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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 use 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.**

## 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:

$$Minimize\ P_L = \sum_{i=1}^{N} |I_i|^2 R_i \tag{1}$$

*Subject to Power Balance Constraints:*

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

*Voltage Constraints:*

$$|V_i|^{min} \leq |V_i| \leq |V_i|^{max} \tag{3}$$

Current Limits: $|I_{ij}| \leq |I_{ij}|^{max}$ (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 Rhapson 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:

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

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

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;

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

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

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.

$$P_L = \sum_{i=1}^{N} \sum_{i=j}^{N} \alpha_{ij}(P_iP_j + Q_iQ_j) + \beta_{ij}(Q_iP_j - P_iQ_j) \quad (14)$$

Where,

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

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.
3. Find out the Loss sensitivity factors based on equations (12), (13) and (16) for all buses.
4. The buses are ranked in ascending order based on their Loss sensitivity factors.
5. 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 | Akwuofu I | 300 | 219 | 410 | 253 | 377 | 94 | 378 | 0.27 |
| 35 | Akwuofu 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 | Akwuofor | 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.

| | | | After DG Placement | | | | Before DG Placement | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S/N | From Bus | To Bus | 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 |

| | | | After DG Placement | | | | Before DG Placement | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **S/N** | **From Bus** | **To Bus** | **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 |

| | | | After DG Placement | | | | Before DG Placement | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **S/N** | **From Bus** | **To Bus** | **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 | IFEBIHOR | FEED MILL | 706.3 | 251 | 0.717 | 0.218 | 505.1 | 179.2 | 0.513 | 0.13 |
| 80 | LAND SURVEY | IFEBIHOR | 1027 | 367 | 1.51 | 0.459 | 734.2 | 262 | 1.08 | 0.274 |

| | | | After DG Placement | | | | Before DG Placement | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **S/N** | **From Bus** | **To Bus** | **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 |

| | | | After DG Placement | | | | Before DG Placement | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **S/N** | **From Bus** | **To Bus** | **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 |

| | | | After DG Placement | | | | Before DG Placement | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S/N | From Bus | To Bus | 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 |
| | **TOTAL LOSSES** | | | | **691.63** | **748.62** | | | **1492.8** | **3599.6** |

Source: Generated from ETAP 12.6.

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

| | | Before DG Placement | | | | | | Afetr DG Placement | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S/N | ID | 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 |

| | | Before DG Placement | | | | | | Afetr DG Placement | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S/N | ID | 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 | IFEBIHOR | 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 |

| | | Before DG Placement | | | | | | Afetr DG Placement | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S/N | ID | Rated kV | 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.

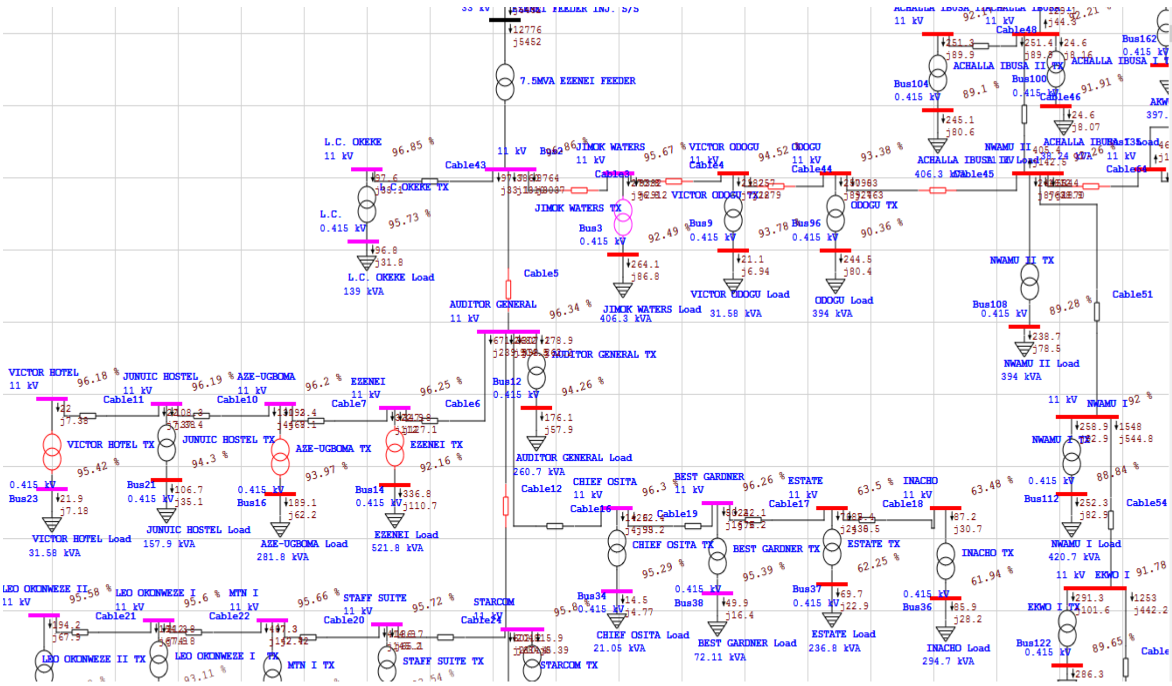


Fig. 1. Section of the Load flow diagram before placement of DG generated from ETAP 12.6.

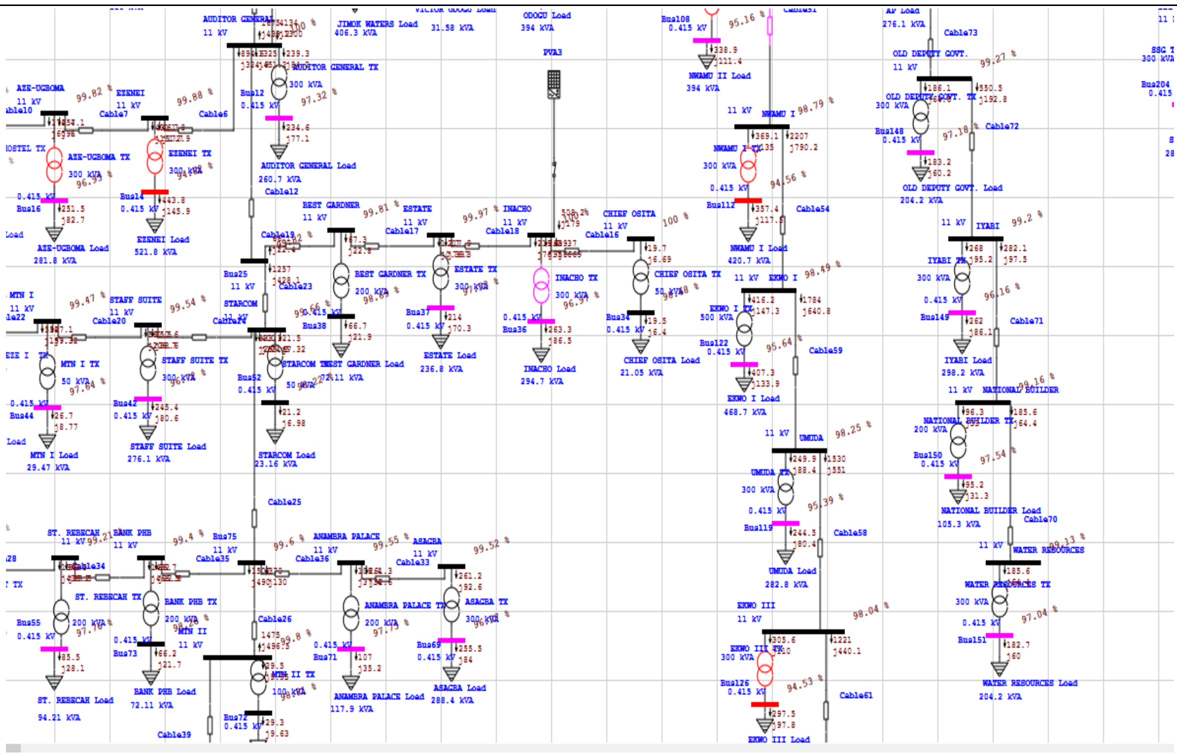

Fig. 2. Section of the Load flow diagram after placement of DG generated from ETAP 12.6.

## 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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