Simulation and Analysis of the Effects of Distributed Generation Using Solar, on the World Bank 11kv/415v Distribution Feeder Network

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Abstract

The solar insolation level affects the output voltage of a PV cell, which is a function of photo current. At the client load location, electrical power generation systems known as distributed generation (DG) are produced. Wattage losses can be reduced, and improvements can be made to the voltage profile and power quality. When constructed appropriately, it saves money by reducing the need to invest in transmission and distribution infrastructure. The 11/415 kv Distribution Network (DN) of the World Bank has been taken into account in this analysis. The findings also demonstrate that DG integration on these specified buses can increase both the voltage on the vehicle and the flow of power to adjacent buses. Two scenarios were considered for situations when there are bus voltage lapses in the distribution network after the power flow analysis was completed with and without the DG. The function of photo current and the level of solar insolation determine the PV cell's output voltage. The integration of DG at this bus would compensate power at the bus and other buses based on the loads on other buses, it was found by examination of bus voltages and voltage differences. The research methodology included the actual collection of essential data from a typical modern Nigerian electricity distribution network, making this study immensely beneficial to society and the country as a whole. The network was modeled using a program named Electrical Transient Analyzer Program [ETAP 16.00]. The bus voltages, power losses, and load flow data for the current network were computed using the Newton-Raphson power flow method by the ETAP 16.0 program.

Keywords: *Renewable Energy, Solar Energy, Solar PV, Newton Raphson, ETAP*

1. Introduction

Both industrialized and emerging nations are increasingly concerned about energy security. According to Obideyi (2017), energy security is commonly considered to mean that everyone has access to enough reliable, inexpensive electricity. Energy policies and plans in many countries throughout the world are increasingly geared on reaching a higher level of energy security. The International Renewable Energy Agency (IRENA), 2015, claims that this is a response to the requirement to continuously ensure the supply of energy in light of the rising energy demand, quick depletion, and the requirement to reduce the "risk of disruptions and volatility of energy supply and price" associated with conventional sources.

The electrical industry is going through a lot of change as a result of greater competition. Energy consumers and electric utilities are being prompted to rethink the benefits of distributed generation (DG) as a result of the 'growing pains' of this revolution, including price volatility, aging populations, infrastructure, and shifting regulatory frameworks (Pepermans, Driesen, Haeseldonckx, D’haeseleer & Belmans, 2003).

The foundation for DG's future growth as a significant energy source is already in place because to utility restructuring, technological advancements, and recent environmental laws. By giving customers a choice of energy sources, technology for distributing those energies, and related services, utility restructuring liberalizes the energy market. In reaction to market signals, market forces favor swift implementation of compact, modular power solutions.

The following reasons are at play as this rearrangement is taking place: Small, modular distributed generation technologies are becoming much more affordable and efficient, and global and domestic demand for electricity is rising.

Efficiency and environmental performance are becoming more and more important due to local and worldwide environmental concerns, and there is growing worry about the dependability and quality of electric power (EIA, 2020).

Any method of producing energy that is integrated into distribution systems and located close to the point of use is referred to as distributed or distributed generation. It is possible to connect distributed generators to a medium- or low-voltage grid. They are typically less than 30 MW in size and are not centrally planned.

Similar to those of many other African countries, Nigeria's power sector continues to operate badly and unreliable due to a variety of problems. These issues consist of low voltages, overloaded transformers, limited generation capacity, and high transmission and distribution losses. The two aims of energy supply security and emission reduction are anticipated to be accomplished with the adoption of renewable energy sources.

The TCN has poor network and grid coverage throughout the nation, as well as an infrastructure shortfall that occasionally causes system collapses (the first one of this year occurred on September 14, 2023). (Punch magazine, 2023). Additionally, the inability of the GENCOs to deploy the available capacity of the energy they produce and the vandalism of transmission lines are factors that contribute to Nigerians' poor quality of energy service delivery.

The overall issue of insufficient network coverage and a lack of infrastructure in the various zones in which the DISCOs hold monopolies is also shared by them. As a result, the distribution business has had to continuously reduce demand in order to make up for inadequate electrical supply and line losses. In order to produce the required amount of power, the majority of Nigerian homes and businesses currently own one kind or another of fossil fuel-powered energy producing facility. Most power plants' incomplete fuel combustion results in the release of toxic gases that are extremely dangerous to human health.

The idea of this work is to simulate and analyze the effects of distribution generation using solar PV on the World Bank 11KV/415V distribution feeder network, establishing a proper study on the impact of distributed generation using alternative clean energy sources in the Nigeria distribution network, and investigating the quality and reliability of power supplies at various load locations, improvements to power supply and also threats to the network in terms of stability and voltage regulation.

2.REVIEW OF LITRATURES

Rapidly increasing the power consumption and shortage in generating and transmission capacities has set the trend towards the Distributed Generation (DG) sources. Research works has been done on distributed generation using renewable energy and such has as shown ascending growth in the past few years in various university and research centres in Nigeria with view of exploring abundant energy potentials to tackle the resolute power problem beseting our nation

Romero ,Aguero Julio. (2012) presented a review of technologies, methodologies and operational approaches aimed at improving the efficiency of power distribution systems, with emphasis in the accurate estimation and reduction of technical and non-technical power and energy losses.
Nath, Megha & Ghimire, Rudra. (2021) did a study to improve the technical and overall efficiency of a distribution feeder. A high loss feeder was selected for efficiency study. Direct method of loss calculation is used to calculate total losses of the feeder and indirect method was used to find the technical losses on the feeder in existing condition. Technical losses of existing feeder and improvement on same distribution system through technical loss reduction options was analyzed by implementing the conductor replacement, rerouting and optimum capacitor placement (OCP) methods using electrical transient analyzer program (ETAP) simulation. Technical efficiency and overall efficiency for the different non-technical loss values were calculated and analyzed.

Eftekharnejad, Sara & Heydt, Gerald & Vittal, V. (2015) investigated the impact of generation redispatch or generation displacement in systems with high PV penetration. Comparing various study scenarios, a method based on regression techniques and Chebyshev’s inequality is introduced in this research.
Sheryazov, S. & Shelubaev, M. & Obukhov, Sergey. (2017) analyzed renewable energy sources for distributed generation. They argued that Distributed energetics allows flexible control of the system itself and energy losses reduction during transmission to consumers. Herewith, that the most promising direction in the framework of energy conservation is usage of renewable sources

Ganguli & Sinha. (2009). presented an Estimation of Grid Quality Solar Photovoltaic Power Generation Potential and its Cost Analysis in Some Districts of West Bengal. The objective of their work was to estimate the potential of grid quality solar photovoltaic power in some districts of West Bengal (Birbhum, Burdwan, Hooghly, Howrah and Kolkata), study the solar radiation level and potential of the above-mentioned districts and finally develop a system corresponding to the potential. Equipment specifications were provided based on the system developed and finally cost analysis was also carried out.

Santos et al (2022) presented an over view of current architectures used in grid connected systems, five key points for comparison based on topology upgradeability, performance under shaded conditions, degraded mode operation, investment costs and ancillary service participation. The proposed method can be adapted to the user's particular needs and expectations of the photovoltaic plant. These evaluation guidelines may assist grid-tied PV system users to choose the most convenient topology for their application by weighting the evaluation criteria

Ganiyu et al. (2017) presented a comprehensive survey of DG integration on utilities distribution system of a power network with a view to measuring the extent of DG Integration on Nigerian Grid and to find out the most commonly used techniques for the optimal placement and sizing of DG problems. The results of this research paper showed that the work done on Nigerian radial distribution system is about 13.20% and this is largely due to scanty availability of Nigerian radial distribution system data.

Ariyo F.Y. and Omoigui M.O. (2013) presented the basic analyses carried out on Nigerian 330kV electrical network with distributed generation (DG) penetration. The analyses include load flow, short circuit, transient stability, modal/eigenvalues calculation and harmonics. The proposed network is an expanded network of the present network incorporating wind, solar and small-hydro sources.

Akpoviroro, Touati and Rabbah (2021) looked at the aged long practice of a centralized system of energy production which generates and transmits electricity over long distances (thereby incurring colossal losses), the limitations of the National grid which covers only some parts of the country, the legal constraints, the resort to self-help by Nigerians who seek to produce their own electricity using generators that emit GHG which pollute the atmosphere and the economic implication of running generators, while proffering an eco-friendly solution in distributed or dispersed generation using Shared Solar Energy aimed at resolving the disparity between the demand and supply of Electricity.

3. MATERIALS AND METHOD

There is need to properly model the utility grid with emphasis on the use of solar energy and PV on the distributed generation scheme. The feeders in which this DG is connected will be designed and also power distribution analysis will be carried out using Etap.

3.1 Materials

For design and simulation purpose, the following materials will be required

- World bank 11 KV/415 V distribution data
- Etap 16.00
- MS Excel

3.2 Method

To achieve the project objectives, the block diagram in figure 3.1 outlines the methods to be applied.

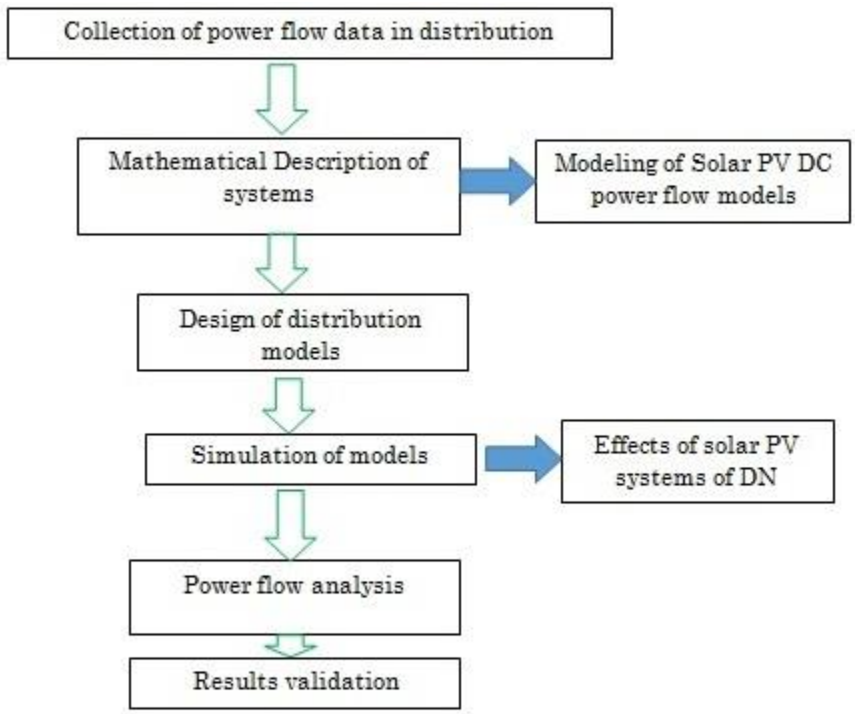

Figure 3.1 Block diagram showing methods

3.2.1 Data collection

The data required for this study will be collected by means of data sheet calculations and load flow data's of the World Bank district, Aba.

The following data's will be collected, power consumption, availability and load rating in KW, KVar and amperes.

3.2.2 Mathematical description of systems

(a) Load flow analysis

Analysis of consumer bus voltage magnitudes and phase angles, power flow on transmission lines, reactive power on generator busses, and power flow on transmission lines are all necessary for the procedure. The Newton Raphson method of load flow analysis, an iterative process that restricts the terms to the first-order approximation and transforms a set of concurrent nonlinear equations into a set of concurrent linear equations, using the Taylor series expansion. The nonlinear equations in charge of the power system network are as follows:

$$S_i = V_i I_i^* = P_i + jQ_i \qquad (3.1)$$

Where S_i is the complex power in the bus i

And V_i is the bus voltage at bus I given as

$$V_i = |V_i| e^{j\sigma_i} \qquad (3.2)$$

And

$$V_i^* = |V_i|e^{-j\sigma_i} \qquad (3.3)$$

Where $\sigma_i$the bus angle at node I and e is the Euler constant

Also V_i^* is the complex bus voltage at node I, therefore we have

$$V_k = |V_k|e^{j\sigma_i} \qquad (3.4)$$

Where V_k is the voltage at bus k and σ_k is the bus angle at node k, while I_i is the current injected into the bus and is given as

$$I_i = \sum_{k=1}^{n} Y_{ik}V_k : i = 1,2,\dots,n \qquad (3.5)$$

$Y_{ik}$is the admittance angle at the bus I and k

$P_i, Q_i$are the real and reactive power respectively at bus i

$$S_i = V_iI_i^* = P_i - jQ_i = \sum_{k=1}^{n} |V_i||V_i||Y_{ik}|e^{j(\sigma_{ik}+\sigma_i-\sigma_k)} \qquad (3.6)$$

Separate the conjugate complex power S_i^*, into real and imaginary power

$$P_i = \sum_{k=1}^{n} |V_i||V_i||Y_{ik}|cos(\sigma_{ik} + \sigma_i - \sigma_k) \qquad (3.7)$$

Compute and add P_i for $i = k \; and \; for \; i \neq k$

$$P_i = V_i^2Y_{ii}\cos\theta_{ii} + \sum_{k=1,k\neq i}^{n} |V_i||V_i||Y_{ik}|cos(\sigma_{ik} + \sigma_i - \sigma_k) \qquad (3.8)$$

Similarly,

$$Q_i = V_i^2Y_{ii}\sin\theta_{ii} + \sum_{k=1,k\neq i}^{n} |V_i||V_i||Y_{ik}|sin(\sigma_{ik} + \sigma_i - \sigma_k) \qquad (3.9)$$

Equations 3.16 and 3.17 constitute the polar form of the power flow equations that provide the calculated values for the net real power P_i, and reactive power Q_i, entering the network at bus i. Denoting the calculated values of P_i by P_{ical} and Q_i by Q_{ical} leads to the definition of mismatches ΔPi and ΔQ_i

$$\Delta P_i = P_{isch} - P_{ical}$$

$$\Delta Q_i = Q_{isch} - Q_{ical}$$

$$P_{isch} = P_{gi} - P_{di}$$

$$Q_{isch} = Q_{gi} - Q_{di}$$

Where

P_{isch} and Q_{isch} are the scheduled net active and reactive power injected into bus i and denote the scheduled generated active and reactive power on bus i. and designates the scheduled active and reactive power demand at the load bus i. Mismatches occur when P_{ical} and Q_{ical} they do not match the planned values. The formed set of linear equations expressing the relationship between changes in the active and reactive power components of the bus voltages can be written in compact form as

$$\begin{bmatrix} \Delta P_i \\ \Delta Q_I \end{bmatrix} = \begin{bmatrix} j_{11} & j_{12} \\ j_{21} & j_{22} \end{bmatrix} \begin{bmatrix} \Delta \sigma_I \\ \Delta V_I \end{bmatrix} \qquad (3.10)$$

The Jacobian matrix$j_{12}j_{12}$ is set up as a partitioned matrix by convention in the form

$$\begin{bmatrix} \frac{\partial P}{\partial \sigma} & \frac{\partial P}{\partial |V|} \\ \frac{\partial Q}{\partial \sigma} & \frac{\partial Q}{\partial |V|} \end{bmatrix} \qquad (3.11)$$

The off-diagonal and diagonal terms in the sub-matrices are real numbers calculated by partial differentiation of equations 3.12 and 3.13 with respect to σi and $|Vi|$ as shown by the following relations.

$$j_{11} = \frac{\partial P}{\partial \sigma} = \begin{bmatrix} \frac{\partial P_i}{\partial \sigma_i} & \cdots & \frac{\partial P_i}{\partial \sigma_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial \sigma_i} & \cdots & \frac{\partial P_i}{\partial \sigma_n} \end{bmatrix} \qquad (3.12)$$

$$j_{12} = \frac{\partial P}{\partial |V|} = \begin{bmatrix} \frac{\partial P_i}{\partial |V|_i} & \cdots & \frac{\partial P_i}{\partial |V|_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial |V|_i} & \cdots & \frac{\partial P_i}{\partial |V|_n} \end{bmatrix} \qquad (3.13)$$

$$j_{21} = \frac{\partial Q}{\partial \sigma} = \begin{bmatrix} \frac{\partial Q_i}{\partial \sigma_i} & \cdots & \frac{\partial Q_i}{\partial \sigma_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial \sigma_i} & \cdots & \frac{\partial Q_n}{\partial \sigma_n} \end{bmatrix} \qquad (3.14)$$

$$j_{22} = \frac{\partial Q}{\partial |V|} = \begin{bmatrix} \frac{\partial Q_i}{\partial |V|_i} & \cdots & \frac{\partial Q_i}{\partial |V|_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial |V|_i} & \cdots & \frac{\partial Q_N}{\partial |V|_n} \end{bmatrix} \quad (3.15)$$

The solution for $\Delta\partial\sigma_i$, ΔVi according to equation 3.23 gives the correction to be applied to $|Vi|$ and σi.

$$|V_i|^{(r+1)} = |V_i|^{(r)} + \Delta|V_i|^{(r)} \quad (3.16)$$

$$|\sigma_i|^{(r+1)} = |\sigma_i|^{(r)} + \Delta|\sigma_i|^{(r)} \quad (3.17)$$

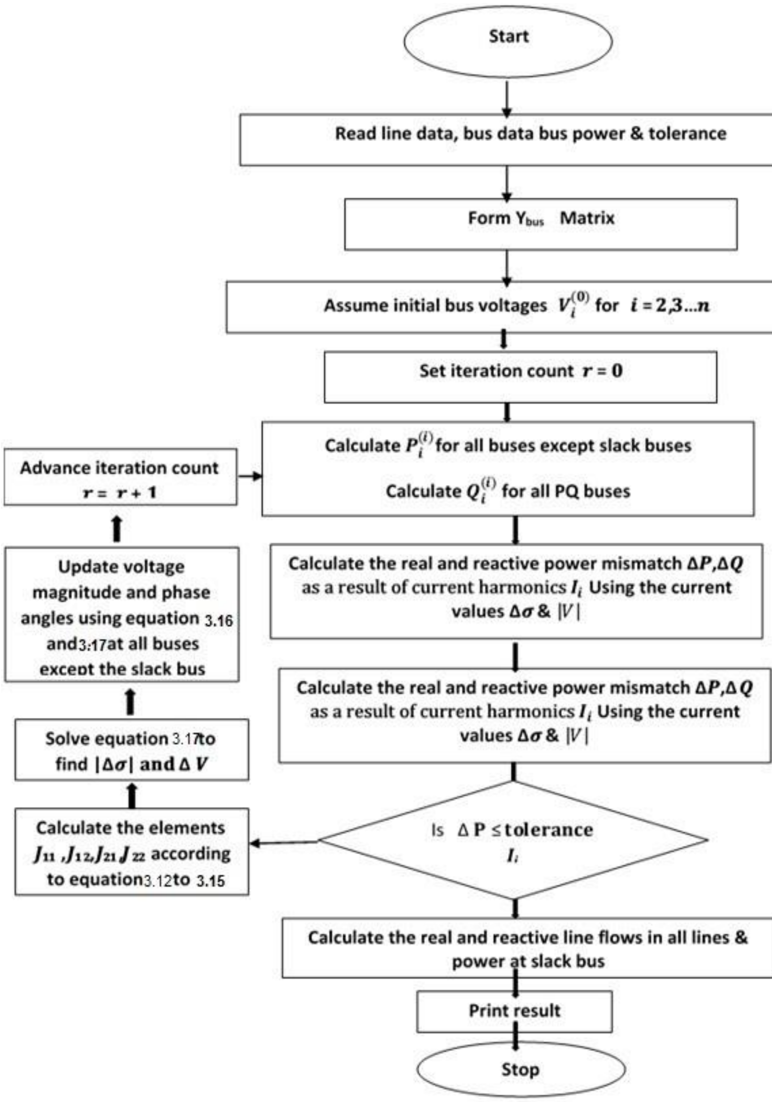

Figure 3.2 Newton Raphson flow chart for power flow in buses

3.2.3 Implementation of the World Bank 11 kv/415 V DN on Etap

From the obtained data, the load distribution along the world bank DN follows mapped out distances and line data's, implementing this structure on Etap will be easier

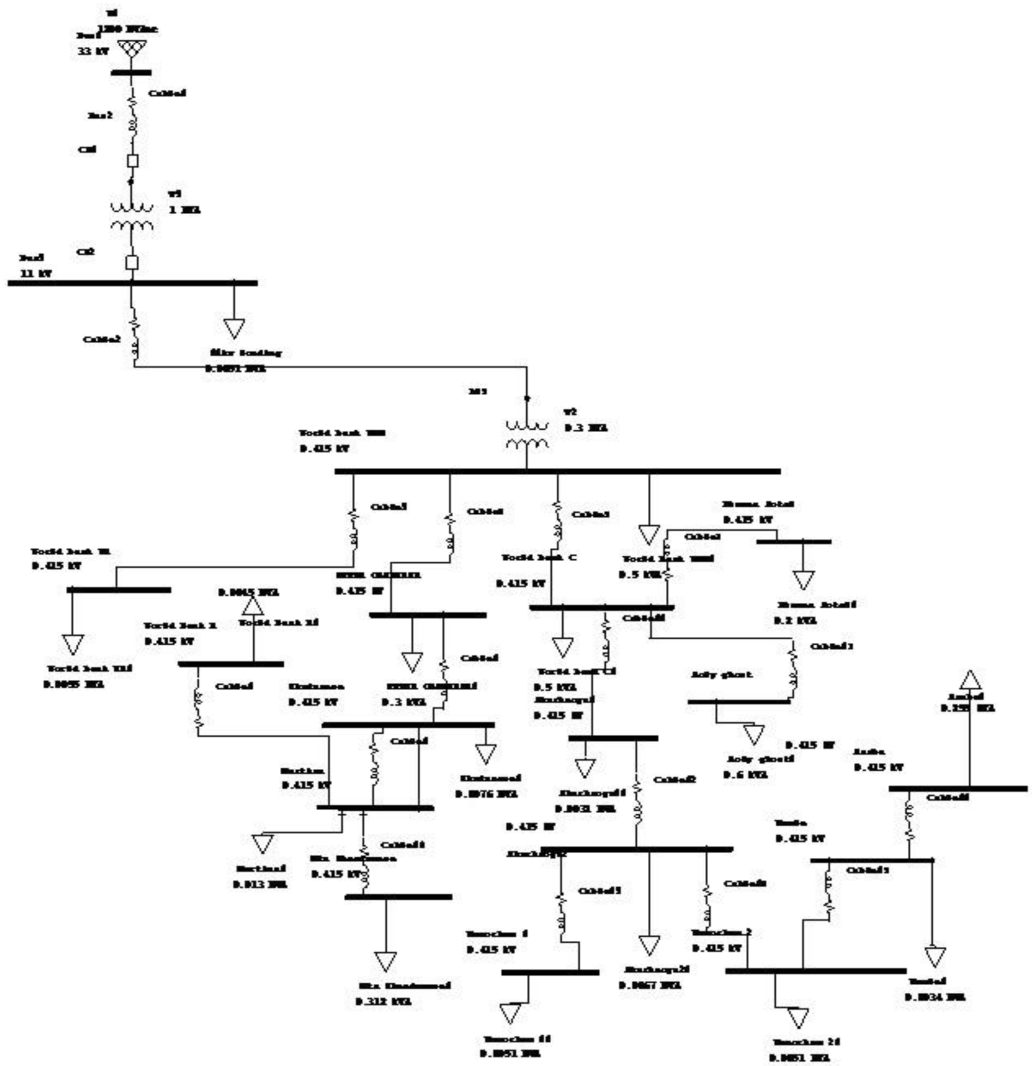

Figure 3.3 World bank distribution network on ETAP

The result of the above simulation was presented in table 4.2 and table 4.3

The voltage at each bus was noted and the data collected. The simulation was repeated on different scenarios as power was injected at different bus through the PV system DG. Improvements on the voltages at different buses were also noted.

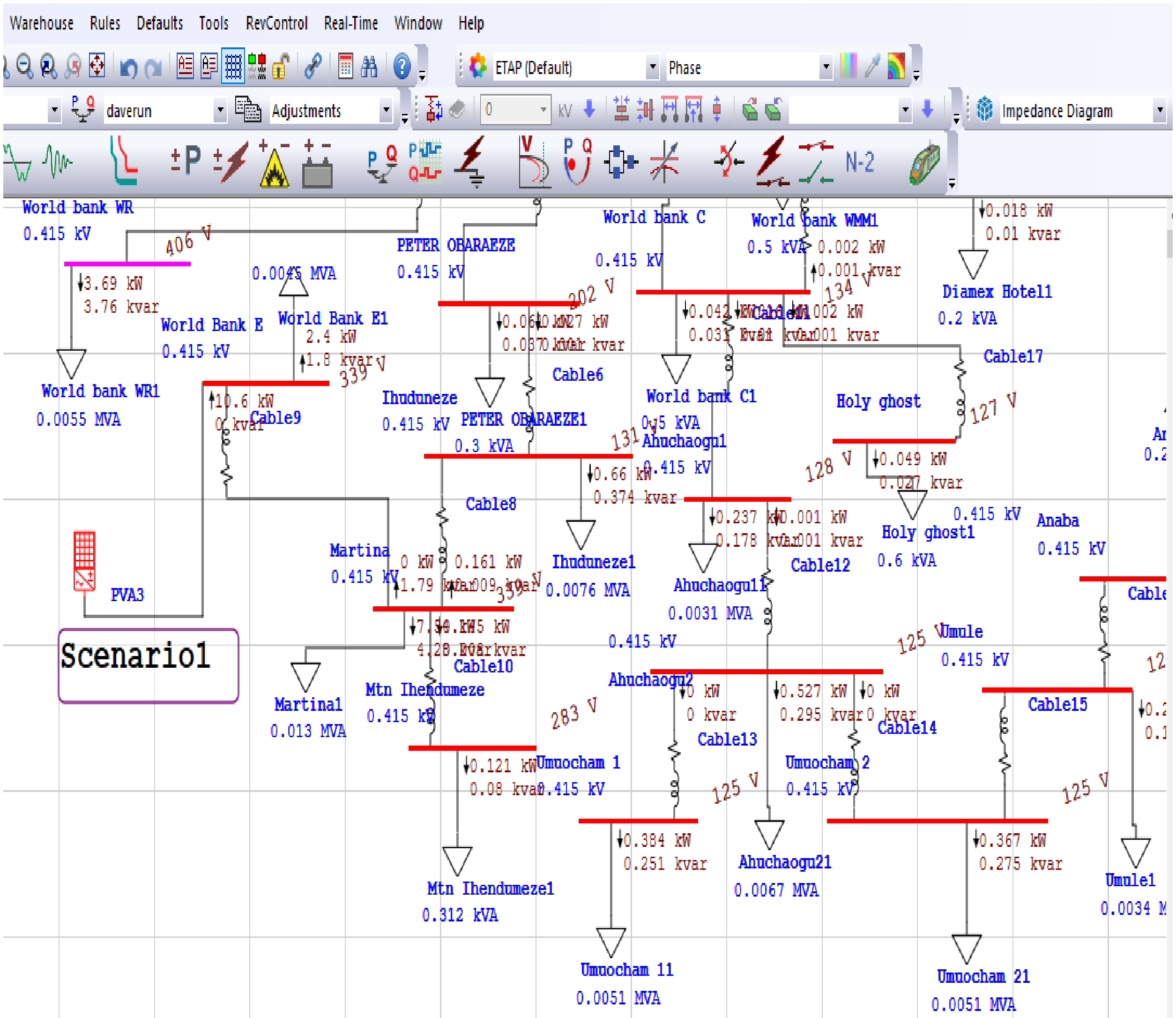

Fig 3.4 DG integration at World Bank east

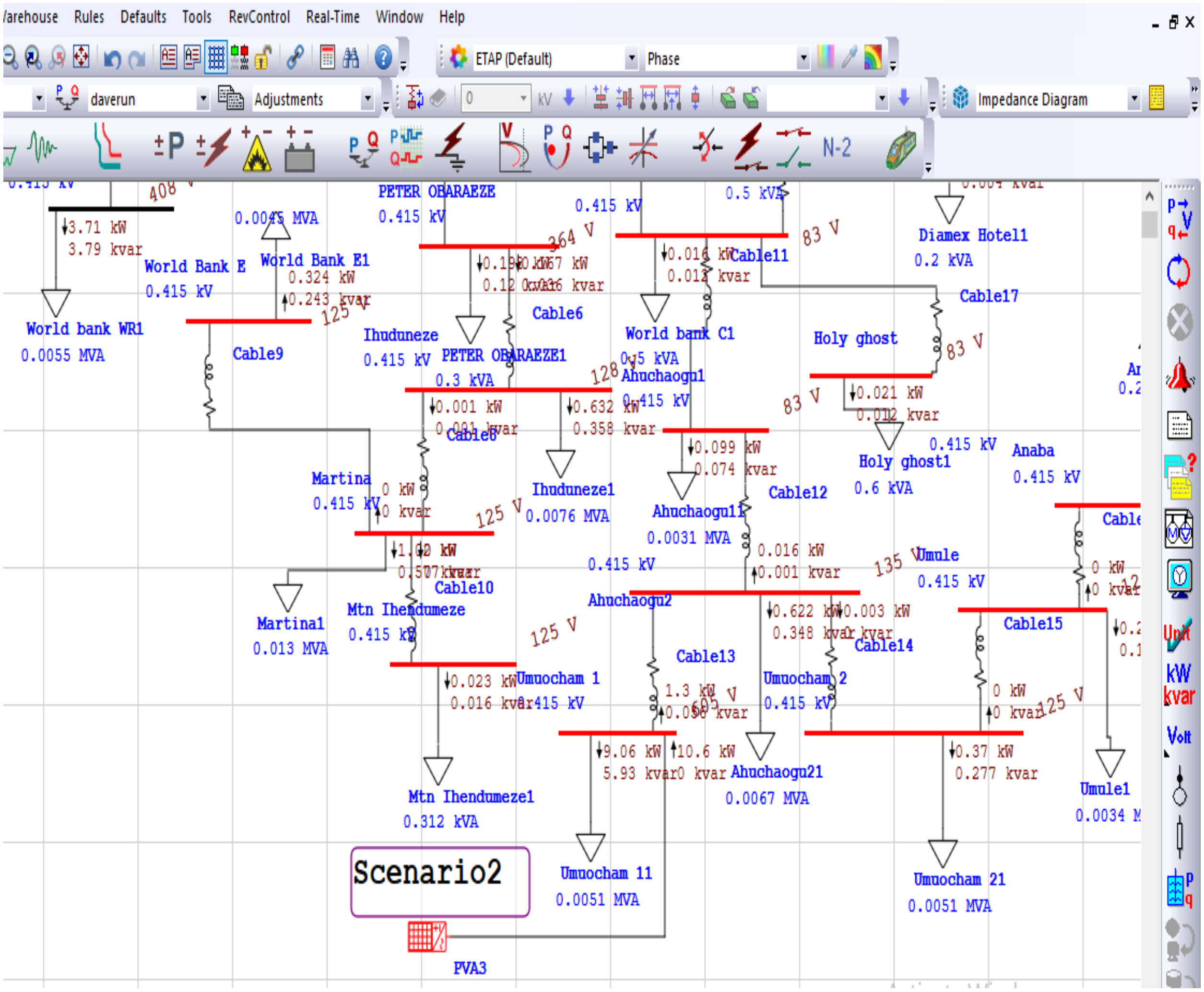

Fig 3.5 DG integration at Umuocham 1

4. RESULTS AND DISCUSSIONS

4.1 RESULTS

The results to be presented will includes the power flow data from Etap, the results will be collected in 4 different scenarios following the injection of solar PV's to areas of poor voltage

The data required for the design and simulation of the solar DG unit and the DN for the world bank on Etap is as shown, table 4.1 shows the simulation data for the PV unit,

Table 4.1: Solar PV rating chosen for DG integration

PV panel	Values
Power	400 watt/panel

Temp.	-40 ~+85degree C
DC volts	1000V/1500V/DC

The flow data at the various buses before the integration of solar PV to the feeders as shown table 4.3, the table shows the nominal at the various buses, each of the 0.415 kv bus are linked to the 11kv bus stepped down by the connected transformers. From the flow data, there is need to integrate solar PV's at Umuocham 1 & 2, world bank east and Ihuduneze buses.

Table 4.3:Bus data of the distribution network

Bus ID	Nominal kV	Type	Voltage (V)	kW Loading	kvar Loading
Ahuchaogu1	0.415	Load	128.4	0.239	0.179
Ahuchaogu2	0.415	Load	124.6	0.527	0.295
Anaba	0.415	Load	124.5	0.0192	0.0126
Bus3	11	Load	10983.7	8.36	7.95
Diamex Hotel	0.415	Load	132	0.0176	0.01
Holy ghost	0.415	Load	126.7	0.0488	0.0273
Ihuduneze	0.415	Load	128.3	0.634	0.359
Martina	0.415	Load	124.5	1.02	0.578
Mtn Ihendumeze	0.415	Load	124.5	0.0234	0.0156
PETER OBARAEZE	0.415	Load	366	0.37	0.168
Umule	0.415	Load	124.5	0.272	0.14
Umuocham 1	0.415	Load	124.5	0.384	0.251
Umuocham 2	0.415	Load	124.5	0.367	0.275
World bank C	0.415	Load	134	0.0624	0.0434
World Bank E	0.415	Load	124.5	0.324	0.243
World bank WMM	0.415	Load	393.005	16.81	4.31
World bank WR	0.415	Load	385.0785	13.26	3.82

4.1.1 PV Integration Scenarios

for proper integration of solar PV to the World Bank Distribution grid, the following scenarios will be adopted.

The scenarios includes

I. Power flow data without integration of solar PV
II. Power flow data with integration of solar PV at world bank east
III. Power flow data with integration of solar PV at Umuocham 1

When an integration is made at the World Bank east bus, there was a significant boost in the Bus voltage from 124.5 to 239.01 (figure 4.1) also there was a significant boost in the bus voltage at Martina from 124.5 V to 339 V. bus voltage in buses like MTN ihendumeze experienced a significant boost in bus voltage from 124.5 V to 282.8 V.

Table 4.5: Bus Data for DG integration at World Bank east Bus

Bus ID	Nominal kV	Type	Voltage	kW Loading	kvar Loading
Ahuchaogu1	0.415	Load	128.4	0.238	0.179
Ahuchaogu2	0.415	Load	124.6	0.527	0.295
Anaba	0.415	Load	124.5	0.0192	0.0126
Bus3	11	Load	10972.2	13.05	14.24
Diamex Hotel	0.415	Load	131.9	0.0176	0.01
Holy ghost	0.415	Load	126.7	0.0488	0.0273
Ihuduneze	0.415	Load	131.2	0.66	0.374
Martina	0.415	Load	339	7.85	6.09
Mtn Ihendumeze	0.415	Load	282.8	0.121	0.0804
PETER OBARAEZE	0.415	Load	201.7	0.317	1.36
Umule	0.415	Load	124.5	0.272	0.14
Umuocham 1	0.415	Load	124.5	0.384	0.251
Umuocham 2	0.415	Load	124.5	0.367	0.275
World bank C	0.415	Load	133.9	0.062	0.0432
World bank E	0.415	Load	239.01	1.4	0.8
World bank WMM	0.415	Load	408.1	9.26	10.56
World bank WR	0.415	Load	406.1	3.69	3.76

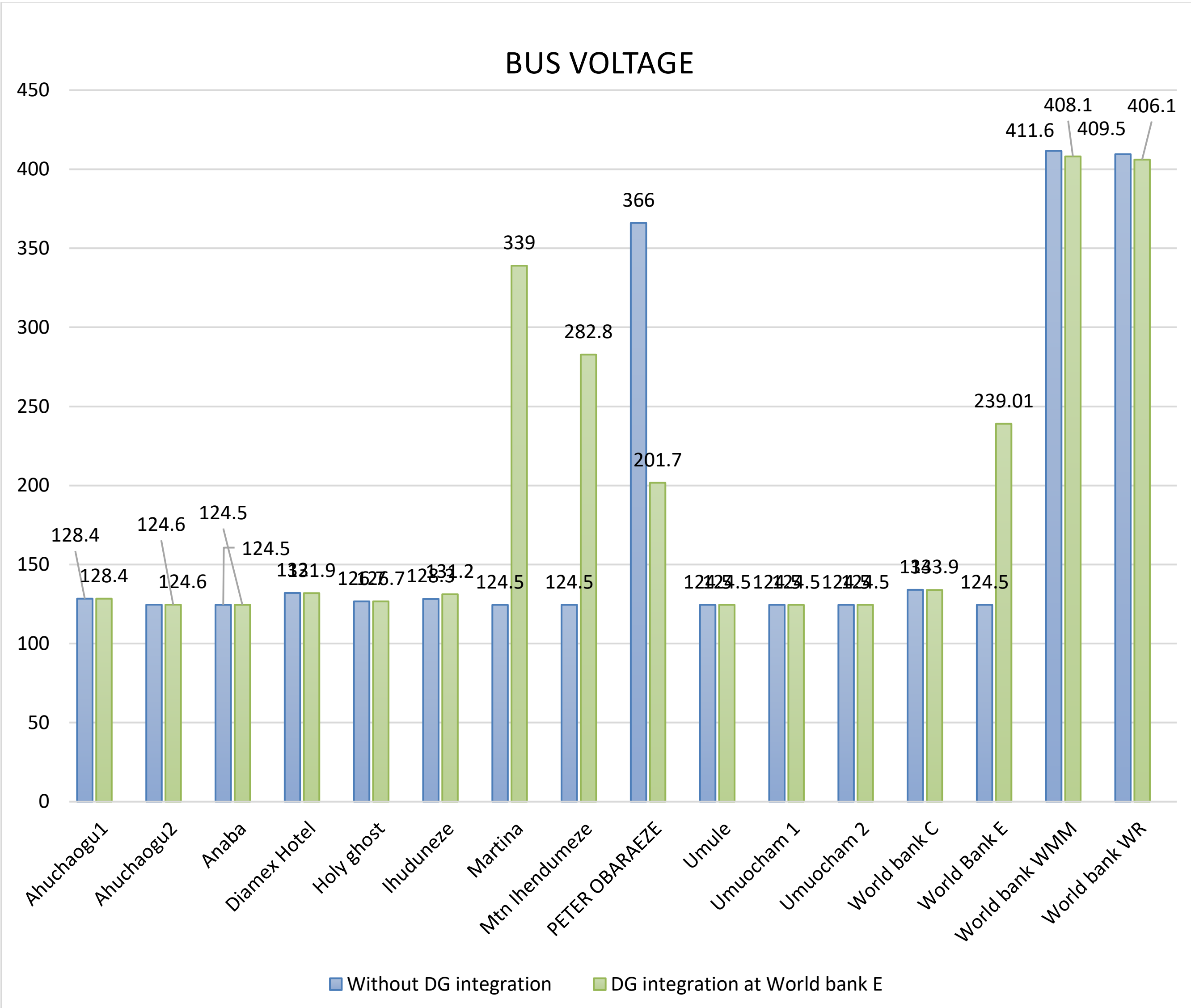

Figure 4.1: bus voltage world bank east DG integration

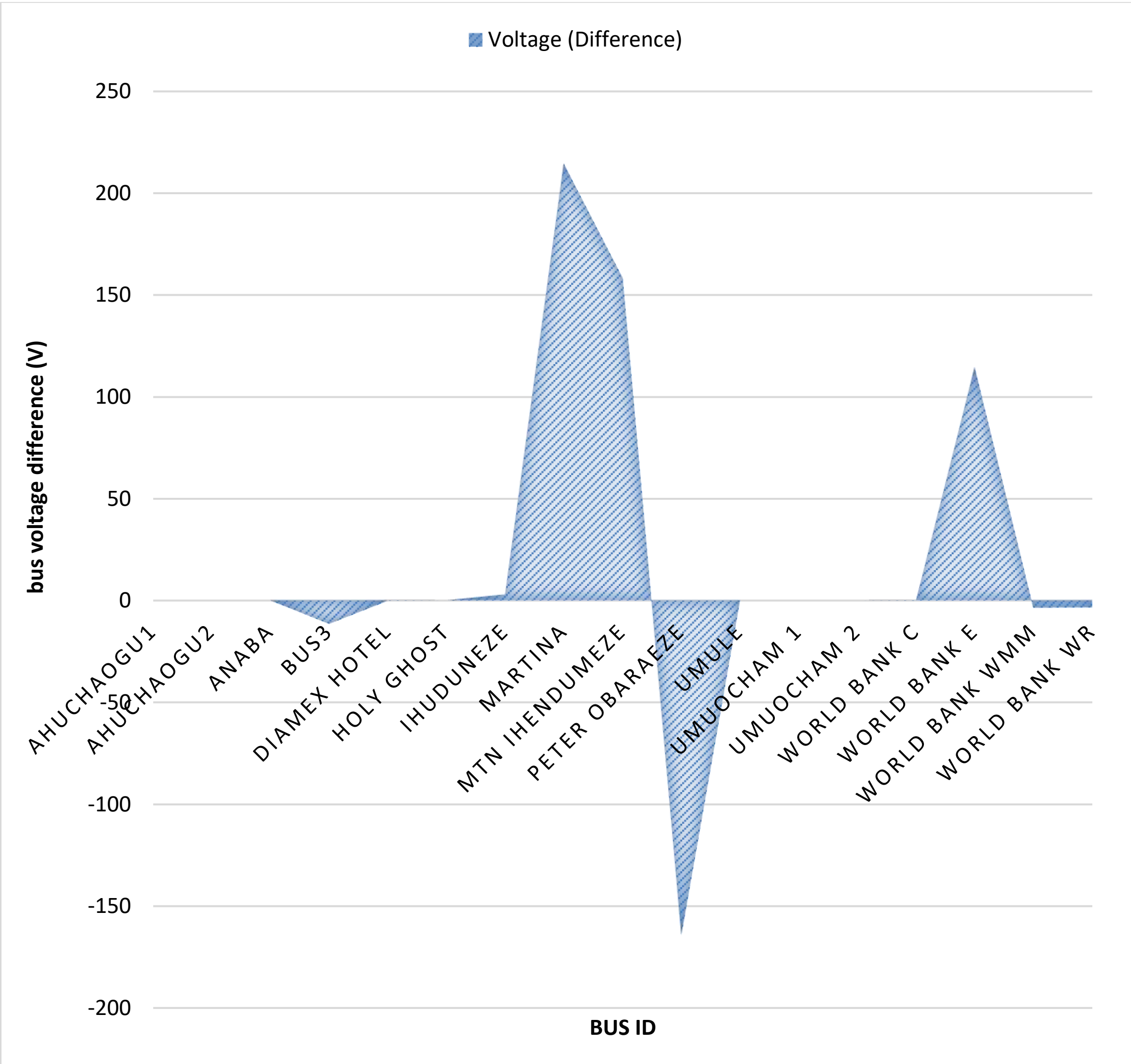

Fig 4.2: Bus voltage difference World Bank east DG integration

When an integration is made at the Umuocham 1 bus, there was a significant boost in the Bus voltage from 124.5 V to 213 V (figure 4.7, also there are also less significant drop in the bus voltage at world bank central from 134 V to 83 V. bus voltage in buses like Ahuchaugo 2 experienced a minor boost in bus voltage from 124.5 V to 235.3 V.

Table 4.7: Bus Data for DG integration at **Umuocham 1** Bus

Bus ID	Nominal kV	Type	Voltage	kW Loading	kvar Loading
Ahuchaogu1	0.415	Load	83	0.0992	0.0744
Ahuchaogu2	0.415	Load	135.3	0.641	0.349
Anaba	0.415	Load	124.5	0.0192	0.0126

Bus3	11	Load	10975.9	10.38	12.92
Diamex Hotel	0.415	Load	83	0.007	0.0039
Holy ghost	0.415	Load	83	0.021	0.0117
Ihuduneze	0.415	Load	128.3	0.633	0.359
Martina	0.415	Load	124.5	1.02	0.578
Mtn Ihendumeze	0.415	Load	124.5	0.0234	0.0156
PETER OBARAEZE	0.415	Load	364.3	0.366	0.166
Umule	0.415	Load	124.5	0.272	0.14
Umuocham 1	0.415	Load	233	1.93	2.06
Umuocham 2	0.415	Load	124.9	0.37	0.277
World bank C	0.415	Load	83	0.0182	0.0285
World Bank E	0.415	Load	124.5	0.324	0.243
World bank WMM	0.415	Load	409.7	6.67	9.26
World bank WR	0.415	Load	407.6	3.71	3.79

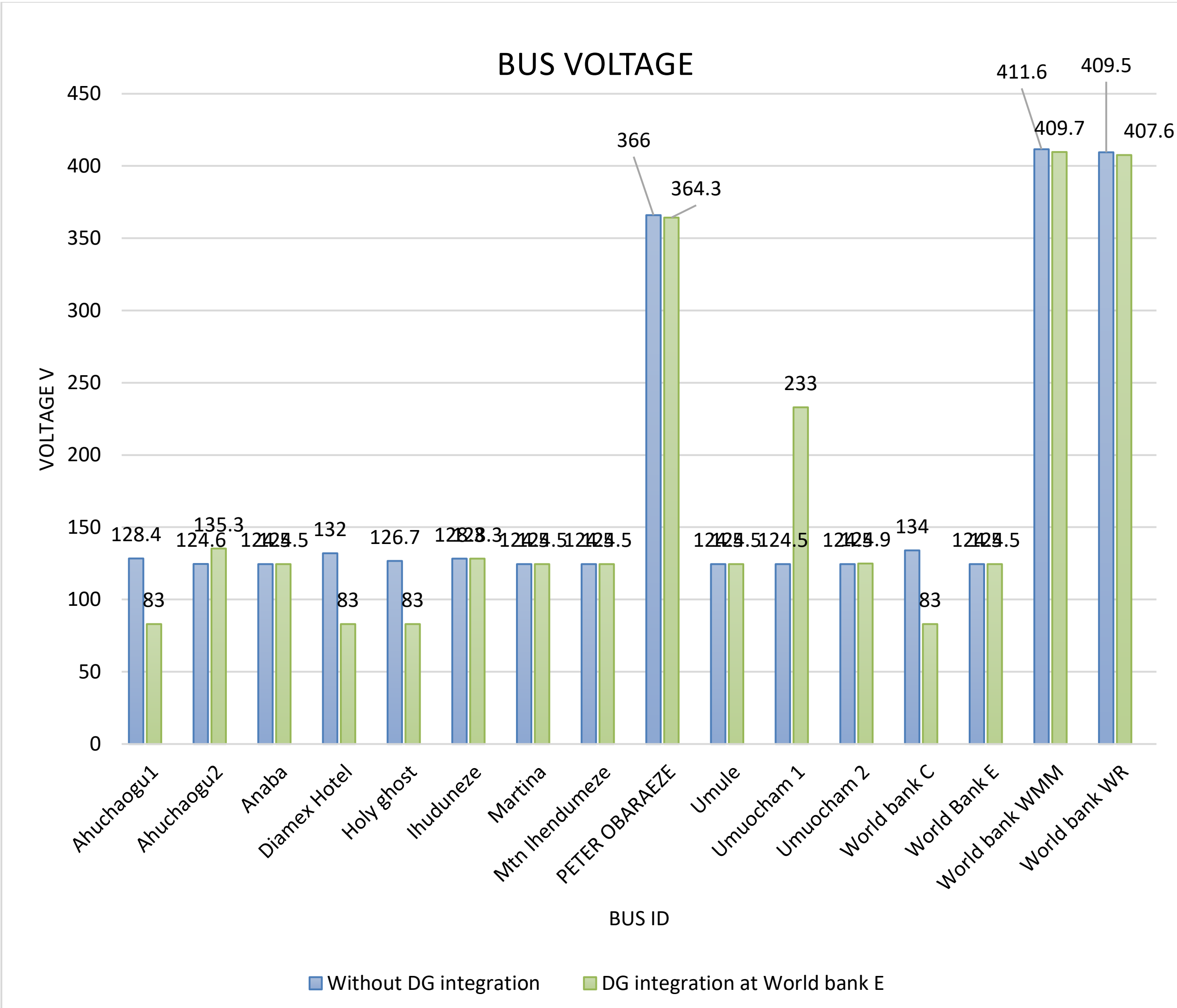

Fig 4.3: Bus voltage Umuocham 1 DG integration

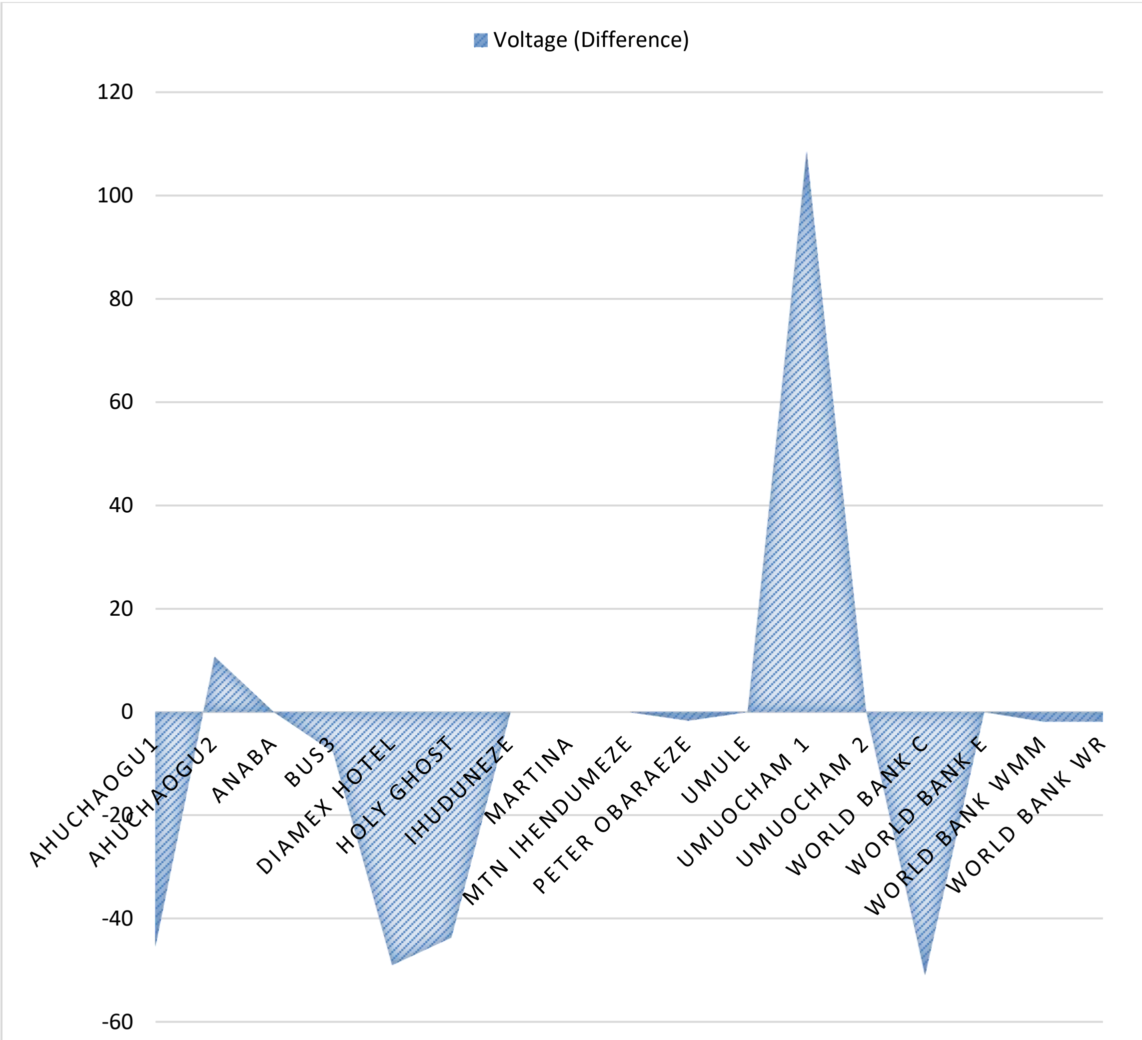

Fig 4.4: Bus voltage difference Umuocham 1 DG integration

4.2 DISCUSION

4.2.1 Voltage Violations

This type of violation occurs at the buses. This suggests that the voltage at the bus is less or higher than the specified value. The operating range of voltage at any bus is generally 0.95p.u - 1.05p.u. i.e. (394.25V – 435.75V). Thus if the voltage falls below 0.95p.u then the bus is said to have low voltage. If the voltage rises above the 1.05p.u then the bus is said to have a high voltage problem. \

4.2.2 DG Integration at World bank east

From the voltage difference plot, as shown in figure 4.2 the chart was generated from data inputted in Microsoft excel. There is a significant difference in the bus voltage before and after the DG integration at the World Bank east improving Martina and MTN Ihendumeze

4.2.3 DG Integration at Umuocham 1

From the voltage difference plot (figure 4.3), there is a significant difference in the bus voltage before and after the DG integration at the Umuocham 1 improving (also shown in figure 4.4), while buses like holy ghost and Diamex hotel experience a significant voltage drop below the nominal value.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The carried out study has shown the importance of renewable energy sources as means of power integration. The study has introduced the integration of Solar PV DG systems to distribution grids/buses as a way of improving the voltage profile as well as the wattage flow in busses so as to enable the production of quality power.

The results presented in this study has taking into case the world bank 11/415kv DN Aba, and the power flow analysis has been done with and without the DG, 2 scenarios were established for cases where there are lapses in bus voltages along the distribution network, the results also show that DG integration at this identified buses can help boost the bus voltage to other buses. Analysis for bus voltages, voltage differences were carried out and the results proved that the integration of DG at this buses would compensate power at the buses and other buses depending on the loadings on other buses.

Proper analysis was carried out with the help of MS excel in this study and the difference calculation were done on Etap software.

5.2 Recommendation

For further improvement of this study, there should be integration of DG at multiple buses so as to compensate power flow into other buses with voltage lapses, also to compensate for harmonic losses in the system; there should be the application of Active Power Filters at DG units so as to improve on power quality.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Akpoviroro O. E., Touati A., and Rabbah N. (2021). Embedded Generation Using Shared Solar. E3S Web of Conferences **229**, 01026

Ariyo F.Y. and Omoigui M.O. (2013). Investigation of Nigerian 330 kV Electrical Network with Distributed Generation Penetration – Part I: Basic Analyses. Published online at http://journal.sapub.org/eee

Eftekharnejad, Sara & Heydt, Gerald & Vittal, V.. (2015). Optimal Generation Dispatch With High Penetration of Photovoltaic Generation. Sustainable Energy, IEEE Transactions on. 6. 1013-1020. 10.1109/TSTE.2014.2327122.

Ganguli, Souvik and Sunanda Shinha(2009). A Study and Estimation of Grid Quality Solar Photovoltaic Power Generation Potential in some districts of West Bengal. National Conference on Trends in Instrumentation and Control Engineering (TICE)

Ganiyu Adedayo Ajenikoko, Olakunle Elijah Olabode, Oladimeji Wasiu Olayanju (2017). Distributed generation (DG) integration on utilities distribution system: A survey. International Journal of Advanced Engineering and Technology. Volume 1; Issue 4; September 2017; Page No. 01-10

IRENA. (2015). Second Ministerial Roundtable: 'The Role of Renewable Energy in Energy Security

Nath, Megha & Ghimire, Rudra. (2021). Efficiency Improvement on a Distribution Feeder: A Case Study. Journal of the Institute of Engineering, Vol **15 (No. 3)**: 97-103 National Beareu of Statistics (2022). Nigeria Electricity Report: Energy Billed, Revenue Generated And Customers By DISCOS. Electricity Report Q1-Q2 2022.

Obideyi Oluwatoni (2017). Integrating Renewable Energy into Nigeria's Energy Mix: Implications for Nigeria's Energy Security. Master's Thesis, Faculty of Landscape and Society Department of International Environment and Development Studies, Norwegian University of Life Sciences.

Pepermans G., Driesen J., Haeseldonckx D., D'haeseleer W. and Belmans R. (2003). Distributed Generation: Definition, Benefits and Issues. Faculty Of Economics And Applied Economic Sciences Center for Economic Studies Energy, Transport & Environment, Katholieke Universiteit, Leuven.

Romero, Aguero Julio. (2012). Improving the efficiency of power distribution systems through technical and non-technical losses reduction. Proceedings of the IEEE Power Engineering Society Transmission and Distribution Conference. 1-8. 10.1109/TDC.2012.6281652.

Santos, Lya & Lima, Lutero & Sacramento, Elissandro & Souto, Raylla. (2022). Performance Analysis of a Photovoltaic System installed in the Northeast of Brazil. International Journal of Advanced Engineering Research and Science. 9. 037-043. 10.22161/ijaers.95.3.

Sheryazov, S. & Shelubaev, M. & Obukhov, Sergey. (2017). Renewable sources in system distributed generation. 1-4. 10.1109/ICIEAM.2017.8076247.

Total blackout as Nigeria power grid collapses. (2023, September 14). Punch magazine. [Online]. Available: https://punchng.com/total-blackout-as-nigerias-power-grid-collapses/

U.S. Energy Information Administration (EIA). (2020). Modeling distributed generation in the building sectors.