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Impact of Distributed Generation from Solar Energy on Power System Distribution in Nigeria

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Abstract: *Distributed generation (DG) are electrical power generations designed at the customer load site. They have the ability to reduce technical losses, improve voltage profile and power quality. When adequately installed, it saves cost by averting the need for investment in the transmission and distribution infrastructure. This research was detailed study and analysis of the benefits of DG from Solar Renewable Energy with the Dumez feeder network of Otovwodo 15MVA, 33/11KV Injection Substation in Nigeria as a case study. This work is of great practical relevance to the society and country at large, the research methodology involved actual collection of relevant data from a typical existing Nigeria Power Distribution network. The network was modelled in Electrical Transient Analyzer Program [ETAP 7.0] software. The power flow was on Newton-Raphson power flow algorithm embedded in ETAP 7.0 software to determine bus voltages, power losses and load flow report for the existing network, Case I DG and Case II DG respectively. The load flow analysis showed that the total losses in the network without DG is 722.7KW, 972.8KVar. Under steady state condition, forty-six (46) buses recorded voltage violations. Only Otovwodo bus was within the marginal voltage acceptable limit with 97.8 %. Case I DG, the losses reduced to 397KW, 492.1KVar. Voltage violation reduced to thirty-nine (39) buses. Case II DG, losses further reduced to 349.1KW, 524.0KVar. All buses fall within marginal voltage acceptable limit. Case II DG, showed the network were within the voltage statutory limit of ± 6%.*

Keywords: *Distributed Generation Technology, Integration of Solar Energy Technology, Renewable Energy, Solar Energy Source, Technical Loss, Voltage Profile.*

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I. Introduction

Distributed generation (DG) consist of electric power generator sources connected to an electric distribution network which are used for generating electricity on-site. They are designed at the customer load site which can be used to meet the load requirement of a particular geographical distribution area in the following ways[1]: (1) Peak shaving: where they are used to generate a portion of customer's electricity onsite to reduce the amount of electricity purchased during peak price periods. (2) Standby generation, where they serve as a backup to power supply and as wholly a green power source using renewable technology for improved reliability. DG have the ability to reduce technical losses, improve voltage profile and power quality, thereby making the distribution system simply reliable. Where it is adequately installed, it saves cost by averting the need for investment in the transmission and distribution infrastructure. It also reduces the need on complexity, interdependencies and inefficiencies on the transmission and distribution. When DG's are operated with renewable technologies they produces zero or near-zero pollutant emissions over its useful life (not taking into consideration of pollution produced during the manufacturing or after decommissioning of the DG system).Ekwue& Akintunde, further stated that the operation of distributed generation from renewable energy sources and its connection into an existing distribution system increases the amount of generation and also raises the following technical concerns: Reversal of power flows, increase in fault levels due to the fault contributions from the renewable generators, Inadvertent islanding etc. And despite the aforementioned technical challenges and issues associated with distributed generation from renewable energy on distribution networks, developed countries are leading the frontier for the battle against global warming and climate change. Thus they are making policies and setting targets to save the environment from imminent damage due to the emission of greenhouse gas (ghg). Such countries are focused on how to meet the energy demand for a growing global population and at the same time avoid the negative consequences of environmental pollution. According to Baker, [3] Scotland continues to lead the frontier for the battle against global warming and climate change and had pledged to reach 100% renewable sustainability for energy production by the year 2020. However, Scotland

currently utilizes 39% renewable energy, 33% nuclear energy and 28% fossil fuel generation.
Nigeria is a country of over 170 million people and it's only about 40% of this population has access to electricity through its conventional system of power generation otherwise called the National grid. This implies that about 60% of its population (majority of the population) have no access to electricity. However, the available electricity capacity that is accessible to about 40% of its population is insufficient to meet the existing power needs [4]. The country is faced with severe electricity problems which have been hampering its economic development. The reason being that the amount of electricity supplied is far less than demand which has led to incessant load shedding by the distribution company to compensate for inadequacy of electricity supply, line losses and system reliability, coupled with the inability of the grid to cover every part of the country.Thishas led to every Nigerian household and businesses to acquire one type of fossil fuelled electricity generating plant or the other to generate the desired power needed. On the other hand, incomplete combustion of fuel from these generating sets (popularly called "I PASS MY NEIGHBOUR") leads to emission of poisonous gases that are very harmful to human health which has killed a lot of people.A report from the International Energy Agency (IEA) [5], stated that the Federal Government of Nigeria instituted National Renewable Energy and Energy Efficiency Policy (NREEP). This policy provides a legislative framework for renewable energy and energy efficiency sectors in Nigeria. The policy indicated hydro power as the most important renewable energy source to be harnessed in full potential and also biomass, wind, and solar are also to be harnessed. Solar energy resource is abundant in Nigeria and countries choose to explore the potentials of most available renewable energy resources.

II. Literature Review

2.1 Review Of Previous Research Works

McDonald, J.D. et al [6], reviewed distribution system; substation and integration of distributed generation. They stated that early power plants ran on water or coal and distributed generation is not a new industry concept. They referenced 1882, when Thomas Edison built his first commercial electric plant named "The Pearl Street" which provided 110V direct current (dc) electric power to fifty nine (59) customers in lower Manhattan. By 1887, there were 121 Edison power stations in the United States delivering dc electricity to customers. However, centralized power generation became possible when it was recognized that alternating current (ac) electricity could be transported at comparatively low cost with reduced power losses across great distances by taking advantages of the ability to raise the voltage at the generation station and lower the voltage near customer loads.

Bollen, M. & Hassan, F. [7] wrote on integration of distributed generation in the power system. In their book, they clearly made understanding the impact of distribution generation on power system and the methods for allowing more distributed generation to be integrated into the power system an essential base. This book is not about showing how good or bad distributed generation is, but about the main changes taking place from the conventional power stations from fossil fuel being replaced by DG from renewable sources and impact of the changes on the lines users.

Ekwue, A.O. & Akintunde, O.A. [2], highlighted the benefits of distributed generation by using a 15 node radial distribution network sourced from a referenced material. Vincent, E.N., & Yusuf, S.D. [8],titled the journal integrating renewable energy and smart grid technology into the Nigerian electricity grid system. They reviewed the Nigeria poor condition of the power sector as a whole and the renewable energy potentials, identified problems with the national grid and proposed a smart grid model for the Nigeria poor sector which will include renewable energy sources.

Kadir, A.F.A., et al [9], analysed the impact of multiple inverter based DG units on resonance and harmonic distortion. Their analysis was carried out on a 13 bus IEEE distribution test system which was connected to an inverter based DG system and simulated on MATLAB / SimPower system. The entire system was used to investigate the effect of simplifying DG model by bundling the realistic model of multiple and small DG units into a single unit. They conducted frequency scan and carried out fast Fourier transform analysis to measure the voltage and current distortion at the point of common coupling and DG connected buses.

Tsado, J. et al; [10], discussed the technologies of smart grid network and presented a development model to illustrate the implementation of Demand Response System (DRS) in the distribution network of the smart grid. Their work also reviewed the potential benefits as compared to the traditional power system grid and highlighted the future challenges.

Begovic, M., et al [11], analysed the impact of renewable distributed generation on power systems. They used Monte Carlo simulations which tend to calculate the boundaries and overall improvements of the impact of randomly placed Distributed Generators on a distribution feeder. However, the study showed that the knowledge of total penetration of small PV systems is significant to estimate the effects of DG on the feeder.

2.2 Centralized Concept Of Power System In Nigeria

The theory behind centralized power system came into existence when it was recognized that alternating current (ac) electricity could be transported at relatively low cost with reduced power losses across great distances by taking advantage of the ability to raise the voltage at the generation station and lower the voltage near the customer loads [6]. Nigeria power system since its inception is designed to operate radially. Whereby electric power flows in one direction from large generating power plants to the customers load along the radial feeder [12]. However, bulk electricity generation is often made from large generating plants which are located far from the customer loads and close to the primary energy sources (i.e hydro, thermal stations, gas transported through pipeline). Electricity is generated at 11KV to 25KV and stepped up to transmission level voltages at 132KV to 330KV using power transmission transformers. The transmission capability of a line is proportional to the square of its voltage and research is ongoing to raise transmission voltages. Transmission level voltages are stepped down at sub-transmission substation with voltage range of 33 to 132KV and next level is stepped down at the distribution substation either at primary/feeder voltage of 33/11KV or secondary/customer voltage of 0.415KV, 3 phases/ 230V single phase. At distribution voltage level electric power is supplied to domestic, industrial and commercial customers through the use of distribution transformers.

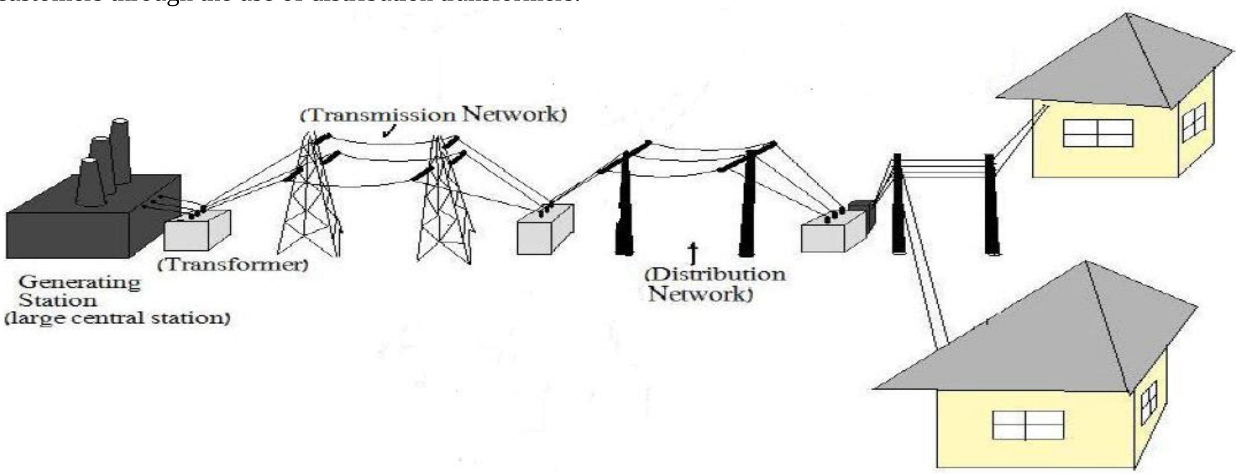

Fig 2.1 Centralized power system showing power flows from large generating station to customer load

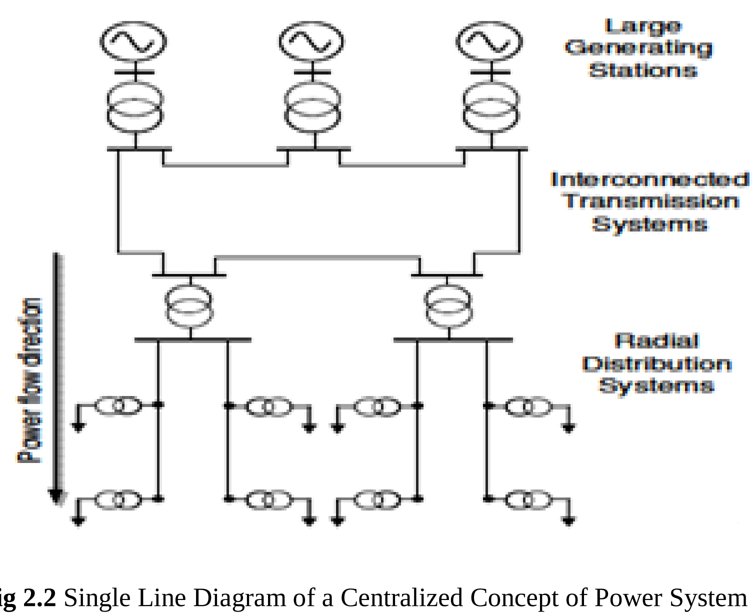

Fig 2.2 Single Line Diagram of a Centralized Concept of Power System Nigeria

Currently, Nigeria operates 25 grid connected electric power plants with a total installed capacity of 12,522MW. Twenty two (22) of these grid-connected power plants are gas thermal power plant with an installed capacity of 10,592MW (85% of installed capacity) and the remaining 1930MW (15%) comes from 3 hydro power plant. The fuel for these power plants are oil, natural gas and water. These plants are run by generation companies including those formally under the Power Holding Company of Nigeria (PHCN), National Integrated Power Project (NIPP) and Independent Power Producers (IPPs) [13].

According to the Nigeria Power Baseline Report, 2015 [13], Nigeria hit its historical highs in August, 2015, for both peak generations (4,811MW peak generation on August, 25) and total energy generated across the system (4,213MWh/h energy generated on August, 5) and also transmission losses fell by 10% (June to August 15th, 2015). With the above development, it still looks like nothing has been done to improve electricity supply in the country. Yet over half of the Nigerian population does not have access to the national grid and those that do suffer from intermittent power supply.

Table 2.1: The 25 grid connected power plant in Nigeria with installed capacity of 12,522MW and total average operational capacity of 3,879MW (31% lower of installed capacity)

S/No.	POWER PLANT	NAME OF GENERATION COMPANY	INSTALLED CAPACITY (MW)	AVE. AVAIL CAPACITY (MW)	AVE.OPERATION CAPACITY (MW)
1	Egbin	IPP	1320	941	539
2	Afam VI	Privatised PHCN	685	587	455
3	Okpai	IPP	900	536	375
4	Delta	NIPP	480	463	374
5	Jebba	IPP	570	431	262
6	Olorunsogo Gas	Privatised PHCN	335	277	189
7	Ihovbor NIPP	Privatised PHCN	434	374	182
8	Geregu NIPP	Privatised PHCN	450	328	179
9	Kainji	NIPP	720	444	173
10	Olorunsogo NIPP	IPP	760	260	171
11	Omotosho NIPP	NIPP	500	306	169
12	Omotosho Gas	Privatised PHCN	335	280	163
13	Shiroro	Privatised PHCN	600	508	153
14	Geregu Gas	NIPP	414	159	131
15	Sapele NIPP	IPP	450	184	111
16	Ibom	Privatised PHCN	190	91	76
17	Sapele	NIPP	504	219	69
18	Alaoji NIPP	IPP	720	158	67
19	Odukpani NIPP	Privatised PHCN	561	234	64
20	Afam IV – V	NIPP	724	3	2
21	Asco	IPP	294	270	0
22	Omoku	Privatised PHCN	110	0	0
23	Trans Amadi	NIPP	150	0	0
24	AES Gas	Privatised PHCN	180	175	0
25	Rivers IPP	IPP	136	0	0
	TOTAL		**12,522**	**7,141**	**3,879**

[Source: Nigeria Power Baseline Report, 2015]

However, stated below are key constraints to operational generation capacity [Nigeria Power Baseline Report, 2015]:

- Insufficient gas supply due to low production, insufficient infrastructure and vandalism.
- Poor water management
- High frequency due to demand imbalances and
- Line constraints due to inadequate transmission infrastructure.

2.3 Distributed Generation / Decentralized Concept Of Power System

Electricity generation under the concept of decentralized generation makes use of new technologies and applications which allow electricity to be generated in small modular size power plants at the distribution network near customer loads to supplement the total energy demand. This concept of power system is not exclusively from the large/bulk generating plant. Sometimes some part of the total energy demand is supplied by the existing centralized generation while the other part is supplied by the distributed generation. There are two way flow of electrical energy in the system. In a situation whereby the centralized generation could not cover the area in question and also it is not cost effective to extend the grid connected power system. Distributed generation can be used to supply the total energy demand of such locality.

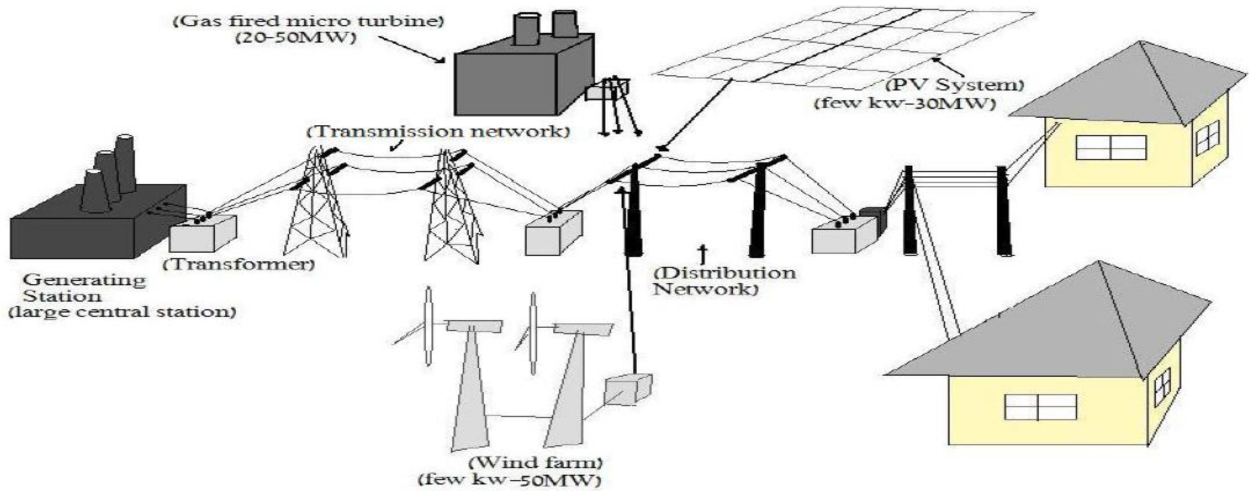

Fig 2.3 Schematic diagram of Distributed Generation Concept.

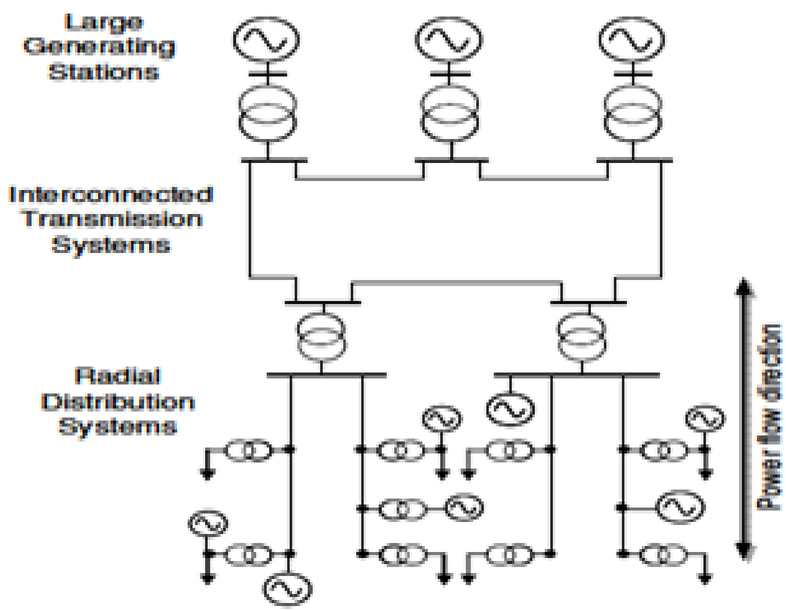

Fig 2.4 Single line diagram of a Distributed Generation concept showing bidirectional power flow

However, with the recent scientific, technological evolutions and environmental policies on climate change and global warming, renewable energy solution can be described as the best alternative energy solution presently in the electricity market. Renewable energy which is the most preferred option because their resource are naturally replenished and they are environment friendly [12].

2.4 Distributed Generation (Dg) Technology

The concept of Distributed generation technology has been defined with different terminologies in many literatures by different authors and no generalized definition of the concept has been achieved because DG involves many technologies and applications. But the purpose of DG cannot be compromised as it has been agreed among authors in literatures and organisations, as it aimed at providing a source of active electric power. However, different countries use different expression to denote Distributed Generation (DG) namely; Anglo-American countries use the term “Embedded Generation”, North American countries often use the term “Dispersed Generation”, Europe and some part of Asia use the term "Decentralized Generation" [14].

But for the purpose of this research***, distributed generation is considered as an electrical power generator source connected or tied to an electric distribution network at consumers site or customer load and is small or modular when compared with the Centralized electric power plant.***

Owing to the above definition and expressions, Distributed Generation technology can be defined in different ways based on the rating of Distributed generation power units. The Gas Research Institute defined Distributed generation power units as typically between 25KW and 25MW. The Electric Power Research Institute defines DG as generation between a few kilo-watts up to 50MW while the International Conference on Large High Voltage Electric Systems (CIGRE) defines DG as smaller than 50 to 100MW. Consequently, due to government regulation of DG by different countries, the rating of each distributed power station varies. Distributed Generation is used for power units with less than 100MW capacity in English and Welsh. This is because, DG units of less than 100MW are not centrally dispatched and cannot be traded in the wholesale market if the capacity is less than 50MW [14].

However, the maximum rating of a DG that can be connected to the distribution system depends on the capacity of the distribution system which is correlated to the voltage level within the distribution system. Distributed generation can therefore be categorized with respect to the capacity of each generating units as follows:

Table 2.2: Categories of DG Unit [14]

S/No.	TYPE OF DG	SIZE/CAPACITY
1	Micro – Distributed Generation	1Watt < 5KW
2	Small - Distributed Generation	5KW < 5MW
3	Medium - Distributed Generation	5MW < 50MW
4	Large - Distributed Generation	50MW < 300MW

2.5 Types Of Distributed Generation Technology

Distributed generation technology can be classified into two major categories namely: Inverter coupled DG technology and Direct Coupled DG technology. Inverter based DG units are either based on static energy conversion like the Photovoltaic [PV] panels or Fuel Cells [FC] or DG's based on rotational energy conversion like the direct driven wind turbine (WT) and micro combined heat and power [Micro CHP] [15]. Directly coupled DG consist of Asynchronous generators such as Wind turbine with a doubly fed induction generator [DFIG], Squirrel-cage induction generator [SCIG] and Synchronous generators [2015].

III. Dumez Feeder Network Of Otovwodo 15mva, 33/11kv Injection Substation

Otovwodo 15MVA, 33/11KV injection substation is located at Otovwodo junction, along the Ughelli–Patani express way, Ughelli, Delta State, Nigeria. It receives its electricity supply from the Transcorp Generating Power Limited through the 30MVA, 132/33KV substation. This substation sends power to Otovwodo 15MVA, 33/11KV injection substation located 18km away through an Aluminium Conductor Steel Reinforced (ACSR) conductor cross sectional area of 120mm^2. The single line diagram in Figure 2.1 below show how power is sent from the utility system to the Dumez distribution feeder of Otovwodo 15MVA, 33/11KV injection substation.

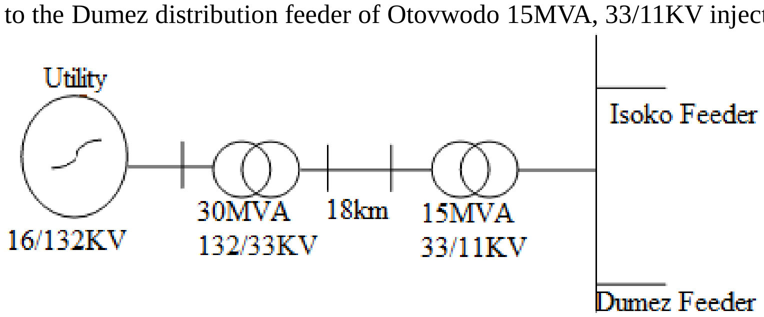

Fig 2.5 Power Supply from Utility to Otovwodo Injection Substation

The Otovwodo 15MVA, 33/11KV injection substation transformer consists of two feeders namely: the Isoko road 11KV feeder and the Dumez road 11KV feeder. However, the Isoko road feeder and Dumez road feeder are made up of 44 and 47 distribution substations respectively. Dumez distribution feederis considered in this research and due to non-availability of relevant data, the data for this work was sourced as follows:

(1) By visits to the injection substation and interactive sessions with the relevant personnel of the distribution network to ascertain route lengths, the list of all 11/0.415KV transformers connected to the injection substation and

their ratings. A 120mm^2 Aluminium Conductor Steel Reinforced (ACSR) was used for the 33KV line from Ughelli generating station to Otovwodo injection substation and 100mm^2 ACSR was used for the 11KV feeder network.
(2) Load readings for each of the distribution substation were taken by measurements using a Digital Clamp-on Meter Mastech Model MS2203 to measure voltage, frequency, current and power factor.
The data are based on route lengths, transformer ratings, conductor type (ACSR) and size of existing network and power factor. The summary of th2 readings showing consumption at each substation are shown in table 2.2.

Table 2.2: Dumez Feeder Showing Transformer Rating, Route Length and Average Load Values

S/No.	NAME OF SUBSTATION	TRANSFORMER RATING (KVA)	ROUTE LENGTH (KM)	AVERAGE LOAD VALUES		
				KW	P.F	KVA
1	Otovwodo 2	500	0.765	259.380	0.713	363.787
2	Otovwodo 3	500	1.305	277.500	0.900	308.333
3	Otovwodo 4	500	1.575	203.600	0.850	239.529
4	Bishop Emuobor	500	1.620	295.410	0.948	311.613
5	Agbarha Junction	300	0.315	197.580	0.758	260.660
6	Agbarhard	500	0.495	134.010	0.726	184.587
7	White house	200	0.945			
8	slaughter House	300	1.260	85.890	0.932	92.157
9	Uduere 2	300	3.600	98.250	0.850	115.588
10	Uduere 1	100	3.240	63.330	0.942	67.229
11	Owevwe	200	5.850	78.45	0.805	97.45
12	Opherin	200	6.480	95.139	0.852	111.665
13	Saniko	500	4.950	187.239	0.891	210.145
14	Gana Junction	200	5.670	112.000	0.730	153.425
15	Omavewe 2	200	7.650	29.040	0.941	30.861
16	Omavewe 1	500	7.785	323.529	0.934	346.390
17	Okpha-Agbara	300	8.730	97.560	0.954	102.264
18	Oteri	200	9.225	75.370	0.978	77.065
19	Etefe	300	10.215	58.040	0.804	72.189
20	Awirhi	200	12.420	44.820	0.797	56.236
21	Mr Biggs (P/L)	200	0.945	63.537	0.850	74.749
22	First Bank (P/L)	100	1.305	41.610	0.897	46.388
23	Olori Estate	500	1.350	411.690	0.902	456.419
24	Grubs (P/L)	100	1.350	37.608	0.811	46.372
25	Olorird Junction	200	1.485	115.530	0.959	120.469
26	Olori Road	300	2.025	243.210	0.850	286.129
27	Low Cost	300	1.755	232.680	0.897	259.397
28	Mudi 1	300	2.295	183.130	0.719	254.701
29	Mudi 2	300	2.610	254.440	0.900	282.711
30	MTN (P/L)	50	2.790	1.212	0.850	1.426
31	Etisalat (P/L)	100	3.195	37.311	0.945	39.483
32	Heroes of Faith (P/L)	300	2.070	13.200	0.942	14.013
33	Oveto (Ighovoja)	300	2.610	47.310	0.850	55.659
34	Union Bank (P/L)	200	2.655	73.760	0.805	91.627
35	NCC (P/L)	50	2.700	23.550	0.931	25.295
36	Omonemu	500	2.835	134.280	0.910	147.560
37	Afiesere Junction	500	3.060	386.100	0.920	419.674
38	PipeLine	500	3.780	343.590	0.752	456.902
39	Orubu	500	3.555	287.130	0.739	388.539
40	Ogele	500	4.050	365.210	0.880	415.011
41	Round about	300	3.690	116.809	0.871	134.109
42	MTN 1 (P/L)	50	4.005	3.210	0.850	3.776
43	Amekpa 3	300	4.545	100.440	0.850	118.165
44	Amekpa 2	300	5.085	275.610	0.866	318.256
45	Holy Salvation	500	5.400	367.701	0.911	403.623
46	Amekpa 1	300	5.805	190.140	0.811	234.451
47	2nd Amekpa	300	6.345	217.29	0.850	255.635

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IV. DUMEZ DISTRIBUTION NETWORK MODELLED IN ETAP 7.0 AND ASSUMPTIONS

Electrical Transient Analyser Program (ETAP 7.0) is a fully integrated suite of electrical power analysis software and it has the ability to analyze the impact of DG from solar energy on distribution network.

The summarized data in table 2.1 together with assumptions in table 3.1 are modelled in the power system analysis software ETAP 7.0 as shown in figure 3.1. Table 3.1 shows the assumptions made for the ETAP 7.0 model.

Table 3.1: Data Consideration Made in ETAP 7.0 Software

PARAMETERS	ASSUMPTIONS
System type	3 phase AC
Distribution line	Overhead line conductors
Conductor type	Aluminium conductor steel reinforced [ACSR]
Line model	Lumped parameter [Pi]
Load type	Constant load
Nominal frequency	50Hz
Nominal voltage	11KV
Percentage Voltage limits	Critical under voltage < 95% ; Critical over voltage > 105% Marginal under voltage < 97% ; Marginal over voltage> 102%
Otovwodo 33KV bus	Slack or reference bus

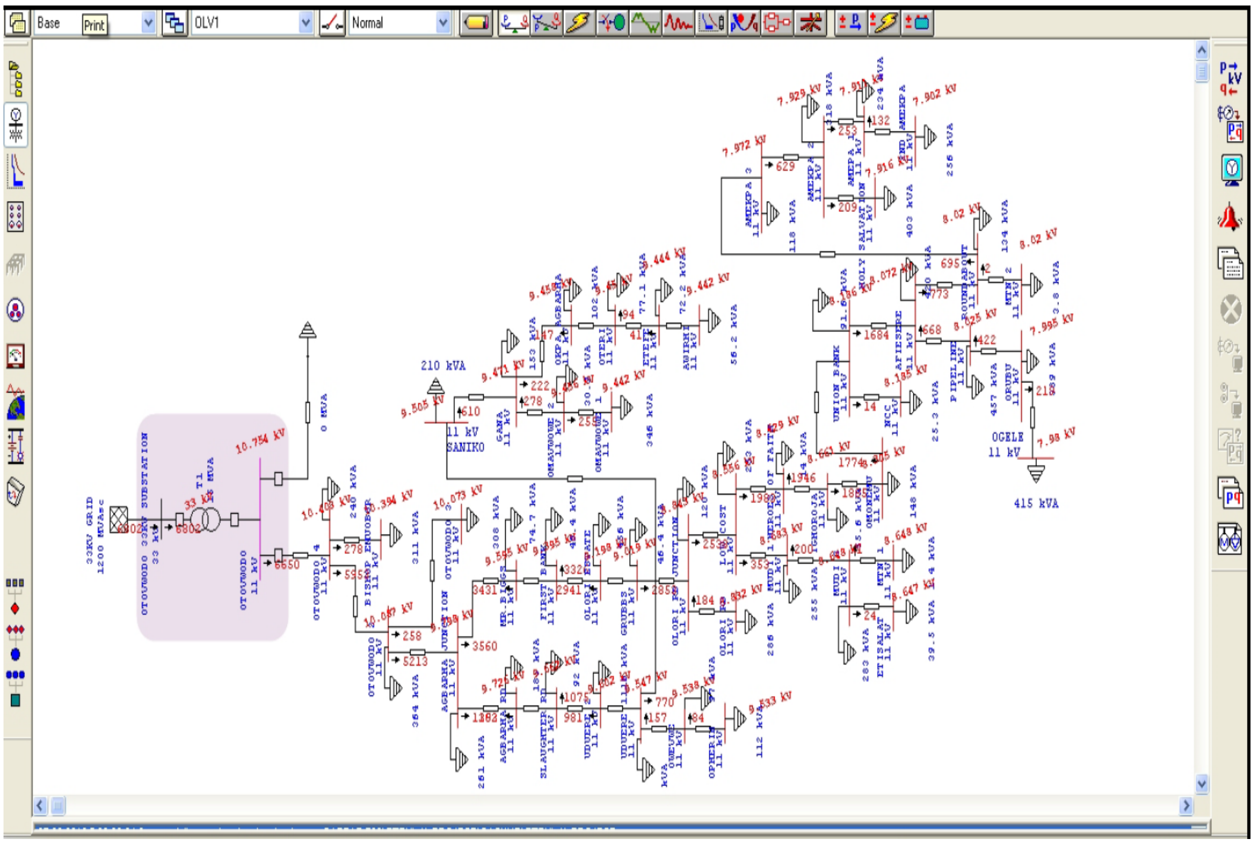

Fig 3.1: Dumez 11KV network modelled in ETAP 7.0 Software [Base case]

Solar Pv Integration To The Distribution Grid

The solar photovoltaic panel produces direct current (dc). Power electronic converters or interfacing circuits are designed to handle the amount of power that comes out of the integrated bank of solar panels that would be injected into the distribution grid. Figure 3.2 below presents a block diagram for interfacing circuit of integrated solar panels.

Strings of solar panel are connected in parallel to obtain the desired power supply.

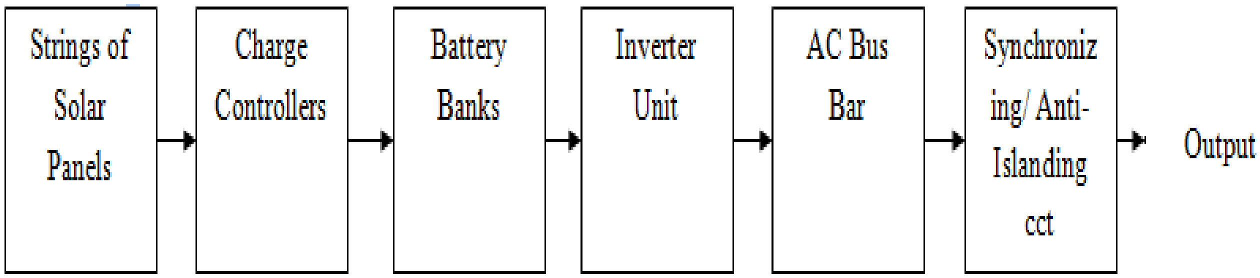

Fig 3.2 Block diagram for interfacing circuit of integrated solar panels

V. DUMEZ FEEDER NETWORK ANALYSIS AND SIMULATION

Power flow analysis was carried out in the existing network before the installation of the DG using Newton-Raphson (N-R) power flow technique in the ETAP 7.0 software to determine the steady state condition. The power flow calculation was successful and converged in 3 iterations.

Subsequently, renewable energy generators representing modern Solar Photovoltaic (PV) as DG was modelled in ETAP 7.0 software environment and placed separately at three bus bar location namely: bus 09 [Uduere I], bus 25 [Omonemu] and bus 34 [Amekpa 3] to investigate the impact of the losses and improvement in voltage profile on the network.

Table 4.1 below shows the capacity of DG from solar energy (KW and KVA) and bus bar location of DG in the existing network. The modelled network with Case I DG and Case II DG penetrations are shown in Figure 4.1 and Figure 4.2 respectively.

Table 4.1: Location and size of DG

BUS NUMBER	LOCATION	CASE I DG (KW)	DG SIZE (KVA)	CASE II DG (KW)	DG SIZE (KVA)
Bus 09	Uduere I	60	70.59	120	141.18
Bus 25	Omonemu	60	70.59	120	141.18
Bus 34	Amekpa 3	60	70.59	120	141.18

However, the choice of location of these buses is arbitrary and there's need for further study on optimal allocation/placement of DG using the already acquired data. The PV system is presumed to generate 50% equal amount of active power.

The Solar PV as DG was modelled in two separate cases namely:

Case I DG penetration involved the addition of a small percentage of DG to the network and Case II DG penetration involved the addition of 50% of the already existing DG while the existing parameters of the network remained the Base Case values. Thus, the PV system is presumed to generate 50% equal amount of active power. Results were compared (without DG, Case I DG and Case II DG) based on technical loss reduction and voltage profile improvement.

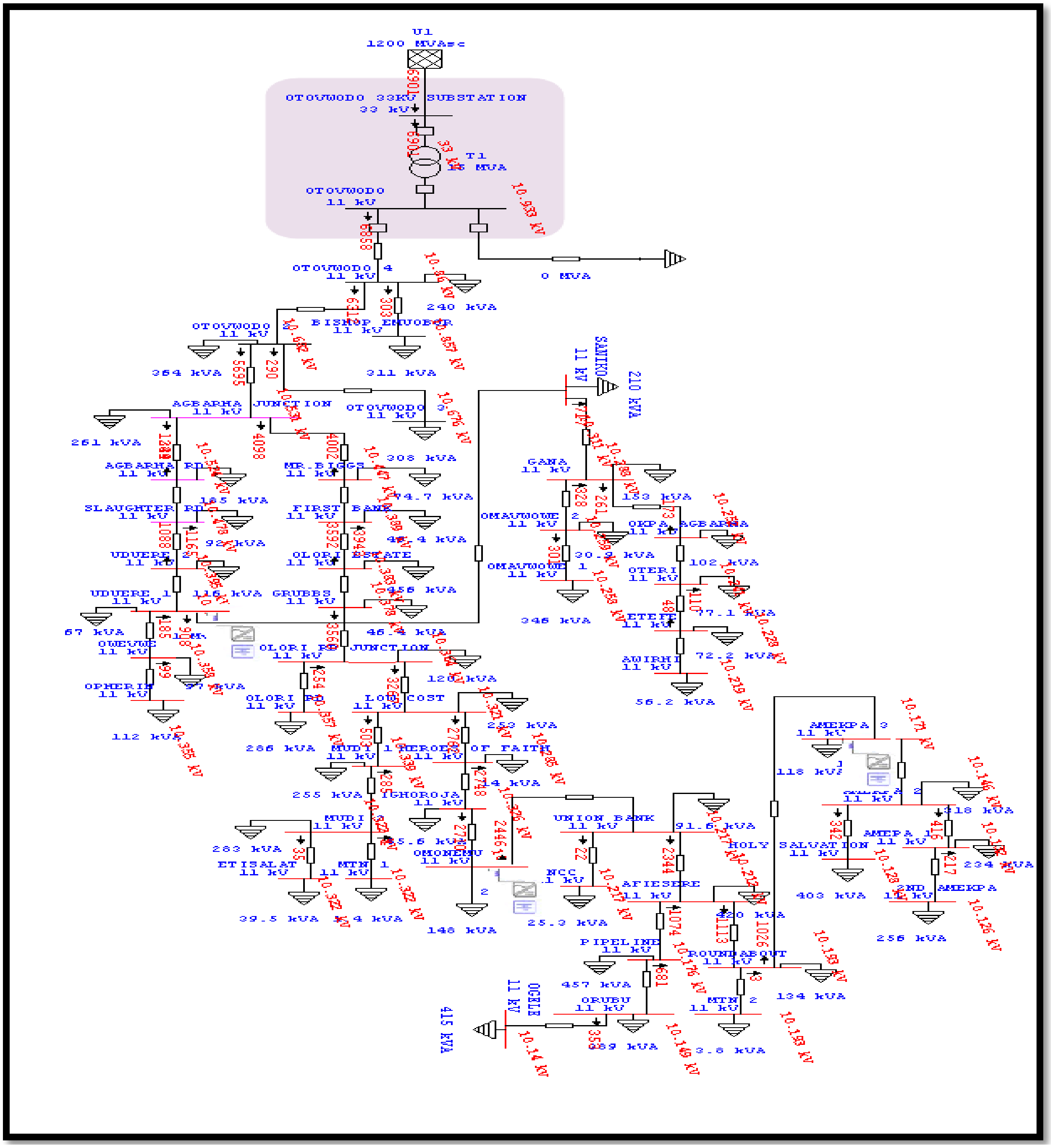

Figure 4.1: Dumez 11KV network modelled in ETAP 7.0 with Case I DG penetration

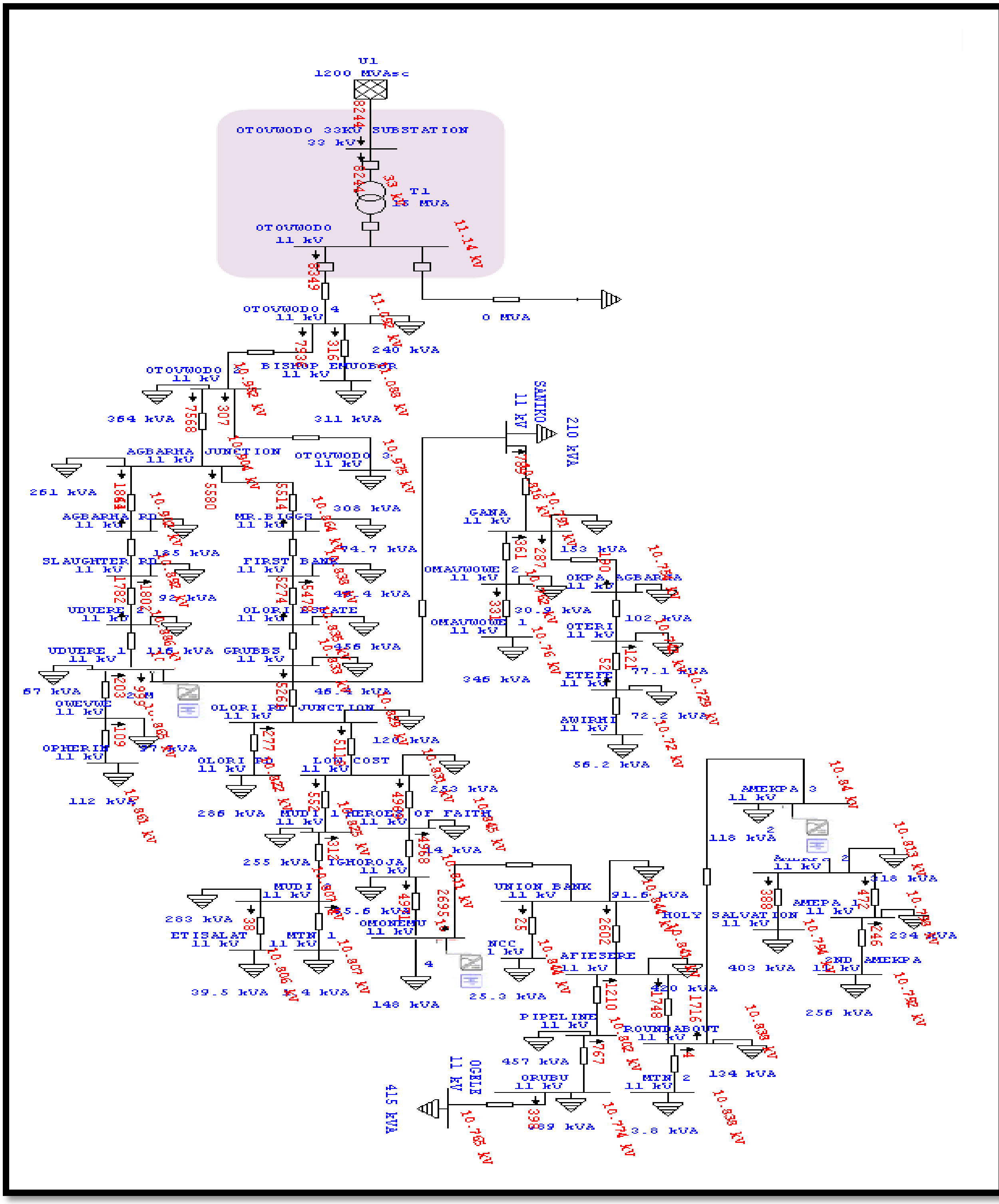

Fig 4.2: Dumez 11KV network modelled in ETAP 7.0 with Case II DG penetration

VI. Resultand Discussion

This research providessome solution to the Nigerian power network. A detailed investigation and analysis of the benefits of DG from solar renewable energy was done. Dumez feeder network of Otovwodo 15MVA, 33/11KV injection substation located at Otovwodo junction, along Ughelli-Patani express way, Ughelli, Delta State, Nigeria was used. The significance of this study is to provide sustainable and reliable power supply through the use of DG technology from abundant resource from solar renewable energy to meet the demand of electricity in the country.

The line data comparing technical losses without DG, with Case I DG and with Case II DG penetration is presented in Table 4.1. Whereas table 4.2 presents comparison of bus voltages without DG, with Case I DG and with Case II DG penetration respectively.

Technical Loss Reduction

The results achieved without DG [base case], case I DG [with 50% penetration of DG] and case II DG [with additional equal penetration of DG] at the same bus with respect to case one are shown in Table 4.1 below.

The line losses = $3 \times I^2R$, Where, I = Current and R = Resistance of the line.

The losses starting from the base-case results through Case I to Case II DG penetration from the load flow results are summarized in Table 4.1. However, the technical losses reduced from 0.7227 MW without DG penetration to 0.397 MW when Case I DG was placed at buses 09, 25 and 34 respectively and further reduced to 0.3491 MW after equal amount of DG was added to the same bus.

Table 4.1: Comparison of losses without DG, with Case I DG and with Case II DG

Line ID	Branch Connections		Without DG	Case I DG penetration	Case II DG penetration
	From Bus	To Bus	Technical Losses [MW]	Technical Losses [MW]	Technical Losses [MW]
Line45	Amekpa 1	2nd Amekpa	0.0001	0.0001	0.0001
Line35	Union Bank	Afiesere	0.0155	0.0009	0.0008
Line36	Afiesere	Pipeline	0.0025	0.0028	0.0025
Line39	Afiesere	Roundabout	0.0034	0.0027	0.0025
Line4	Otovwodo 2	Agbarha junction	0.0977	0.0819	0.0619
Line5	Agbarhajunctn	Agbarha RD	0.0065	0.001	0.001
Line11	Agbarhajunctn	MR Biggs	0.0483	0.0339	0.0231
Line6	Agbarha RD	Slaughter RD	0.0051	0.0069	0.0052
Line42	Amekpa 3	Amekpa 2	0.0023	0.002	0.0022
Line43	Amekpa 2	Holy Salvation	0.0003	0.0004	0.0004
Line44	Amekpa 2	Amekpa 1	0.0004	0.0004	0.0004
Line41	Amekpa 3	Roundabout	0.0027	0.0031	0.0066
Line23	Etefe	Awirhi	0.0002	0.0001	0.0001
Line3	Otovwodo 4	Bishop Emuobor	0.0004	0.0001	0.0001
Line22	Oteri	Etefe	0.0002	0.0001	0.0001
Line28	Mudi 2	Etisalat	0.0002	0.0001	0.0001
Line12	MR Biggs	First Bank	0.0468	0.0235	0.0313
Line13	First Bank	Olori Estate	0.0458	0.0023	0.0031
Line17	Saniko	Gana	0.0015	0.0012	0.0014
Line18	Gana	Omavwowe 2	0.0003	0.0007	0.0008
Line20	Gana	OkpaAgbarha	0.0002	0.0007	0.0008
Line14	Olori Estate	Grubbs	0.0374	0.0019	0.0038
Line15	Grubbs	Olori RD Junctn	0.0366	0.0057	0.0043
Line30	Low Cost	Heroes of Faith	0.0191	0.008	0.0106
Line31	Heroes of Faith	Ighoroja	0.0179	0.0159	0.0122
Line32	Ighoroja	Omonemu	0.0183	0.0189	0.0112
Line25	Olori RD Junctn	Low Cost	0.0308	0.0095	0.0075
Line26	Low Cost	Mudi 1	0.0006	0.0005	0.0004
Line29	Mudi 2	MTN 1	0.0002	0.0001	0.0001
Line40	Roundabout	MTN 2	0.0003	0.0002	0.0002
Line27	Mudi 1	Mudi 2	0.0002	0.0001	0.0001
Line34	Union Bank	NCC	0.0002	0.0001	0.0001
Line38	Orubu	Ogele	0.0003	0.0002	0.0002
Line21	OkpaAgbarha	Oteri	0.0001	0.0002	0.0002
Line24	Olori RD Junctn	Olori RD	0.0002	0.0001	0.0001

Line19	Omavwowe 2	Omavwowe 1	0.0003	0.0001	0.0002
Line33	Omonemu	Union Bank	0.0167	0.0055	0.0051
Line10	Owevwe	Opherin	0.0002	0.0001	0.0001
Line37	Pipeline	Orubu	0.001	0.0014	0.0015
Line1	Otovwodo	otovwodo 4	0.1396	0.042	0.039
T1	Otovwodo 33KV	Otovwodo	0.0135	0.0136	0.0115
Line2	Otovwodo 4	Otovwodo 2	0.0975	0.0877	0.0765
Line320	Uduere 1	Owevwe	0.0002	0.0001	0.0001
Line290	Otovwodo 2	Otovwodo 3	0.0004	0.0003	0.0003
Line16	Uduere 1	Saniko	0.0024	0.0047	0.0034
Line7	Slaughter RD	Uduere 2	0.0045	0.0127	0.0129
Line8	Uduere 2	Uduere 1	0.0038	0.0025	0.003
TOTAL			**0.7227**	**0.397**	**0.3491**

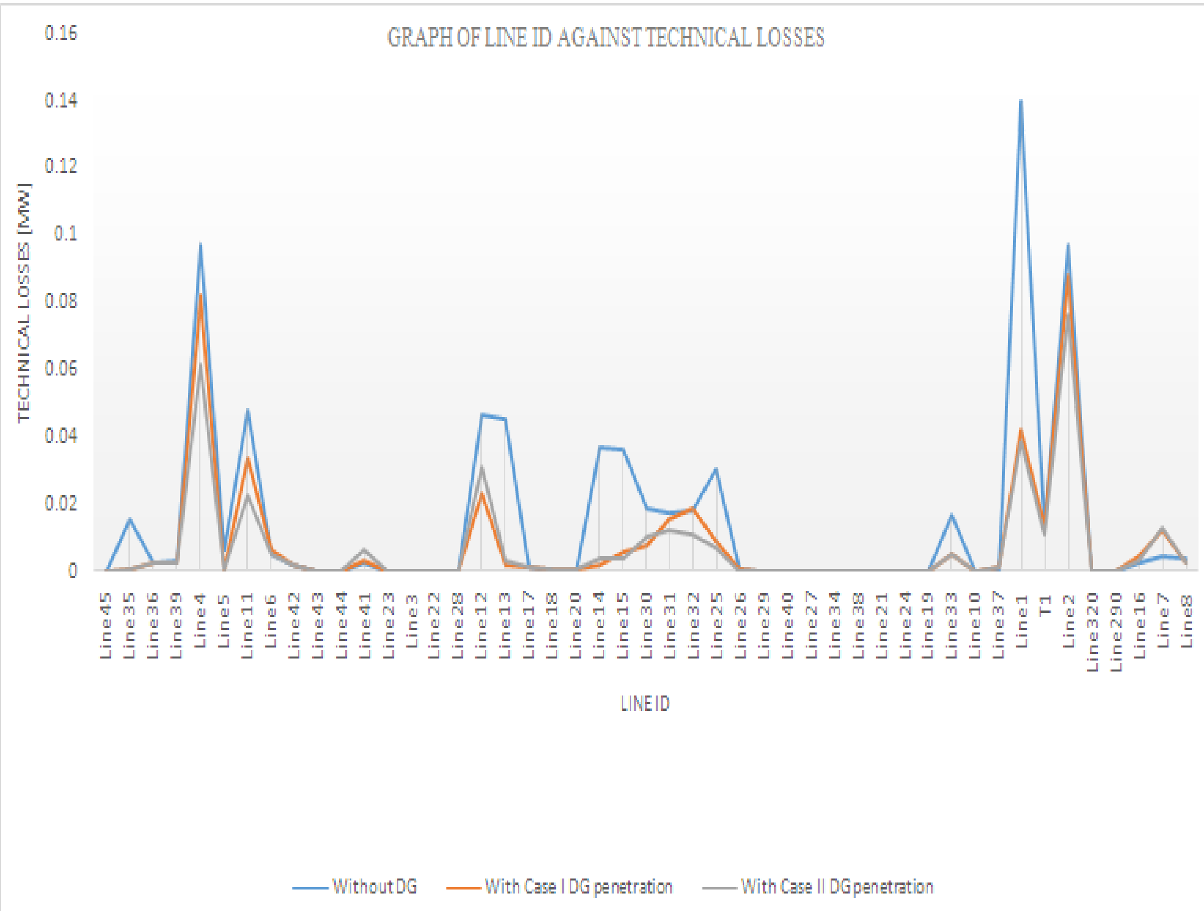

Fig4.3: Graph Comparing Losses without DG, with Case I DG and Case II DG

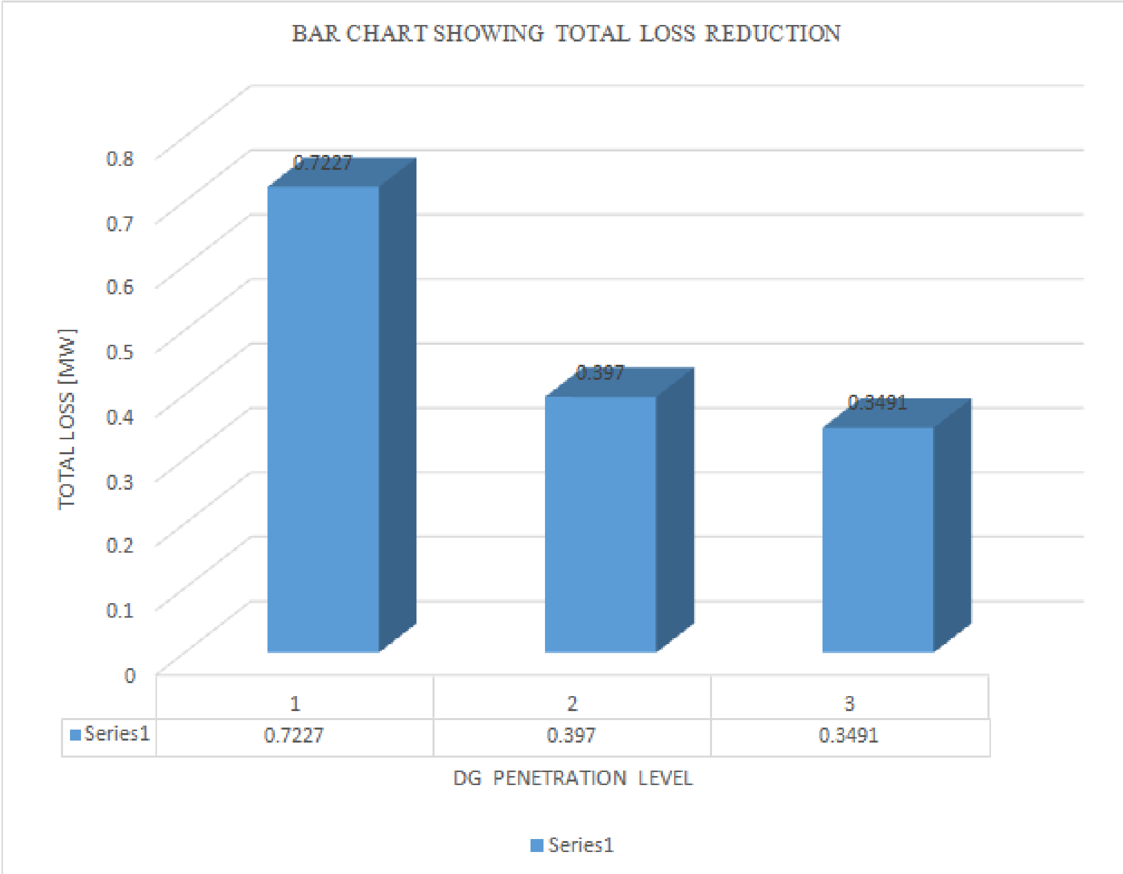

Figure 4.4: Bar chart comparing total Losses without DG, with Case I DG and Case II DG

Improvement in Voltage Profile

Before the introduction of distributed generation, it was observed from the load flow calculation [base-case] that the system recorded a high/massive condition of under voltage [i.e below the stipulated 95.0 % Alert Settings for Critical under voltage]. Except the Otovwodo bus with the highest percentage operating voltage at 97.8% and 2nd Amekpa bus had the lowest percentage operating voltage with 72.513% because it is farthest from the source [Otovwodo substation].

The entire system voltage had slight improvement after Case I DG penetration at buses 09, 25 and 34 as shown in table 4.5 below. This operation saw Agbarha junction, Agbarha RD and Slaughter road buses move away from Critical % Operating condition of Under Voltage to Marginal % operating condition.

The 2nd case of DG penetration represents a massive improvement on the entire Dumez feeder network. The entire voltages improved such that all the buses moved from the Critical % operating condition of under voltage to Marginal % operating condition.

Table 4.2 Comparison of bus voltages without DG, with Case I DG and Case II DG

Bus Name	Voltage % Mag		
	Without DG	After Case I DG penetration	After Case II DG penetration
2nd Amekpa	72.513	92.057	98.108
Afiesere	74.071	92.836	98.553
AgharhaJunctn	89.91	95.738	99.131
Agharha RD	89.245	95.671	99.105
Amekpa 2	72.762	92.233	98.296
Amekpa 3	73.156	92.466	98.544
Amekpa 1	72.597	92.106	98.161
Awirhi	86.642	92.903	97.451
Bishop Emuobor	94.421	98.696	100.804

Etefe	86.665	92.981	97.533
Etisalat	79.349	93.833	98.24
First Bank	86.213	94.442	98.524
Gana	86.905	93.524	98.103
Grubbs	82.765	94.345	98.486
Heroes of Faith	78.512	93.825	98.461
Holy Salvation	72.635	92.073	98.126
Ighoroja	77.349	93.5	98.589
Low Cost	79.681	93.99	98.405
Mr Biggs	88.046	94.973	98.763
MTN 1	79.361	93.84	98.248
MTN 2	73.589	92.66	98.528
Mudi 1	79.472	93.877	98.286
Mudi 2	79.361	93.841	98.248
NCC	75.111	92.878	98.586
Ogele	73.228	92.186	97.864
OkpaAgbarha	86.793	93.203	97.766
Olori Estate	84.403	94.39	98.501
Olori RD	81.043	94.157	98.385
Olori RD Junctn	81.149	94.214	98.445
Omavwowe 1	86.643	93.25	97.816
Omavwowe 2	86.769	93.266	97.833
Omonemu	76.209	93.128	98.782
Opherin	87.482	94.132	98.74
Orubu	73.363	92.259	97.941
Oteri	86.717	93.098	97.656
Otovwodo	97.764	99.389	101.277
Otovwodo 2	92.557	97.113	99.84
Otovwodo 3	92.433	97.051	99.777
Otovwodo 4	94.592	98.731	100.84
Otovwodo 33kv substn	100	100	100
Owevwe	87.526	94.161	98.771
Pipeline	73.636	92.507	98.204
Roundabout	73.591	92.66	98.529
Saniko	87.217	93.734	98.323
Slaughter RD	88.662	95.255	99.016
Uduere 1	87.611	94.362	98.982
Uduere 2	88.112	94.499	98.96
Union Bank	75.119	92.879	98.586

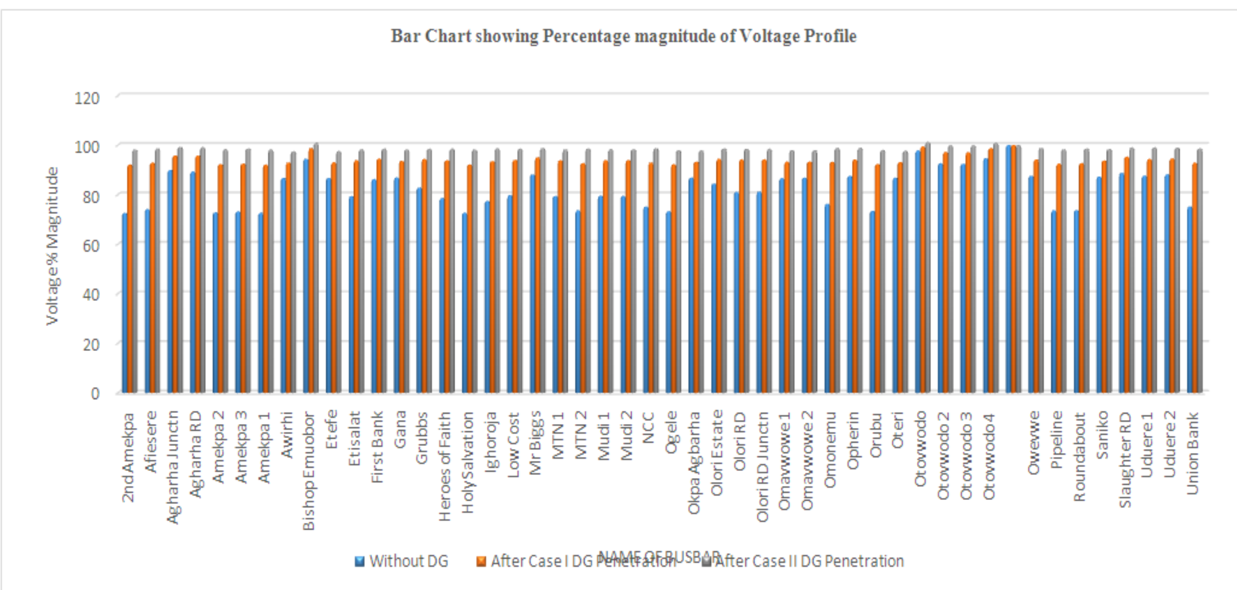

FIGURE 4.8: BAR CHART COMPARING VOLTAGE PROFILE (% MAG) WITHOUT DG, CASE I DG & CASE II DG.

References

[1] EPCOR, (2002) www.epcor.com/efficiency-conservation/Documents/Distributed-Generation Edmonton.pdf, Date accessed: 10/01/2017.
[2] Ekwue, A.O. & Akintunde, O.A., (2015) The Impact of Distributed Generation on Distribution Networks: Nigerian Journal of Technology (NIJOTECH), Vol. 34 No.2, pp.325-331
[3] Baker, M. (2016) "Scotland holds the largest Oil reserve in the E.U but proved they don't need it" (Interestingengineering.com/Scotland-largest-oil-reserve-eu-proved-they-do-not-need it) Date accessed 14/08/2017.
[4] Ministry of Power, Federal Republic of Nigeria, (2015). "National Renewable Energy and Energy Efficiency Polic(NREEEP)"Available at: http://www.power.gov.ng/download/NREEE%20POLICY%202015 %20FEC%20APPROVED%20COPY.pdf, Date accessed: 10/01/2017.
[5] A Report from International Energy Agency (IEA), [2015]: www.iea.org/policiesandmeasures/pams/nigeria/name-140453-en.php?s=, Date accessed 10/01/2017.
[6] McDonald, J.D., Wojszezyk, B., Flynn, B. &Voloh, I. (2013) "Distribution System, Substation and Integration of Distributed Generation" Encyclopedia of Sustainability Science and Technology.
[7] Bollen, M. & Hassan, F., (2011*)* "Integration of DG in the power system"IEEE press series on Power Engineering.
[8] Vincent, E.N & Yusuf, S.D. (2014) "Integrating Renewable Energy and Smart grid technology into the Nigerian Electricity Grid System" Smart Grid and Renewable Energy, 5, 220-238.
[9] Kadir, A.F.A., Mohamed, A., Shareef, H. &Wanik, M.Z.C., (2012) "Impact of Multiple Inverter Based Distributed Generation Units on Harmonic Resonance" International Conference on Renewable Energies and Power Quality.
[10] Tsado, J., Imoru, O. & Segun, O.D. (2012) "Power System Stability Enhancement through Smart Grid Technologies with DRS" International Journal of Engineering and Technology. Vol 2, No.4.
[11] Begovic, M., Pregelj, A., Rohatgi, A. &Novosel, D. (2001) "Impact of Renewable Distributed Generation on Power Systems"Proceedings of the 34th Hawaii International Conference on System Science.
[12] Sarabia, A.F., (2011) "Impact of Distributed Generation on Distribution System" Masters Dissertation, Dept. of Energy Technology, Aalborg University Denmark.
[13] Nigeria Power Baseline Report, (2015), Available online at: www.nesistats.org/index.html Date accessed: 25/04/2017.
[14] Ackermann, T., Andersson, G., &Soder, L., (2001) "Distributed Generation: A Definition" Electric Power System Research, Vol. 57, 195-204.
[15] Kaddah, S.S., El-Saadawi, M.M. & El-Hassanin, D.M. (2015) "Influence of Distributed Generation on Distribution Networks during Fault" Electrical Power Components and Systems, Vol.43 (16), 1781 – 1792.

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