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# Improving Power Supply of a Deficient 11kv Feeder Line

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**Abstract** – Increase in economic activities resulting from increase in population and social advancement has led to increase in electrical energy demand. This has enlarged the burden on the existing distribution assets across Nigeria and in some cases, has caused the loading of the distribution network beyond their design limits; with consequent reduction in power quality and increased power outages in extreme cases. In this research work, Newton - Raphson (N-R) algorithm in Electrical Transient and Analysis Program (ETAP) was used to simulate and analyze Ezenei 11kV injection substation network in Delta State, Nigeria with the placement of Distributed Generation (DG) units on the network to mitigate violations. Result obtained from the power flow study showed that without the placement of DG, the total average active and reactive power losses of the system was 1492.78 kW, 3599.564 kVar and Eleven (11) buses which are Bank PHB (0.95p.u), MTN II (0.946p.u), Starcom (0.968p.u), Junuic Hostel (0.945p.u), Victor Odogu (0.946p.u), Anambra Palace (0.945p.u), MTN I (0.95p.u), Chief Osita (0.953p.u), Best Garden (0.95p.u), Victor Hotel (0.954p.u) and L.C. Okeke (0.957p.u) load buses were within the voltage limit out of the sixty - seven (67) buses in the network. When DG was placed on the network, distribution line loss reduced by 53.67% (1492.8kW, 3599.6kVar to 691.63kW, 748.62kVar) and five (5) buses which are Starcom (93.2%), MTN I (93.3%), Achalla Ibusa (93.3%), Ministry of Trans. (93.3%) and Land survey (93.6%) out of the Sixty Seven (67) load buses violated the statutory voltage limit.

**Keywords** – Distributed Generation, Load Flow, Network, Newton - Raphson.

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## I. INTRODUCTION

The energy demand in Nigeria far exceeds its supply. The country is faced with intense electrical problems and this hinders its development in spite of the availability of vast natural resources. It is far extensively believed that there is interrelationship between socio-economic development and the provision of electricity [1]. The need to provide quality power supply in addition to efficient marketing and ensuring adequate network coverage and customer service delivery cannot be overstressed. Some challenges identified are, feeble and inadequate network coverage, low quality distribution lines, overloaded transformers and bad feeder pillars, poor billing system, unhealthy practices by staff and very poor customer service, inadequate logistic facilities such as tools, working vehicles, poor and obsolete communication equipment, low staff motivation and lack of frequent training, inadequate funds for equipment maintenance [2]. The distribution system is also characterized by poor voltage profile in most parts of the network, frequent system collapse and exceedingly high technical losses [3] – [4]. Thus, there is need to have a sustainable, reliable and stable supply to create an enabling balanced economy [5]. The unreliability of the System Network has impacted on the nation's socio-economic development and industrialization hence, the recent launch of the roadmap of the power sector reform by the Federal Government [6]. Distributed generation (DG) is normally defined as small generation units (<10 MW) installed in distribution systems [7]. The applications of DG include combined heat and power, standby power, peak shaving, grid support, and stand-alone power. The DG technologies include photovoltaic, wind turbines, fuel cells, small and micro-sized turbine packages, internal combustion engine generators, and reciprocating

engine generators [8]. Many of DG units are fueled by fossil and non-fossil fuel sources. When a cluster of large and capable generating units exist in a confined locality, they pose high potential for creating a distributed resources domain. It is quite possible to create a confined distribution network defined as a Micro Grid (MGR) generating and distribution system [9]. In distribution systems, DG can provide benefits for the consumers as well as for the utilities, especially in sites where the central generation is impracticable or where there are deficiencies in the transmission system [10]. Planning of DG has recently become more important and has gotten the attention of researchers to obtain maximum benefit from the recent power generation technology. Researchers made various methods for loss reduction in a distribution system using a DG allocation so proper DG allocation and sizing of DG units lead an important role in loss minimization technique. An analytical method was proposed by [11] to find out the appropriate location of DG unit in radial network system for minimization of losses based on unity power factor. Although optimal sizing problem of DG unit was not taken into account. There are faster analytical methods which are basically based on current injection matrix and without use of impedance or inverse admittance matrix optimal place for DG allocation can be obtained [12]. In this paper, power flow of Ezenei 11kV distribution injection substation was carried out using N-R algorithm in ETAP 12.6 to investigate the level of violations in the network and thereafter DG units is placed in the network by using Loss Sensitivity Factor (LSF) to determine the suitable bus of placement to mitigate the level of violations.

## II. OPTIMAL LOCATION OF DG

The placement technique for the DG is to minimize the real power loss and to improve the voltage profile at the distribution level thereby enhancing the reliability of the network. The real power loss reduction in a distribution system is required for efficient power system operation. The loss in the system can be calculated using (3.48) in [13] called the ‘exact loss formula’ given the system operating conditions. The objective of the placement technique is to minimize the total real power loss and improved voltage profile. Mathematically, the objective function can be written as:

$$\text{Minimize } P_L = \sum_{i=1}^N |I_i|^2 R_i \quad (1)$$

*Subject to Power Balance Constraints:*

$$\sum_{i=1}^N P_{DGi} = \sum_{i=1}^N P_{Di} + P_L \quad (2)$$

*Voltage Constraints:*

$$|V_i|^{min} \leq |V_i| \leq |V_i|^{max} \quad (3)$$

$$\text{Current Limits: } |I_{ij}| \leq |I_{ij}|^{max} \quad (4)$$

where  $i$  is the number of bus,  $N$  is the total number of buses,  $P_L$  is the real power loss in the system,  $P_{DGi}$  is the real power generation of DG at bus  $i$ ,  $P_{Di}$  is the power demand at bus  $i$ ,  $I_{ij}$  is the current between buses  $i$  and  $j$  and  $R_i$  is the resistance. The current  $I_i$  is determined from the load flow using Newton Raphson algorithm. For single source network all the power is supplied by the source but with DG that are optimally placed there is going to be reduction in power loss [9]. This reduction in power loss is determined as the difference of the power loss with DG and without DG. Thus, the new power loss in the network with DG is:

$$P_{L-new} = \sum_{i=1}^N |I_i^{new}|^2 R_i \quad (5)$$

$$P_{L-new} = \sum_{i=1}^N I_i^2 R_i - 2J I_i I_{DG} R_i - J I_i I_{DG}^2 R_i \quad (6)$$

where  $j=1$  for a feeder with DG or else  $j = 0$ . Hence, the power loss reduction value for bus  $i$  with DG is obtained by subtracting (5) from (6) as;

$$PLR = P_{L-new} - P_L \quad (7)$$

$$PLR_i = - \sum_i^N (2J I_i I_{DG} R_i - J I_i I_{DG}^2 R_i) R_i \quad (8)$$

The bus that gives the highest value of PLR is selected as the optimal location of DG. The emphasis is to place the DG at a location that will give maximum loss reduction. To obtain the DG current that will give maximum loss reduction, equation (8) is differentiated with respect to  $I_{DG}$  and equated to zero, hence the current is given by equation (9) below.

$$I_{DGI} = - \frac{\sum_{i=1}^n I_{ai} R_i}{\sum_{i=1}^n R_i} \quad (9)$$

The procedure is repeated for all the buses in order to obtain the highest power loss reduction value as the DG units are singly located. Assuming there are no significant changes in the voltage as DG units are connected, the power that can be generated is:

$$P_{DGI} = I_{DGI} V_i \quad (10)$$

Where  $V$  is the voltage magnitude of the bus  $i$  and the optimum DG size is obtained from equation (10).

### III. LOSS SENSITIVITY FACTOR

The active power loss in a distribution network can be find out by the equation;

$$P_{linelos}(q) = \frac{[P_{eff}(q)^2 + Q_{eff}(q)^2] R_k}{V_q^2} \quad (11)$$

Where  $P_{eff}(q)$  and  $Q_{eff}(q)$  are the effective active and reactive power flows supplied beyond the node ‘q’

$$\frac{\partial P_{linelos}(q)}{\partial P_{eff}(q)} = \frac{2 * P_{eff}(q) * R_k}{V_q^2} \quad (12)$$

$$\frac{\partial P_{linelos}(q)}{\partial Q_{eff}(q)} = \frac{2 * Q_{eff}(q) * R_k}{V_q^2} \quad (13)$$

Equation (12) and (13) are used to find the sensitivity factors and bus is ranked in the value. The buses having high value of LSF is considered as highest priority one. It is necessary to consider both LSF based priority and proximity of buses towards load and generation. Because, considering LSF based priority list alone may indicate nearby buses as optimal site for placing DGs which make the identified sites ineffective to satisfy the objectives. The exact loss formula for finding the active power loss of the system is derived from the active power injected based on loss sensitivity factor.

$$P_L = \sum_{i=1}^N \sum_{j=1}^N \alpha_{ij} (P_i P_j + Q_i Q_j) + \beta_{ij} (Q_i P_j - P_i Q_j) \quad (14)$$

Where,

$$\alpha_{ij} = \frac{r_{ij}}{V_i V_j} \cos(\delta_i - \delta_j); \beta_{ij} = \frac{r_{ij}}{V_i V_j} \sin(\delta_i - \delta_j) \quad (15)$$

Based on the active power injected on the  $i$  th bus, the loss sensitivity factor of the particular bus can be represented as:

$$\alpha_{ij} = \frac{\partial P_L}{\partial P_i} = 2 \sum_{j=1}^N (\alpha_{ij} P_j - \beta_{ij} Q_j) = \frac{2QR}{V^2} \quad (16)$$

The following steps have been followed for the optimal allocation of Distributed generators in the network:

1. Run the Base case power flow distribution network and find out the voltage magnitude of each buses.
2. Identify the prospective buses by their location, reactive power drawn, voltage magnitude and distance from the injection substation.
3. Determine the number of DGs that needs to be placed for the transforming the distribution network.
4. Find out the Loss sensitivity factors based on equations (12), (13) and (16) for all buses.
5. The buses are ranked in ascending order based on their Loss sensitivity factors.
6. Buses having high priority, proximity to load and other generation units is considered for placing the multiple DG units for the distribution network.

#### IV. DATA PRESENTATION

The Benin Electricity Distribution Company (BEDC) Asaba Ezenei 33/11kV injection substation comprises three (3) number of 11KV feeders which are outwardly radiated from this injection substation. The feeders are:

1. Ezenei feeder 2. Okwe feeder, and 3. SIO feeders. From transformer ( $T_2$ ) is radiated one number 11KV feeders namely: Ezenei feeder. Power transformers  $T_1$  and  $T_2$  are connected to a dual load bus with a bus coupler. On normal operating conditions, the bus coupler is left on open position so that each 7.5MVA power transformer delivers 11KV power to a defined network of the injection substation. The power circuit involving only Ezenei 11kV feeder which is the focus of this study consist of sixty - seven (67) numbers of secondary distribution transformer. Table 1 shows the various transformer capacity, the recorded voltages on the different lines and the average and peak load in MW captured from the various substations transformer secondary side of the distribution network.

Table 1. Power readings of 11/0.415KV substations transformers of Ezenei feeder.

S/N	Transformer Name	Capacity (KVA)	Voltage (Recorded)	AMPS					Peak Load (MW)
				R	Y	B	N	Average Load	
1	Eze-Ugboma	300	219	336	56	376	35	267.67	0.19
2	Victor hotel	100	30	50	30	30	10	30	0.01
3	Mammy Market	300	218	393	253	322	190	386	0.28
4	MTN I	50	30	35	25	31	13	28	0.05
5	Land Survey	300	220	305	219	307	19	283.33	0.2
6	Staff suite	300	220	409	27	169	182	262.33	0.19
7	Leo Okonweze I	300	217	356	218	326	29	309.67	0.22
8	Leo Okonweze II	300	219	109	254	388	71	274	0.2

S/N	Transformer Name	Capacity (KVA)	Voltage (Recorded)	AMPS					Peak Load (MW)
				R	Y	B	N	Average Load	
9	Ezenei	500	220	470	367	594	56	495.67	0.36
10	Auditor General	300	218	285	144	291	23	247.67	0.18
11	St Rebacah	200	178	110	112	101	35	89.5	0.1
12	Bank PHB	200	130	90	70	89	25	68.5	0.1
13	Asagba	300	219	109	254	388	71	274	0.2
14	MTN II	100	30	50	30	30	10	30	0.01
15	Anambra Placae	200	120	120	112	98	50	112	0.1
16	Jimok waters	300	218	393	253	322	190	386	0.28
17	Best garden	200	130	90	70	89	25	68.5	0.1
18	Marine I	300	220	389	357	377	76	399.67	0.29
19	Odogu	300	220	330	237	391	165	374.33	0.27
20	Estate	300	280	210	280	320	90	225	0.25
21	Victor odogu	100	30	50	30	30	10	30	0.01
22	L.C. Okeke	300	218	302	79	126	74	193.67	0.14
23	Inacho	300	218	233	321	250	36	280	0.2
24	Chief Osita	50	25	19	24	30	14	20	0.05
25	Starcom	50	27	19	24	26	9	22	0.05
26	Ekwo I	500	219'	377	208	662	89	445.33	0.32
27	Ekwo II (Igbe)	300	219	389	120	322	12	281	0.2
28	Ifebihor	300	219	400	221	395	45	353.67	0.25
29	Afadia II	300	220	419	270	389	81	386.33	0.28
30	Afadia I	300	218	393	253	322	190	386	0.28
31	Water Resources	300	220	208	161	200	13	194	0.14
32	Junuic Hostel	200	180	190	170	160	50	150	0.1
33	National Builder	200	120	120	80	90	40	100	0.19
34	Akwofu I	300	219	410	253	377	94	378	0.27
35	Akwofu II	500	218	715	525	670	222	710.67	0.51
36	Ministry of Transport	300	219	288	102	265	40	231.67	0.17
37	Ministry of Transport I	300	219	400	221	395	45	353.67	0.25
38	Ogbeke I	300	219	400	221	395	45	353.67	0.25
39	Achalla Ibusa I	300	220	419	270	389	81	386.33	0.28

S/N	Transformer Name	Capacity (KVA)	Voltage (Recorded)	AMPS					Peak Load (MW)
				R	Y	B	N	Average Load	
40	Achalla Ibusa II	300	218	393	253	322	190	386	0.28
41	Stanley	300	220	208	161	200	13	194	0.14
42	Iyabi	300	220	305	219	307	19	283.33	0.2
43	ONaje	300	220	409	27	169	182	262.33	0.19
44	Old deputy Govt.	300	220	208	161	200	13	194	0.14
45	Nikwu	300	220	305	219	307	19	283.33	0.2
46	AP	300	220	409	27	169	182	262.33	0.19
47	Umuda	300	220	411	109	219	67	268.67	0.19
48	Jarret II	315	218	405	329	210	63	335.67	0.24
49	Jarret I	500	219	629	475	538	36	559.33	0.40
50	Ogbeorie	500	218	595	347	507	49	499.33	0.36
51	Nwamu I	300	220	389	357	377	76	399.67	0.29
52	Nwamu II	300	220	330	237	391	165	374.33	0.27
53	MTN III	100	80	54	60	70	30	50	0.09
54	Feed mill	200	120	120	112	98	50	112	0.1
55	Church	300	220	403	61	399	108	323.67	0.23
56	Winner	500	219	504	321	458	195	492.67	0.35
57	Nira Sound	500	219	658	261	509	113	513.67	0.37
58	Ibusa	300	218	335	215	367	82	333	0.24
59	SSG	300	219	336	56	376	35	267.67	0.19
60	Ogbeke	315	218	405	329	210	63	335.67	0.24
61	Ibusa II	500	219	629	475	538	36	559.33	0.4
62	Akwofor	500	218	595	347	507	49	499.33	0.36
63	Inter Bau	300	220	389	357	377	76	399.67	0.29
64	Camp	300	220	330	237	391	165	374.33	0.27
65	DePark Plaza	200	120	120	112	98	50	112	0.1
66	Ekwo III	300	218	335	215	367	82	333	0.24
67	Chief ofili	200	150	130	140	160	70	150	0.18
	Total							10447.85	

Source: Data was gotten from different substation reading.

## V. RESULT OBTAINED

Simulation was carried out on the network and the results obtained is as show in Table 2 – 3. Sectional diagram of figure 1 shows how some of the buses was out of the statutory voltage limit and Figure 2, shows how DG was able to mitigate the deficient network by injecting more power into the network.

Table 2. Load flow result showing active and reactive power flow and losses before and after DG placement.

S/N	From Bus	To Bus	After DG Placement				Before DG Placement			
			kW Flow	kvar Flow	kW Losses	kvar Losses	kW Flow	kvar Flow	kW Losses	kvar Losses
1	ACHALLA IBUSA I	Bus100	35.21	11.7	0.104	0.157	26.8	8.9	0.0795	0.119
2	ACHALLA IBUSA II	Bus104	356.1	130	10.92	16.38	271	98.81	8.31	12.47
3	AFADIA I	Bus134	346	126	10.61	15.91	263.5	96.06	8.08	12.12
4	AFADIA II	Bus127	346.5	126	10.63	15.95	263.9	96.22	8.1	12.15
5	AKWUOFOR	Bus188	464.3	166	11.13	16.69	331.9	118.4	7.95	11.93
6	AKWUOFU I	Bus162	358.4	130	10.77	16.15	256.1	93.18	7.69	11.54
7	AKWUOFU II	Bus158	670	247	22.62	33.94	478.7	176.3	16.16	24.25
8	ANAMBRA PALACE	Bus71	107.3	37	1.46	2.18	87.85	30.27	1.19	1.79
9	AP	Bus139	248.8	87.9	5.24	7.85	183.5	64.84	3.86	5.79
10	ASAGBA	Bus69	258.4	91.6	5.67	8.51	211.6	75	4.65	6.97
11	AUDITOR GENERAL	Bus12	232.7	81.9	4.63	6.94	197.6	69.55	3.93	5.9
12	AZE-UGBOMA	Bus16	250	88.5	5.37	8.05	212.3	75.11	4.56	6.84
13	BANK PHB	Bus73	65.99	22.3	0.551	0.827	54.06	18.3	0.451	0.677
14	BEST GARDNER	Bus38	65.8	22.3	0.55	0.824	55.13	18.66	0.46	0.691
15	Bus2	JIMOK WATERS	30.48	534	0.355	0.108	9544.3	3345.5	147.6	37.37
16	JIMOK WATERS	VICTOR ODOGU	326.3	-404	0.334	0.102	9099.6	3199.8	138.4	35.03
17	Bus2	AUDITOR GENERAL	211.9	583	0.477	0.145	4235.8	1456.7	28.96	7.33
18	EZENEI	AUDITOR GENERAL	870	316	1.06	0.323	738.7	268.2	0.903	0.229
19	AZE-UGBOMA	EZENEI	419.8	148	0.246	0.0749	356.5	125.2	0.209	0.053
20	JUNUIC HOSTEL	AZE-UGBOMA	169.6	59	0.0402	0.0122	144	50.07	0.0341	0.0086
21	VICTOR HOTEL	JUNUIC HOSTEL	28.7	9.68	0.0011	0.0003	24.37	8.22	0.001	0.0002
22	AUDITOR GENERAL	Bus25	892.4	-184	1.03	0.313	3270.5	1111.6	17.45	4.42
23	INACHO	CHIEF OSITA	19.67	6.69	0.0005	0.0002	5.77	1.96	0.0002	0
24	BEST GARDNER	ESTATE	9.99	1.45	0.123	0.0374	251.1	78.3	102.4	25.91

S/N	From Bus	To Bus	After DG Placement				Before DG Placement			
			kW Flow	kvar Flow	kW Losses	kvar Losses	kW Flow	kvar Flow	kW Losses	kvar Losses
25	ESTATE	INACHO	228	77.7	0.0701	0.0213	84.77	30	0.0333	0.0084
26	Bus25	BEST GARDNER	55.95	20.9	0.0044	0.0013	306.4	97	0.153	0.0386
27	MTN I	STAFF SUITE	571.9	203	0.457	0.139	474	168.5	0.378	0.0958
28	LEO OKONWEZE II	LEO OKONWEZE I	256.2	90.8	0.0918	0.0279	212.3	75.24	0.0761	0.0193
29	LEO OKONWEZE I	MTN I	544.8	194	0.415	0.126	451.6	160.8	0.344	0.0871
30	Bus25	STARCOM	949.5	-163	1.15	0.349	2946.6	1010.2	14.34	3.63
31	STAFF SUITE	STARCOM	819.3	291	0.935	0.284	679.1	240.9	0.775	0.196
32	STARCOM	Bus75	1794	136	3.98	1.21	2235.7	759.7	8.32	2.11
33	Bus75	MTN II	3662	755	17.05	5.18	710.9	255.7	0.858	0.217
34	ST. REBECAH	MAMMY MRT	1328	431	2.42	0.735	1088	353.2	1.98	0.502
35	ANAMBRA PALACE	ASAGBA	258.5	91.6	0.0926	0.0281	211.7	75.02	0.0759	0.0192
36	ST. REBECAH	BANK PHB	1416	461	2.74	0.833	1160.3	377.7	2.25	0.569
37	BANK PHB	Bus75	1485	485	3	0.913	1216.8	396.6	2.46	0.623
38	Bus75	ANAMBRA PALACE	365.9	129	0.185	0.0562	299.7	105.3	0.152	0.0384
39	MARINE I	OGBEORIE	478.7	171	0.312	0.0948	383	136.6	0.25	0.0632
40	MTN II	MARINE I	3709	770	17.33	5.26	686.3	247.5	0.802	0.203
41	MAMMY MRT	JARET I	970.8	301	1.29	0.391	795.3	246.7	1.05	0.267
42	JARET I	JARET II	453	115	0.273	0.0828	371.2	94.09	0.223	0.0566
43	JARET II	CHIEF OFILI	142.4	3.5	0.0254	0.0077	116.7	2.87	0.0208	0.0053
44	L.C. OKEKE	Bus2	126.2	43.1	0.0221	0.0067	108.5	37.01	0.019	0.0048
45	VICTOR ODOGU	ODOGU	355.4	-394	0.349	0.106	8937.8	3156.9	137.7	34.85
46	ODOGU	NWAMU II	702.3	-268	0.699	0.212	8528.3	3023.3	129.3	32.73
47	ACHALLA IBUSA I	NWAMU II	575.8	206	0.463	0.141	438.3	156.4	0.352	0.0892
48	ACHALLA IBUSA II	ACHALLA IBUSA I	356.2	130	0.178	0.0542	271.2	98.85	0.136	0.0343
49	STANLEY	ACHALLA IBUSA I	183.9	63.8	0.047	0.0143	140	48.57	0.0358	0.0091
50	NWAMU II	NWAMU I	2567	921	9.2	2.8	1954.2	700.2	7.01	1.77
51	NWAMU I	EKWO I	2191	784	6.75	2.05	1668.3	596.4	5.14	1.3
52	UMUDA	EKWO III	1519	547	3.28	0.998	1156.4	416.2	2.5	0.633

S/N	From Bus	To Bus	After DG Placement				Before DG Placement			
			kW Flow	kvar Flow	kW Losses	kvar Losses	kW Flow	kvar Flow	kW Losses	kvar Losses
53	EKWO I	UMUDA	1771	636	4.44	1.35	1348.6	483.9	3.38	0.856
54	EKWO II	NIKWU	953	345	1.3	0.396	725.7	262.6	0.993	0.251
55	EKWO III	EKWO II	1212	437	2.1	0.638	923	332.5	1.6	0.405
56	AFADIA II	AFADIA I	346.1	126	0.173	0.0526	263.6	96.09	0.132	0.0334
57	NIKWU	AFADIA II	693.4	253	0.694	0.211	528	192.4	0.528	0.134
58	NWAMU II	Bus135	4214	992	22.95	6.97	5742.7	2038	60.39	15.29
59	Bus135	AP	984.8	345	1.33	0.405	726.4	254.4	0.983	0.249
60	NATIONAL BUILDER	WATER RESOURCES	184.9	64.2	0.0472	0.0144	136.4	47.33	0.0348	0.0088
61	IYABI	NATIONAL BUILDER	281	97.1	0.109	0.0331	207.3	71.63	0.0803	0.0203
62	OLD DEPUTY GOVT.	IYABI	548.5	192	0.415	0.126	404.6	141.7	0.306	0.0776
63	AP	OLD DEPUTY GOVT.	734.6	257	0.743	0.226	541.9	189.3	0.548	0.139
64	AKWUOFU II	Bus135	5235	1348	35.28	10.72	4955.9	1768.3	45.96	11.64
65	AKWUOFU I	AKWUOFU II	358.6	131	0.176	0.0534	256.2	93.21	0.126	0.0318
66	MINISTRY OF TRANS.	AKWUOFU II	224.3	78.6	0.0682	0.0207	160.3	56.17	0.0488	0.0123
67	AKWUOFU II	Bus167	5616	2007	42.95	13.05	4014.7	1431	30.71	7.77
68	MINISTRY OF TRANS. I	Bus167	2461	885	8.39	2.55	1759.1	632.3	5.99	1.52
69	OGBEKE	MINISTRY OF TRANS. I	314.1	113	0.137	0.0418	224.5	80.5	0.0983	0.0249
70	DE PARK PLAZA	MINISTRY OF TRANS. I	1809	651	4.56	1.39	1293	465.1	3.26	0.825
71	IBUSA II	DE PARK PLAZA	519.4	187	0.378	0.115	371.3	133.6	0.27	0.0684
72	INTER BAU	DE PARK PLAZA	1178	426	1.95	0.591	842.3	304.4	1.39	0.352
73	AKWUOFOR	INTER BAU	464.6	166	0.303	0.092	332.1	118.5	0.216	0.0548
74	CAMP	INTER BAU	344.8	125	0.167	0.0509	246.4	89.58	0.12	0.0303
75	NIRA SOUND	WINNER	2044	729	5.91	1.8	1461.9	520.8	4.23	1.07
76	IBUSA	NIRA SOUND	2527	901	8.97	2.72	1807	643.5	6.41	1.62
77	SSG	IBUSA	2847	1015	11.29	3.43	2035.3	724.8	8.08	2.04
78	Bus167	SSG	3112	1109	13.38	4.06	2225	790.9	9.57	2.42
79	IFE BIHOR	FEED MILL	706.3	251	0.717	0.218	505.1	179.2	0.513	0.13
80	LAND SURVEY	IFE BIHOR	1027	367	1.51	0.459	734.2	262	1.08	0.274

S/N	From Bus	To Bus	After DG Placement				Before DG Placement			
			kW Flow	kvar Flow	kW Losses	kvar Losses	kW Flow	kvar Flow	kW Losses	kvar Losses
81	CHURCH	LAND SURVEY	1288	459	2.37	0.719	920.7	328.1	1.69	0.429
82	WINNER	CHURCH	1586	566	3.58	1.09	1134.1	404.4	2.56	0.648
83	OGBEKE I	ONAJE	316.9	115	0.146	0.0443	226.7	81.97	0.104	0.0264
84	ONAJE	MTN III	555.5	199	0.446	0.135	397.3	142.2	0.319	0.0807
85	MTN III	FEED MILL	602.2	215	0.523	0.159	430.7	153.6	0.374	0.0946
86	CAMP	Bus195	344.6	125	10.26	15.38	246.3	89.55	7.33	11
87	CHIEF OFILI	Bus91	142.4	3.5	2.33	3.5	116.7	2.86	1.91	2.86
88	CHIEF OSITA	Bus34	19.67	6.69	0.191	0.287	5.77	1.96	0.0561	0.0842
89	CHURCH	Bus212	294.8	106	7.62	11.43	210.8	75.67	5.45	8.17
90	DE PARK PLAZA	Bus177	106.5	36.7	1.45	2.17	76.15	26.24	1.03	1.55
91	EKWO I	Bus122	413.1	146	8.85	13.28	314.5	111.3	6.74	10.11
92	EKWO II	Bus123	257	91.2	5.78	8.68	195.7	69.48	4.4	6.61
93	EKWO III	Bus126	303.4	109	8.06	12.09	231	83.11	6.14	9.2
94	ESTATE	Bus37	217.9	76.3	3.94	5.92	63.99	22.39	1.16	1.74
95	EZENEI FEEDER INJ. S/S	Bus2	369.8	1176	1.3	16.88	14109.3	7708.7	220.7	2869.4
96	EZENEI	Bus14	449.1	168	17.53	26.3	381.3	142.8	14.89	22.33
97	FEED MILL	Bus215	103.4	35.6	1.4	2.11	73.92	25.47	1	1.51
98	IBUSA II	Bus183	519.1	187	13.89	20.84	371	133.6	9.93	14.89
99	IBUSA	Bus205	308.2	111	8.19	12.28	220.3	79.26	5.85	8.78
100	IFEBIHOR	Bus214	318.8	115	8.98	13.47	228	82.45	6.42	9.63
101	INACHO	Bus36	269.3	95.6	6.04	9.06	78.97	28.03	1.77	2.66
102	INTER BAU	Bus191	367	134	11.64	17.46	262.3	95.97	8.32	12.48
103	IYABI	Bus149	267	94.9	6.06	9.09	197	69.97	4.47	6.7
104	JARET I	Bus87	516.5	186	13.82	20.73	423.1	152.3	11.32	16.99
105	JARET II	Bus89	310.3	111	7.92	11.89	254.2	91.17	6.49	9.74
106	JIMOK WATERS	Bus3	356	130	10.92	16.38	297.1	108.3	9.11	13.66
107	JUNUIC HOSTEL	Bus21	140.8	49.3	2.55	3.82	119.6	41.84	2.17	3.25
108	L.C. OKEKE	L.C.	126.2	43.1	1.35	2.03	108.5	37.01	1.16	1.74

S/N	From Bus	To Bus	After DG Placement				Before DG Placement			
			kW Flow	kvar Flow	kW Losses	kvar Losses	kW Flow	kvar Flow	kW Losses	kvar Losses
109	LAND SURVEY	Bus213	258.6	91.9	5.87	8.8	184.9	65.68	4.19	6.29
110	LEO OKONWEZE I	Bus45	288.3	103	7.13	10.7	238.9	85.45	5.91	8.87
111	LEO OKONWEZE II	Bus46	256.1	90.8	5.62	8.44	212.3	75.22	4.66	6.99
112	MAMMY MRT	Bus59	354.9	129	10.88	16.32	290.7	106	8.91	13.37
113	MARINE I	Bus81	378.2	138	11.99	17.99	302.5	110.7	9.59	14.39
114	MINISTRY OF TRANS. I	Bus174	329.5	119	9.28	13.92	235.5	85.19	6.63	9.95
115	MINISTRY OF TRANS.	Bus166	224.3	78.6	4.18	6.27	160.2	56.16	2.99	4.48
116	MTN I	Bus44	26.61	9.17	0.361	0.542	22.06	7.6	0.3	0.449
117	MTN II	Bus72	29.35	9.9	0.215	0.322	23.75	8.01	0.174	0.261
118	MTN III	Bus230	46.18	15.8	0.561	0.841	33.02	11.32	0.401	0.601
119	NATIONAL BUILDER	Bus150	95.98	32.9	1.17	1.75	70.79	24.27	0.86	1.29
120	NIKWU	Bus130	258.3	91.8	5.86	8.79	196.7	69.87	4.46	6.69
121	NIRA SOUND	Bus206	473.7	169	11.67	17.5	338.6	121.1	8.34	12.51
122	NWAMU I	Bus112	366.3	134	11.62	17.43	278.9	102	8.84	13.27
123	NWAMU II	Bus108	346.7	126	10.32	15.48	263.9	95.94	7.85	11.78
124	ODOGU	Bus96	346.2	126	10.3	15.45	271.8	98.82	8.09	12.13
125	OGBEKE I	Bus227	316.8	115	8.92	13.39	226.6	81.95	6.38	9.57
126	OGBEKE	Bus175	314	113	8.02	12.03	224.4	80.48	5.73	8.6
127	OGBEORIE	Bus82	478.4	171	11.46	17.2	382.7	136.5	9.17	13.76
128	OLD DEPUTY GOVT.	Bus148	185.4	64.3	2.9	4.35	136.7	47.45	2.14	3.21
129	ONAJE	Bus226	238.1	84.1	5.01	7.52	170.3	60.18	3.58	5.38
130	SSG	Bus204	252	89.2	5.41	8.11	180.1	63.72	3.87	5.8
131	ST. REBECAH	Bus55	85.51	29.2	0.931	1.4	70.05	23.92	0.762	1.14
132	STAFF SUITE	Bus42	246.5	87.1	5.19	7.78	204.3	72.18	4.3	6.45
133	STANLEY	Bus106	183.8	63.8	2.88	4.32	139.9	48.56	2.19	3.28
134	STARCOM	Bus52	21.1	7.2	0.226	0.339	17.49	5.97	0.187	0.281
135	UMUDA	Bus119	248	87.8	5.34	8.01	188.8	66.82	4.07	6.1
136	VICTOR HOTEL	Bus23	28.7	9.68	0.21	0.315	24.37	8.22	0.178	0.268

S/N	From Bus	To Bus	After DG Placement				Before DG Placement				
			kW Flow	kvar Flow	kW Losses	kvar Losses	kW Flow	kvar Flow	kW Losses	kvar Losses	
137	VICTOR ODOGU	Bus9	28.84	9.73	0.211	0.317	23.35	7.88	0.171	0.256	
138	WATER RESOURCES	Bus151	184.9	64.2	2.89	4.34	136.4	47.33	2.13	3.2	
139	WINNER	Bus207	452.5	161	10.7	16.05	323.6	115.3	7.65	11.48	
	<b>TOTAL LOSSES</b>					<b>691.63</b>	<b>748.62</b>			<b>1492.8</b>	<b>3599.6</b>

Source: Generated from ETAP 12.6.

Table 3. Load flow results showing bus voltages on the load buses before and after dg placement.

S/N	ID	Before DG Placement						Afetr DG Placement					
		Rated kV	kW	kvar	Amp	% PF	Bus Voltage (%)	kW	kvar	Amp	% PF	Bus Voltage (%)	
1	CHIEF OFILI	0.415	114.8	0	182.5	100	87.47	35.1	11.54	52.29	95	98.3	
2	CHIEF OSITA	0.415	5.71	1.88	15.65	95	53.44	345.1	113.4	534.5	95	94.6	
3	STARCOM	0.415	17.3	5.69	28.57	95	88.67	335.3	110.2	526.9	95	93.2	
4	MTN I	0.415	21.76	7.15	36.14	95	88.16	335.9	110.4	527.5	95	93.3	
5	VICTOR ODOGU	0.415	23.18	7.62	38.62	95	87.9	453.2	148.9	696.6	95	95.3	
6	MTN II	0.415	23.58	7.75	38.95	95	88.66	347.6	114.3	530.9	95	95.9	
7	VICTOR HOTEL	0.415	24.19	7.95	39.45	95	89.79	647.4	212.8	993.3	95	95.4	
8	ACHALLA IBUSA I	0.415	26.72	8.78	45.62	95	85.76	105.8	34.77	159.4	95	97.2	
9	MTN III	0.415	32.62	10.72	59.14	95	80.78	243.6	80.07	370.2	95	96.4	
10	BANK PHB	0.415	53.6	17.62	88.74	95	88.46	252.7	83.05	385.3	95	96.0	
11	BEST GARDNER	0.415	54.67	17.97	89.62	95	89.34	228.1	74.97	348.1	95	96.0	
12	ESTATE	0.415	62.83	20.65	174.1	95	52.85	244.6	80.4	374.8	95	95.6	
13	ST. REBECAH	0.415	69.29	22.77	115.3	95	87.99	65.44	21.51	98.05	95	97.7	
14	NATIONAL BUILDER	0.415	69.93	22.99	122.5	95	83.61	65.25	21.45	97.91	95	97.6	
15	FEED MILL	0.415	72.91	23.97	132.3	95	80.68	334.3	109.9	518	95	94.5	
16	DE PARK PLAZA	0.415	75.12	24.69	134.3	95	81.89	140.1	0	201.7	100	96.6	
17	INACHO	0.415	77.2	25.38	215.3	95	52.51	19.47	6.4	28.9	95	98.7	
18	ANAMBRA PALACE	0.415	86.65	28.48	144.3	95	87.96	287.2	94.4	446.5	95	94.2	
19	L.C. OKEKE	0.415	107.3	35.27	174.3	95	90.14	105.1	34.54	158.9	95	96.9	
20	JUNUIC HOSTEL	0.415	117.4	38.59	194.4	95	88.47	404.3	132.9	621.3	95	95.3	
21	WATER RESOURCES	0.415	134.2	44.12	236.3	95	83.19	251.2	82.56	389.1	95	94.6	

S/N	ID	Before DG Placement						After DG Placement					
		Rated kV	kW	kvar	Amp	% PF	Bus Voltage (%)	kW	kvar	Amp	% PF	Bus Voltage (%)	
22	OLD DEPUTY GOVT.	0.415	134.6	44.24	236.6	95	83.3	295.3	97.06	459.2	95	94.2	
23	STANLEY	0.415	137.7	45.27	239.4	95	84.26	214	70.33	321.3	95	97.5	
24	MINISTRY OF TRANS.	0.415	157.2	51.68	279.5	95	82.38	431.6	141.9	677.4	95	93.3	
25	ONAJE	0.415	166.7	54.8	306.2	95	79.73	102	33.51	156.5	95	95.4	
26	SSG	0.415	176.2	57.92	318.1	95	81.13	505.2	166	778.4	95	95.0	
27	AP	0.415	179.7	59.05	317.9	95	82.76	300	98.6	462.8	95	94.9	
28	LAND SURVEY	0.415	180.7	59.39	331.3	95	79.87	309.8	101.8	484.7	95	93.6	
29	UMUDA	0.415	184.7	60.72	326.3	95	82.93	263.3	86.54	397.6	95	97.0	
30	EKWO II	0.415	191.3	62.87	339.5	95	82.5	355.4	116.8	551.9	95	94.3	
31	NIKWU	0.415	192.2	63.18	341.7	95	82.37	261	85.78	398.2	95	96.0	
32	IYABI	0.415	192.5	63.27	342	95	82.43	502.6	165.2	776.4	95	94.8	
33	AUDITOR GENERAL	0.415	193.7	63.66	320.7	95	88.43	302.4	99.4	466.6	95	94.9	
34	STAFF SUITE	0.415	200	65.73	335.4	95	87.32	345.1	113.4	534.5	95	94.6	
35	CHURCH	0.415	205.4	67.5	377.6	95	79.66	138.3	45.45	210.9	95	96.0	
36	ASAGBA	0.415	207	68.03	348.7	95	86.91	124.8	41.02	188	95	97.2	
37	LEO OKONWEZE II	0.415	207.6	68.23	349.2	95	87.05	252.7	83.06	391.8	95	94.4	
38	AZE-UGBOMA	0.415	207.7	68.27	345.3	95	88.08	281.1	92.4	432.1	95	95.3	
39	IBUSA	0.415	214.4	70.48	391.3	95	80.25	250.5	82.32	383.6	95	95.6	
40	OGBEKE	0.415	218.7	71.88	396.8	95	80.71	344	113.1	533.6	95	94.4	
41	OGBEKE I	0.415	220.2	72.37	408.7	95	78.9	366.2	120.4	560.2	95	95.7	
42	IFE BIHOR	0.415	221.5	72.81	409.9	95	79.14	320.3	105.3	492.9	95	95.2	
43	EKWO III	0.415	224.8	73.9	400.7	95	82.17	220.1	72.33	330.7	95	97.5	
44	MINISTRY OF TRANS. I	0.415	228.9	75.23	416.7	95	80.45	26.25	8.63	39.7	95	96.8	
45	LEO OKONWEZE I	0.415	233	76.58	393.4	95	86.74	29.13	9.58	43.29	95	98.5	
46	CAMP	0.415	239	78.55	438	95	79.91	45.62	14.99	69.94	95	95.5	
47	JARET II	0.415	247.7	81.43	422.3	95	85.9	94.81	31.16	142.6	95	97.4	
48	AKWUOFU I	0.415	248.4	81.64	448.7	95	81.06	252.4	82.97	391.6	95	94.4	
49	INTER BAU	0.415	254	83.49	466.6	95	79.72	462	151.9	713.4	95	94.8	
50	AFADIA I	0.415	255.4	83.94	459.8	95	81.34	354.7	116.6	551.4	95	94.2	
51	AFADIA II	0.415	255.8	84.08	460.3	95	81.38	336.4	110.6	519.6	95	94.8	

S/N	ID	Before DG Placement						After DG Placement					
		Rated kW	kvar	Amp	% PF	Bus Voltage (%)	kW	kvar	Amp	% PF	Bus Voltage (%)		
52	NWAMU II	0.415	256.1	84.16	453.4	95	82.71	335.9	110.4	519.2	95	94.7	
53	ACHALLA IBUSA II	0.415	262.7	86.35	466.3	95	82.5	307.9	101.2	483.2	95	93.3	
54	ODOGU	0.415	263.7	86.69	460.1	95	83.94	306	100.6	469.4	95	95.5	
55	NWAMU I	0.415	270	88.75	481.1	95	82.2	467	153.5	707.1	95	96.7	
56	MAMMY MRT	0.415	281.8	92.63	483	95	85.45	182.5	59.99	275.5	95	97.0	
57	JIMOK WATERS	0.415	288	94.66	488.2	95	86.38	233.1	76.62	362.1	95	94.3	
58	MARINE I	0.415	292.9	96.28	501.1	95	85.61	246.5	81.04	376.2	95	96.0	
59	EKWO I	0.415	307.8	101.2	542.1	95	83.14	84.58	27.8	127.4	95	97.2	
60	WINNER	0.415	315.9	103.8	577.7	95	80.08	241.3	79.31	368.4	95	95.9	
61	AKWUOFOR	0.415	323.9	106.5	589	95	80.55	181	59.48	274.4	95	96.6	
62	NIRA SOUND	0.415	330.3	108.6	603.2	95	80.19	20.87	6.86	31.38	95	97.4	
63	IBUSA II	0.415	361.1	118.7	658.1	95	80.35	242.7	79.76	373.9	95	95.0	
64	EZENEI	0.415	366.5	120.4	624.2	95	85.98	28.49	9.36	42.81	95	97.4	
65	OGBEORIE	0.415	373.5	122.8	632.4	95	86.49	28.63	9.41	42.92	95	97.7	
66	JARET I	0.415	411.8	135.3	702.8	95	85.81	182	59.82	275.2	95	96.9	
67	AKWUOFU II	0.415	462.6	152	839.6	95	80.68	441.8	145.2	683.2	95	94.7	

Source: Generated from ETAP 12.6.

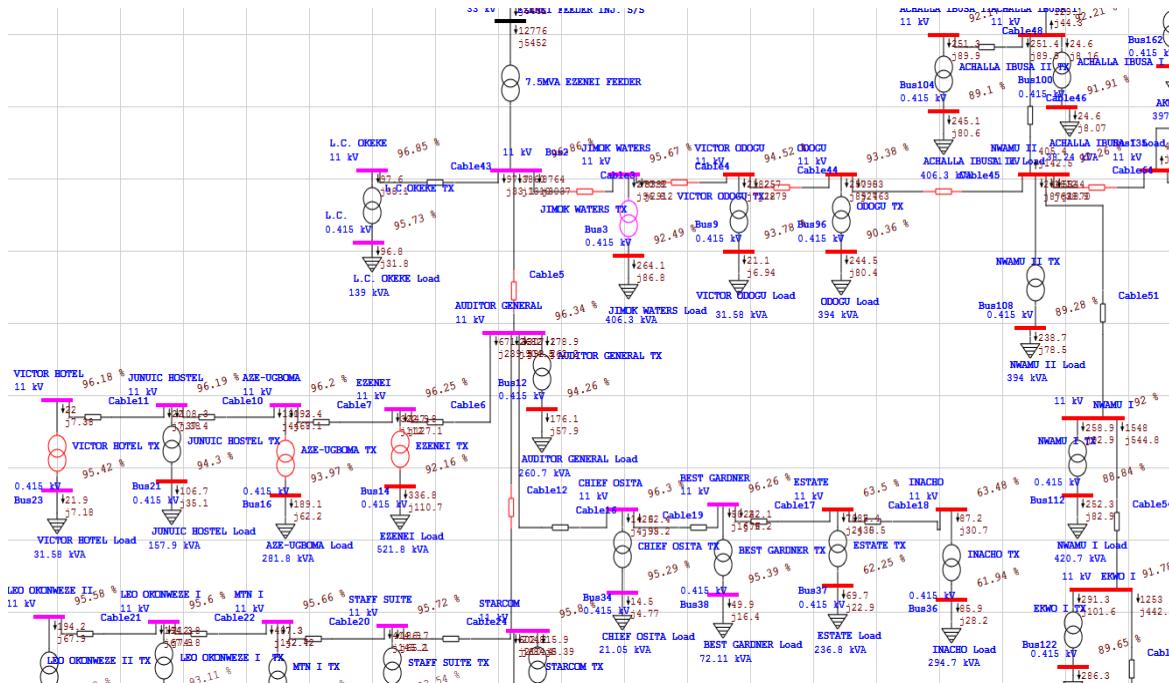


Fig. 1. Section of the Load flow diagram before placement of DG generated from ETAP 12.6.

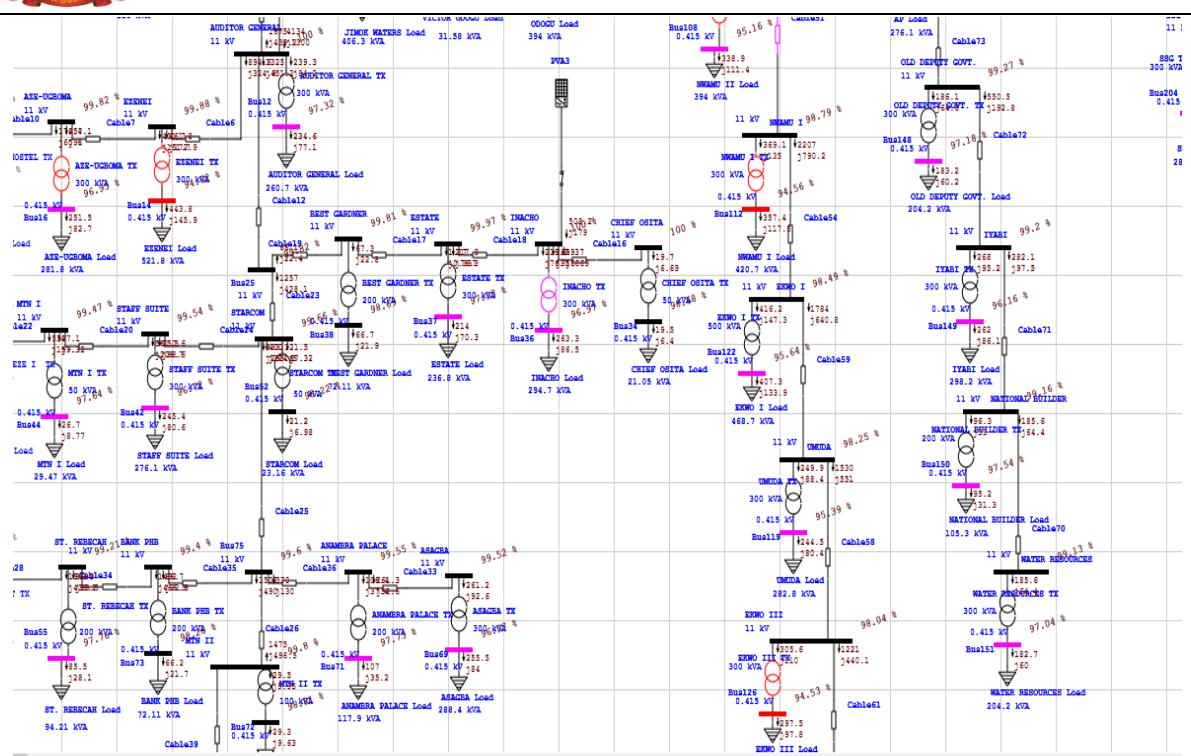


Fig. 2. Section of the Load flow diagram after placement of DG generated from ETAP 12.6.

## VI. ANALYSIS AND DISCUSSION

Base on the result shown in Table 2 – 3 in section V, the load flow analysis carried on the network shows that out of a total of Sixty-seven (67) load buses in the network, fifty-six (56) buses were out of the statutory voltage limits (0.95p.u – 1.05p.u) during the load period. Eleven (11) buses which are Bank PHB (0.95p.u), MTN II (0.946p.u), Starcom (0.968p.u), Junuic Hostel (0.945p.u), Victor Odogu (0.946p.u), Anambra Palace (0.945p.u), MTN I (0.95p.u), Chief Osita (0.953p.u), Best Garden (0.95p.u), Victor Hotel (0.954p.u) and L.C. Okeke (0.957p.u) load buses were within the voltage limit. Total average active and reactive power losses of the system was 1492.78 kW, 3599.564kVar. A DG of 4.5MW was placed in each location based on the order of priority of LSF result and had its best effect when it was incorporation on Akwuofu II, Jaret I and Inacho buses base on the algorithm for finding the optimal location of DG.

The results obtained when the DG was placed at the Akwuofu II, Jaret I and Inacho buses shows that five (5) buses which are Starcom (93.2%), MTN I (93.3%), Achalla Ibusa (93.3%), Ministry of Trans. (93.3%) and Land survey (93.6%) out of the Sixty Seven (67) load buses were out of the statutory voltage limit and the distribution line loss was reduced from 1492.8kW, 3599.6kVar to 691.63kW, 748.62kVar (i.e. 53.67% decrease in the loss) as presented in table 2-3.

## VII. CONCLUSION

The study shows that the active power losses in the distribution network prior to the optimal installation of DG were more as compared to when DG were not installed hence, this device did not only affect the weak buses, but the entire power flow results of the network under study. Thus, optimally installing the DG in the Asaba Ezenei network 33/11KV, 7.5MVA injection substation will plays a vital role in maintaining good voltage profile and reducing losses in the network.

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