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Performance Evaluation of 11/0.415kV Power Distribution Network

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***Abstract* - Efficient distribution of high-quality power for commercial, industrial and residential purposes is a major issue in Nigeria. The performance evaluation of Rumuomoi 11/0.415kV distribution network is the focus of this research work. It was done to determine the status of the power network for efficient performance. The Port Harcourt Electricity Distribution Company supplied the data used in this study. Rumuola 33kV injection substation consists of eight (8) 11kV outgoing feeders of which Rumuomoi distribution network is one of them. The network consists of twelve (12) distribution transformers. The 11KV distribution network has a total load of 5.2MVA. The network was modelled using Electrical Transient Analyzer Program (ETAP 19.0) software. The Newton-Raphson power flow technique embedded in the software was used to run the load flow simulation. The simulation results showed that the performance status of the network was not satisfactory as there were violations of the statutory bus voltage limits and some of the transformers were overloaded. Using transformers of higher ratings in the weak buses and capacitor banks as improvement measures, the result showed significant improvement of the voltage profile. The load flow results before and after improvement were compared and there was 69.9% reduction in voltage drop, 41.2% reduction in kW losses and 70.7% reduction in kVAR losses after improvement.**

Keywords: Voltage drop, ETAP, Voltage profile, Transformer, Capacitor bank.

I. INTRODUCTION

As the foundation for any country's socioeconomic and technical progress, electricity's significance in modern society cannot be overstated. Its availability in the proper ratio is essential for the improvement of commercial, industrial, and home activities [1].In reality, the need for electricity is always greater than the supply, especially in emerging economies like Nigeria. This leads to unfavorable power distribution and an inefficient power grid. Practically speaking, in Nigeria, factors that contribute to inefficient and undependable power supply, aside from low power production, may include poor or inefficient voltage control mechanisms, poor transmission systems, heavily loaded transmission feeders as a result of poor planning, defective distribution systems on the part of electrical vendors, damage to the distribution system, and low-quality distribution networks. These flaws over time have led to erratic and false voltage changes as well as periodic power failures. An effective electric power grid aims to address the aforementioned issues and provide consumers and commercial users in the area with higher-quality power.

The power flow evaluation is an essential and basic technique for distribution systems. Any system's functional phases, including the phases of expansion and design, control, and economic planning, heavily rely on its results. Any load flow analysis's objective is to determine the exact stable voltages and voltage angles of all network buses, as well as the actual and reactive power flows into each line and transformer, under the premise that generation and load are known. Many approaches have been devised to address the load flow issue, including Newton-Raphson (NR) and its decoupled variations, as well as Gauss-Siedel. A number of techniques are being developed nowadays such as static VAR compensators, capacitor banks, synchronous condensers (SVC) etc, are used to compensate for reactive power, boost power factor and thus improve the power quality, however they have limitations such instability issues and the production of large transients when connected and disconnected [2].The final step in delivering electricity to end customers, and the most visible part of the power system, is the electric power distribution system. The distribution system is divided into three subsystems, called primary, secondary, and tertiary distribution, depending on the voltage level. These subsystems have corresponding voltages of 33kV, 11kV, and 0.415kV [3]

This study focuses on the load flow analysis of Rumuomoi 11kV distribution network located in Port Harcourt, Nigeria and using capacitor banks to improve the power quality. The network consists of twelve (12) distribution transformers with total installed capacity of 5.2MVA.

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II. LITERATURE REVIEW

Power Transmission System

According to [4], the government-established agency has been responsible for the electric power transmission division of Nigeria's power sector for a number of years. The government periodically restructures the company to carry out the responsibility of delivering power. Nonetheless, despite numerous revisions taken to improve service delivery, to the end consumers in terms of adequate electricity generation, transmission, and distribution. As their names suggest, Genco represent generation company, Transco represent transmission company, and Discos represent distribution company, are businesses that currently oversee the various parts of the power sector. The change makes it possible for Nigeria's Transmission Company (TCN) to succeed Power Holding Company of Nigeria (PHCN). It was incorporated in November 2005, and in July 2006 it received a license to transfer electricity. The license covers duties such electric power transmission, power system operation, and electricity trading. The Nigerian Electricity Transmission System now has a transmission capacity of around 5,523.8 km of 330 KV lines and 6, 801.9 km of 132 KV lines. The power transmission industry's grid power network is made up of steel towers, capacitor banks, switchgear, transformers, transmission lines, generators, etc. [5][6]. According to [7], medium voltages, categorized as primary and secondary distribution voltages, make up the power distribution system. Compared to the secondary distribution (feeder) voltage, which is rated at 11KV, the primary distribution voltage is 33KV. Substations for distribution, transformers for distribution, feeders for distribution, etc. are all parts of the distribution industry. 11KV and 33KV both use a 3-phase, 3-wire arrangement (for a balanced load). A 3-phase, 4-wire system makes up the tertiary distribution portion (for unbalanced load).

Power System Losses

[8] States that losses occur at the point where a load is connected to a distribution system when it is powered up because of the resistance of all connecting conductors and the load. Inevitably, there will be a power loss when current flows through cables and other electrical devices (such as transformers), which is denoted by the symbol I2R. This power loss is referred to as a technical loss, while non-technical losses are those that do not involve the physical power system, such as those caused by electric theft and billing and metering system errors. According to [9], the aforementioned losses will decrease the entire system's efficiency and raise operational costs for providing services, which will result in high electricity prices for end consumers. According to [10], a significant amount of the power losses in every power system are attributable to transmission and distribution losses. Distribution businesses will suffer if real power losses are higher than demand. Thus, it is quite crucial for the system engineers to put in place the necessary mechanism.

Power Quality Improvement

[11] Asserts that adding series compensating capacitors to power transmission lines increases transmission capacity by reducing the line's impedance. Because of its ease of use and low cost of installation, series capacitor usage is beneficial. It offers greater voltage management, decreased system losses, and improved system stability. Increase in the number of transmission lines improves transmission capabilities, as we highlighted in [11]. This method entails modifying existing transmission towers to add a second transmission line to the structure. It allows for the addition of a new line to an existing circuit to create a double circuit, lowering line impedance while increasing the line's capacity to carry current and, consequently, enhance the line's capacity to transmit power.

[12] Worked on improving the power quality by reducing the harmonic content in the network. In the paper, to remove the network's 5th, 7th, and 11th order harmonics, three single tuned filters were connected and Simulations were performed with and without the single tuned filter to demonstrate the filter's influence in reducing harmonic content, and the results revealed a notable reduction, which improved the power quality and voltage profile.

A transmission network's performance will be improved by the addition of flexible alternating current transmission systems (FACTS) devices, allowing for the compensation of reactive power loss in light of [13]. The component is designed to offer shunt compensation, series compensation, or a combination of the two. The use of these compensators depends on the line's characteristics as well as the stated needs and deficiencies. Power flow through the transmission line is boosted upon application of the device. The power transmission system's voltage margin can be improved with the use of FACTS devices. According to [13], power systems experience stress due to growing load demands and this has resulted to the implementation of reactive power injection to ensure a stable and efficient power network. To cushion this effect, this paper proposed the use of Flexible Alternating Current Transmission Systems (FACTS) technology amongst other technologies for reactive power compensation. In view of [14], Static Var Compensator (SVC) was used to compensate for reactive power losses in 132/33kV Benin network in Nigeria thus improving the voltage profile and reducing the transformer loading. According to [15], when the

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voltage at a bus is less than the rated value, capacitive reactive volt-amperes (VARs) should be injected to raise the bus voltage, and when the bus voltage exceeds the reference value, inductive VARs should be initiated to lower the bus voltage. In high voltage transmission, this is the function of shunt compensation-static var systems (SVS). It is possible to use it to keep the voltage constant. Capacitor banks are used in the idea for the static variables. As highlighted in [16], an energy-storing system called a capacitor bank is composed of an array or a cluster of two or more capacitors with the same rating that are linked serially, parallelly, or in serial-parallel connection to reduce reactive power losses. This shows the importance of static VAR compensators (SVC) in power transmission systems. A power factor lags or phase shift in an alternating current (AC) power source is combated by the capacitor bank. It essentially functions as a passive component that adds reactive power to a system. It enhances a power system's bus voltage levels [17].

III. MATERIALS AND METHOD

This study focuses on the load flow analysis of Rumuomoi 11kV distribution network located in Port Harcourt, Nigeria. The materials required for the load flow analysis are shown in tables1, 2 and 3. They are: line input data, load data, calculated load data and ETAP 19.0 software for modeling the single line diagram and simulation of the network. The Newton-Raphson power flow technique was the method used to evaluate the operating conditions of the distribution network and for locating the stressed buses in the network. In the Newton-Raphson technique, the real and reactive power injected in the network is given by

$$S_i = V_i^* I_i^* = P_i + jQ_i \qquad (3.1)$$

$$I_i = \left(\frac{S_i}{V_i}\right)^* = \frac{P_i - jQ_i}{V_i^*} \qquad (3.2)$$

$$I_i = \frac{P_i - jQ_i}{V_i^*} = \sum_{k=1}^{n} Y_{ik} V_k \qquad (3.3)$$

$$P_i - jQ_i = V_i^* \left(\sum_{k=1}^{n} Y_{ik} V_k\right) \qquad (3.4)$$

Let $V_i^* = V_i \angle -\delta_i, V_k = V_k \angle \delta_k$ and $Y_{ik} = Y_{ik} \angle \theta_{ik}$ (3.5)

$$P_i - jQ_i = V_i^* \left(\sum_{k=1}^{n} Y_{ik} V_k \angle \delta_k + \theta_{ik} - \delta_i\right) \qquad (3.6)$$

$$P_i - jQ_i = \sum_{k=1}^{n} |Y_{ik}||V_i||V_k| \left[\cos(\delta_k + \theta_{ik} - \delta_i) + j\sin(\delta_k + \theta_{ik} - \delta_i)\right] \qquad (3.7)$$

Real and Imaginary parts of equation 3.7 are given below,

$$P_i = \sum_{k=1}^{n} |Y_{ik}||V_i||V_k| \cos(\delta_k + \theta_{ik} - \delta_i) \qquad (3.8)$$

$$Q_i = -\sum_{k=1}^{n} |Y_{ik}||V_i||V_k| \sin(\delta_k + \theta_{ik} - \delta_i) \qquad (3.9)$$

Where

Y_{ik} = the admittance matrix
P_i = the injected real power
Q_i = the injected reactive power
δ_i = phase angle

The two equations, 3.8 and 3.9, together with the independent variables of voltage magnitude represented in units and phase angle expressed in radians, constitute a set of non-linear algebraic equations. The results of expanding the initial estimate-related first two equations in the Taylor series while disregarding all higher order terms are shown below.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J\delta & J_4 \end{bmatrix} \begin{bmatrix} \delta\Delta \\ \Delta|V| \end{bmatrix} \qquad (3.10)$$

J1 has its diagonal and off diagonal elements written as:

$$\frac{\partial Pi}{\partial \delta i} = \sum_{j \neq j}^{n} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \qquad (3.11)$$

$$\frac{\partial Pi}{\partial \delta i} = -|V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i \qquad (3.12)$$

J4 has its diagonal and off diagonal elements written as:

$$\frac{\delta Qi}{\delta|V_i|} = -2|V_i||Y_{ii}| \sin\theta_{ii} - \sum_{i \neq j} |V_i||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \qquad (3.13)$$

$$\frac{\partial Qi}{\partial|V_i|} = -|V_i||Y_{ii}| \sin(\theta_{ij} - \delta_i + \delta_j) \qquad (3.14)$$

The power residuals are written as:

$$\Delta Pi^{(k)} = Pi^{(sch)} - Pi^{(k)} \qquad (3.15)$$

$$\Delta Qi^{(k)} = Qi^{(sch)} - Qi^{(k)} \qquad (3.16)$$

The bus voltages have their new estimates written as:

$$\delta i^{(k-1)} = \delta i^{(k)} - \Delta Pi^{(k)} \qquad (3.17)$$

$$|Vi^{(k+1)}| = |Vi^{(k)}| + \Delta|Vi^{(k)}| \qquad (3.18)$$

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Table 1: Rumuomoi Distribution Network Load Data [18]

Bus no	Bus Name	Transformer Rating (KVA)	Nominal Voltage (kV)	I_R (A)	I_Y (A)	I_B (A)	I_N (A)
1	Ohiamini Road	500	11/0.415	270	240	200	80
2	Location Road	500	11/0.415	200	190	210	90
3	Ideogu Road	500	11/0.415	265	356	314	128
4	Omunakwa Road	300	11/0.415	419	380	400	102
5	Okabie Road	300	11/0.415	420	386	412	150
6	Amadi Road 1	300	11/0.415	460	420	440	60
7	Amadi Road 2	500	11/0.415	332	330	330	80
8	Bakery Road	500	11/0.415	300	380	375	85
9	Silicon Valley Ltd	500	11/0.415	295	385	365	75
10	PHWC	500	11/0.415	310	374	370	82
11	Super Geometrics	300	11/0.415	326	380	375	70
12	Ichiegbo Road	500	11/0.415	358	385	365	96

Table 2: Rumuomoi Distribution Network Line Data [18]

Line ID	From Bus	To Bus	Impedance (Z)
1-2	Ohiamini Road	Location Road	0.015+j0.057
2-3	Location Road	Ideogu Estate	0.037+j0.049
3-4	Ideogu Estate	Omunakwa Road	0.026+j0.028
4-5	Omunakwa Road	Okabie Road	0.049+j0.041
5-6	Okabie Road	Amadi Road 1	0.083+j0.025
6-7	Amadi Road 1	Amadi Road 2	0.040+j0.011
7-8	Amadi Road 2	Bakery Road	0.058+j0.030
8-9	Bakery Road	Silicon Valley Ltd	0.027+j0.059
9-10	Silicon Valley Ltd	PHWC	0.042+j0.013
10-11	PHWC	Super Geometrics	0.055+j0.047
11-12	Super Geometrics	Ichiegbo Road	0.088+j0.060

Table 3: Rumuomoi Distribution Network Calculated Static Load Data [18]

Bus No	Bus Name	I_L (A)	S (KVA)	P (kW)	Q (kVar)
1	Ohiamini Road	263.33	189.28	160.89	99.71
2	Location Road	230.00	165.32	140.53	87.09
3	Ideogu Estate	354.33	254.70	216.49	134.17
4	Omunakwa Road	433.67	311.72	264.96	164.21
5	Okabie Road	456.00	327.77	278.61	172.67
6	Amadi Road 1	460.00	330.65	281.05	174.18
7	Amadi Road 2	357.33	256.85	218.32	135.30
8	Bakery Road	380.00	273.14	232.17	143.89
9	Silicon Valley Ltd	373.33	268.35	228.10	141.36
10	PHWC	378.67	272.19	231.36	143.38
11	Super Geometrics	383.67	275.78	234.41	145.28
12	Ichiegbo Road	401.33	288.48	245.21	151.97

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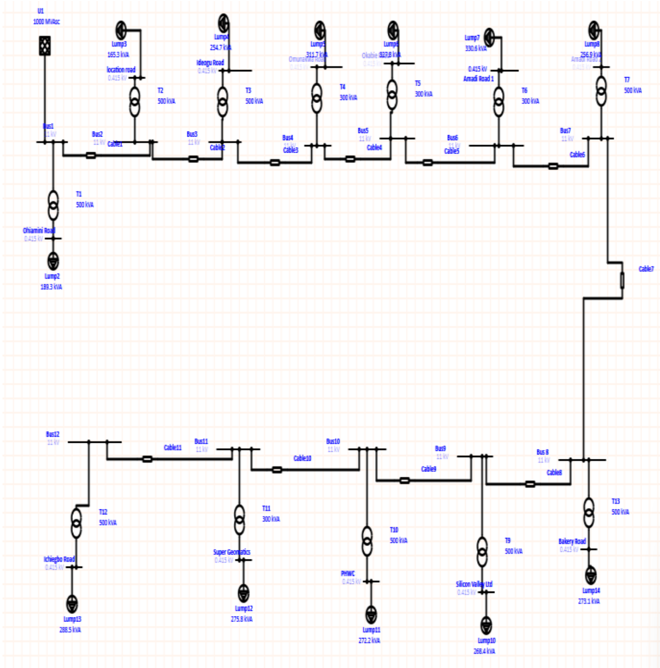

Figure 1: Single line diagram of Rumuomoi distribution network before improvement [18]

IV. RESULTS AND DISCUSSION

4.1 Load Flow Analysis Results

The load flow analysis results obtained for the Rumuomoi 11kV distribution network analyzed using Newton Raphson numerical technique embedded in ETAP 19.0 software for power flows, bus voltages and power losses before and after improvement are shown below. The improvement measures taken in this study include installation of capacitor banks at weak buses and upgrade of distribution transformers to reduce the percentage loadings thus increasing the lifespan of the transformers. Fig. 1 shows the load flow simulation of the study case.

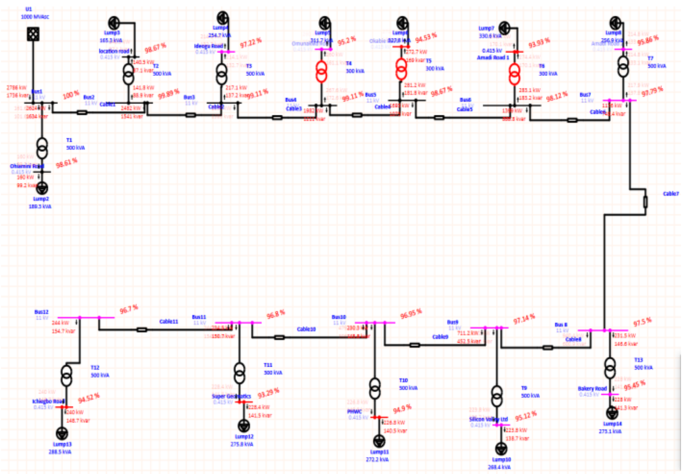

Figure 2: Load flow simulation of the study case

4.2 Voltage Profile before Improvement

Table 4 shows the % bus voltages at 11kV before improvement. In this study, the normal bus voltage limit is above 98%, the marginal bus voltage limit is between 95% and 98%, the critical bus voltage limit is below 95%. From table 4, buses 1, 2, 3, 4, 5, and 6 are in the normal range while bus 7 to bus 12 are in the marginal range and would require improvement for quality power supply because any sudden change in load may subject these buses at marginal range to the critical range.

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Table 4: Load flow results for % bus voltage and power flow at 11kV without improvement

S/N	BUS ID	NOMINAL KV	% BUS VOLTAGE	KW LOADING	KVAR LOADING	AMP LOADING
1	Bus1	11	100	2786.1	1735.7	172.3
2	Bus2	11	99.89	2623.3	1629.6	162.3
3	Bus3	11	99.11	2467.1	1520.6	153.5
4	Bus4	11	99.11	2250	1383.4	139.9
5	Bus5	11	98.67	1974.4	1257.2	124.5
6	Bus6	11	98.12	1682.1	1071.9	106.7
7	Bus7	11	97.79	1393.4	887.2	88.66
8	Bus 8	11	97.5	1171.9	747.4	74.83
9	Bus9	11	97.14	938.4	596.3	60.08
10	Bus10	11	96.95	709.6	452	45.55
11	Bus11	11	96.8	478.7	305.6	30.79
12	Bus12	11	96.7	244	154.7	15.68

Table 5: Load flow results for % bus voltage and power flow at 0.415kV without improvement

S/N	BUS ID	NOMINAL KV	% BUS VOLTAGE	KW LOADING	KVAR LOADING	AMP LOADING
1	Amadi Road 1	0.415	93.93	274.4	170.1	478.1
2	Amadi Road 2	0.415	95.86	214.8	133.1	366.8
3	Bakery Road	0.415	95.45	228	141.3	391
4	Ichiegbo Road	0.415	94.52	240	148.7	415.6
5	Ideogu Road	0.415	97.22	214.1	132.7	360.5
6	location road	0.415	98.67	140.5	87.08	233.1
7	Ohiamini Road	0.415	98.61	160	99.17	265.6
8	Okabie Road	0.415	94.53	272.7	169	472.1
9	Omunakwa Road	0.415	95.2	260	161.1	447
10	PHWC	0.415	94.9	226.8	140.5	391.1
11	Silicon Valley Ltd	0.415	95.12	223.8	138.7	385.1
12	Super Geomatics	0.415	93.29	228.4	141.5	400.6

From table 5, location road and Ohiamini 0.415kV buses are in the normal bus voltage range, Amadi road 2, Bakery road, Ideogu road, Omunakwa and Silicon valley ltd 0.415kV buses are all in the marginal % bus voltage range and would require improvement to increase the power quality power because an increase in load may force the buses in the marginal range to the critical range. However, Amadi road 1, Ichiegbo road, Okabie road, PHWC, and super geomatics 0.415kV buses are all in the critical % bus voltage range and would require improvement measures to increase the power quality.

Table 6: Load flow result showing power flows and % loading of the transformers

S/N	ID	KW FLOW	KVAR FLOW	% LOADING
1	Line1	2624.4	1634.1	-
2	Line 2	2481.5	1540.6	70.2
3	Line 3	2250	1383.4	64
4	Line 4	1974.4	1257.2	45.8
5	Line 5	1693.2	1075.4	48.8
6	Line 6	1399	888.8	40.6
7	Line 7	1175.5	749.4	34.2
8	Line 8	940.4	600.9	27.5

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9	Line 9	711.2	452.5	20.8
10	Line 10	479.4	306.2	14.1
11	Line 11	244.2	154.8	7.2
12	T1	161.6	101.6	38.2
13	T2	141.8	88.95	33.5
14	T3	217.1	137.2	51.4
15	T4	267.6	172.6	106.1
16	T5	281.2	181.8	111.6
17	T6	283.1	183.2	112.4
18	T7	217.9	137.8	51.6
19	T9	227.2	143.8	53.8
20	T10	230.3	145.8	54.5
21	T11	234.5	150.7	92.9
22	T12	244	154.7	57.8
23	T13	231.5	146.6	54.8

Table 6 shows the percentage loading of the transformers before improvement. Table III displays the state of the transformers following the completion of a load flow study, and the findings show that transformers T4, T5, T6, and T11 are overloaded in compliance with the standards of IEC Standard 60354 [19]. According to the IEC standard, oil-immersed transformers whose continuous loading exceeds 80% will have a shorter useful lifetime.

Table 7: Load flow result showing % voltage drop and power losses before improvement

S/N	**ID**	**% VOLTAGE DROP**	**KW LOSSES**	**KVAR LOSSES**	**S/N**	**ID**	**% VOLTAGE DROP**	**KW LOSSES**	**KVAR LOSSES**
1	Line1	0.11	1.18	4.5	12	T1	1.39	1.62	2.43
2	Line 2	0.78	14.4	20.01	13	T2	1.22	1.25	1.87
3	Line 3	0	0.0066	0.0075	14	T3	1.89	2.98	4.47
4	Line 4	0.44	7.95	-46.36	15	T4	3.91	7.63	11.45
5	Line 5	0.55	11.08	3.5	16	T5	4.13	8.52	12.78
6	Line 6	0.33	5.57	1.61	17	T6	4.19	8.74	13.1
7	Line 7	0.29	3.62	1.97	18	T7	1.92	3.08	4.63
8	Line 8	0.36	2.01	4.6	19	T9	2.02	3.4	5.1
9	Line 9	0.18	1.57	0.51	20	T10	2.05	3.51	5.26
10	Line 10	0.15	0.671	0.602	21	T11	3.51	6.13	9.2
11	Line 11	0.1	0.236	0.169	22	T12	2.18	3.96	5.94
					23	T13	2.05	3.5	5.26
					Total		**33.75**	**102.6136**	**72.6085**

Table 7 shows the voltage drop and power losses through the cables and transformers. Before improvement, the total % voltage drop is 33.75%, the total kW loss is 102.6136kW and the total kVAR loss is 72.6085kVAR.

4.3 Voltage Profile after Improvement

In this study, capacitor banks of 200kvar rating were installed at the weak buses as shown in fig. 3 below to improve the voltage profile and increase the power quality. Transformer upgrade was also done to reduce overloading so as to increase the lifespan of the transformers. The upgrade is shown in table VI below.

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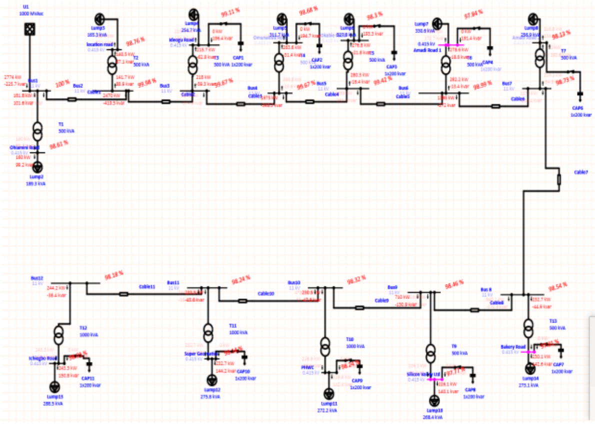

Figure 3: Load flow simulation of the study case after improvement

Table 8: transformer upgrade for power quality improvement

ID	KVA Rating (before)	KVA Rating (after)	ID	KVA Rating (before)	KVA Rating (after)
T1	500	500	T7	500	500
T2	500	500	T9	500	500
T3	500	500	T10	500	500
T4	300	500	T11	500	1000
T5	300	500	T12	300	1000
T6	300	500	T13	500	1000

The load flow simulation results after improvement is presented below for % bus voltage, % voltage drop, active power loss and % loading of the transformer.

Table 9: Load flow results for % bus voltage and power flow at 11kV after improvement

S/N	BUS ID	NOMINAL KV	% BUS VOLTAGE	KW LOADING	KVAR LOADING
1	Bus1	11	100	2774.3	327.3
2	Bus2	11	99.98	2611.8	419.5
3	Bus3	11	99.67	2459.5	434.2
4	Bus4	11	99.67	2241.5	374.9
5	Bus5	11	99.42	1968.9	299.3
6	Bus6	11	98.99	1680.7	285.4
7	Bus7	11	98.73	1394.4	273.2
8	Bus 8	11	98.54	1172.8	219.8
9	Bus9	11	98.46	938.6	178.2
10	Bus10	11	98.32	708.9	131.3
11	Bus11	11	98.24	477.9	83.86
12	Bus12	11	98.18	244.2	38.38

Table 9 shows the % bus voltages at 11kV after improvement. From table 9, buses 1, 2, 3, 4, 5, and 6 are in the normal range while bus 7 to bus 12 which were in the marginal range before improvement have their bus voltages moved to the normal range after improvement measures were done. This has improved the voltage profile and increased the power quality supplied to consumers.

Table 10: Load flow results for % bus voltage and power flow at 0.415kV after improvement

S/N	BUS ID	NOMINAL KV	% BUS VOLTAGE	KW LOADING	KVAR LOADING
1	Amadi Road 1	0.415	97.84	278.6	191.4

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2	Amadi Road 2	0.415	98.13	216.8	192.6
3	Bakery Road	0.415	97.81	230.1	191.4
4	Ichiegbo Road	0.415	98.03	243.3	192.2
5	Ideogu Road	0.415	99.11	215.7	196.4
6	location road	0.415	98.76	140.5	87.08
7	Ohiamini Road	0.415	98.61	160	99.17
8	Okabie Road	0.415	98.3	276.8	193.3
9	Omunakwa Road	0.415	98.68	263.6	194.7
10	PHWC	0.415	98.24	229.8	193
11	Silicon Valley Ltd	0.415	97.77	226.1	191.2
12	Super Geomatics	0.415	98.14	232.7	192.6

Form table 10, location road and Ohiamini 0.415kV buses are in the normal bus voltage range. After improvement, Amadi road 2, Ideogu road and Omunakwa, which were in the marginal range have their bus voltages moved to the normal range, while bakery road and Silicon Valley ltd have their bus voltages improved but still in the marginal range. However, Amadi road 1 whose bus voltage was in the critical range before improvement has its bus voltage now moved to marginal range after improvement. Ichiegbo road, Okabie road, PHWC, and super geomatics whose bus voltages were in the critical % bus voltage range are now in the normal range after improvement thus, improving the voltage profile and increasing the power quality supplied to consumers.

Table 11: Load flow result showing power flows and % loading of the transformers after improvement

S/N	ID	KW FLOW	KVAR FLOW	% LOADING	S/N	ID	KW FLOW	KVAR FLOW	% LOADING
1	Line1	2612.7	-327.3		12	T1	161.6	101.6	38.2
2	Line 2	2470.1	-419.5	60.2	13	T2	141.7	88.94	33.5
3	Line 3	2241.5	-374.9	54.8	14	T3	218	-59.33	45.2
4	Line 4	1974.7	-348.3	38.8	15	T4	266.8	-26.59	53.6
5	Line 5	1688.7	-282.9	41.4	16	T5	280.3	-16.44	56.2
6	Line 6	1398.5	-272	34.6	17	T6	282.2	-13.36	56.5
7	Line 7	1175.4	-218.4	29.1	18	T7	219.1	-54.79	45.2
8	Line 8	940.1	-174.9	23.3	19	T9	228.6	-47.28	46.7
9	Line 9	710	-130.9	17.6	20	T10	230.5	-47.87	23.5
10	Line 10	478.3	-83.43	11.9	21	T11	233.5	-45.6	23.8
11	Line 11	244.4	-38.26	6	22	T12	244.2	-38.38	24.7
					23	T13	232.7	-44.88	47.4

The load flow simulation result shown in table 11 reveals that after improvement, the % loading of the transformers T4, T5, T6 and T11 have reduced tremendously below 80% which is the acceptable range as stipulated in the IEC standard which states that continuous loading of the transformer above 80% will reduce the transformer lifespan.

Table 12: Load flow result showing % voltage drop and power losses after improvement

S/N	ID	% VOLTAGE DROP	KW LOSSES	KVAR LOSSES	S/N	ID	% VOLTAGE DROP	KW LOSSES	KVAR LOSSES
1	Line1	0.02	0.859	3.27	12	T1	1.39	1.62	2.43
2	Line 2	0.32	10.57	14.7	13	T2	1.22	1.24	1.86
3	Line 3	0	0.0049	0.0055	14	T3	0.56	2.28	3.42
4	Line 4	0.24	5.76	-48.98	15	T4	0.99	3.21	4.82
5	Line 5	0.43	7.95	2.51	16	T5	1.12	3.54	5.31
6	Line 6	0.26	4.04	1.17	17	T6	1.16	3.61	5.42
7	Line 7	0.19	2.61	1.42	18	T7	0.6	2.32	3.48

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8	Line 8	0.08	1.44	3.31	19	T9	0.69	2.49	3.74
9	Line 9	0.14	1.12	0.364	20	T10	0.08	0.788	2.76
10	Line 10	0.08	0.475	0.426	21	T11	0.1	0.806	2.82
11	Line 11	0.06	0.167	0.12	22	T12	0.15	0.871	3.05
					23	T13	0.73	2.57	3.85
					Total		**10.61**	**60.3409**	**21.2755**

Table 12 shows the % voltage drop and the power losses after improvement. By comparing the results of the load flow analysis before and after improvement, there was 69.9% reduction in voltage drop, 41.2% reduction in kW losses and 70.7% reduction in kVAR losses. The result shows significant reduction in the voltage drop and power losses. This reduction will increase the overall efficiency of the power system, improve the voltage profile and increase the quality of power supplied to customers. Fig. 4 and 5 gives a comparative display of the active power losses and % voltage drop before and after improvement to show the impact of the improvement measures used in this study.

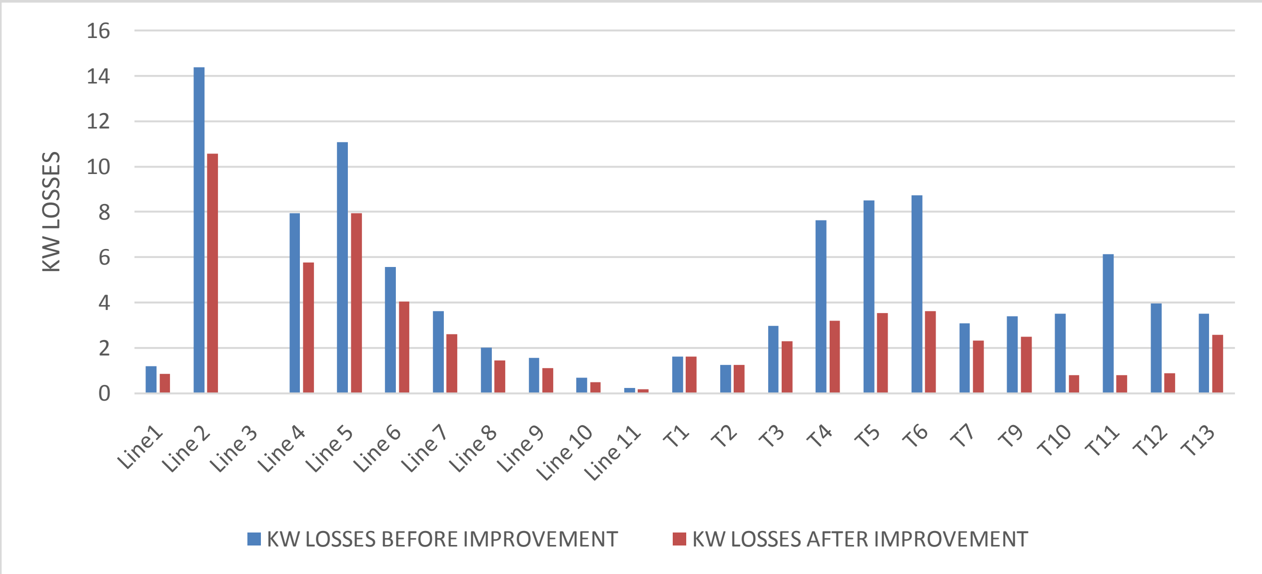

Figure 4: Active power losses with and without improvement

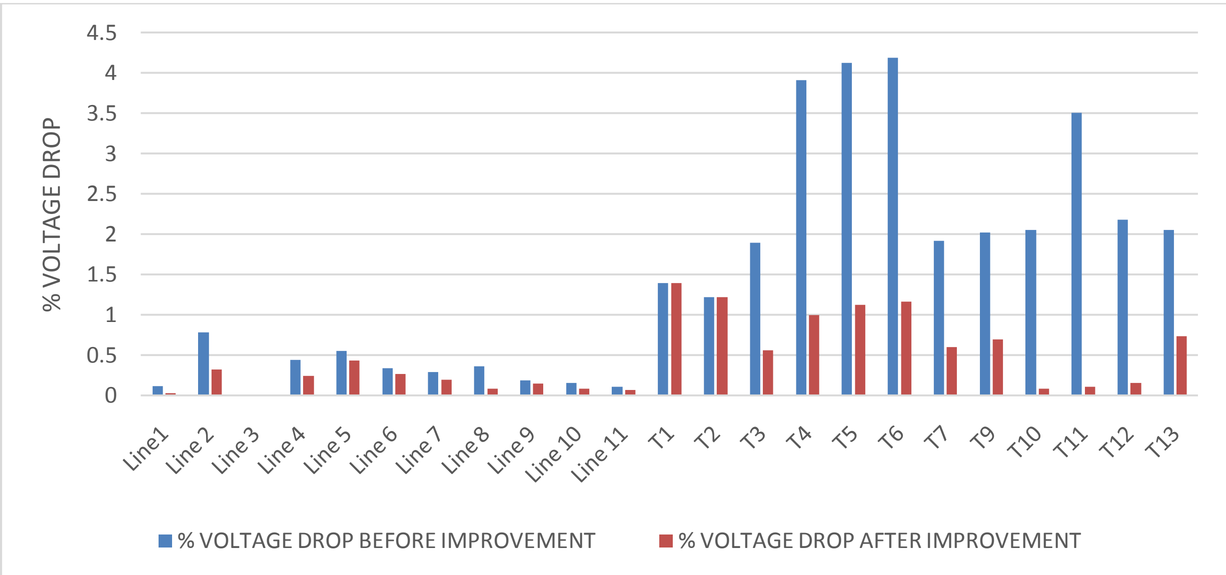

Figure 5: % voltage drop with and without improvement

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V. CONCLUSION

This study focuses on the performance analysis of Rumuomoi 11kV distribution network located in Port Harcourt, Nigeria and using capacitor banks and higher rating transformers to improve the power quality. The network consists of twelve (12) distribution transformers with total installed capacity of 5.2MVA. The network was modelled using Electrical Transient Analyzer Program (ETAP 19.0) software. The Newton-Raphson power flow technique embedded in the software was used to run the load flow simulation. The simulation results showed that the performance status of the network was not satisfactory as there were violations of the statutory bus voltage limits and some of the transformers were overloaded. Using transformers of higher ratings in the weak buses and capacitor banks as improvement measures, the result showed significant improvement of the voltage profile. The load flow results before and after improvement were compared and there was 69.9% reduction in voltage drop, 41.2% reduction in kW losses and 70.7% reduction in kVAR losses after improvement.

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