International Journal of Innovative Scientific & Engineering Technologies Research 10(2):1-10, April-June, 2022

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Improvement of Electricity Supply to Choba Community Using Newton-Raphson's Technique

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ABSTRACT

The analysis of power flow problem is highly challenging and complex, particularly when the available power is not matching the needed energy for consumer utilization (at the receiving end). These consequences over the years have resulted to unreliable power supply and outages. This means that an efficient energy arrangement and control are key drivers to overcome the short coming in order to provide quality power supply to the point of delivery. This research work considered the application of numerical technique using Newton Raphson's power flow method in DigSilent (15.1) PowerFactory to evaluate the performance of the Choba 11/0.415kv distribution network. The results obtained shows that the transformer named Royal Highness was marginally loaded at 68.18% while Playground (Owhipa) and Evergreen were 83.07% and 81.24% critically loaded respectively. The bus voltage regulation is within the acceptable declared range of +/- 5% of the nominal voltage. Based on the findings, inclusion of relief transformer improvement approach was used in this research. The penetration of 3 units of 500kVA (1.5MVA) as relief transformers to the existing network under investigation at the respective zones, reduced the total system reactive power losses which was 0.07MVAr (70KVAr) representing 71.43%, with 28.57% (that is reduction in reactive power losses). The final results show that the system will now continue to experience reliable power supply and efficient power quality to the point of consumer utility and satisfaction.

Keywords: Distribution system, Power flow studies, Digsilent Powerfactory, Improvement of Power Supply, Buses, Newton Raphson's Technique

I INTRODUCTION

The demand for electrical power always exceeds the supply especially in the developing countries like Nigeria, resulting to undesirable power sharing thereby causing wasteful power supply system. Generally, in Nigeria, apart from low power generation other contributing factors to inefficient and unreliable power supply include highly overloaded transmission and distribution feeders due to lack of planning, ineffective voltage control system, poor transmission networks, faulty distribution system, voltage drop along the line and from the distribution system due to the flow of current and load variations on the consumer end, damage to substation, transmission and distribution network, short circuit or overloading of electrical mains, and tripping of power system. These shortcomings over the years have resulted to unreliable and spurious voltage variations and frequent power outages. An efficient power supply system is one that seeks to overcome the above shortcomings and delivers a better quality of power to local consumers and industrial users [1].

A power flow program is a computer code that implements a power flow solution procedure. The power flow solution contains the voltages and angles at all buses, and from this information, we may compute the real and reactive generation and load levels at all buses and the real and reactive flows across all circuits

The load demand determines the voltage at which power is to be supplied. The loads may be residential, industrial, or commercial which brings about the peak load and off-peak load hours. Power is transmitted from low demand areas to high load demand in the grid network. The control of generation, transmission, distribution, and area exchange is performed from a centralized location.

To perform the control functions satisfactorily, the steady state power flow must be known. The entire system is modelled as an electric network and a solution is simulated using a digital program. This is called power flow analysis. The power flow analysis (also known as the load flow problem) is a very important and fundamental tool involving numerical analysis applied to a power system. The results play a major role in the day-to-day operation of any system for its control and economic schedule. The analysis is also employed during power system design procedures, planning expansion and development of control strategies. The purpose of any load flow analysis is to compute precise steady-state voltages and voltage angles of all buses in the network, for specified load, generator real power and voltage conditions [2]. Once this information is known, the real and reactive power flows into every line and transformer, as well as generator reactive power output can be analytically determined. Due to the nonlinear nature of this problem, numerical methods are employed to obtain a solution that is within an acceptable tolerance [3].

In this dissertation, power flow analysis will be carried out on the Choba electrical distribution network in order to improve the power supply in the network. The analysis is performed by simulation of the Choba community Network under DigSILENT powerfactory environment.

II LITERATURE REVIEW

Load flow studies are used to ensure that electrical power transfer from generators to consumers through the grid system is stable, reliable, and economic.

To obtain a reliable power system operation under normal balanced three phase steady state conditions, it is required to have the following:

a. Generation supplies the load demand and losses.
b. Bus voltage magnitudes remain close to rated values.
c. Generator operates within specific real and reactive power limits.
d. Transmission lines and transformers are not overloaded.

Bus Classification

A bus is a node in which one or more lines, one or more loads and generators are connected. In a power system, each node or bus is associated with 4 quantities such as voltage magnitude, voltage phase angle, active or true power, and reactive power. 2 of these four quantities are determined, and the remaining 2 must be determined by solving the equation .

Depending on the quantities that have been specified, the buses are classified into 3 categories [4][5][6][7][8].

(a) Load Bus: No generator is connected to the bus. At this bus the real and reactive power are specified. It is desired to find out the voltage magnitude and phase angle through load flow solutions. It is required to specify only P_{ns} and Q_{ns} at such bus as at a load bus voltage can be allowed to vary within the permissible values

Complex power $S_{ns} = P_{ns} + jQ_{ns}$ taken from or injected into the system is defined. Such nodes may also include links to other systems. At these load nodes, the voltage magnitude $|V_n|$ and phase angle δ_n must be calculated .

(b) Generator Bus or Voltage Controlled Bus: Here the voltage magnitude, V_n corresponding to the generator voltage and real power P_{ns} corresponds to its rating are specified. It is required to find out the reactive power generation Q_g and phase angle of the bus voltage .

These constraints reflect the generator's operating characteristics, in which power is controlled by the governor and terminal voltage is controlled by the automatic voltage regulator. At the generator nodes the voltage phase angle δ_n must be calculated

(c) **Slack (Swing) Bus**: For the Slack Bus (Floating bus), it is assumed that the voltage magnitude |V| and voltage phase are known, whereas real and reactive powers P_{ns} and Q_{ns} are obtained through the load flow solution. This node acts as the reference node and is commonly chosen to have a phase angle $\delta_n = 0^o$.

Load Flow Solution Methods

The following three methods are mostly used for the solution of a Load Flow Problem.

a. Fast-Decoupled Technique.
b. Gauss-Seidel Technique.
c. Newton-Raphson Technique

The choice of a solution method for practical application is usually difficult. It requires a careful analysis of the comparative merits and demerits of the many available methods. The best method to be considered fit must possess the following properties or characteristics:

a. Low computer storage like where minicomputers are used for on-line application.
b. High computational speed.
c. Fast convergence characteristics.
d. Simplicity- that is, the algorithm can easily be coded in the computer.
e. Reliability of solution – that is for ill conditioned and for real time application solution will be possible.
f. Versatility – to have the ability to handle conventional and social features like the adjustment of tap ratios on transformers and different representation of power system apparatus

The problem or difficulty is that no one method possesses all the desired features or characteristics.

III MATERIALS AND METHOD

Materials

i. The assessment of the physical state of Choba 11kV/0.415kV distribution network was done with exact reference to the type and size of conductors, transformers ratings and route length as shown in the data gotten from Port Harcourt Electricity Distribution Company (PHEDC).
ii. DigSilent (15.1) PowerFactory Software was used for the simulation [9].

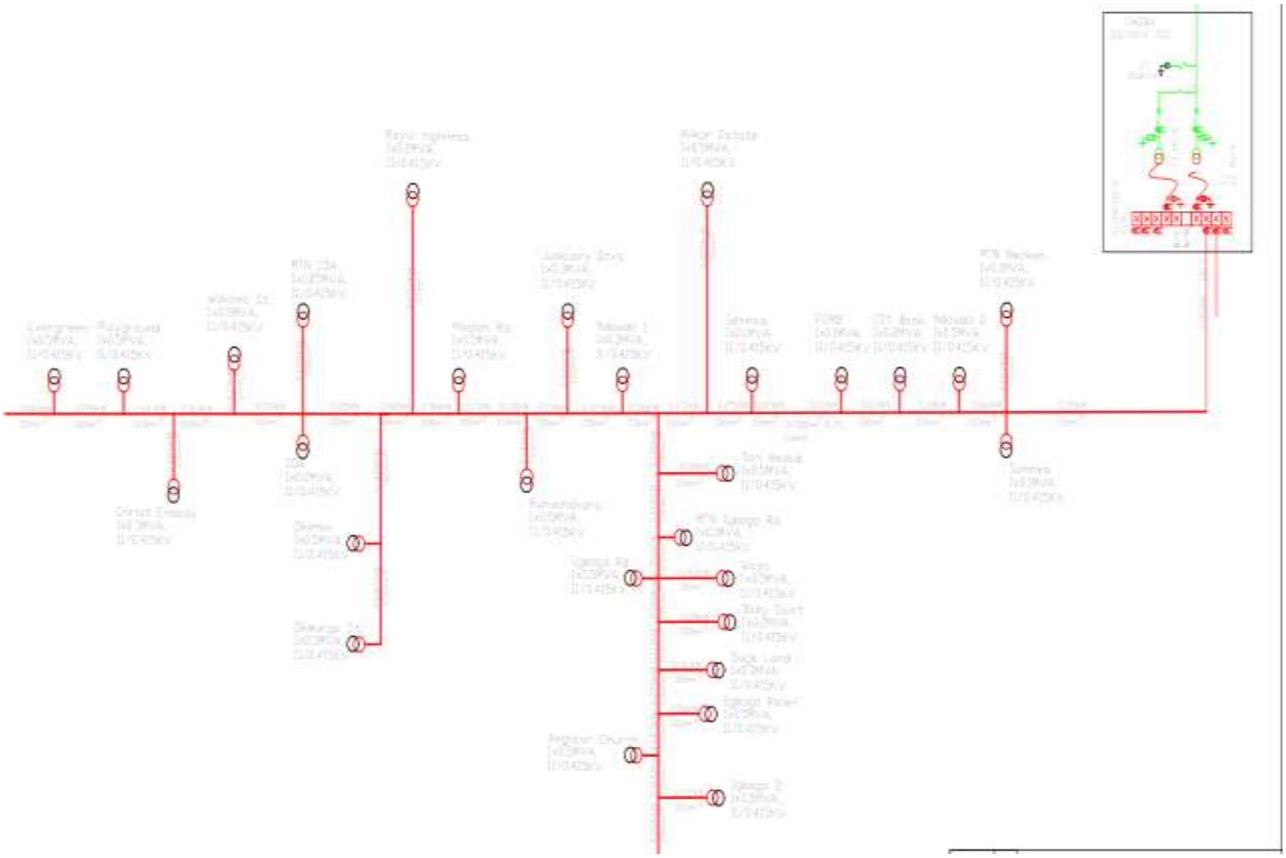


Figure 3.1: Single Line Diagram of the Existing Choba 11/0.415KV Distribution Network Layout

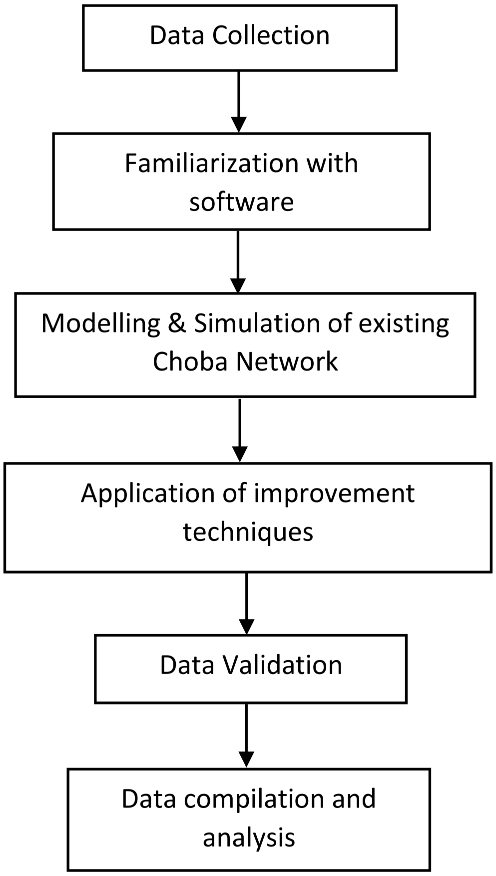
Table 3.1: Details of Examined Transformers

S/N	NAME OF STREET / LOCATION OF TRANSFORMER	TRANSFORMER RATING (MVA)	READINGS			
			R (A)	Y (A)	B (A)	N (A)
1	MTN Nwokem	0.100	25	20	24	12
2	Sammies	0.100	32	30	24	12
3	Ndoudo 2	0.500	232	243	234	130
4	First Bank	0.200	80	82	78	30
5	FCMB	0.100	35	30	27	17
6	Genesis	0.100	30	30	29	12
7	Alikor Estate	0.500	304	308	302	73
8	Sam Amadi	0.500	281	173	300	88
9	MTN Igbogo Rd	0.100	26	29	24	11
10	Waso	0.500	311	166	247	140
11.	Igbogo Road	0.500	165	94	202	94
12	Baby Giant	0.200	100	90	85	35
13	Sugar Land	0.300	110	105	112	38
14	Igbogo Relief	0.500	285	171	381	94
15	Anglican Church	0.500	261	122	139	120
16	Igbogo 2	0.500	321	318	316	54
17	3JS Villa	0.200	92	84	80	37
18	Ndoudo 1	0.300	124	96	139	90
19	Judiciary Qtrs	0.300	187	177	266	64
20	Rumuchakara	.500	370	323	265	93
21	Mission Rd	0.500	229	215	144	60
22	Royal Highness	0.200	83	91	95	40
23	Okemini	0.500	278	77	357	230
24	Okwunga	0.300	117	110	113	72
25	SDA	0.200	150	120	90	38
26	MTN SDA	0.050	20	18	20	5
27	Wokoma	0.500	348	492	502	150
28	Christ Embassy	0.300	300	295	303	40
29	Playground	0.500	515	511	518	163
30	Evergreen	0.500	512	502	506	150

Source: Port Harcourt Electricity Distribution Company (PHEDC)

Method

The overall methodology is explained in the chart shown below.



3.1 Determination of Overloaded Transformer

The apparent power performance index is used to determine the percentage loading of transformers in the network. Based on the principle of loading of distribution transformers being 60% on rating for design purpose, transformers with loadings in excess of this figure are considered overloaded

$$Percentage\ loading = \left[\frac{S_{MVA}}{S_{MAX}}\right] x\ 100 \qquad (3.1)$$

Where; S_{MAX} is the MVA rating of the transformer

S_{MVA} is the operating MVA from power flow calculations.

3.2 Determination of Percentage Voltage Regulation

$$Voltage\ drop, V = IZ \tag{3.2}$$

$$End\ Voltage, V_{end} = Source\ Voltage, V_s - Voltage\ drop, V \tag{3.3}$$

$$V_{end} = V_s - V \tag{3.4}$$

$$Percentage\ Voltage\ Regulation = \frac{Source\ Voltage - End\ Voltage}{Source\ Voltage}\ x\ 100\% \tag{3.5}$$

$$= \frac{V_s - V_{end}}{V_s}\ x\ 100\% \tag{3.6}$$

Where;

I = Current flowing through the feeder
Z = Impedance of the feeder
V = Voltage drop of the feeder
V_s = Voltage at the source
V_{end} = Voltage at the end

1V RESULTS AND DISCUSION

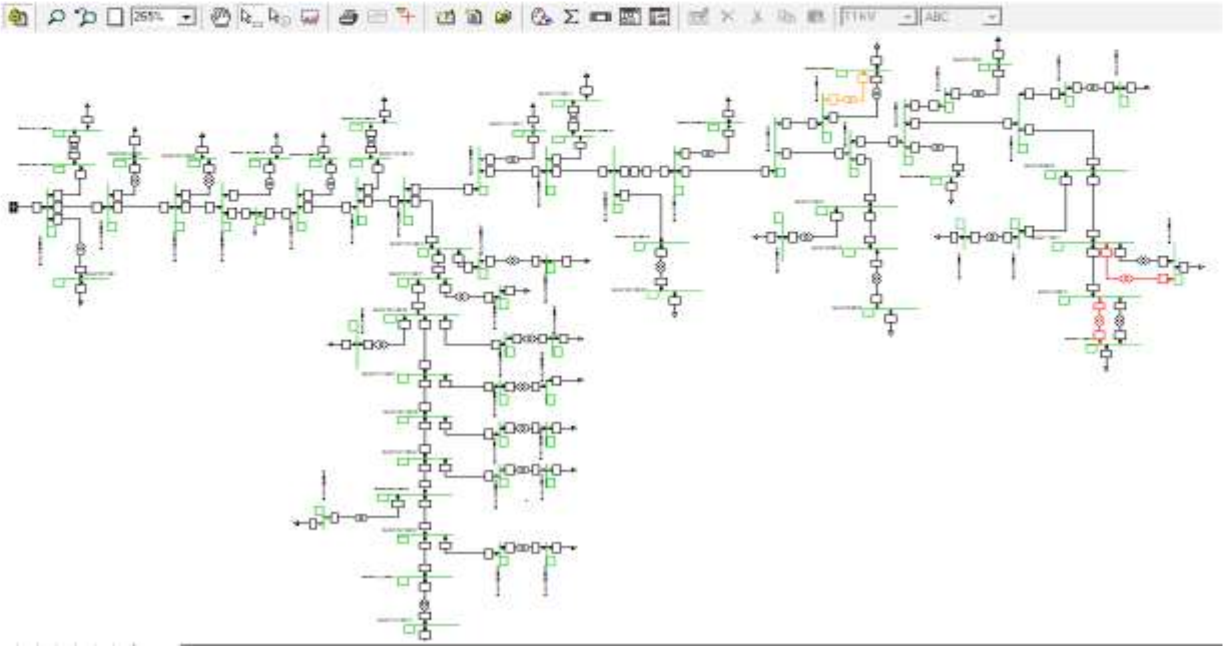


Figure 4.1: Presentation of the existing State of Choba 11kV/0.415V Distribution Network

Figure 4.1 gives the single line diagram of the present condition of the Choba 11kV/0.415V distribution network, Port Harcourt. The simulation shows that while all other transformers are black, indicating normal loading conditions of not greater than 60%, transformer 16 (Royal Highness) is orange in color, indicating marginal loading condition of 68.18%. Transformers 23 and 25 (Playground and Evergreen) respectively are flagged red, indicating critically loaded conditions of 83.07% and 81.24% respectively. The entire bus bars in the network are flagged in green, indicating a healthy bus bar.

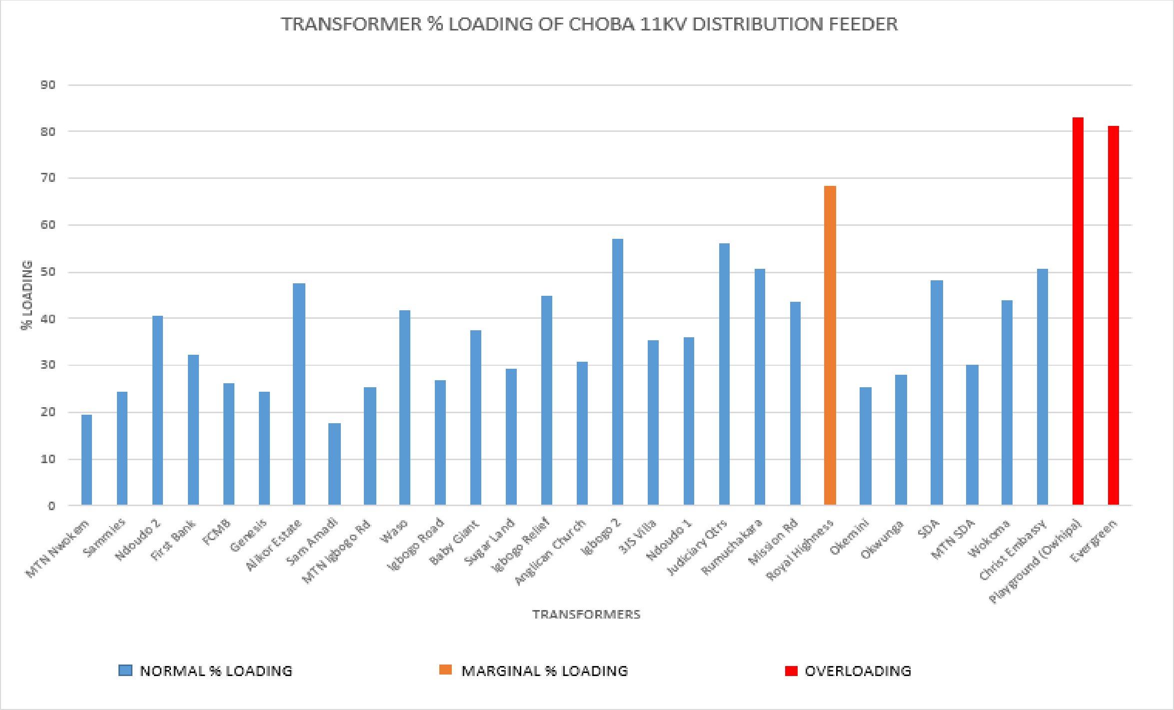


Figure 4.2: **Graph Showing Present State of Transformer Percentage Loading of Choba 11kV/0.415V Distribution Network**

4.1 Comparison of the Improved States of the Overloaded Transformers

The graph below gives a comparison of the various levels of improvement observed in the distribution.

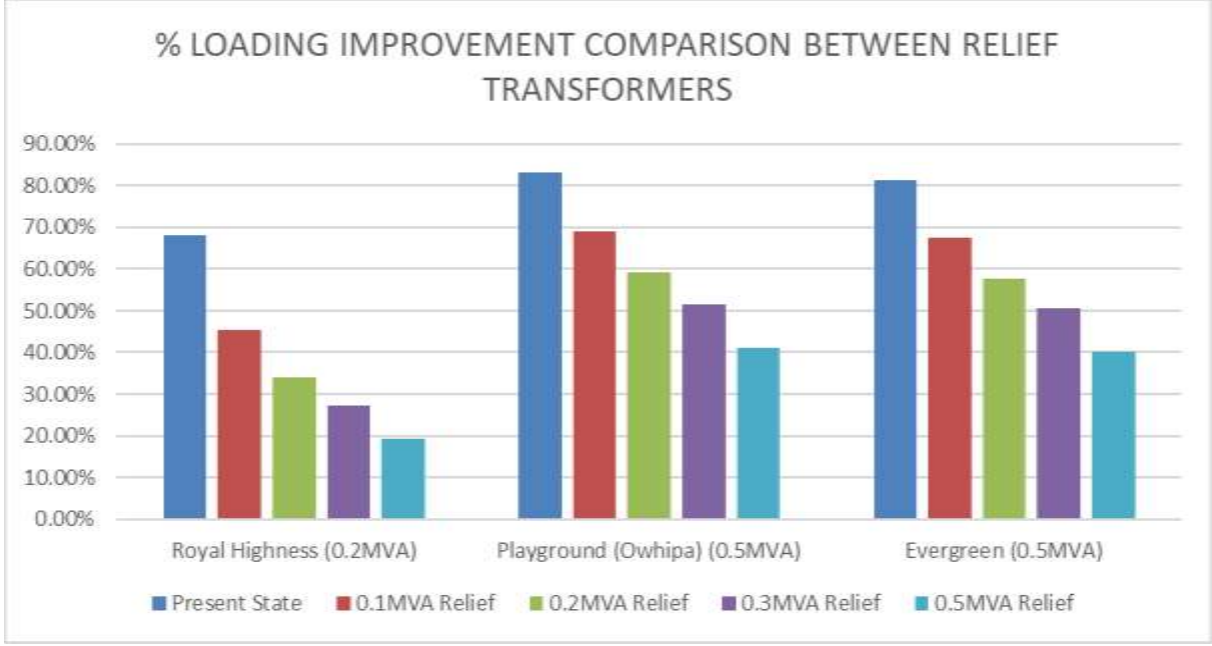


Figure 4.3: Comparison of Improved States of the Overloaded Transformers

Figure 4.3 shows a graph of the improvements on the three overloaded transformers in the network when various standard ratings of transformers are connected as relief at the various points.

The improvements observed were as follows when a 0.5MVA relief transformer was used; 68.2% loading to 19.3% loading, 81.2% to 40.3% and 83.1% to 41.2% for Royal Highness, Evergreen and Playground transformers respectively

4.2 Network Losses

The graph below shows the comparison of losses observed in the distribution network before and after improvement.

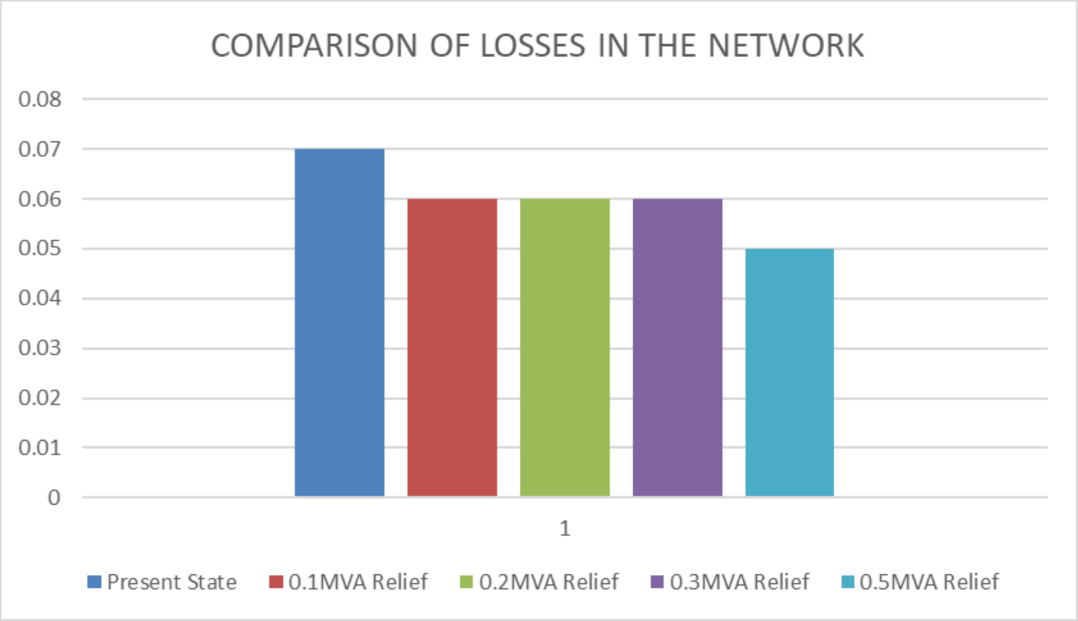


Figure 4.4: Graph Showing the Losses in the Network

Figure 4.4 shows a graph of the network's losses. The losses stood at 0.07Mvar before improvement techniques were applied. The losses dropped to 0.05Mvar when a 0.5MVA relief transformer rating was connected at all overloaded points.

V CONCLUSION

This study examined the existing 11/0.415kV electrical distribution network for Choba Community which consists of 44 lines, 30 transformers and 75 buses. The distribution network was modelled in DigSilent PowerFactory software using Newton Raphson's power flow equation. Power flow analysis was conducted for both existing network and modified network. The results were analysed, overloaded transformers and feeders were identified. Transformer loading above 60% are taken as overloading condition. According to the simulation results, the bus bars in the network are all operating within the acceptable standard of percentage voltage regulation of ±5%. The reasons for overloading of a few transformers in the network under study were identified. Relief transformers of various ratings were introduced to improve the network while considering its financial cost implications, having possible future expansions in mind. From the distribution system studies performed, the following improvement such as reduction of transformer loading to 19.3% from 68.2% of the Royal Highness Transformer, 41.2% from 83.1% of the Playground transformer and 40.3% from 81.2% of the Evergreen transformer is obtained.

Based on the findings the upgrading of distribution transformers and feeders, were found to reduce losses and eliminate overloading from the system.

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