MIGRATION INTO SMART GRID STRUCTURE: Optimal Power Performance Evaluation a Case Study of Basiri Distribution Network in Ado Ekiti, Nigeria

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ABSTRACT- The electricity structure across the globe has changed from the vertically integrated to horizontally integrated where technologies like distributed Generators, electric vehicle, renewables energy are integrated into the distribution network with a view of providing voltage upgrade, reducing power loss and to relieve transmission and distribution congestion. This is further transformed into smart grid through the use of computational intelligence techniques. In this paper, the optimal power analysis and performance evaluation of Basiri distribution network with and without DG integration was carried out. A detail modeling of the network was carried out in Matlab environment as well as the codes for the Genetic Algorithm (GA). The performance analysis was conducted using the voltage level at various bus bars as an index. Different scenarios were considered and the simulations were carried out based on the integration of different capacities of DG located manually and optimally. The steady state results show that the voltage levels in some locations were below the standard voltage level. This is addressed using genetic Algorithm to placed the DG at optimal point so as to minimize voltage drop. The GA results was able to improved the voltage level to the standard level and also to determine whether the network is capable of accommodating more DG then determining the penetration level.

Keywords: Renewable energy, distributed Generation, Vertical structure, Horizontal Structure, Penetration level

1. INTRODUCTION

Electricity plays a very important role in the socio-economic and technological development of every nation. The electricity demand in Nigeria far exceeds the supply and the available energy is epileptic in nature, [1]. The country is faced with acute electricity problems, which is hindering her development notwithstanding the availability of vast natural resources in the country. To solve the problem, many countries of the world utilize the use of energy inherent in nature such as sun, wind, waste, Tidal wave, water, etc. The energy sources are very vast and abundant in nature [2] and are located in remote places in Nigeria and Ekiti. However, most remote villages in Ekiti can not get access to electricity despite this vast deposit of energy resources.

Power generation through the abundant local resources can be made available to rural dwellers through standalone system. In case of excess generation, the excess can be supplied or marketed to the utility operators. This is known as distributed generation (DG) or embedded generation.

Generally, DG units, if properly planned and controlled, may offer improved voltage profile and power losses reduction of the distribution network, better economics and a reduced dependence on the local utility [3] The benefits can be achieved only through efficient coordination of the DG units operation, voltage regulation (voltage regulators, ULTC) and reactive power compensation (VAR compensators) within the distribution network. This is an Optimal Power Flow (OPF) problem [4]. During grid integration, the structure of the power system is altered from vertically integrated structure to horizontally integrated structure. The vertically integrated structure involve generation of power, transmission of this power and distribution to end-users. However, the horizontally integrated structure involve the use of DG integrated into the distribution network [5]. Globally this new structure called vertically integrated structured have been researched extensively and applied to the existing network and as such, sufficient information such as penetration level, and integration models that will help in the process are supplied. Due to this the new structure, DG integration has been able to provide voltage support, relieve congestion and enhance adequacy in energy provision. Unfortunately, Nigeria has not been named among nations of the world where this structured is currently being implemented. To switch into this new structure, there are technical, legal, economical etc information necessary to provide support in term of knowledge for the operators

2. DISTRIBUTED GENERATION (DG)

Distributed generation (DG) refers to the production of power near or at the consumption place. The distributed generation resources are the cogeneration (combined heat and power - CHP) units and the renewable energy sources (RES) [6]. The renewable energy sources include wind energy, solar energy, hydro energy, geothermal energy and the energy from biomass. In the central generation system the power produced by large power plants is delivered to the consumers using the transmission and distribution system. In the central generation system the power flow is unidirectional, from the power plants to the consumers. In the DG system distribution where DG unit such as wind turbines, photovoltaic system or CHP units are integrated into the consumer's uints. In this system, the power flow can be bidirectional, resulting into instabilities, lower power quality and reliability. The power supplied by the DG sources can vary according to the availability of their primary energy source (e.g. Solar), so the best location for the installation of a distributed energy source is where the primary energy source has the best potential. Researches shown that the use of DG has not effective because of it fit and forget rules. Of recent the use of intelligent algorithms has been deployed to locate the DG and make it effective in reducing voltage drop and power loassess thereby improving the system stability, energy availability and adequacy

3. SMART ENERGY OR INTELLIGENT POWER GRIDS

A Smart Grid is an electricity grid that allows the massive integration of unpredictable and intermittent renewable sources and distributes power efficiently. According to [8], the development of a "smart grid" is an evolutionary process that happens over time, and not in a single step. Often the deployment of smart grid technologies is referred to as "smartening the grid" or "modernizing the electricity system". From a starting point of an existing grid, or a construction of new networks (or extensions of networks), the deployment of smart grid technologies is not a goal in itself but rather an enabler to the provision of secure, reliable, clean, economic electricity required by end users [8].

Smart energy is an approach that overturns the traditional way of producing and consuming energy, seeking to maximize the efficiency of the process [9]. The consumer becomes the centre of the system and the Smart Energy approach is about providing the service in the most efficient and environmentally friendly way possible. A Smart grid as shown in Fig.2.4 is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it generators, consumers and those that do both in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety for supply [9].

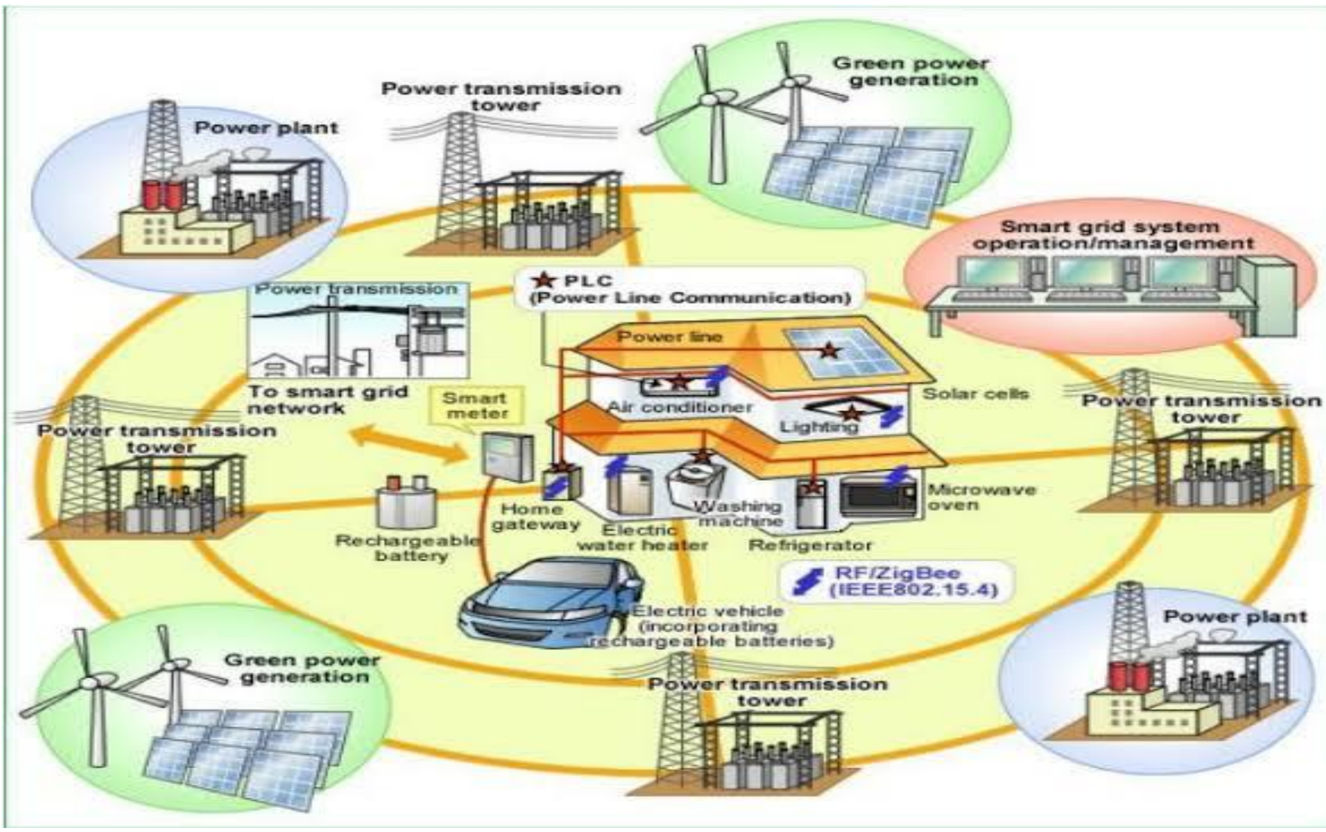

Fig. 1: Smart Grid Diagram showing various components [10]

4. SMART GRID WITH OPTIMIZATION

According to Joe [13] smart grid operation and assessment is better carried out with the use of optimization techniques. Various optimization techniques have been suggested in literatures such as Particle swarm optimization (PSO), Genetic Algorithm (GA), etc. Optimization techniques can handle problems related to reduction of loses on transmission line, reliability, economics dissipated, efficiency and environmental factors. A broad set of interrelated decisions on obtaining, operating, and maintaining physical and human resources for electricity generation, transmission, and distribution that minimize the total cost of providing electric power to all classes of consumers, subject to engineering, market and regulatory constraints, [13]. Power system optimization is aimed at improvements in more areas than cost, reliability, efficiency, economics, environmental friendliness and security. The use of modern optimization techniques has proved to be efficient and effective in the operation of smart grid. Modern optimization techniques that proved to be smarter are Genetic algorithm (GA), Particle swarm optimization (PSO), etc.

An optimized system will reduce the installation and operating cost, improve overall distribution system performance, and increase its reliability and security. According to [11] Smart Grid optimization is to make the power grid "as good as possible". There is need to find the perfect balance between reliability, availability, efficiency and cost. Optimization also aim to improve the utilization of current infrastructure and defer investments in new generation, transmission, and distribution facilities; reduce the overall cost of delivering power to end users; improve the reliability of power grid and reduce resource usage and emissions of greenhouse gases and other pollutants. In the literatures, several algorithm have been used to optimize such as PSO, GA, etc.

5. OPTIMIZATION USING GENETIC ALGORITHMS

GA can be applied in complex non-linear process controller for the optimization of parameters. Some issues are important to be considered for proper implementation of genetic algorithms to a plant to be optimized. Deciding of population size is an important issue while applying genetic algorithm. It is recommended that the population size should be of about 20-30 chromosomes. A very big population size causes more time for finding optimum solution which may deteriorate the performance of genetic algorithms. Genetic Algorithms may suffer from the problem of premature convergence due to improper selection of crossover rate. Higher crossover rate of about 85 percent to 95 percent is recommended to minimize premature convergence problems [14].
Low mutation rate at about 0.5 percent to 1 percent is generally recommended to obtain optimized results from genetic algorithms. Mutation is an artificial and forced method of changing the numerical value of the chromosomes. Mutation should be avoided as far as possible because it is totally adhoc and random in nature, small mutation rate prevent genetic algorithm from falling into local maxima or minima. Deciding of selection method for selecting good chromosomes is another important issue while applying genetic algorithms for process control applications. Rank selection method and roulette wheel selection method have shown grown good result over other methods of selection [14].
This research will focus on deployment of DG into the distribution network to carry out the optimal power analysis and to employ the use of optimization techniques.

6. RESEARCH METHODOLOGY

The sequence of methods listed below was followed to carry out the research work
1. Data gathering and processing
2. Modeling of Basiri distribution network
3. Modeling of the system using optimization method (GA)

Study Area

Basiri 11 kV feeder: This originates from Basiri 11 kV injection substation 15 MVA transformer T_2 and is feeding basiri, GRA, NTA road and Fabian Hotel part of Ado-Ekiti and the network is feeding twenty six different transformers of different ratings, the necessary data were taking from the transformers on the network for the modeling and simulated in MATLAB.
Table 1 shows the data gathering for Basiri 11 kV feeder. The data were taking from the daily record in Ado-Ekiti distribution network at Basiri injection substation control by Benin Electricity Distribution Company (BEDC).

7. MODELING OF ADO EKITI DISTRIBUTION NETWORK USING GENERIC ALGORITHM

Impedance modeling method to model Basiri feeder network. The load flow simulation was carried out using MATLAB software. The load taking representing the network impedance, hence the current load point was obtain from the secondary side of the transformer and the various load obtained from each of the transformer which represent the load on various transformers on the feeder were used for modeling and simulation. Basiri feeder Without been embedded, available energy from Basiri15 MVA was 6 MW of energy which was injected into the feeder and the results was low which resulted to integrating of 840kW,1MW, 2.5MW, and 4MW into the feeder before using Genetic algorithm.

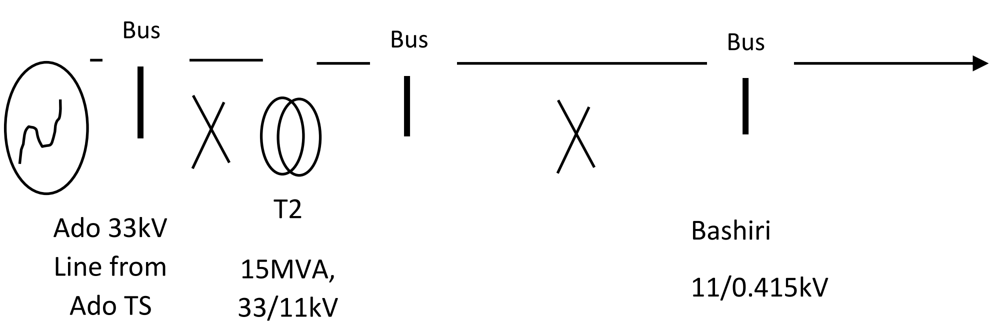

Figure 2: SINGLE LINE DIAGRAM OF BASIRI 11/0.415kV INJECTION SUB STATION

8. RESULTS AND DISCUSSION

In the results, two scenario were considered

1. Scenario 1: Optimal power flow without DG integration
2. Scenario 2: Optimal power flow with DG integration
3. Scenario 2: Optimal power flow with and without DG with increasing penetration

SCENARIO 1

OPTIMAL POWER FLOW WITH AND WITHOUT DG INTEGRATION

Optimal power flow of Basiri, distribution network was carried out and the results on Basiri 26 buses, were written in the Table 1 below which show voltage in PU**,** angle, active power on load, reactive power on load, active power on generation, reactive power on generation. The optimal power flow was carried out without DG integration and with DG integration of 840KW, 2.5 MW, 4MW.

Table 1: Optimal Load Flow of Basiri without DG Integration

Bus No	Voltage (Pu)	Angle (degree)	Active Load MW	Reactive Load Mvar	Active Generation MW	Reactive generation Mvar	Injection power MW
ADELEYE TS	0.900	0	51.000	41.000	719.524	235.494	0.000
AWEDELE TS	0.880	-0.926	22.000	15.000	79	123.915	0.000
BETTER LIFE 1 TS	0.910	-4.203	64.000	50.000	20	64.692	0.000
BETTER LIFE 2 TS	0.900	-3.556	25.000	10.000	100	55.666	0.000
BIMDOC TS	0.910	1.182	50.000	30.000	300	131.688	0.000
EGBEWA 1 TS	0.900	-2.514	76.000	29.000	0	0	0.000
EGBEWA 2 TS	0.890	-3.172	0.000	0.000	0	0	0.000
FIBIAN TS	0.860	-3.271	0.000	0.000	0	0	0.000
FOUNTAIN TS	0.920	-5.363	89	50	0	0	0.000
IKINGBINSIN TS	0.950	-5.529	0	0	0	0	0.000
ILAMOJI TS	0.880	-3.165	25	15	0	0	0.000
IREAKARI TS	0.880	-4.663	89	48	0	0	0.000
ISINLA TS	0.900	-4.415	31	15	0	0	0.000
JUDGES QTR TS	0.900	-5.021	24	12	0	0	0.000
MOYOSADE 1 TS	0.900	-5.516	70	31	0	0	0.000
MOYOSADE 2 TS2	0.910	-5.853	55	27	0	0	0.000
ODO URO TS	0.930	-4.933	78	38	0	0	0.000
OGUNBIYI TS	0.930	-1.792	153	67	0	0	0.000
OLORUNSOGO 2 TS	0.920	-6.339	75	15	0	0	0.000
PARADISE TS	0.930	-5.992	48	27	0	0	0.000
SATELITE TS	0.880	-5.731	46	23	0	0	0.000
SURULERE TS	0.890	-6.403	45	22	0	0	0.000
TEXTILE TS	0.910	-7.043	25	12	0	0	0.000
FALEGAN	0.920	-7.302	54	27	0	0	0.000

OLORUNSOGO 1	0.930	-6.721	28	13	0	0	0.000

From the above load flow result, the voltage ranges from 0.967 pu to 1.045 pu without DG integration to the network, the average result from the buses is less than 1.0 pu. This shows that the results on basiri under the Optimal load flow without DG integration with the network was not totally stable except on buses 1,2,3,4,5,9.13 and 26 which have a stable voltage of 1.01 pu to 1.015 pu.

SCENARIO 2

Table 2: Optimal Load Flow of Basiri with 2.5 MW of DG Integration

Bus No	Voltage (Pu)	Angle (degree)	Active Load MW	Reactive Load Mvar	Active Generation MW	Reactive generation Mvar	Injection power MW
ADELEYE TS	0.950	0	51.000	41.000	719.524	235.494	0.000
AWEDELE TS	0.930	-0.926	22.000	15.000	79	123.915	0.000
BETTER LIFE 1 TS	0.960	-4.203	64.000	50.000	20	64.692	0.000
BETTER LIFE 2 TS	0.950	-3.556	25.000	10.000	100	55.666	0.000
BIMDOC TS	0.960	1.182	50.000	30.000	300	131.688	0.000
EGBEWA 1 TS	0.950	-2.514	76.000	29.000	0	0	2.500
EGBEWA 2 TS	0.940	-3.172	0.000	0.000	0	0	0.000
FIBIAN TS	0.910	-3.271	0.000	0.000	0	0	0.000
FOUNTAIN TS	0.970	-5.363	89	50	0	0	0.000
IKINGBINSIN TS	0.900	-5.529	0	0	0	0	0.000
ILAMOJI TS	0.930	-3.165	25	15	0	0	0.000
IREAKARI TS	0.930	-4.663	89	48	0	0	0.000
ISINLA TS	0.960	-4.415	31	15	0	0	0.000
JUDGES QTR TS	0.950	-5.021	24	12	0	0	0.000
MOYOSADE 1 TS	0.950	-5.516	70	31	0	0	0.000
MOYOSADE 2 TS2	0.960	-5.853	55	27	0	0	0.000
ODO URO TS	0.980	-4.933	78	38	0	0	0.000
OGUNBIYI TS	0.940	-1.792	153	67	0	0	0.000
OLORUNSOGO 2 TS	0.960	-6.339	75	15	0	0	0.000
PARADISE TS	0.980	-5.992	48	27	0	0	0.000
SATELITE TS	0.930	-5.731	46	23	0	0	0.000
SURULERE TS	0.940	-6.403	45	22	0	0	0.000
TEXTILE TS	0.960	-7.043	25	12	0	0	0.000
FALEGAN	0.960	-7.302	54	27	0	0	0.000
OLORUNSOGO 1	0.980	-6.721	28	13	0	0	0.000

From load flow result recorded in Table 2, the voltage range from 0.967 pu to 1.045 pu with 2.5 MW Solar PV integration to the network, the average result from the buses is not up to 1.0 pu. This shows that the results on Basiri under the optimal load flow with DG integration is almost the same with network without DG integration.

SCENARIO 3

Simulated Results of Ado-Ekiti Distribution Network with Increase in Penetration

In this section, the penetration level of the DG is increased from no DG to 840 kW, to 2.5MW and finally to 4MW. At the moment, there is no single panel that can supply 840KW at once. Even the combination of many panels that will give the desired output might have control or integration problem. Hence, in this research a distributed approach is use where the desired output is split into smaller wattage and located at different locations on the network.

The following penetration levels (PL) were considered,

PL1: Steady State results without DG Integration – Base case

PL2 Steady State results when 840 kW of DG was integrated

PL3: Steady State results when 2.5MW of DG was integrated

PL4: Steady State results when 4 MW of DG was integrated

From the analysis above, PL2 to PL4 is considered to be distributed arbitrarily across the selected feeders. The distribution is as shown in Table 3

Table 3: Arbitrary location of DG in Basiri feeder

S/N	840kW	Locations	2.5 (in MW)	Locations	4MW	Locations
1	240	Egbewa	1	Egbewa	1	Egbewa
2	200	Isinla	0.5	Isinla	1	Isinla
3	200	Fibian	0.5	Fibian	1	Fibian
4	200	Ireakari	0.5	Ireakari	1	Ireakari

Table 4: Steady State Voltage Results of Basiri feeder with and without DG Integration

SUBSTATION	No Distributed generation (pu)	Voltage (pu) when 840kW Was connected	Voltage (pu) when 2.5MW Was connected	Voltage (pu) when 4MW Was connected
ADELEYE TS	0.900	0.920	0.950	0.970
AWEDELE TS	0.880	0.900	0.930	0.950
BETTER LIFE 1 TS	0.910	0.930	0.960	0.980
BETTER LIFE 2 TS	0.900	0.920	0.950	0.970
BIMDOC TS	0.910	0.930	0.960	0.980
EGBEWA 1 TS	0.900	0.920	0.950	0.970
EGBEWA 2 TS	0.890	0.910	0.940	0.950
FIBIAN TS	0.860	0.880	0.910	0.930
FOUNTAIN TS	0.920	0.940	0.970	0.990
IKINGBINSIN TS	0.850	0.870	0.900	0.920
ILAMOJI TS	0.880	0.900	0.930	0.950
IREAKARI TS	0.880	0.900	0.930	0.950
ISINLA TS	0.900	0.920	0.960	0.970
JUDGES QTR TS	0.900	0.920	0.950	0.970
MOYOSADE 1 TS	0.900	0.920	0.950	0.970
MOYOSADE 2 TS2	0.910	0.930	0.960	0.980
ODO URO TS	0.930	0.950	0.980	1.000
OGUNBIYI TS	0.890	0.910	0.940	0.960
OLORUNSOGO2 TS	0.920	0.930	0.960	0.980
PARADISE TS	0.930	0.950	0.980	1.000
SATELITE TS	0.880	0.900	0.930	0.940
SURULERE TS	0.890	0.910	0.940	0.960
TEXTILE TS	0.910	0.930	0.960	0.980
FALEGAN	0.920	0.930	0.960	0.980
OLORUNSOGO 1	0.930	0.950	0.980	1.000

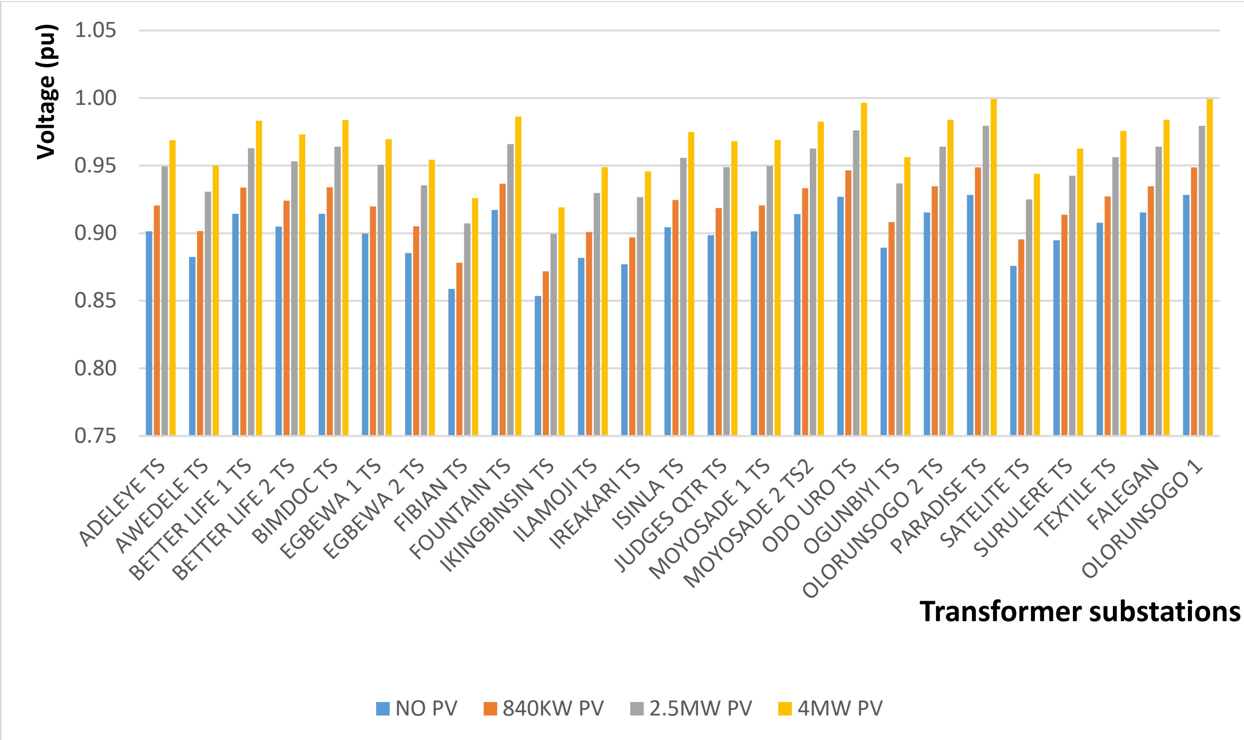

Figure 3: Steady State Voltage of Basiri Distribution Network

Steady State Voltage Result of Basiri Feeder when it was Optimally Located by GA is carried out here according the earlier scheduled penetration level i.e PL1-PL4

The distribution is done optimally and reported in this table 5 for Basiri feeder.

Table 5: Optimal location of DG on Basiri feeder with GA

S/N	840kW	Substations	2.5 (in MW)	Substations	4MW	Substations
1	240	Better life 1 TS	1	Better life 1 TS	1	Better life 1 TS
2	200	Paradise TS	0.5	Paradise TS	1	Paradise TS
3	200	Judges Qtr TS	0.5	Judges Qtr TS	1	Judges Qtr TS
4	200	Falegan TS	0.5	Falegan TS	1	Falegan TS

Table 5, shows the optimal location of DG using GA. The location was optimally done and it is shown in Table 4.13.

Table 6: Steady State Voltage Results of Basiri feeder with/without DG when GA was used for optimal location

SUBSTATION	No Distributed generation (pu)	Voltage (pu) when 840kW Was connected	Voltage (pu) when 2.5MW Was connected	Voltage (pu) when 4MW Was connected
ADELEYE TS	0.920	0.930	0.970	1.000
AWEDELE TS	0.900	0.910	0.950	1.010
BETTER LIFE 1 TS	0.920	0.940	0.980	1.000

BETTER LIFE 2 TS	0.920	0.930	0.970	1.020
BIMDOC TS	0.920	0.940	0.980	1.030
EGBEWA 1 TS	0.910	0.930	0.970	1.020
EGBEWA 2 TS	0.900	0.920	0.960	1.010
FIBIAN TS	0.900	0.910	0.940	1.010
FOUNTAIN TS	0.930	0.950	0.980	1.030
IKINGBINSIN TS	0.870	0.920	0.960	1.020
ILAMOJI TS	0.890	0.910	0.950	1.010
IREAKARI TS	0.900	0.920	0.950	1.010
ISINLA TS	0.920	0.930	0.980	1.030
JUDGES QTR TS	0.910	0.930	0.970	1.020
MOYOSADE 1 TS	0.910	0.920	0.970	1.020
MOYOSADE 2 TS2	0.920	0.930	0.980	1.020
ODO URO TS	0.930	0.950	1.000	1.040
OGUNBIYI TS	0.900	0.920	0.960	1.020
OLORUNSOGO2 TS	0.930	0.940	0.980	1.010
PARADISE TS	0.930	0.950	1.000	1.040
SATELITE TS	0.900	0.920	0.950	1.020
SURULERE TS	0.900	0.920	0.960	1.020
TEXTILE TS	0.920	0.940	0.980	1.030
FALEGAN	0.940	0.950	0.980	1.030
OLORUNSOGO 1	0.930	0.940	1.000	1.040

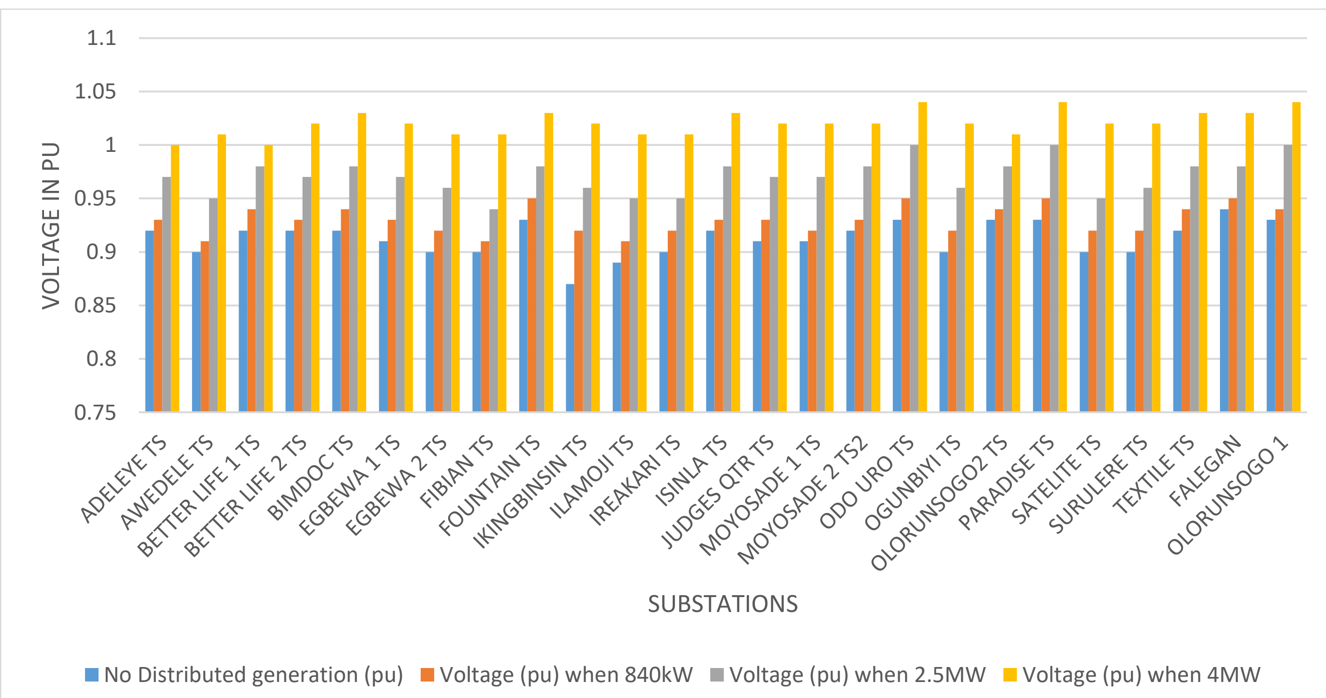

Figure 4: Steady State Voltage Results of Basiri feeder with GA

Table 7: Comparison of Load Flow result and optimal load flow results of 2.5MW for Basiri feeders with GA

BASIRI FEEDERS	Voltage (PU)	Voltage(PU) with GA
ADELEYE TS	0.950	0.970
AWEDELE TS	0.930	0.950
BETTER LIFE 1 TS	0.960	0.980
BETTER LIFE 2 TS	0.950	0.970
BIMDOC TS	0.960	0.980
EGBEWA 1 TS	0.950	0.970
EGBEWA 2 TS	0.940	0.960
FIBIAN TS	0.910	0.940
FOUNTAIN TS	0.970	0.980
IKINGBINSIN TS	0.900	0.960
ILAMOJI TS	0.930	0.950
IREAKARI TS	0.930	0.950
ISINLA TS	0.960	0.980
JUDGES QTR TS	0.950	0.970
MOYOSADE 1 TS	0.950	0.970
MOYOSADE 2 TS2	0.960	0.980
ODO URO TS	0.980	1.000
OGUNBIYI TS	0.940	0.960
OLORUNSOGO 2 TS	0.960	0.980
PARADISE TS	0.980	1.000
SATELITE TS	0.930	0.950
SURULERE TS	0.940	0.960
TEXTILE TS	0.960	0.980
FALEGAN	0.960	0.980
OLORUNSOGO 1	0.980	1.000

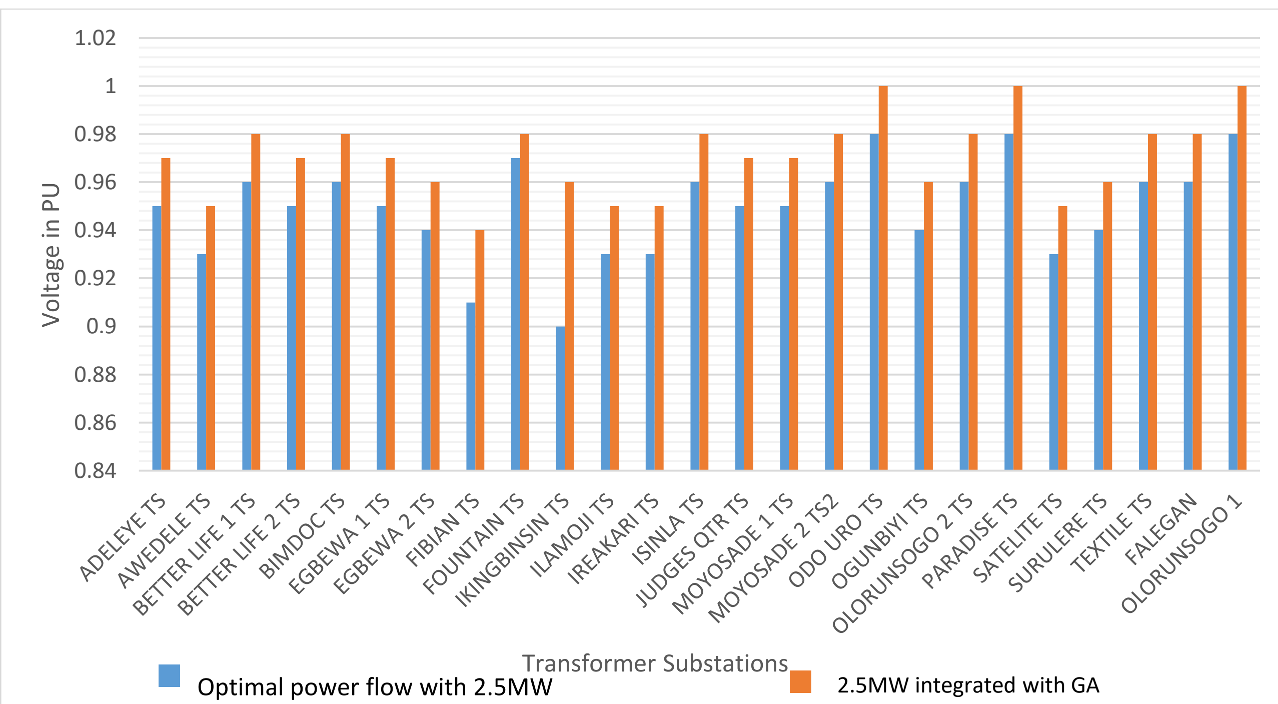

Figure 5: Comparison of Load Flow result and optimal load flow results of 2.5MW for Basiri feeders with GA

9. CONCLUSION

The conversion and switching from the present grid to the new grid called smart Grid requires the knowledge of some fact and technicality. This technically involves the use of computational intelligence techniques. In this research an algorithm called Genetic Algorithm is developed for the optimal placement of distributed generation on Basiri Network and to effectively configure the system to a new grid that is smart in decision taking and that will enhance the functions and advantages of DG to costomers.

The result shows that when there is no DG integration into the network, the voltage was low in the distribution network, but when Basiri network was integrated with 840 kW of Solar PV, the voltage was not enough to stabilize the system, but when integrated with: 2.5 MW, 4 MW of Solar PV, the voltage improved and became stable.

It is also discovered that the more the penetration, the closer is it to the Voltage margin. This is due to the fact that the system is already loaded and small additional load will make the system to be stressed.

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