MATLAB. Then, the bus data and the line data of the test network were extracted and subsequently loaded into the PSAT environment. The bus data contains the name and code number of each of the 10 buses in the test network. The slack bus is code named 1, load (PQ) are code named 2, while the generator buses are code named 3. There is 1 slack bus, 1 generator bus, and 9 load buses. Since the Aba 132KV bus is the only generator bus, it was chosen as the slack bus. To run the load flow proper, the N-R algorithm is first selected on PSAT, then the bus and line data are loaded into the PSAT, which then converts them into useable format. The software is then instructed to execute the load flow analysis by clicking the "run load flow" icon on the PSAT environment. On completion of the load flow, the "static report" icon was used to tabulate the result. The obtained load flow results are presented in Table 1 and Table 2. Specifically, Table 1 presents the 10 buses and their respective per unit (pu) voltage magnitude, voltage angle in radian (rad) and change in real and power generated (in pu). Meanwhile, Table 2 specifically presents the system lines and their corresponding line flows (in pu) and the line losses (in pu).

3.2.2 System Modeling

Generally, in computational model research design, the accuracy of the result depends on the accuracy of the model. Against this backdrop, it is pertinent to model the test network correctly and accurately. Thus, the system was modeled using PSAT-Simulink. A new PSAT workspace was created on MATLAB by calling PSAT on the command window of MATLAB. The component blocks required to build the system is sourced from the toolbox. These components, generator, transmission lines, buses, and loads are imported into the new workspace. With the help of the line diagram of the network, the blocks are connected and configured accordingly, using the bus and line data. The model of the test distribution system is presented in Figure 1.

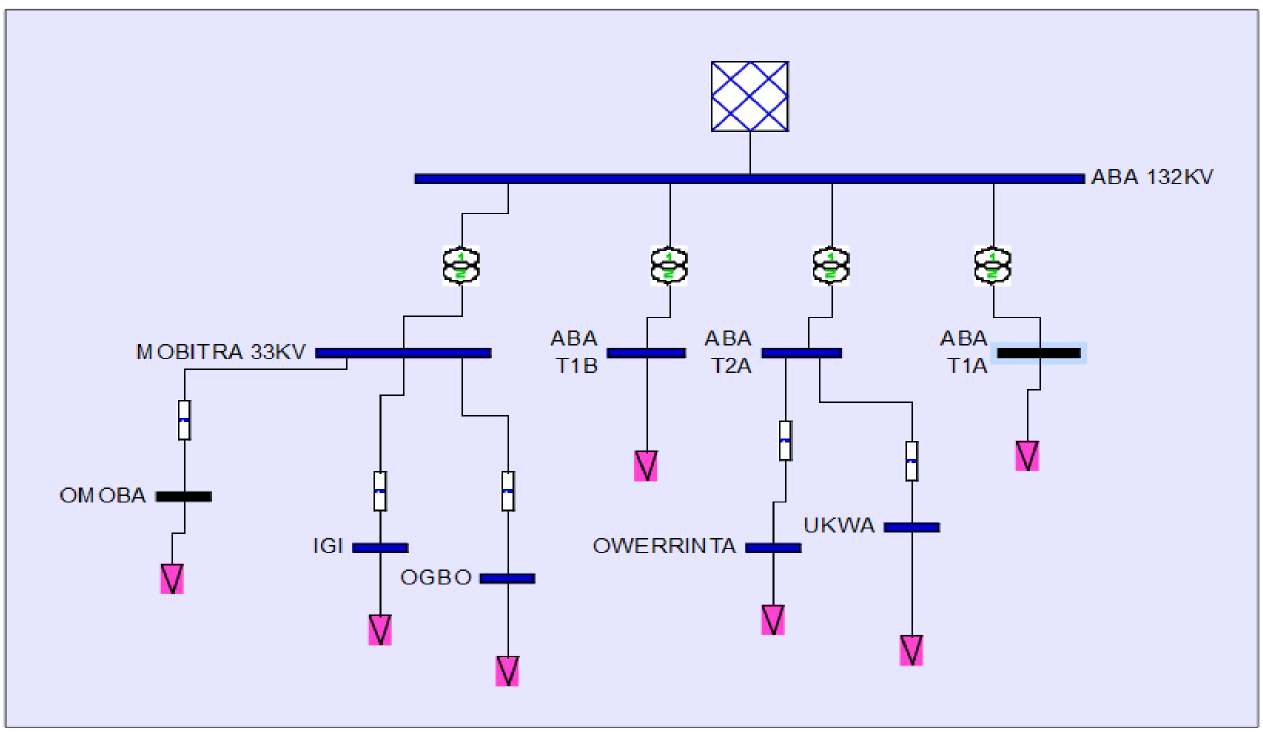

Figure 1: PSAT-Simulink model of 10-bus Aba 33 KV power distribution system

3.2.3 Optimal Integration of Photovoltaic Distributed Generation

The suitable number of PVDGs required to maximally compensate the loss in the test network was determined using modal analysis. The analysis technically revealed the weakest bus and the buses that contribute the highest to the fragility of the system. Specifically, these buses that contribute the most to the weakness of the weakest bus were determined by obtaining the participation factors from the performed eigenvalue analysis.

The first step in modal analysis is determining the reduced Jacobian matrix (Jr). In the Newton

Raphson power flow method, there is a Jacobian matrix that represents the injected real power (P) and reactive power (Q) in buses as shown in Equation (10). The second step in modal analysis is to determine the most critical mode. The eigenvalues and eigenvectors of can be used to determine the modes of the power system. The lowest value of eigenvalue denotes the most critical mode of the power system Equation (11) depicts their relationship (Ahmad et al. 2019).

$$J_r = \xi \Delta \eta \quad (11)$$

where

ξ is the right eigenvector of J_r

Δ is the diagonal eigenvalue of J_r

η is the left eigenvector of J_r

The result of the eigenvalue analysis and the participation factors were used to perform repeated load flow on the test network and the result obtained at the revealed optimal locations is presented in section four.

IV. Discussion of Results

4.1 Results of Characterization of the Test Network

The result of the characterization of the test power distribution system is presented in this section. Table 1 presents the 10 buses and their respective per unit (pu) voltage magnitude, voltage angle in radian (rad) and real and reactive power generated (in pu). Similarly, Table 2 presents the system lines and their corresponding line flows (in pu) and the line losses (in pu).

Table 1 The result of the load flow performed on the test power distribution system

Bus Name	Bus N0	V [pu]	Phase [rad]	P gen [pu]	Q gen [pu]	P load [pu]	Q Load [pu]
ABA 132KV	1	1	0	0.480138	0.108474	0	0
MOBITRA 33KV	2	0.896716	-0.03986	-1.5E-12	1.94E-12	0	0
ABATIB	3	0.95535	-0.04922	8.33E-17	-3.1E-16	0.15	0.012
ABAT2A	4	0.960706	-0.03373	3.51E-15	2.87E-15	0	0
ABAT1A	5	0.918561	-0.08946	3.68E-16	1.45E-16	0.0325	0.0023
OMOBA	6	0.852172	-0.07574	2.33E-12	-6.1E-13	0.1	0.022
IGI	7	0.88303	-0.04632	2.05E-13	-1.1E-13	0.03	0.011
OGBO	8	0.889342	-0.04603	1.59E-13	-1.1E-13	0.01875	0.003
OWERRINTA	9	0.952148	-0.03942	-1.7E-16	-8.2E-16	0.1	0.022
UKWA	10	0.959802	-0.03373	-1.3E-16	3.2E-16	0.015	0.002
				0.480137647	**0.10847403**	**0.44625**	**0.0743**

From the load flow analysis presented in Table 1, it is evident that the voltage profiles of five buses; Mobitra (0.8967 pu), Aba T1A (0.9186 pu), Omoba (0.8522 pu), Igi (0.8830 pu), and Ogbo (0.8893 pu), are below the IEEE acceptable range of 0.95 to 1.05 pu. This under-voltage condition indicates that these areas are experiencing power levels insufficient for the optimal performance of electrical equipment. Such low voltage levels lead to poor power quality, which causes inefficiencies and frequent disturbances in the power supply. Additionally, the low voltage profiles signal potential issues with the stability of the distribution system. Inadequate voltage at these buses suggests a lack of capacity to meet demand during peak loads, which can result in voltage collapses or frequent outages. Moreover, the generated active and reactive power at most buses is near zero, particularly at critical buses like Omoba and Ogbo, which indicates a substantial imbalance between the generated and demanded power. This reinforces the need for system reinforcement through compensation techniques, such as photovoltaic generators.

Table 2 Line flow result showing Power flow and Power losses in the lines of the test network

From Bus	To Bus	P Flow [pu]	Q Flow [pu]	From Bus	To Bus	P Flow [pu]	Q Flow [pu]	P Loss	Q Loss
2	6	0.10433	0.026831	6	2	-0.1	-0.022	0.00433	0.004831
2	7	0.030392	0.011287	7	2	-0.03	-0.011	0.000392	0.000287
2	8	0.018887	0.003061	8	2	-.01875	-0.003	0.000137	6.15E-05
4	9	0.100771	0.022771	9	4	-0.1	-0.022	0.000771	0.000771
4	10	0.015014	0.002002	10	4	-0.015	-0.002	1.41E-05	1.87E-06
1	2	0.169336	0.052713	2	1	-.15361	-.04118	0.015727	0.011533
1	3	0.156203	0.02027	3	1	-0.15	-0.012	0.006203	0.00827
1	4	0.119583	0.029836	4	1	-.11579	-.02477	0.003798	0.005063
1	5	0.035016	0.005655	5	1	-0.0325	-0.0023	0.002516	0.003355
TOTAL								0.033888	0.034174

The line flow results presented in Table 2 demonstrate the real power losses and reactive power losses occurring within the power distribution network. The total real power loss is recorded at 3.389 MW, which indicates significant inefficiencies in the system. These losses occur as power is transmitted across various buses, particularly between Bus 1 (ABA 132 KV) and the other buses, which account for the majority of the losses. For instance, the line between Bus 1 and Bus 2 exhibits a real power loss of 0.0157 pu and a reactive power loss of 0.0115 pu, indicating that the bulk of the power flowing through this connection is not being utilized effectively. Furthermore, Bus 2 (Mobitra) exhibits considerable power flow to Buses 6, 7, and 8, with Bus 6 showing a notable real power loss of 0.00433 pu, which contributes to overall inefficiencies in the system. The smaller losses observed between Bus 4 (AbaT2A) and Buses 9 and 10 suggest that these sections of the network are relatively stable, yet still contribute to minor inefficiencies.

The results emphasize the urgent need to compensate for these power losses, particularly in the buses and lines exhibiting the highest losses, by integrating photovoltaic (PV) generators at strategic points in the network. Adequately sized and located PV generators can inject power locally. This has the capacity to reduce the amount of power that must flow through the system, thereby minimizing both real and reactive power losses. This approach can significantly improve system efficiency, stabilize voltage profiles, and enhance the reliability of power at Aba 33KV distribution network.

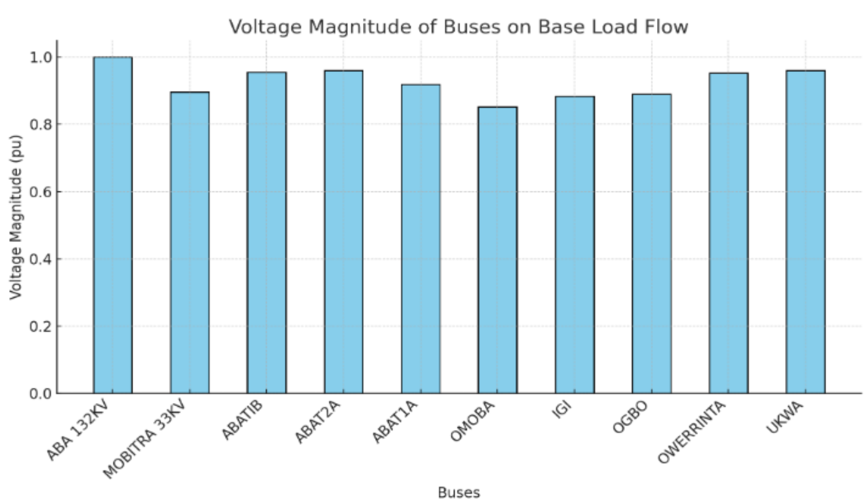

Figure 2: Bar chart showing voltage magnitude of buses of the test network on base load flow

The chart in Figure 2 highlights the voltage levels for each bus. It shows that several buses, particularly Mobitra 33KV, Aba T1A, Omoba, Igi, and Ogbo, fall below the IEEE acceptable range of 0.95 to 1.05 pu, indicating weak voltage profiles that need compensation for improved power distribution stability.

4.2 Optimal Location and Size of the PVDG

The eigenvalue analysis showed that Aba T1A bus has the smallest real part of 0.33494, and thus, is the weakest bus of the test network. However, the bus is closely followed by Omoba bus with a real part of 0.46818. The analysis of the participation factor presented shows that Aba T1A is solely responsible for its weakness, while Omoba have highest participation factors in several modes (Igi, Omoba, and Ogbo), making it critical in terms of stability. The implication of this is that there are two (2) possible buses (Aba T1A and Omoba) in which the PVDGs can be installed to compensate the losses in the test network, to stabilise the network, and improve the voltage profiles. From the RPF, it was found that the optimal sizes of the PVDGs to bring about minimum total power loss in the test network are 3.0 + j2.25 MW at Aba T1A and 10.0 + j7.5 MW at Omoba. Having arrived at these optimal values, the results of the load flow analysis with these parameters are presented in Table 3 and Table 4.

Table 3 Load flow result performed on the test network after first PVDG optimization and integration

Bus Name	Bus N0	V [pu]	Phase [rad]	P gen [pu]	Q gen [pu]	P load [pu]	Q load [pu]
ABA 132KV	1	1	0	0.329794	0.020204	0	0
MOBITRA 33KV	2	0.985084	-0.0334	8.82E-16	1.89E-16	0	0
ABATIB	3	0.95535	-0.04922	8.33E-17	-3.1E-16	0.15	0.012
ABAT2A	4	0.960706	-0.03373	3.51E-15	2.87E-15	0	0
ABAT1A	5	1	-0.01046	0.03	0.004196	0.0325	0.0023
OMOBA	6	1	-0.04684	0.1	0.066083	0.1	0.022
IGI	7	0.972664	-0.03874	4.86E-17	5.2E-17	0.03	0.011
OGBO	8	0.978386	-0.03851	-3.5E-16	8.67E-19	0.01875	0.003
OWERRINTA	9	0.952148	-0.03942	-1.7E-16	-8.2E-16	0.1	0.022
UKWA	10	0.959802	-0.03373	-1.3E-16	3.2E-16	0.015	0.002
				0.459794	**0.090483**	**0.44625**	**0.0743**

Table 4 Line flow result performed on the test network after PVDG optimization and integration

From Bus	To Bus	P Flow [pu]	Q Flow [pu]	From Bus	To Bus	P Flow [pu]	Q Flow [pu]	P Loss	Q Loss
2	6	0.000584	-0.04352	6	2	-1.4E-6	0.044083	0.000584	0.000564
2	7	0.030323	0.011206	7	2	-0.03	-0.011	0.000323	0.000206
2	8	0.018863	0.00302	8	2	-.01875	-0.003	0.000113	2.03E-05
4	9	0.100771	0.022771	9	4	-0.1	-0.022	0.000771	0.000771
4	10	0.015014	0.002002	10	4	-0.015	-0.002	1.41E-05	1.87E-06
1	2	0.051489	-0.02803	2	1	-.04977	0.029293	0.001718	0.00126
1	3	0.156203	0.02027	3	1	-0.15	-0.012	0.006203	0.00827
1	4	0.119583	0.029836	4	1	-.11579	-0.02477	0.003798	0.005063
1	5	0.00252	-0.00187	5	1	-0.0025	0.001896	1.97E-05	2.62E-05
TOTAL								**0.013544**	**0.016183**

The results of the Tables 3 and 4, clearly show that the optimal integration of the PVDGs improved the voltage profile of the five buses (Mobitra, Aba T1A, Omoba, Igi and Ogbo) whose voltages were below the IEEE benchmark of 0.95pu. Thus, the hitherto significantly vulnerable buses have been strengthened reasonably above the IEEE benchmark of 0.95pu. Evidently, from the results, the integration of the second PVDGs produced the best result, followed by that of first PVDG. The comparison of the voltage profile of the test network before the integration and after the integration is presented in the Figure 3.

Meanwhile, the integration of the first PVDG at bus 5 resulted in a total network loss of 3.1MW, while the integration of the second PVDG at bus 6 resulted in a total network loss of 1.4MW. These are against the 3.4MW recorded when there were no PVDGs in the network.

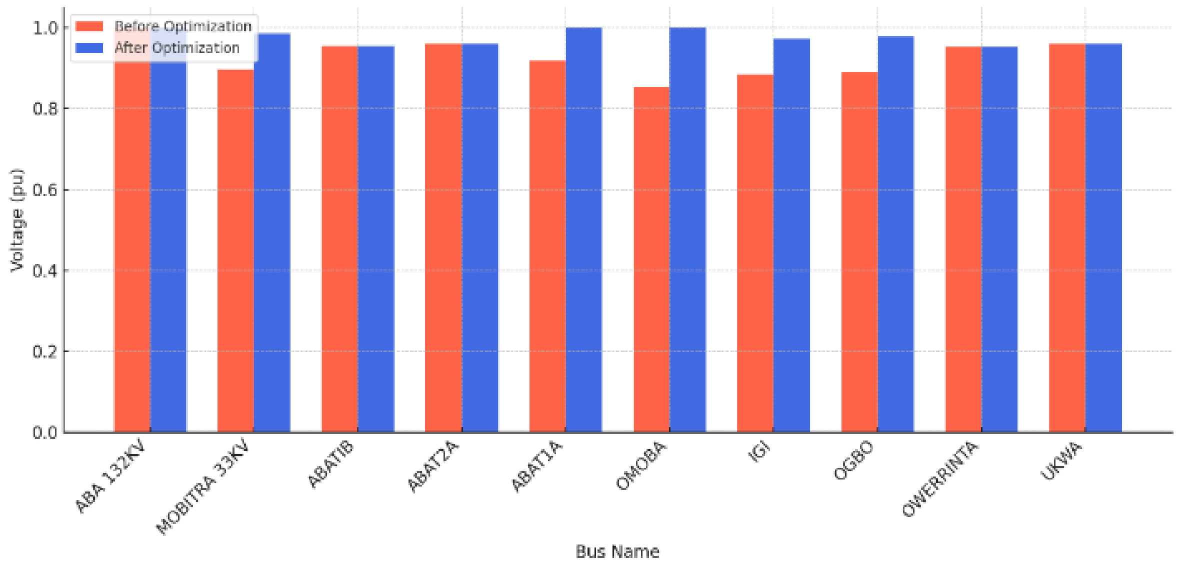

Figure 3: Comparison of the voltage profiles before and after the integration of PVDG.

Figure 3 is a bar chart comparing voltage profiles before and after the PVDG optimization. The bar charts highlight significant improvements in voltage levels across several buses in the test network. Notably, the buses MOBITRA 33KV, OMOBA, IGI, and OGBO exhibited substantial voltage increases after the optimization process. For instance, the voltage at MOBITRA increased from 0.897 pu to 0.985 pu, while OMOBA improved from 0.852 pu to 1 pu. More so, the optimal integration of the PVDGs minimized the total real power loss in the test network from 3.40 MW to 1.40 MW (58.82%).

V. Conclusion and Recommendation

This study highlights the critical challenges faced by the Aba 33 KV power distribution system and offers a sustainable solution to minimize power losses through the integration of photovoltaic (PV) generators. The results of the load flow analysis, performed using MATLAB/Simulink and PSAT, revealed that several buses in the system exhibit voltage profiles below the IEEE acceptable limits. The identification of weak buses such as Mobitra, Aba T1A, and Omoba, along with a real power loss of 3.40 MW, underscores the inefficiencies prevalent in the distribution network. This study addressed this problem by optimally integrating photovoltaic distributed generation in the test system resulting in loss reduction and improvement of the voltage profiles. It is therefore concluded that photovoltaic distributed generation (PVDG) is an effective tool in compensation of real power losses in Aba 33kV distribution network.

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