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Voltage Improvement and Genetic Algorithm for Optimal Location: A Case Study of Okesha Distribution Network, Ado Ekiti, Nigeria

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Abstract— **This research was carried out to assess the voltage improvement of Okesha distribution network using genetic algorithm. This paper outlines in detail voltage improvement and genetic algorithm for optimal location of Okesha distribution network, with DG integration. The study was carried out on Okesha feeder. The modelling was performed in MATLAB and codes were written for the Genetic Algorithm (GA). The performance analysis was conducted using the voltage level at various bus bars. Simulation on MATLAB of the Feeder was carried out without any integration and with integration of 500kV, 1 MW and 2MW. DG was then located manually and the voltage results were compared with optimal location using GA. From the findings, it was discovered that low power source on the distribution network cannot be sufficient for power distribution network, hence the consumers will not receive adequate voltage supply. Therefore, this study concludes that various capacity of the feeder should be ascertained while adequate DG should be integrated at the appropriate points to enhance adequate power supply to the users/consumers. The study therefore recommend that, while integrating DG on the distribution network, adequate precautionary measures should be taken to prevent the end users from receiving excessive voltage which can damage their appliances. Also, the various sources of energy to be integrated should be within the scope of the feeder.**

Index Terms— **Voltage improvement, Distribution network, Genetic Algorithm, Distributed generation,**

I. INTRODUCTION

Electricity plays a very important role in the socio-economic and technological development of every nation. This has made the electricity demand in Nigeria to be more than the energy generated. Electricity demand in Nigeria far exceeds the generated capacity [9].This has caused the demand for additional generation of electricity horizontally across the globe, and has changed from the vertically integrated to horizontally integrated structure where technologies like distributed Generators, electric vehicle, renewables energy are integrated into the distribution network with a view of providing voltage improvement, reducing power loss and to relieve transmission and distribution congestion.

This paper outlines in detail voltage improvement and genetic algorithm for optimal location: a case study of Okesha distribution network, with DG integration. The study was carried out on Okesha feeder. The modelling was performed in MATLAB and codes were written for the Genetic Algorithm (GA). The performance analysis was conducted using the voltage level at various bus bars. Simulation on MATLAB of the Feeder was carried out without any integration and with integration of 500kV, 1 MW and 2MW. DG was then located manually and the voltage results were compared with optimal location using GA.

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II. DISTRIBUTED GENERATION

Distributed generation (DG) refers to the production of power near or at the consumption place.According to [4] DG set-up can improve the voltage profile if it is well placed and positioned. There shall be a lot of reduction in voltage losses on the DG network.The distributed generation resources are the co-generation (combined heat and power - CHP) units and the renewable energy sources (RES) [1]. The renewable energy sources include wind energy, solar energy, hydro energy, geothermal energy and the energy from biomass. Also, the power produced by these sources is relatively small. 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 this system, the power flow is bidirectional, from the consumer to the distribution level. Due to the connection of these DG sources, the power losses are lower and the power quality and reliability of the grid are improved. These 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 [8].The DG sources can also be used to supply power to an isolated consumer, which is not connected to the power grid. The power supplied by the DG sources can vary according to the availability of their primary energy source (e.g. Solar PV), so the best location for the installation of a distributed energy source is where the primary energy source has the best potential. The optimization will consider the minimization of the power losses and of the generation costs. The solar PV is integrated with the distribution network [1].

III. 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 [3] smart grid optimization is to make the power grid "as good as possible". It is an electricity network that uses distributed energy resources as well as advanced communication and control technologies to deliver electricity more cost-effectively, with lower greenhouse intensity and active involvement of the customers [2]. To balance the load of the consumers on the power system, smaller forms of electricity generation are combined with energy management. Small generators include wind turbines, solar panels, micro turbines, fuel cells and co-generation (combined heat and power).A small capacity power plant based on either combustion-based technologies, such as reciprocating engines and turbines, or non-combustion based technologies such as fuel cells, photovoltaic, wind turbines, located on or near end-users and are characterized as renewables or cogeneration non-dispatched sources [7], [6], [1].According to [2], these types of energy sources can be closer to the users in comparison to the large centralized source in a long way, and can improve the efficiency of the electric system by reducing grid losses. Smart grids are a way to get massive amounts of renewable energy with no greenhouse emissions into the system [2].

When renewable energy, smart meter and intelligent system are introduced to the Grid, it has been upgraded into Smart system. Smart Grids is defined as electricity networks that can intelligently integrate the behaviour and actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies [5].Smart grid is basically the embedding of intelligence to enable bi-directional power flows between sources of electric power generation (traditional and renewable sources), and smart devices (traditional loads, energy storage, etc.), within some specified constraints and performance requirements" [10].

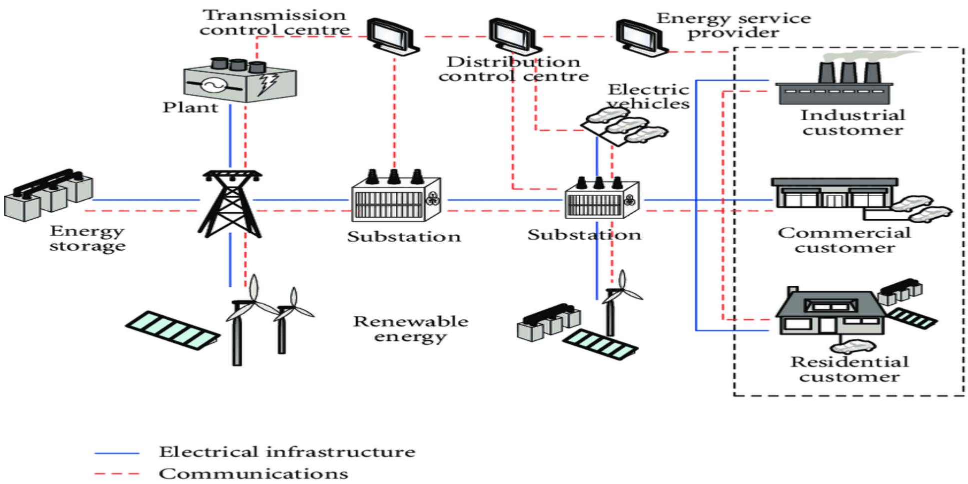

Fig. 1: Smart Grid Technology [2]

IV. RESEARCH METHODOLOGY

The sequence of methods listed below was followed to carry out the research work

1. Data gathering and processing
2. Modelling of Okesha distribution network
3. Modelling of the system using optimization method (GA)

STUDY AREA

Okesha 11 kV feeder: This originates from Basiri 11 kV injection substation 15 MVA transformer T2 and is feeding Okesha, Okela, GRA, Afao road, part of Ado Ekiti, etc. The network is feeding 40 different transformers of diverse ratings. The necessary data were taken from the transformers on the network for modelling and simulated in MATLAB.

Data gathering

Appropriate data were gathered from Benin Electricity Distribution Company (BEDC) as shown in Table 1 below

Table 1: Current load capacity on Ado Ekiti feeder (Data collected from 1st of March to 20th of March, 2021)

Date	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Unit	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)
Okesha	5.5	5.4	5.4	5.6	5.6	5.4	5.6	5.4	5.5	5.5
Date	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Unit	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)
Okesha	5.7	5.6	5.5	5.5	5.7	5.5	5.6	5.6	5.8	5.7

Table 1 shows the data gathering for Okesha 11 kV feeder. The data were taking from the daily record in Ado-Ekiti distribution network at Okesha injection substation control by Benin Electricity Distribution Company (BEDC).

V. MODELLING OF OKESHA DISTRIBUTION NETWORK USING GENETIC ALGORITHM

Impedance modelling method to model Okesha feeder network. The load flow simulation was carried out using MATLAB software. The load taken represents 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 transformers represent the load on various transformers on the feeder which was used for modeling and simulation. Without embedding the Okesha feeder, the available energy from 15 MVA source was 6 MW of energy which was injected into the feeder and the results obtained was low which led to the integration of 840kW, 1MW, 2.5MW, and 4MW into the feeder.

The Feeder has one circuit breaker and a load capacity of 9MW and feeds 44 transformers of different ratings. Both public and private substations in various locations of the network and data were collected on all these transformer for modelling and simulation in MATLAB.

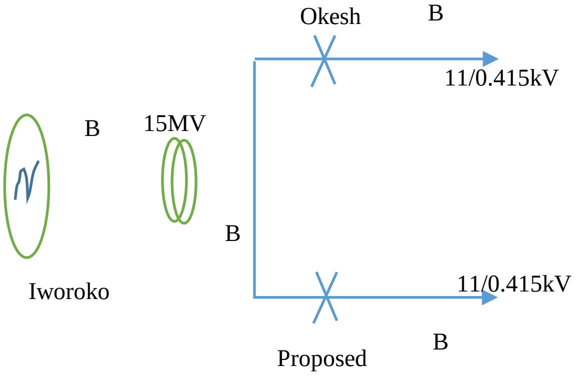

Figure 2: Modelling and of Okesha distribution network

RESULTS AND DISCUSSION

OPTIMAL POWER FLOW WITH AND WITHOUT DG INTEGRATION

Optimal power flow of Okesha, distribution network was carried out and the results on Okesha 38 buses, were written in the table below which show voltage in PU. The optimal power flow was carried out without DG integration and with DG integration of 500KW, 1 MW, 2MW in which the results are shown below.

In this section, the penetration level of the DG is increased from no DG to 500 kW, to 1MW and finally to 2MW. At the moment, there is no single panel that can supply 2MW 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.

To carried out scenario 1-3, the following penetration levels (PL) were considered,

PL1: Steady State results without DG Integration – Base case
PL2 Steady State results when 500 kW of DG was integrated
PL3: Steady State results when 1 MW of DG was integrated
PL4: Steady State results when 2 MW of DG was integrated

Steady State Voltage Result of Okeisha Feeder

The following penetration levels were carried out

i. without DG integration
ii. with 500 kW DG integration
iii. with 1 MW DG integration
iv. with 2 MW DG integration

From the analysis above, ii to iv is considered to be distributed arbitrarily across the selected feeders. The distribution is as shown in Table 4.9

Table 2: Arbitrary location of DG in Okeisha feeder

S/N	500kW	Locations	1 (in MW)	Locations	2MW	Locations
1	100	Police station	0.25	Police station	0.5	Police station
2	100	Old garage	0.25	Old garage	0.5	Old garrage
3	150	Okese	0.25	Okese	0.5	okese
4	150	SUBEB	0.25	SUBEB	0.5	SUBEB

TABLE 3: STEADY STATE RESULT OF OKEISHA FEEDER WITH AND WITHOUT DG

SUBSTATION	NO DISTRIBUTED GENERATION	VOLTAGE (PU) WHEN 500KW WAS CONNECTED	VOLTAGE (PU) WHEN 1MW WAS CONNECTED	VOLTAGE (PU) WHEN 2MW WAS CONNECTED
SOUTH WESTERN HOTEL	0.880	0.900	0.940	0.960
DALLIMORE TS	0.880	0.900	0.930	0.950
EKITI 1 TS	0.900	0.920	0.950	0.980
EKITI 2 TS	0.910	0.930	0.960	0.980
FED HOUSING 1 TS	0.860	0.880	0.910	0.930
FED HOUSING 2 TS	0.860	0.880	0.920	0.940
FED HOUSING 3 TS	0.890	0.920	0.950	0.970
FED HOUSING PH 2 TS	0.900	0.920	0.950	0.980
HOUSING CORP TS	0.880	0.900	0.930	0.950
IDOLOFIN TS	0.850	0.870	0.900	0.920
ODO OROBO TS	0.870	0.890	0.920	0.940
OKE ESE TS	0.890	0.910	0.940	0.960
OKE ILA 2 TS	0.880	0.900	0.930	0.950
OKE ILA 3 TS	0.890	0.910	0.940	0.960
OKE IYINMI TS	0.890	0.910	0.940	0.960
OLD GARAGE TS	0.850	0.870	0.900	0.920
ONALA TS	0.880	0.900	0.930	0.960
PALACE TS	0.870	0.890	0.920	0.940
PARK VIEW 1 TS	0.870	0.890	0.920	0.940
PARK VIEW 2 TS	0.880	0.900	0.930	0.950
POLICE STATION TS	0.860	0.880	0.910	0.930

PRISON TS	0.910	0.930	0.960	0.990
SHELTER VIEW TS	0.900	0.920	0.960	0.980
SUBEB TS	0.890	0.910	0.950	0.970
UPPERLAND TS	0.890	0.910	0.940	0.960
CAPTAIN COOK	0.870	0.890	0.920	0.940
HIGH COURT	0.890	0.910	0.940	0.960
MR BIGGS	0.880	0.900	0.930	0.950
ENTERPRISE BANK	0.890	0.910	0.940	0.960
NITEL	0.890	0.910	0.940	0.960
OLD GOV. OFFICE	0.850	0.870	0.900	0.920
JOLUADE	0.880	0.900	0.930	0.960
MATHEW	0.870	0.890	0.920	0.940
ELEMI	0.870	0.890	0.920	0.940
IGIRIGIRI	0.880	0.900	0.930	0.950
SAINT PAUL	0.870	0.890	0.920	0.940
ADO GRAMMER	0.880	0.900	0.930	0.950
ITA EKU	0.860	0.880	0.910	0.930
IMMIGRATION I	0.910	0.930	0.960	0.990
IMMIGRATION II	0.900	0.920	0.960	0.980

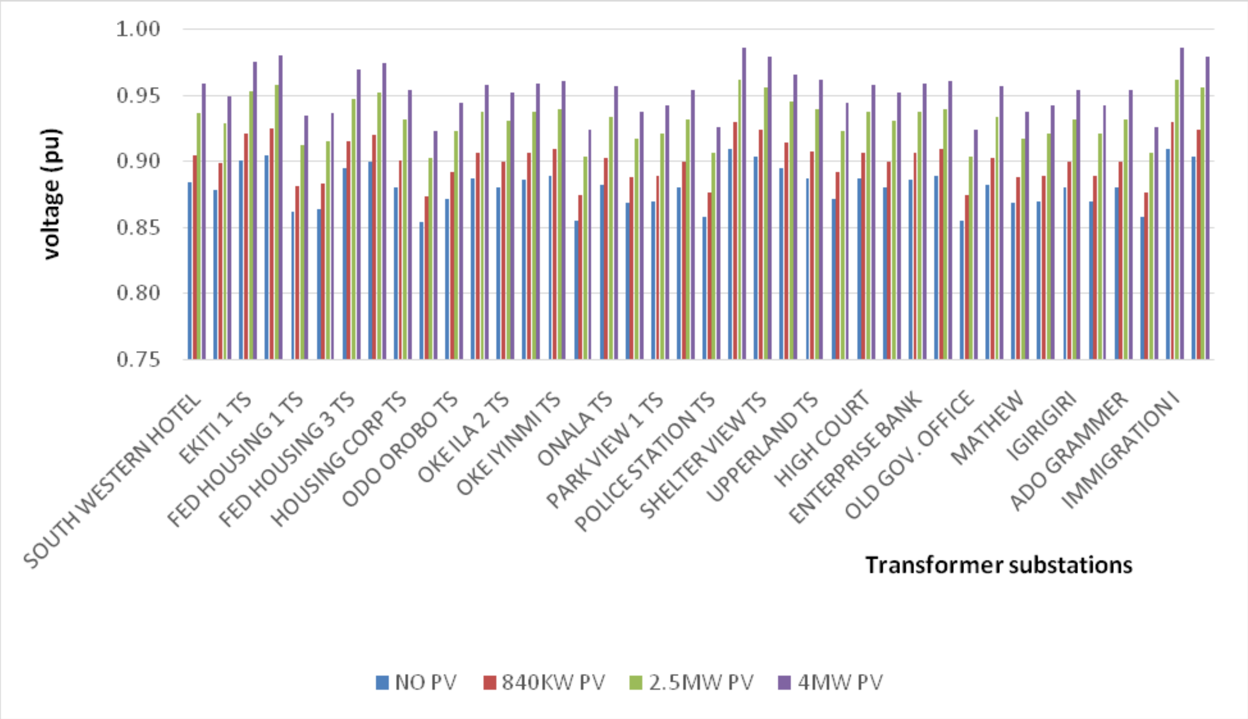

Figure 3: Steady State Voltage of Okesha Distribution Network

Steady State Voltage Result of Okesha Feeder when DG was Optimally Located by GA

The existing penetration level is

i. without DG integration
ii. with 500 kW DG integration
iii. with 1 MW DG integration
iv. 2 MW DG integration

The distribution was done optimally on Okesha feeder and the result are reported in Table 4.19

Table 4: Optimal location of DG with GA on Okesha feeder

S/N	500kW	Substations	1 (in MW)	Substations	2MW	Substations
1	100	Police Station	0.25	Police Station	0.5	Police Station
2	100	Federal Housing 2	0.25	Federal Housing 2	0.5	Federal Housing 2
3	150	High Court	0.25	High Court	0.5	High Court
4	150	Immigration	0.25	Immigration	0.5	Immigration

TABLE 5: STEADY STATE VOLTAGE RESULT OF OKESHA FEEDER WITH/WITHOUT DG WHEN GA WAS USED FOR OPTIMAL LOCATION

SUBSTATION	NO DISTRIBUTED GENERATION	VOLTAGE (PU) WHEN 500KW WAS CONNECTED	VOLTAGE (PU) WHEN 1MW WAS CONNECTED	VOLTAGE (PU) WHEN 2MW WAS CONNECTED
SOUTH WESTERN HOTEL	0.880	0.920	0.960	0.990
DALLIMORE TS	0.900	0.920	0.950	0.980
EKITI 1 TS	0.920	0.940	0.970	1.020
EKITI 2 TS	0.930	0.950	0.980	1.020
FED HOUSING 1 TS	0.880	0.900	0.930	0.970
FED HOUSING 2 TS	0.880	0.900	0.950	0.970
FED HOUSING 3 TS	0.900	0.940	0.970	1.000
FED HOUSING PH 2 TS	0.920	0.940	0.970	1.010
HOUSING CORP TS	0.900	0.920	0.950	0.990
IDOLOFIN TS	0.870	0.890	0.920	0.970
ODO OROBO TS	0.890	0.900	0.940	0.970
OKE ESE TS	0.900	0.930	0.960	0.980
OKE ILA 2 TS	0.900	0.920	0.950	0.980
OKE ILA 3 TS	0.900	0.930	0.960	0.990
OKE IYINMI TS	0.900	0.930	0.960	0.990
OLD GARAGE TS	0.870	0.890	0.920	0.960
ONALA TS	0.900	0.920	0.950	0.990
PALACE TS	0.890	0.900	0.940	0.970
PARK VIEW 1 TS	0.890	0.900	0.940	0.970
PARK VIEW 2 TS	0.900	0.920	0.950	0.980
POLICE STATION TS	0.880	0.900	0.930	0.980
PRISON TS	0.930	0.950	0.980	1.010
SHELTER VIEW TS	0.920	0.940	0.980	1.010
SUBEB TS	0.900	0.930	0.970	1.000

UPPERLAND TS	0.900	0.930	0.960	1.000
CAPTAIN COOK	0.890	0.900	0.940	0.970
HIGH COURT	0.900	0.930	0.960	0.990
MR BIGGS	0.900	0.920	0.950	0.980
ENTERPRISE BANK	0.900	0.930	0.960	0.990
NITEL	0.900	0.930	0.960	0.990
OLD GOV. OFFICE	0.870	0.890	0.920	0.960
JOLUADE	0.900	0.920	0.950	0.990
MATHEW	0.890	0.900	0.940	0.970
ELEMI	0.890	0.900	0.940	0.970
IGIRIGIRI	0.900	0.920	0.950	0.990
SAINT PAUL	0.890	0.900	0.940	0.980
ADO GRAMMER	0.900	0.920	0.950	0.980
ITA EKU	0.880	0.900	0.930	0.970
IMMIGRATION I	0.930	0.950	0.980	1.010
IMMIGRATION II	0.920	0.950	0.980	1.000

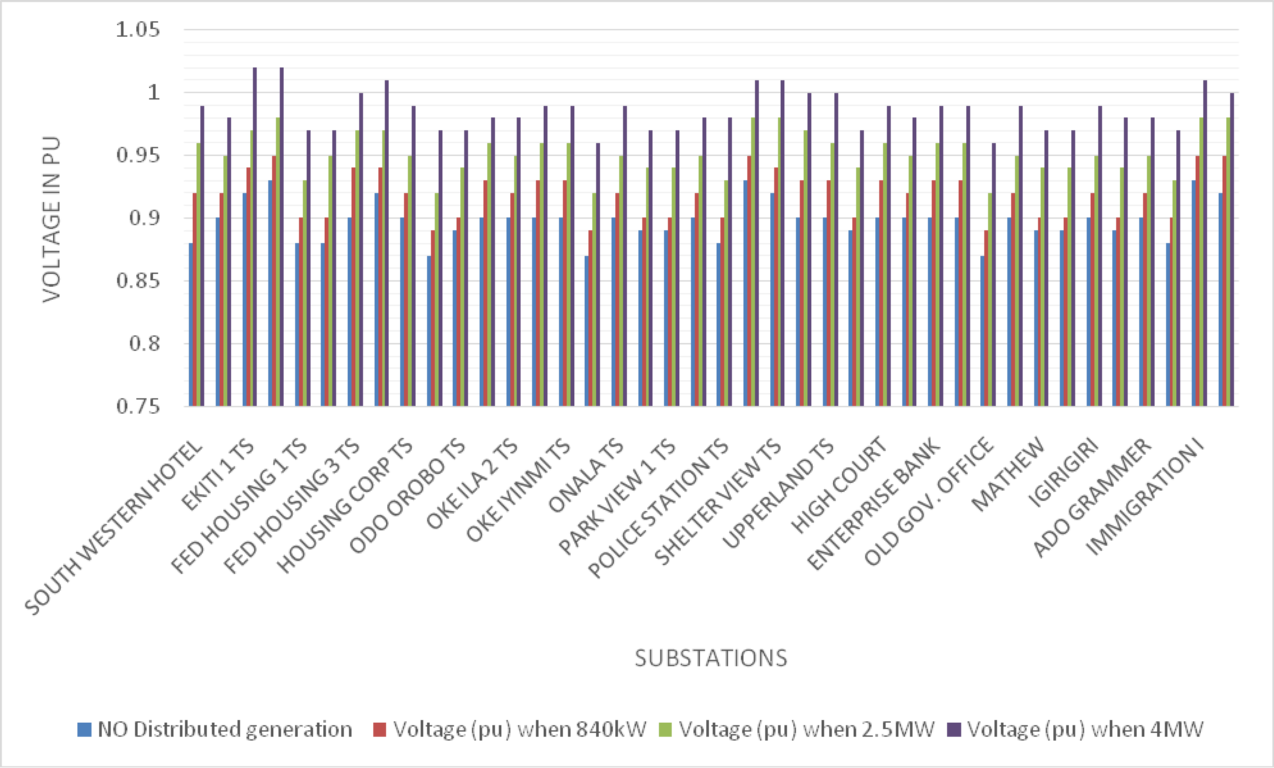

Figure 4: Steady State Result of Okeshafeeder with DG using GA for optimal location

Table 6: Comparison of Steady State Result of 1MW for Okesha feeder with and without DG

SUBSTATION	VOLTAGE (PU) WHEN 1MW WAS INTEGRATED	VOLTAGE (PU) WHEN 1MW GA WAS CONNECTED
SOUTH WESTERN HOTEL	0.940	0.960
DALLIMORE TS	0.930	0.950
EKITI 1 TS	0.950	0.970
EKITI 2 TS	0.960	0.980
FED HOUSING 1 TS	0.910	0.930
FED HOUSING 2 TS	0.920	0.950
FED HOUSING 3 TS	0.950	0.970
FED HOUSING PH 2 TS	0.950	0.970
HOUSING CORP TS	0.930	0.950
IDOLOFIN TS	0.900	0.920
ODO OROBO TS	0.920	0.940
OKE ESE TS	0.940	0.960
OKE ILA 2 TS	0.930	0.950
OKE ILA 3 TS	0.940	0.960
OKE IYINMI TS	0.940	0.960
OLD GARAGE TS	0.900	0.920
ONALA TS	0.930	0.950
PALACE TS	0.920	0.940
PARK VIEW 1 TS	0.920	0.940
PARK VIEW 2 TS	0.930	0.950
POLICE STATION TS	0.910	0.930
PRISON TS	0.960	0.980
SHELTER VIEW TS	0.960	0.980

SUBEB TS	0.950	0.970
UPPERLAND TS	0.940	0.960
CAPTAIN COOK	0.920	0.940
HIGH COURT	0.940	0.960
MR BIGGS	0.930	0.950
ENTERPRISE BANK	0.940	0.960
NITEL	0.940	0.960
OLD GOV. OFFICE	0.900	0.920
JOLUADE	0.930	0.950
MATHEW	0.920	0.940
ELEMI	0.920	0.940
IGIRIGIRI	0.930	0.950
SAINT PAUL	0.920	0.940
ADO GRAMMER	0.930	0.950
ITA EKU	0.910	0.930
IMMIGRATION I	0.960	0.980
IMMIGRATION II	0.960	0.980

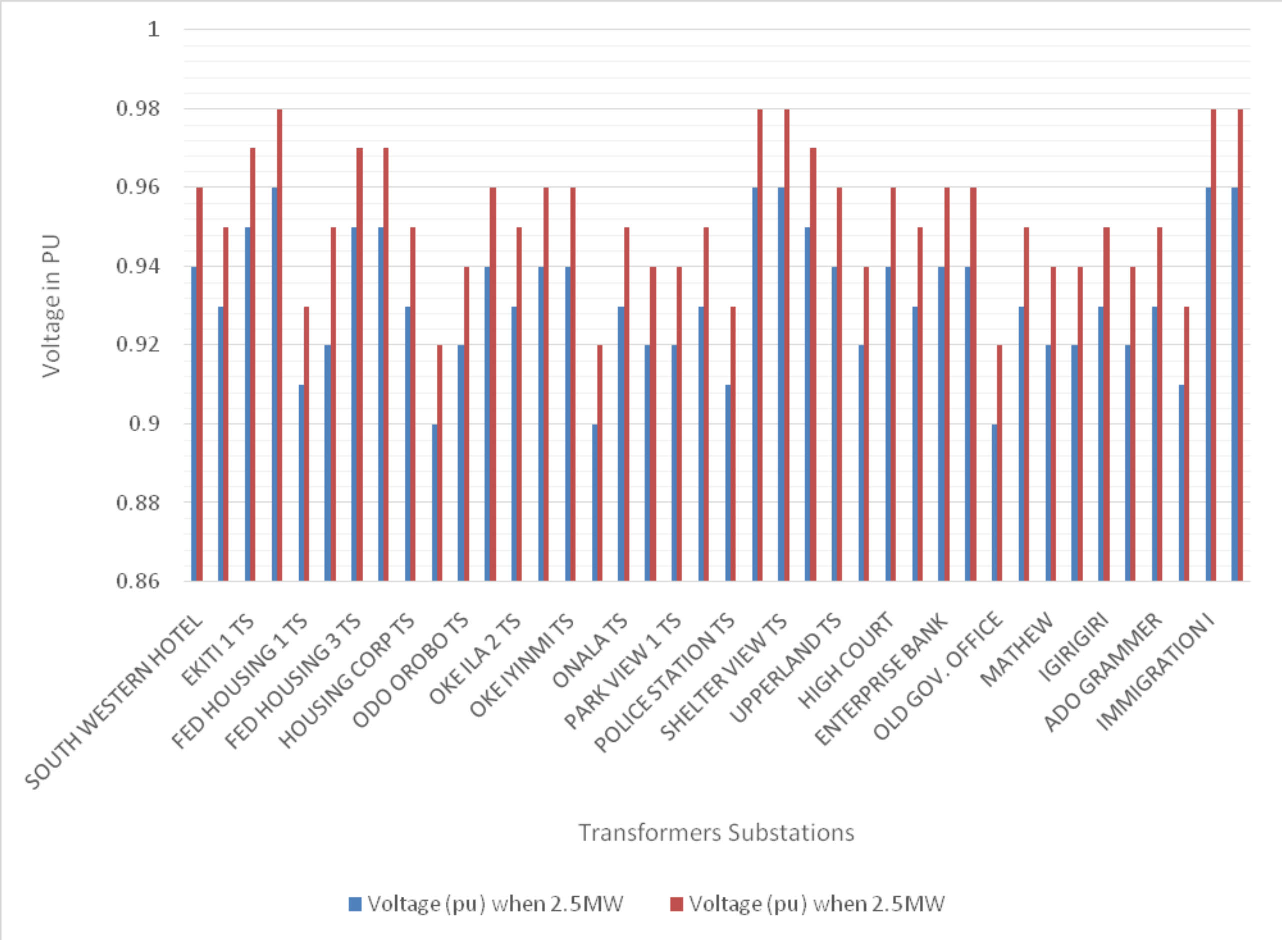

Figure 5: Comparison of Load Flow result and optimal load flow results of 1 MW for Okesha feeders with GA

VI. CONCLUSION AND RECOMMENDATIONS

From the research conducted, it is obvious that low power source on the distribution network cannot be sufficient for power distribution network, hence the consumers will not receive adequate voltage supply. Therefore, this study concludes that various capacity of the feeder should be ascertained while adequate DG should be integrated at the appropriate points to enhance adequate power supply to the users/consumers.

More so, while integrating DG on the distribution network, adequate precautionary measures should be taken to prevent the end users from receiving excessive voltage which can damage their appliances. Also, the various sources of energy to be integrated should be within the scope of the feeder.

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