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Improvement of 33KV/11KV Distribution Network at Gboko, Buruku and Guma Agasha in Benue State, Nigeria.

Prof. D.C Idoniboyeobu, Dr. L.S. Braide and Saaronee, Halliday Jackson

Department of Electrical Engineering, Rivers State University, Port Harcourt.

ABSTRACT

The distribution system is arranged or configured based on the area served (rural, urban or suburban), the load level, reliability and extra equipment, the rural distribution configuration presents a radial structure and one transformer is sufficient to deliver electric power demanded by customers and the transformer is protected based on the rating of the transformer, this configuration consists of high voltage and medium voltage buses, the medium voltage bus is connected to the primary distribution line and over current relay is employed for the protection system. The 33KV/11KV distribution network at Gboko, Buruku and Guma-Agasha, Apir area in Makodi Local Government Area in Benue State, are faced with the following difficulties: Overloading of distribution transformers on the listed feeders (Gboko community 11KV feeder, Buruku community 11KV feeder and Guma-Agasha community 11KV feeder), Low voltage profile problem in 11kV network of these communities and Single line fault on the network. The result of Active Power, Reactive Power, Frequency Power Factor, Complex Power, Transformer Percentage Loading and current rating on each Transformer in 33KV/11KV distribution network at Gboko, Buruku and Guma-Agasha, Apir area in Makodi Local Government Area, Benue State, Nigeria was determined. Newton-Raphson method were used to determine the fault current and line impedance on the network, Microsoft Excel was used to justify the current while Electrical Transient analyzer program (ETAP) was used for the simulation. We recommend that transformer load tap changer should be used as optimization tool for the improvement of the voltage profile of the network since is cheaper compared to capacitor bank placement and the fault at Akaa-Kusugh should be clear or worked upon to avoid electrocution of persons or damage of appliances. The single line to ground fault at Akaa-Kusugh on the distribution network should be clear or worked upon to avoid electrocution of persons or damage of appliances. Transformer load tap changer should be used as optimization technique for the improvement of the voltage profile of the network.

1. INTRODUCTION

1.1 Background of the Study

Electric power distribution network systems form the last part of the network that deliver electricity from generation stations to the consumers via the transmission or sub transmission systems. The first component of the electrical distribution system is the distribution substation, which is a place where the transmission line voltage (132KV) or sub transmission line voltage (33KV) is lowered by step down transformer to obtain primary distribution line voltage (11KV) and this primary distribution line called feeder takes the energy to the load center and the distribution transformer at the load center further steps down the voltage to secondary distribution line voltages, which are: 415volts for three phase supply while 240volts for single phase supply and neutral (Luis, 2016).

The distribution system is arranged or configured based on the area served (rural, urban or suburban), the load level, reliability and extra equipment.

The rural distribution configuration presents a radial structure and one transformer is sufficient to deliver electric power demanded by customers and the transformer is protected based on the rating of the transformer. This configuration consists of high voltage and medium voltage buses. The medium voltage bus is connected to the primary distribution line and over current relay is employed for the protection system. This type of configuration is less expensive and simple in nature. The urban distribution configuration presents a close loop arrangement. In this configuration, the medium voltage buses take a closed loop and circuit breakers connected to separate different parts, so that load transfer can be done and maintenance services can be carried out with ease. This type of configuration requires more equipments and it is more expensive than the rural configuration. The suburban distribution configuration requires two more transformers to deliver electric power to the load centers and a normally open-tie switch, so that in the event of fault on one transformer; electric power can be delivered to the load centers by the remaining transformers when the normally open-tie switch is operated. This type of configuration facilitates voltage control, minimize fault level and more expensive than the rural configuration (Nack, 2005).

A good distribution system must have the following requirements: The rated voltage of the system must not be interrupted, the distribution system should not be over loaded, the dielectric strength of the insulation used in the system should be high, the system should be reliable and losses in the line should be minimum and the efficiency should be high (Patil & Kiran, 2013).

The role of an electric power system is to fulfill the customers demand requirements with good assurance of quality and supply continuity, electric power is the utmost engine for any form of development such as: economic development and technological development, so the availability of electric power is very crucial for any form of development in any nation (Jaya *et al.*, 2017).

Apir in Makodi Local Government Area in Benue State electric power distribution network is faced with the following problems:

i. Overloading of distribution transformers on the following feeders as listed below:

   a. Gboko community 11KV feeder

   b. Buruku community 11KV feeder

   c. Guma-Agasha community 11KV feeder

ii. Low voltage profile problem in 11kV network of these communities

iii. Single line fault on the network

This research work shall be an improvement of 33KV/11KV distribution network at Gboko, Buruku and Guma-Agasha in Benue State, Nigeria.

The objectives of this research work are: Physical examination of existing network,

- Collection of data from the Jos Electricity Distribution Network (JEDN) ,Formation of equation and Implementation of those data collected from the existing equation.The scope of this research work is targeted at the analysis of 33KV/11KV electric power distribution network for Gboko, Buruku and Guma Agasha comunities in Benue State, Nigeria. It will proffer solution to the poor state of electricity power infrastructure in that area for improved system performance and also minimise the cost effect on the commercial consumers, if evenly distributed.

2. RELATED WORK

A fault in any location in electric distribution network has the potential to cause temporary interruption such as voltage drop, temporary losses of supply, or even a blackout in the whole network. The duration of such interruption is measured in terms of Customer Minute Loss (CML), apparently, very often interruption in distribution networks is caused by faults (Awalin *et al.*, 2012). Electricity has been in existence in Nigeria for more than 100 years with various reforms of the electricity sector but its development and availability to Nigerians have been so epileptic. In 1898, the colonial masters installed the first Electricity generating plant that gave rise to a few kilowatts in Lagos, Nigeria. By the Act of Parliament in 1951, the Electricity Corporation of Nigeria (ECN) was established. Niger Dams Authority (NDA) was set up in 1962 to develop hydroelectricity and was merged with ECN to form the National Electric Power Authority (NEPA) in 1972. Despite various efforts by NEPA to control the power sector by providing electricity to the increasing population, it became clear that NEPA was not meeting up demand of electricity consumers in the 1990s. in 2001, the National Electric Power Policy (NEPP) was set up to reform the power sector which also leads to several other reforms that created the roadmap for Nigeria's Power Sector Privatization, but due to government bureaucracy; the policy was not signed into law until 2005. The Electric Power Sector Reform (EPSR) Act signed in 2005 was expected to level the playing ground for potential investors and improve the wellbeing of its citizens. The EPSR Act led to the incorporation of the Power Holding Company of Nigeria (PHCN) from NEPA, which was later defunct and divided into subsectors (Emodi Yusuf, 2015). The sub-sectors are made up of 18 companies which include: 11 Distribution Companies (DISCOs), 6 Generation Companies

(GENCOs) and 1 Transmission Company (TCN). These companies are saddled with the responsibility of carrying out the functions relating to the generation, transmission, distribution, trading and bulk supply as well as resale of electricity in the country (Oseni, 2011). The electricity generated are transmitted through transmission lines that use three phases namely alternating current (AC), single-phase AC current and high-voltage direct current system. However, transmission of electricity using high voltage (110 KVA or 330 kVA used in Nigeria, aids in the reduction losses (Oseni, 2011).

For a distribution system to be operated safely, much ideal equipments are required (Luis 2016). The major equipments involved in Mile 2, Diobu Port Harcourt distribution network include: supply lines, line supports, circuit breakers, power transformers, current transformers, potential transformers, relays, fuse, switch, and lightning / surge arresters.

These are lines conductors in the distribution system that convey electrical energy from one point of the distribution system to another. The overhead supply lines used are aluminum type conductor while for the underground supply lines used are cupper conductors and polymer-insulated. These line conductors are distinguished by the current carrying capacity and the rated voltage. In rural and suburban areas, the supply lines used are always overhead while in urban areas, the supply lines used are underground cable (Luis, 2013).

According to John *et al*, (2013) supply lines are linked to substation though a high voltage isolating switch for isolation to be done from any part, so that maintenance can be carried out safely.

These are structures used to support overhead line conductors and they are made up of wood, concrete, aluminum or steel. Line supports are of two types: the electrical pole type and the electrical tower type. In any electrical power system, line supports play an essential role in the transmission and distribution systems, they provide appropriate spacing between conductors. The maintenance expenses of the line supports should be low and they should have long life span (www.powerelectricalblog.com, 2018).

In any electrical safety system, circuit breakers are the major components. Circuit breakers are applied in power system to open and close a circuit when the circuit is operating normally and abnormally (fault condition). The main function is to break off the electric power continuity under fault condition thereby separating the defected part of the power system from the healthy part by opening the contacts. The different types of circuit breakers employed are: oil circuit breaker, air-blast circuit breaker, vacuum circuit breaker and SF6 circuit breaker (Isibor, 2015). These are the utmost and most expensive of all the components in the distribution systems. These electrical devices consist of two or more windings and perform voltage transformation without changing the frequency. Turn ratio is an essential factor of a transformer, it is used to vary the voltage level. Transformers power ratings are usually express in kilo volts-amperes (KVA) or mega volts-amperes (MVA), it represents the amount of power that can be transferred through the transformer (Syed, 2016). Transformer voltage rating is shown by the manufacturer. If a transformer is 33/11KV rated, it shows that 33KV is the rated voltage for the high-voltage winding of the transformer while the 11KV is the rated voltage for the low-voltage winding of the transformer between different phases (John et al, 2013). The current transformer is an instrument transformer that has primary and secondary windings insulated from each other. It is connected in a way that the primary winding is in series with the circuit carrying the line current and the secondary winding is connected to the protective relays, ammeters and power meters (Ewesor, 2010). Current transformers are used in the following ways: used to transform high current to low current and to operate protective relays (Syed, 2016). This is also called voltage transformer which is connected to the bus bars in the substation to reduce line voltage to low and safe level to be used by measuring instruments and protective relays. It has the following uses: it is used to transform high voltage to low voltage for measuring purpose and used to reduce voltage for protective purpose (Short, 2004). A relay is an electronic device that differentiates between normal and abnormal operating conditions of a circuit. In distribution system, it is used to energized a high powered device in order to protect feeders and distribution system components, it does this by issuing a tripping command in the event of fault to the circuit breaker corresponding to it, so that, the circuit breaker interrupts the fault current (Luis, 2013). The commonly used relays are: frequency relay, earth fault relay, under voltage relay, inverse time over current relay and instantaneous over current relay (Syed, 2016). It is an over current protective device with a circuit-opening fusible link that when over current passes through it, heats up and get melted. Fuses are readily obtainable at different ranges of voltage, current and interrupting ratings for both indoor and outdoor uses. They are also used in power system to protect secondary distribution circuits and small size power transformer (John *et al.*, 2013). This is a mechanical switching device used to isolate a section of the power system for maintenance or repair. A must be able to carry and break current during normal operating condition of the circuit.These are electrical protective devices used in distribution system connected at beginning of a substation and at the point near the transformer terminals. They are used to protect distribution system equipments from lightning strokes and voltage surges (Isibor, 2016).

Electric power distribution is usually done by different distribution schemes, which are:

I. Radial Distribution Scheme

II. Ring Main Distribution Scheme

III. Interconnected Distribution Scheme (www.powerelectricalblog.com, 2018)

In radial distribution scheme, a number of separate feeders radiated from a substation to supply electric energy to the consumers. Radial distribution scheme is very simple to implement and the cheapest to build but presents the following drawbacks: in this type of scheme, the consumers at the end of the distributors will experience voltage fluctuation and in the event of fault on one feeder, all loads that received supply from the feeder will experience electric power interruption because it has only one supply, because this, it is applied for short distance only (Pritam, 2013).

In this scheme, a number of feeders form a ring or a loop (ABCD) and it is connected to a substation in order to supply electric power to the consumers. In the event of fault on one feeder in this scheme, electric power can be maintained through the other healthy feeders in the ring or loop by operating the isolator switches connected in the scheme. The ring main distribution scheme is more reliable than the radial scheme and voltage fluctuation experienced by the consumers at the end of the distributor is less. This scheme presents the following drawbacks: the construction of this type of scheme is complicated and it is costly at the initial stage (Harikrishna, 2013).

When feeder ring or loop (EFGH) is applied and the energy supplied is by two or more substations at different points, then the distribution system is called interconnected distribution system circuit. This type of distribution scheme is more reliable than the radial and ring main schemes and improves the efficiency of the system but in terms of construction, it is complicated and more expensive (Smarajit, 2009). The single line diagram is given below. Various numerical methods developed for load flow analysis from time to time are listed below:Linear equation solutions are products of (Direct and Iteration method). Direct methods are product of Cramer's (Determinant) Method, Gauss Elimination Method (only for smaller systems), Linear Factorization (more preferred method), etc. While Iterative method are products of Gauss Method and Gauss-Siedel Method (for diagonally dominant systems). Iterative methods are the only method used for nonlinear equations solution while Gauss-Siedel Method (for smaller systems) and Newton-Raphson Method (if corrections for variables are small). Euler and Modified Euler method, RX IV-order method, Milne's predictor-corrector method, etc. are used for Iterative methods only for solving Differential Equations.

3. METHODOLOGY

3.1 Materials and Method

The appraisal of Buruku, Mamse and Gboko 11KV distribution network started with the evaluation of the physical state of the network with exact reference to the type and size of conductors, pole supports, spans and clearances, cross-arms, type of insulators and route length. Direct patrol and inspection of the distribution network, as well as personal visits to the injection substations for on the spot assessment of the state of equipment. Three years (2016-2018) transformer load readings were gotten from Apir area in Makodi Local Government Area in Benue State. Newton-Raphson method were used to determine the fault current and line impedance while Microsoft Excel was used to justify the current and Electrical Transient analyzer program (ETAP) was used for the simulation.

3.2 Description of Buruku, Mamse and Gboko 11KV/0.415kV Distribution Network

Injection substation receives electricity supply from Apir substation in Makodi Local Government Area in Benue State and its capacity rating is 2x15MVA, 11KV/0.415kV which consists of one HV bus bars, two HV/MV transformers, two grounding transformers, one MV bus bars and three outgoing feeders (Buruku, Mamse and Gboko), as shown in Figure 3.1 below, the distribution of electricity to the load centres within the network is through the respective 11KV feeders.

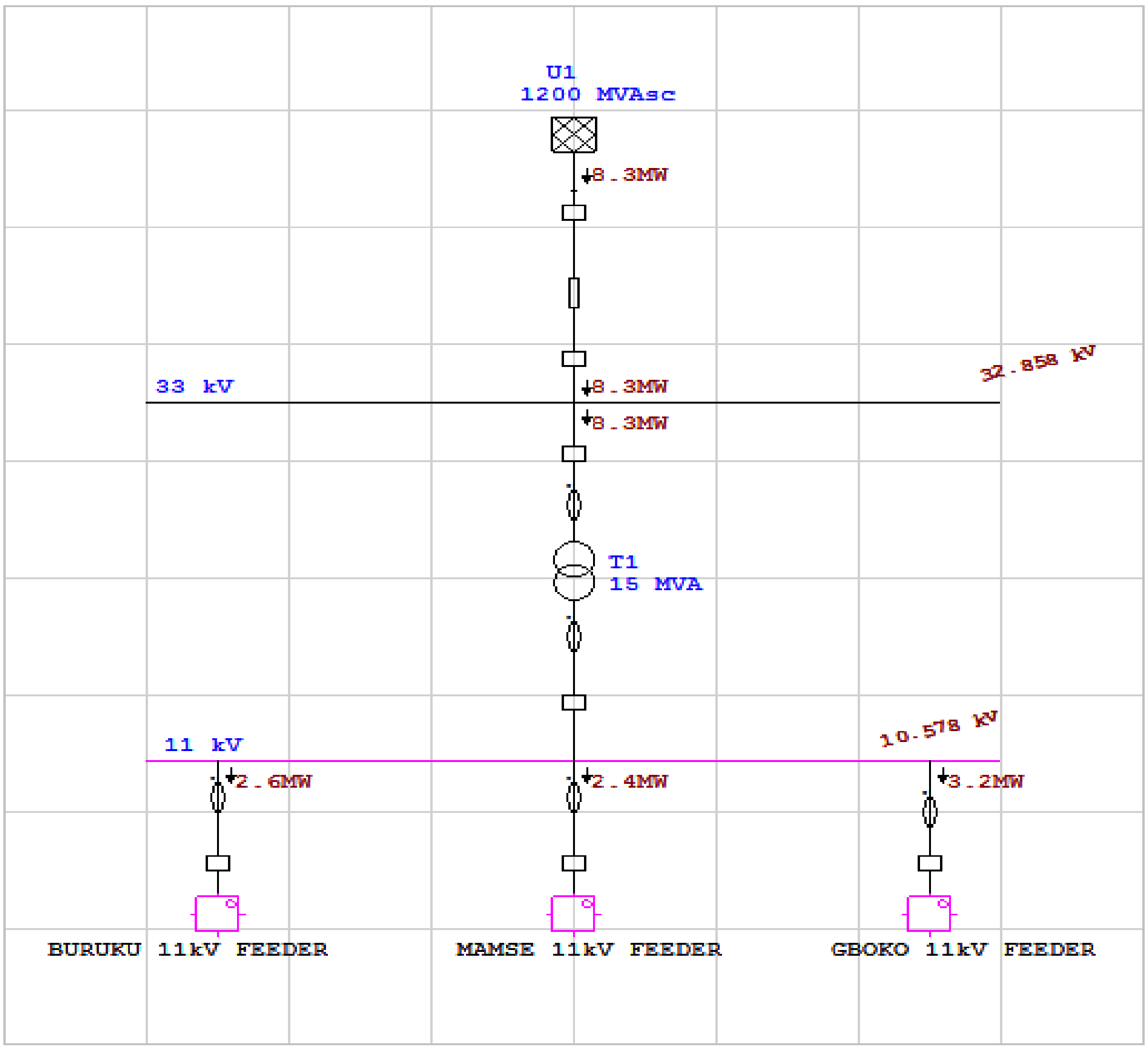

Figure 3.1: Pre-Upgrade Simulation of 33kV/11KV Injection Substation of Buruku, Mamse and Gboko, Distribution Feeders

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The 11KV Buruku, Mamse and Gboko, distribution feeder in Benue State are radial type system, which is commonly used. It encompasses isolated feeders with, each feeder serving a given area, the circuits radiating out of the substation or source (Olusuyi, *et al.*, 2014). The networks are large interconnected with several buses and transformers through distribution lines, as shown in figure 3.2.

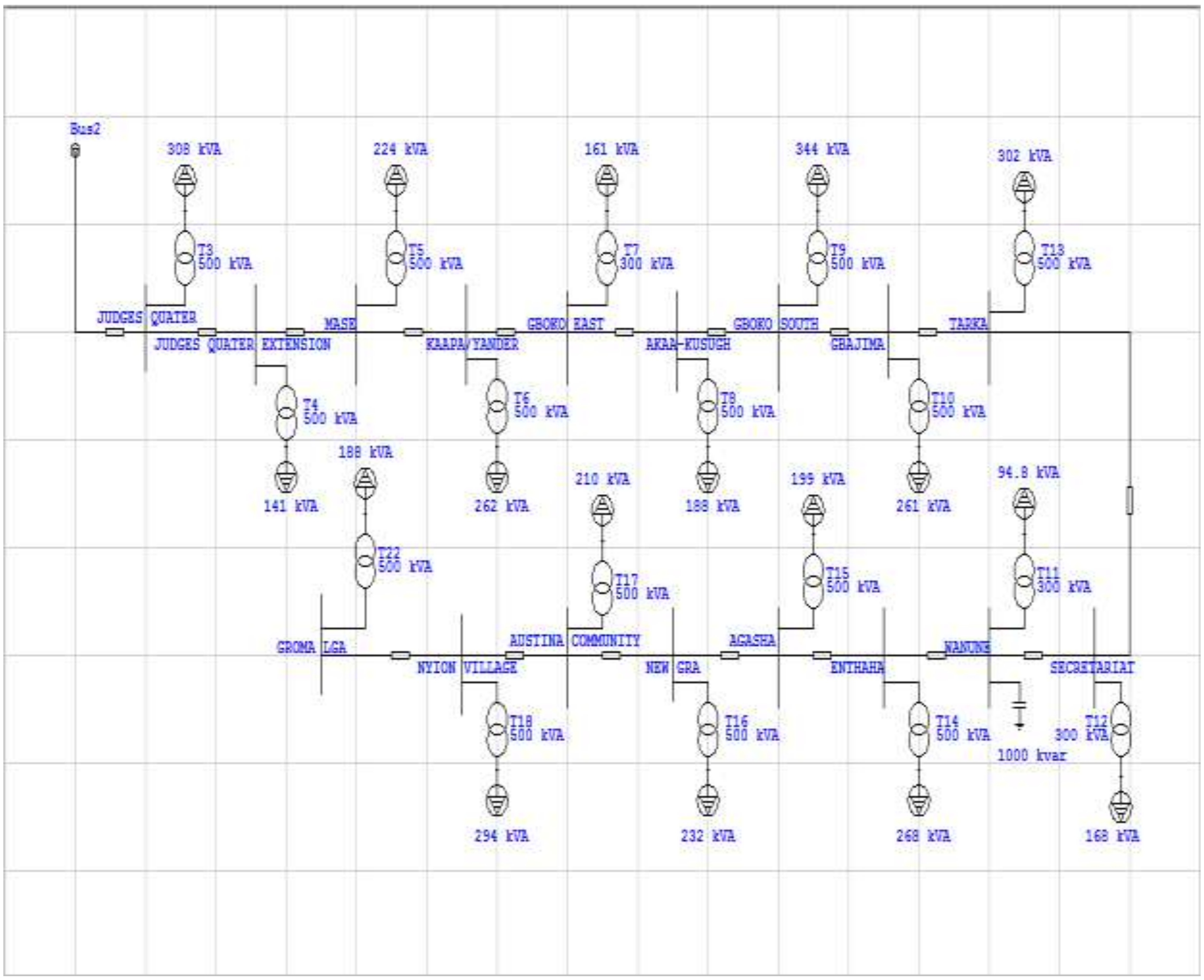

Figure 3.2: The Existing Network of Buruku, Mamse and Gboko, 11KV/0.415 Distribution Feeder

3.3 Current Data Collected on 11KV/0.415 Primary and Secondary Transformer in Buruku, Mamse and Gboko, Substation

The data used in this research work were collected from Apir substation in Makodi Local Government Area in Benue State. The data collected includes; line impedance, bus voltage ratings, transformer data and transformer load readings:

Product of C. T=ABB

C.T Ratio=400:1

RHSV 36KV

Type =outdoor

Frequency =50 Hz

Burden =50VA core

Core 1=400/1A=10P10

Core 2=10P10 400-1A

Core 3=10P10 400-1A

3.3.1 Calculation of Load Current in Buruku, Mamse and Gboko 11KV/0.415 Feeder

Power Triangle was used in analyzing the reactive power, apparent power and power factor.

Transformer load in SVA= $\sqrt{3}IV$ (3.1)

Active power in watts or kW= $\sqrt{3}IV\cos\theta$ (3.2)

Reactive power in VAR or kVAR= $\sqrt{3}VI\sin\theta$ (3.3)

Apparent power in VA or kVA= $\sqrt{\mathrm{kW}^2+\mathrm{kVAR}^2}$ (3.4)

Power factor, $\cos\theta = \frac{\text{Active power}}{\text{Apparent power}} = \frac{\mathrm{kW}}{\mathrm{kVA}}$ (3.5)

Complex power, S = P + JQ (3.6)

Current $I \; = \frac{P(KVA)}{\sqrt{3}IV}$ (3.7)

Where, I, represent Current. V, represent Voltage and $\cos\theta$ represent the power factor at primary and secondary of transformers respectively.

Using the above equation (3.1 -3.7) to determine the transformer connection in Delta/Star since the system, consists of 15MVA, 33/11KV transformer and a 300KVA, 11/0.415KV transformer to explain the above formula deductions.

(i) The 15MVA, 11/0.415KV transformer is connected in Delta/Star,

Equation (3.5) above was used in determining the primary and secondary current of the 15MVA, 11/0.415KV transformer, we have Power (P) in KVA = $\sqrt{3}IV$

Hence, $I \; = \frac{P(KVA)}{\sqrt{3}IV}$

Primary Load current$I_p = \frac{P(KVA)}{\sqrt{3}IV} = \frac{15*10^{\wedge 6}}{\sqrt{3}*11*10^{\wedge 3}} = \frac{90}{297} = 262.4$A

While,

Secondary load current $I_s = \frac{P(KVA)}{\sqrt{3}IV} = \frac{15*10^{\wedge 6}}{\sqrt{3}*11*10^{\wedge 3}} = 787.29582162222 \cong 787.3$A

Equation (3.5) above was used in determining the primary and secondary current of the 300KVA, 11/0.415KV transformer, we have

Primary Load current$I_p = \frac{P(KVA)}{\sqrt{3}IV} = \frac{300*10^{\wedge 3}}{\sqrt{3}*11*10^{\wedge 3}} = 5.248638810814779 \cong 5.25$A

While,

Secondary load current $I_s = \frac{P(KVA)}{\sqrt{3}IV} = \frac{300*10^{\wedge 3}}{\sqrt{3}*11*10^{\wedge 3}} = 15.74591643244433 \cong 15.75$A

Table 3.1 below, shows the 15MVA, 11/0.415KV transformer load current rating in the primary and the load current rating on 300KVA, 11/0.415KV secondary transformer in Buruku, Mamse and Gboko substation.

Table 3.1: The Transformer Load Current Rating in the Primary and Secondary Transformer in Buruku, Mamse and Gboko Injection Substation.

Base Transformer Rating	Transformer Load Current	Current Connected in Delta/Star
15MVA, 11/0.415KV transformer	Primary Load current I_p	262.4A
	Secondary load current I_s	2.858A
300KVA, 11/0.415KV transformer	Primary Load current I_p	5.25A
	Secondary load current I_s	15.75A

3.5 Determination of Transformer in Apir Substation

Table 3.1: below, shows the total number of transformers on each feeder. The bus bar voltages, the transformer currents and the feeder currents are monitored by the protection system. Besides its normal function of protecting the electricity system, the protection system, it also transmits the measurements to the dispatch Centre in case of a fault.

Table 3.2: The Total Number of Transformers on each Feeder in Apir Injection Substation

Injection Substations	Examined Feeders	Route length (km)	No of Transformers in KVA				
			500	300	200	100	50
Apir	Buruku community feeder	9.88	18	3	-	-	-
	Mamse Community feeder	15.46	30	-	1	-	-
	Gboko Community feeder						

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3.5.1 Determination of Overloaded Transformers on Apir Feeders

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.

$$\%Loading = \sum_{i=1}^{N_T} \left(\frac{S_{MVA}}{S_{MAX}}\right) \times 100$$

(3.16)

Where;

S_{MAX}Represent the MVA rating of the transformer

S_{MVA}Represent the operating MVA from power flow calculation

N_TRepresent the number of transformers

Table 3.3 shows the transformer current reading in Buruku, Mamse and Gboko 11/0.415KV distribution feeder in Port Harcourt, Nigeria.

Table 3.3: The Location of Transformers and it's rating on 11/0.415KV distribution Feeder in Buruku, Mamse and Gboko Community for Three Years (2016- 2018).

S/N	NAME, CAPACITY AND VOLTAGE RATIO	LOAD READING (Amps)			
		R	Y	B	N
1	AKAA-KUSUGH, 300KVA, 11/0.415KV	148	145	141	49
2	AUSTINA COMMUNITY, 300KVA, 11/0.415KV	165	155	167	46
3	Bus1, 300KVA, 11/0.415KV	166	157	168	50
4	ENTHAHA, 300KVA, 11/0.415KV	161	157	161	55
5	GBAJIMA, 300KVA, 11/0.415KV	145	157	156	50
6	GBOKO EAST, 300KVA, 11/0.415KV	178	168	175	56
7	GBOKO SOUTH, 300KVA, 11/0.415KV	155	152	189	59

8	GROMA LGA, 300KVA, 11/0.415KV	197	195	198	58
9	JUDGES QUATER, 300KVA, 11/0.415KV	145	148	141	49
10	JUDGES QUATER EXTENSION, 300KVA, 11/0.415KV	167	155	165	46
11	KAAPA/YANDER, 300KVA, 11/0.415KV	168	157	166	50
12	MASE, 300KVA, 11/0.415KV	161	157	161	55
13	NEW GRA, 300KVA, 11/0.415KV	147	155	156	50
14	NYION VILLAGE, 300KVA, 11/0.415KV	175	168	178	56
15	SECRETARIAT, 300KVA, 11/0.415KV	152	155	189	59
16	TARKA, 300KVA, 11/0.415KV	198	195	197	58
17	WANUNE, 300KVA, 11/0.415KV	145	148	141	49

3.5.1.1 Determining each Transformer Loading and its Percentage Load in Buruku Community 11/0.415KV Feeder.

The loading reading data collected in table 3.3 on each transformer in Buruku community was determined as follows,

1. AKAA-KUSUGH, 300KVA, 11/0.415KV

The load reading data collected in table 3.4 above, was used in calculating the total current that flows through this transformer, we have

$$\text{Current, } I = \frac{\text{Current load reading}}{3} \tag{3.17}$$

$$\text{Current, } I = \frac{148+145+141+49}{3} = \frac{483}{3} = 161\text{A}$$

Equation 3.1 above was used in calculating transformer-loading SVA:

$$SVA = \sqrt{3} \times V \times I = \sqrt{3} \times 0.415 \times 362.33 = 1.7320 \times 0.415 \times 161 = 115.72\text{KVA}$$

Since 60% rating was used for design purpose, calculating for overloaded transformer using equation 3.17 above, we have

$$\% \text{ loading} = \frac{SVA}{S_{MAX}} \times 100\% = \frac{115.72}{300} \times 100\% = 38.57 \cong 39\%$$

Equation (3.3) above was used in calculating for the reactive power (kVAR), we have

The reactive power, kVAR= $\sqrt{3}VIsin\theta$

Note that $\sqrt{3} \times V \times I = 115.72$KVA, since $sin\theta = 0.6$

Hence,

kVAR $= 115.72 \times 0.6 = 69.43KVA_r$

Equation (3.2) above was used in calculating for the active power (kW), we have

The active power, $\text{kW} = \sqrt{3} \times \text{V} \times \text{Icos}\phi$

Note that $\sqrt{3} \times V \times I = 115.72$ kW, since $\cos\phi = 0.8$

Hence,

$\text{kW} = 115.72 \times 0.8 = 92.58$ kW

Using equation (3.5) above in determining for the value of Complex power S, we have
Complex power, $S = \text{kW} + j\text{kVAR} = 92.58 + j69.43$

Using equation (3.4) above in determining for the value of apparent power kVA, we have

Apparent power in VA or kVA= $\sqrt{\text{kW}^2 + \text{kVAR}^2} = \sqrt{92.58^2 + 69.43^2} = 115.72$kVA

Using equation (3.5) above in determining for the value of Power factor ($\cos\theta$), we have

Power factor, $\cos\theta = \frac{\text{Active power}}{\text{Apparent power}} = \frac{\text{kW}}{\text{kVA}} = \frac{92.58}{115.72} = 0.8$

2. AUSTINA COMMUNITY, 300KVA, 11/0.415KV

Equation (3.17) with the load reading data collected in table 3.4 above, was used in calculating the total current that flows through this transformer, we have

Current, $I = \frac{165+155+167+46}{3} = \frac{533}{3} = 178\text{A}$

Equation 3.1 above was used in calculating transformer-loading SVA:

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$SVA = \sqrt{3} \times V \times I = \sqrt{3} \times 0.415 \times 317.33 = 1.7320 \times 0.415 \times 178 = 128\text{KVA}$

Since 60% rating was used for design purpose, calculating for overloaded transformer using equation 3.17 above, we have

$$\% \text{ loading} = \frac{SVA}{S_{MAX}} \times 100\% = \frac{128}{300} \times 100\% = 43\%$$

Equation (3.2) above was used in calculating for the active power (kW), we have

The active power, $\text{kW} = \sqrt{3} \times \text{V} \times \text{I}\cos\phi$

Note that $\sqrt{3} \times V \times I = 128\text{KVA}$, since $\cos\phi = 0.8$

Hence,

$\text{kW} = 128 \times 0.8 = 102.4\text{kW}$

Equation (3.3) above was used in calculating for the reactive power (kVAR), we have

The reactive power, kVAR$= \sqrt{3}VIsin\theta$

Note that $\sqrt{3} \times V \times I = 128\text{KVA}$, since $sin\theta = 0.6$

Hence,

$\text{kVAR} = 128 \times 0.6 = 76.8\text{KVA}_r$

Using equation (3.5) above in determining for the value of Complex power S, we have

Complex power, $S = \text{kW} + j\text{kVAR} = 102.4 + j76.8$

Using equation (3.4) above in determining for the value of apparent power kVA, we have

Apparent power in VA or kVA$= \sqrt{\text{kW}^2 + \text{kVAR}^2} = \sqrt{102.4^2 + 76.8^2} = 128\text{kVA}$

Using equation (3.5) above in determining for the value of Power factor ($\cos\theta$), we have

Power factor, $\cos\theta = \frac{\text{Active power}}{\text{Apparent power}} = \frac{\text{kW}}{\text{kVA}} = \frac{102.4}{128} = 0.8$

3. ENTHAHA, 300KVA, 11/0.415KV

Equation (3.17) with the load reading data collected in table 3.4 above, was used in calculating the total current that flows through this transformer, we have

Current, $I = \frac{\text{Current load reading}}{3} = \frac{161+157+161+55}{3} = \frac{534}{3} = 178\text{A}$

Equation 3.1 above was used in calculating transformer-loading SVA:

$SVA = \sqrt{3} \times V \times I = \sqrt{3} \times 0.415 \times 302.33 = 1.7320 \times 0.415 \times 178 = 127.94\text{KVA}$

Since 60% rating was used for design purpose, calculating for overloaded transformer using equation 3.17 above, we have% loading $= \frac{SVA}{S_{MAX}} \times 100\% = \frac{127.94}{300} \times 100\% = 43\%$

Equation (3.2) above was used in calculating for the active power (kW), we have

The active power, $\text{kW} = \sqrt{3} \times \text{V} \times \text{I}\cos\phi$

Note that $\sqrt{3} \times V \times I = 127.94\text{KVA}$, since $\cos\phi = 0.8$

Hence, $\text{kW} = 127.94 \times 0.8 = 102.35$ kW

Equation (3.3) above was used in calculating for the reactive power (kVAR), we have

The reactive power, kVAR= $\sqrt{3}VIsin\theta$

Note that $\sqrt{3} \times V \times I = 127.94\text{KVA}$, since $sin\theta = 0.6$

Hence, $\text{kVAR} = 127.94 \times 0.6 = 76.76\text{KVA}_r$

Using equation (3.5) above in determining for the value of Complex power S, we have

Complex power, $S = \text{kW} + j\text{kVAR} = 102.35 + j76.76$

Using equation (3.4) above in determining for the value of apparent power kVA, we have

Apparent power in VA or kVA= $\sqrt{\text{kW}^2 + \text{kVAR}^2} = \sqrt{102.35^2 + 76.76^2} = 127.94\text{kVA}$

Using equation (3.5) above in determining for the value of Power factor ($\cos\theta$), we have

Power factor, $\cos\theta = \frac{\text{Active power}}{\text{Apparent power}} = \frac{\text{kW}}{\text{kVA}} = \frac{102.35}{127.94} = 0.80000036805 \cong 0.8$

4. GBAJIMA, 300KVA, 11/0.415KV

Equation (3.17) with the load reading data collected in table 3.4 above, was used in calculating the total current that flows through this transformer, we have

Current, $I = \frac{\text{Current load reading}}{3}$

Current, $I = \frac{145+157+156+50}{3} = \frac{508}{3} = 169\text{A}$

Equation 3.1 above was used in calculating transformer-loading SVA:

$SVA = \sqrt{3} \times V \times I$

$SVA = \sqrt{3} \times 0.415 \times 389.67 = 1.7320 \times 0.415 \times 169 = 121.71\text{KVA}$

Since 60% rating was used for design purpose, calculating for overloaded transformer using equation 3.17 above, we have% loading $= \frac{SVA}{S_{MAX}} \times 100\% = \frac{121.71}{300} \times 100\% = 41\%$

Equation (3.2) above was used in calculating for the active power (kW), we have

The active power, $\text{kW} = \sqrt{3} \times \text{V} \times \text{I}\cos\phi$

Note that$\sqrt{3} \times V \times I = 280.1\text{KVA}$, since $\cos\phi = 0.8$

Hence, $\text{kW} = 280.1 \times 0.8 = 224.56$ kW

Equation (3.3) above was used in calculating for the reactive power (kVAR), we have

The reactive power, kVAR= $\sqrt{3}VIsin\theta$

Note that $\sqrt{3} \times V \times I = 280.1\text{KVA}$, since $sin\theta = 0.6$

Hence, $\text{kVAR} = 280.1 \times 0.6 = 168.06\text{KVA}_r$

Using equation (3.5) above in determining for the value of Complex power S, we have

Complex power, $S = \text{kW} + j\text{kVAR} = 224.56 + j168.06$

Using equation (3.4) above in determining for the value of apparent power kVA, we have

Apparent power in VA or kVA= $\sqrt{\text{kW}^2 + \text{kVAR}^2} = \sqrt{224.56^2 + 168.06^2} = 280.48414785866 \cong 280.5\text{kVA}$

Using equation (3.5) above in determining for the value of Power factor ($\cos\theta$), we have

Power factor, $\cos\theta = \frac{\text{Active power}}{\text{Apparent power}} = \frac{\text{kW}}{\text{kVA}} = \frac{224.56}{280.5} = 0.80061565587 \cong 0.8$

5. GBOKO EAST, 300KVA, 11/0.415KV

Equation (3.17) with the load reading data collected in table 3.4 above, was used in calculating the total current that flows through this transformer, we have

Current, $I = \frac{\text{Current load reading}}{3} = \frac{178+168+175+56}{3} = \frac{577}{3} = 192.33\text{A}$

Equation 3.1 above was used in calculating transformer-loading SVA:

$SVA = \sqrt{3} \times V \times I = \sqrt{3} \times 0.415 \times 292 = 1.7320 \times 0.415 \times 192.33 = 138.25\text{KVA}$

Since 60% rating was used for design purpose, calculating for overloaded transformer using equation 3.17 above, we have% loading $= \frac{SVA}{S_{MAX}} \times 100\% = \frac{138.25}{300} \times 100\% = 46\%$

Equation (3.2) above was used in calculating for the active power (kW), we have

The active power, $\text{kW} = \sqrt{3} \times \text{V} \times \text{I}\cos\phi$

Note that $\sqrt{3} \times V \times I = 209.9\text{KVA}$, since $\cos\phi = 0.8$

Hence, $\text{kW} = 209.9 \times 0.8 = 167.92$ kW

Equation (3.3) above was used in calculating for the reactive power (kVAR), we have

The reactive power, kVAR= $\sqrt{3}VIsin\theta$

Note that $\sqrt{3} \times V \times I = 209.9\text{KVA}$, since $sin\theta = 0.6$

Hence, $\text{kVAR} = 209.9 \times 0.6 = 125.94\text{KVA}_r$

Using equation (3.5) above in determining for the value of Complex power S, we have

Complex power, $S = \text{kW} + j\text{kVAR} = 167.92 + j125.94$

Using equation (3.4) above in determining for the value of apparent power kVA, we have

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Apparent power in VA or kVA= $\sqrt{\text{kW}^2 + \text{kVAR}^2} = \sqrt{167.92^2 + 125.94^2} =$ 209.9kVA

Using equation (3.5) above in determining for the value of Power factor ($\cos\theta$), we have

Power factor, $\cos\theta = \frac{\text{Active power}}{\text{Apparent power}} = \frac{\text{kW}}{\text{kVA}} = \frac{167.92}{209.9} = 0.8$

3.6 Distribution Network with Unbalanced Three-Phase Fault

The Akaa-Kusugh distribution network was faced with Unbalanced Three-Phase Fault as shown in figure 3.3.

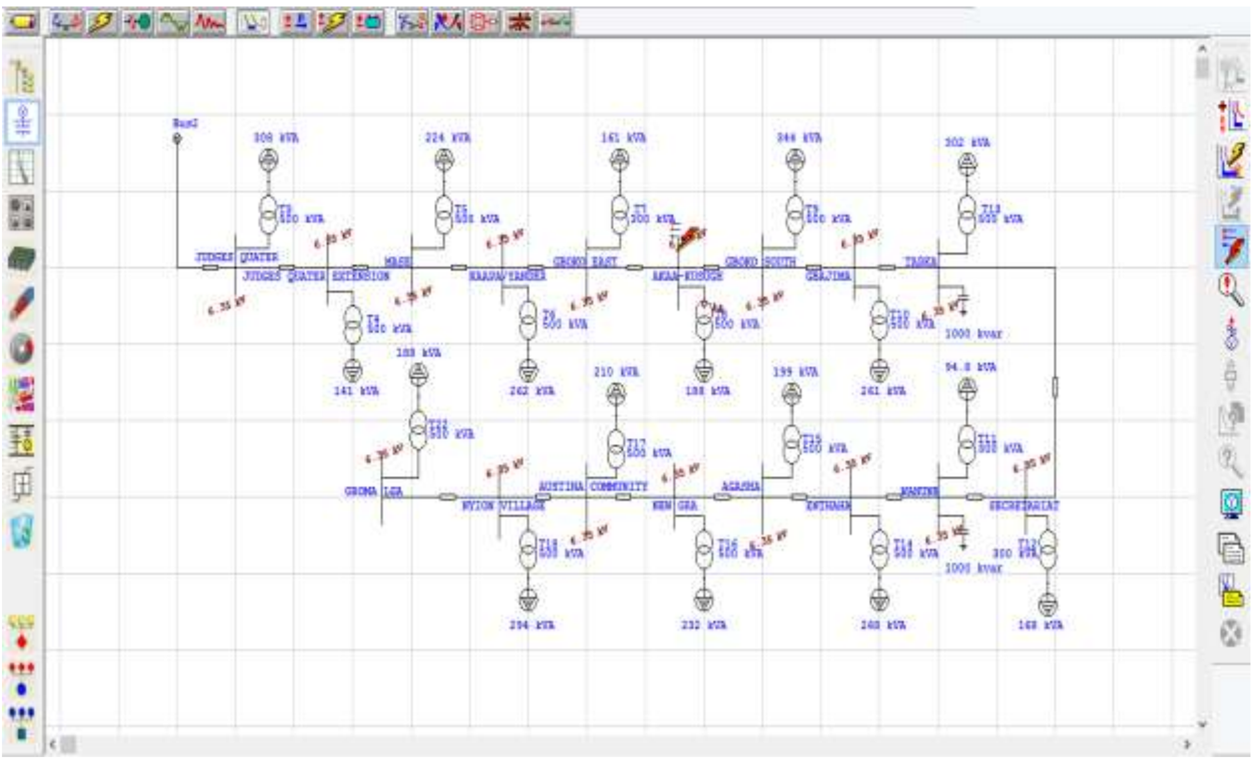

Figure 3.3: Distribution Network with Unbalanced Three-Phase Fault

4. RESULTS and DISCUSSIONS

4.1 The Result on each Transformer in Buruku, Mamse and Gboko Community

The 11KV Buruku, Mamse and Gboko, distribution feeder in Benue State are made of radial type system with several buses and transformers through distribution lines, the circuits radiating out of the substation. The networks are large interconnected, as shown in figure 3.1 and 3.2. the result on Current Rating, Transformer Percentage Loading, Active Power, Reactive Power, Apparent Power, Power Factor, Frequency and Complex Power on each Transformer on each Transformer in Buruku, Mamse and Gboko Community as shown in Table 4.1a and b.

Table 4.1a: The Name, Capacity, Voltage Ratio, Current Rating, Transformer Percentage Loading, Active Power, and Reactive Power on each Transformer in Buruku, Mamse and Gboko Community.

S/N	NAME, CAPACITY AND VOLTAGE RATIO	Current (A) Rating	Transformer %Loading	Active Power (kW)	Reactive Power (kVar)
1	AKAA-KUSUGH, 300KVA, 11/0.415KV	161	39%	92.58	69.43
2	AUSTINA COMMUNITY, 300KVA, 11/0.415KV	178	43%	102.4	76.8
3	ENTHAHA, 300KVA, 11/0.415KV	178	43%	102.35	76.76
4	GBAJIMA, 300KVA, 11/0.415KV	169	41%	224.56	168.06
5	GBOKO EAST, 300KVA, 11/0.415KV	192.33	46%	167.92	125.94
6	GBOKO SOUTH, 300KVA, 11/0.415KV	185	44%	184.97	138.73
7	GROMA LGA, 300KVA, 11/0.415KV	216	52%	124.21	93.15
8	JUDGES QUATER, 300KVA, 11/0.415KV	161	39%	92.58	69.43

9	JUDGES QUATER EXTENSION, 300KVA, 11/0.415KV	177.67	43%	159.63	76.62
10	KAAPA/YANDER, 300KVA, 11/0.415KV	180.33	43%	103.7	77.78
11	MASE, 300KVA, 11/0.415KV	178	43%	102.35	76.76
12	NEW GRA, 300KVA, 11/0.415KV	169	41%	224.56	168.06
13	NYION VILLAGE, 300KVA, 11/0.415KV	192.33	46%	167.92	125.94
14	SECRETARIAT, 300KVA, 11/0.415KV	185	44%	184.97	138.73
15	TARKA, 300KVA, 11/0.415KV	216	52%	124.21	93.15
16	WANUNE, 300KVA, 11/0.415KV	161	39%	92.58	69.43

Table 4.1b: The Name, Capacity, Voltage Ratio, Apparent Power, Power Factor, Frequency and Complex Power on each Transformer on each Transformer in Buruku, Mamse and Gboko Community

S/N	NAME, CAPACITY AND VOLTAGE RATIO	Apparent Power (kVA)	Power Factor Cos Ø	Frequency (Hz)	Complex Power
1	AKAA-KUSUGH, 300KVA, 11/0.415KV	115.72	0.8	50	92.58 + j69.43
2	AUSTINA COMMUNITY, 300KVA, 11/0.415KV	128	0.8	50	102.4 +j76.8
3	ENTHAHA, 300KVA, 11/0.415KV	127.94	0.8	50	102.4 +j76.8
4	GBAJIMA, 300KVA, 11/0.415KV	280.5	0.8	50	224.56 + j168.06
5	GBOKO EAST, 300KVA, 11/0.415KV	209.9	0.8	50	167.92 + j125.94

6	GBOKO SOUTH, 300KVA, 11/0.415KV	231.2	0.8	50	184.97 + j138.73
7	GROMA LGA, 300KVA, 11/0.415KV	155.26	0.8	50	124.21 + j93.15
8	JUDGES QUATER, 300KVA, 11/0.415KV	115.72	0.8	50	92.58 + 69.43
9	JUDGES QUATER EXTENSION, 300KVA, 11/0.415KV	177.07	0.8	50	159.63 + j76.62
10	KAAPA/YANDER, 300KVA, 11/0.415KV	129.63	0.8	50	103.7 + j77.78
11	MASE, 300KVA, 11/0.415KV	127.94	0.8	50	102.35 + j76.76
12	NEW GRA, 300KVA, 11/0.415KV	280.5	0.8	50	224.56 + j168.06
13	NYION VILLAGE, 300KVA, 11/0.415KV	209.9	0.8	50	167.92 + 125.94
14	SECRETARIAT, 300KVA, 11/0.415KV	231.2	0.8	50	184.97 + j138.73
15	TARKA, 300KVA, 11/0.415KV	155.26	0.8	50	124.21 + j93.15
16	WANUNE, 300KVA, 11/0.415KV	115.72	0.8	50	92.58 + j69.43

The result in figure 4.1 shows that the Apparent Power rating at Gbajima and Nyion Village was rated (280.5A) respectively has the highest while the Apparent Power rating at Akaa-Kusugh, Judges Quater, and Wanune has the lowest current rating of 115.72A respectively. The Current Rating at Groma LGA and Tarka has the highest rating of 216A respectively, while the current rating at Akaa-Kusugh, Judges Quater, and Wanune has the lowest value of 115.72A respectively. The Transformer Percentage Loading at location Akaa-Kusugh, Judges quater, and Wanune, has the lowest value of 39% respectively while at location Groma LGA and Tarka has the highest value of 52% respectively. The Active Power on transformer located to Akaa-Kusugh, Judges quater, and Wanune, has the lowest value of 92.58KW respectively while the highest value of 224.56KW was on the active power located at Gbajima and New GRA. The Reactive Power at location Gbajima and New GRA has the highest value of 168.06KVR respectively while the lowest value of 92.58KVR was on transformer located at Akaa-Kusugh, Judges Quater, and Wanune. The value of the Power Factor and the Frequency on all the transformers were all equal in Buruku, Mamse and Gboko Community.

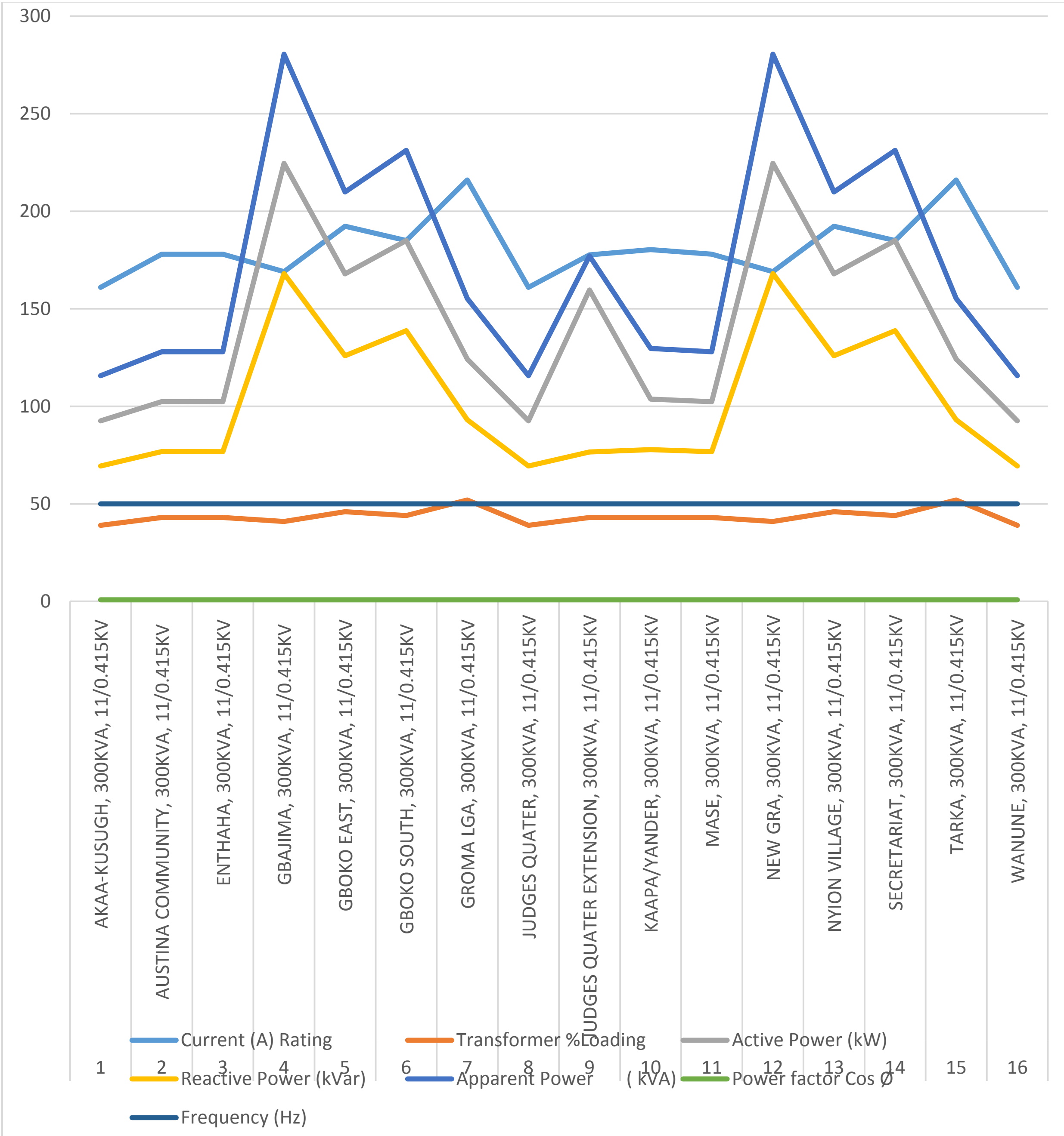

Figure 4.1: The Current Rating, Transformer Percentage Loading, Active Power, Reactive Power Apparent Power, Power Factor, Frequency and Complex Power on each Transformer on each Transformer in Buruku, Mamse and Gboko Community.

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4.2 Pre-Upgrade Simulation of Gboko 11kV Distribution Network

The pre-upgrade simulation result in figure 3.2 and 3.3, shows that the current rating on each bus were not equal due to voltage drop and fault on the network as shown in table 4.2.

Table 4.2: The Pre-Upgrade Simulation on Bus ID, Nominal kV and its Voltage on 11/0.415KV Distribution Feeder in Buruku, Mamse and Gboko Community

S/No.	Bus ID	Nominal kV	Voltage
1	Agasha	11	10.155
2	Akaa-Kusugh	11	10.31
3	Austina Community	11	10.143
4	Enthaha	11	10.165
5	Gbajima	11	10.244
6	Gboko East	11	10.337
7	Gboko South	11	10.272
8	Groma Lga	11	10.124
9	Judges Quater	11	10.494
10	Judges Quater Extension	11	10.461
11	Kaapa/Yander	11	10.385
12	Mase	11	10.416
13	New Gra	11	10.15
14	Nyion Village	11	10.134
15	Secretariat	11	10.196
16	Tarka	11	10.215
17	Wanune	11	10.179

The result shown in figure 4.2, indicate that Judges Quater has the highest voltage of 10.494V, while Groma Lga has the list voltage of 10.124V. The nominal voltage of the network were equal.

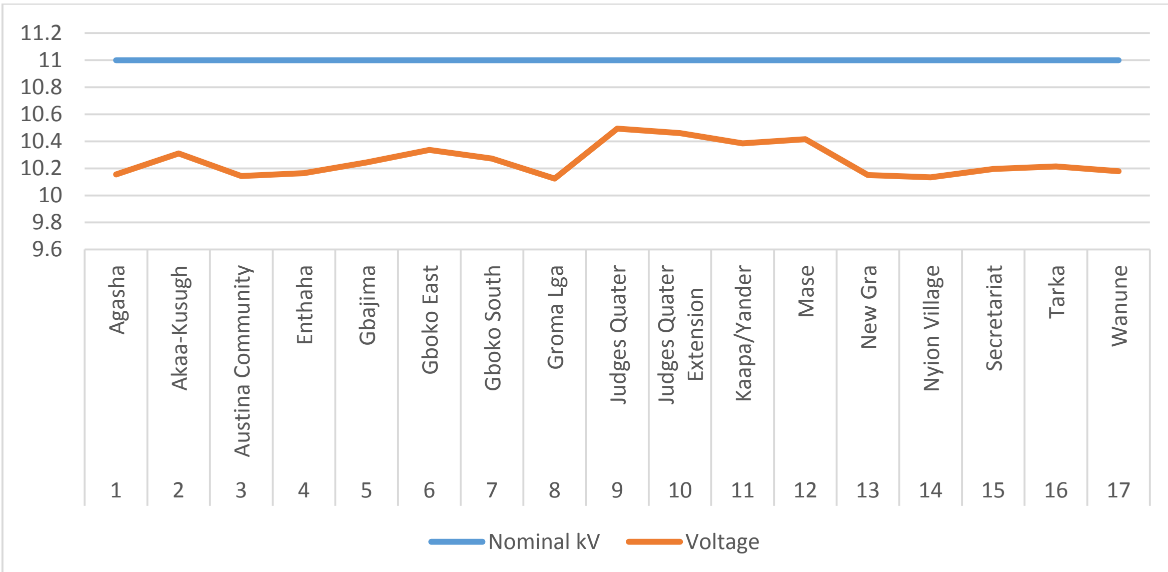

Figure 4.2: Nominal kV and Voltage on 11/0.415KV Distribution Feeder in Buruku, Mamse and Gboko Community

The result shown in figure 4.3, indicate that Judges Quater has the highest voltage of 10.494V, while Groma Lga has the list voltage of 10.124V. The nominal voltage of the network were equal. Per Unit System Voltage of the network were below the approved standard of (95% to 105%).

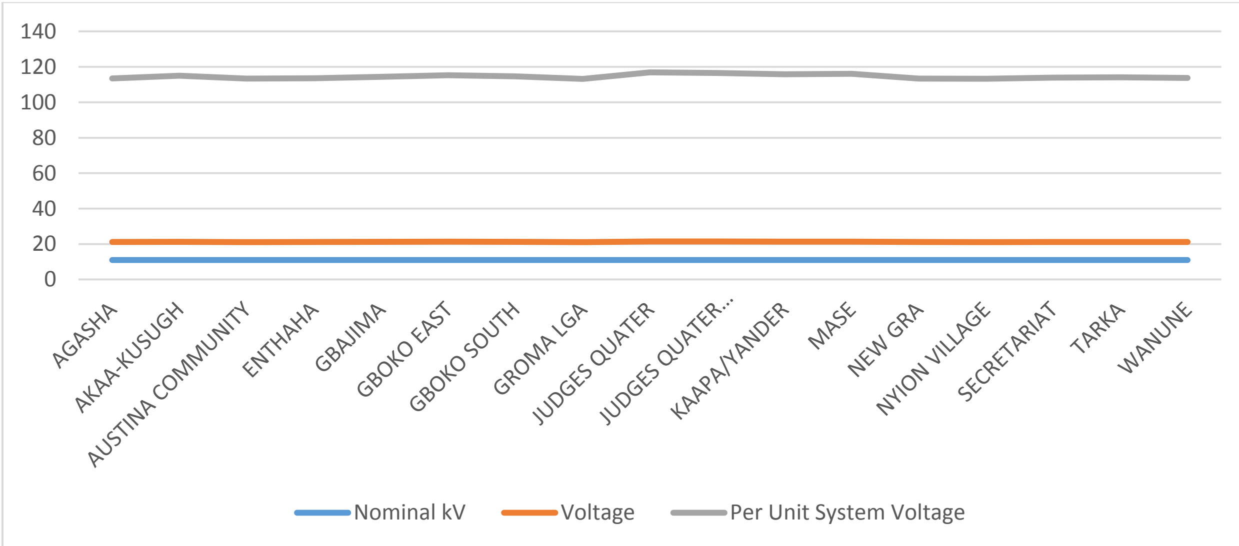

Figure 4.2: The Bus ID, Nominal kV, Voltage and its Per Unit System Voltage on 11/0.415KV Distribution Feeder in Buruku, Mamse and Gboko Community

Transformer load tap changer was used as optimization technique to improve on the voltage profile of the network.

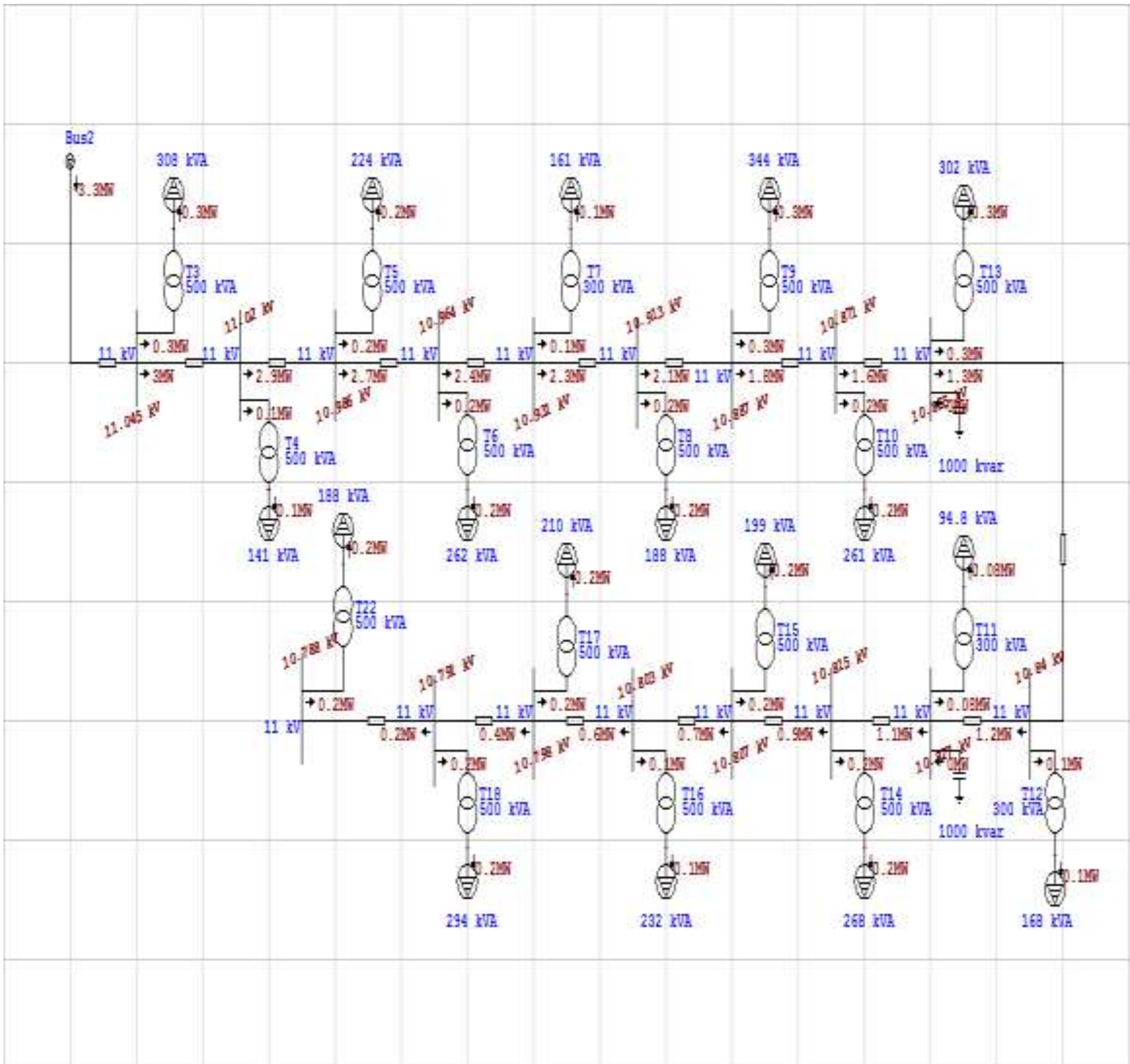

Figure 4.6: Post-Upgrade Simulation of Gboko 11kV Distribution Network

Table 4.2: The Post-Upgrade Simulation on Bus ID, Nominal kV and its Per Unit System Voltage on 11/0.415KV Distribution Feeder in Buruku, Mamse and Gboko Community

S/No.	Bus ID	Nominal kV	Voltage	Per Unit System
1	AGASHA	11	10.807	98.25
2	AKAA-KUSUGH	11	10.913	99.21
3	AUSTINA COMMUNITY	11	10.798	98.16
4	ENTHAHA	11	10.815	98.32
5	GBAJIMA	11	10.871	98.83
6	GBOKO EAST	11	10.931	99.37
7	GBOKO SOUTH	11	10.887	98.97
8	GROMA LGA	11	10.788	98.07
9	JUDGES QUATER	11	11.045	100.41
10	JUDGES QUATER EXTENSION	11	11.02	100.18
11	KAAPA/YANDER	11	10.964	99.67
12	MASE	11	10.986	99.87
13	NEW GRA	11	10.803	98.21
14	NYION VILLAGE	11	10.791	98.10
15	SECRETARIAT	11	10.84	98.55
16	TARKA	11	10.855	98.68
17	WANUNE	11	10.827	98.43

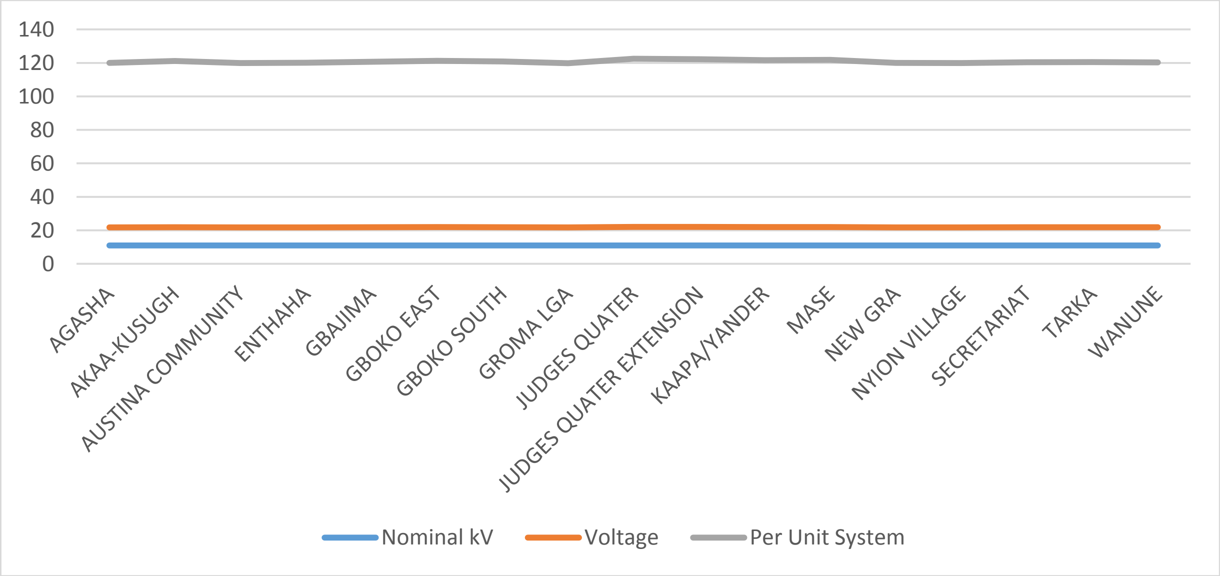

Figure 4.6: The Post Upgrade of the System on 11/0.415KV distribution Feeder in Buruku, Mamse and Gboko Communities.

The result in figure 4.6 shows that the Post upgrade Voltage on 11/0.415KV distribution Feeder in Buruku, Mamse and Gboko Communities was improved upon using Transformer load tap changer was used as optimization technique to improve on the voltage profile of the network.

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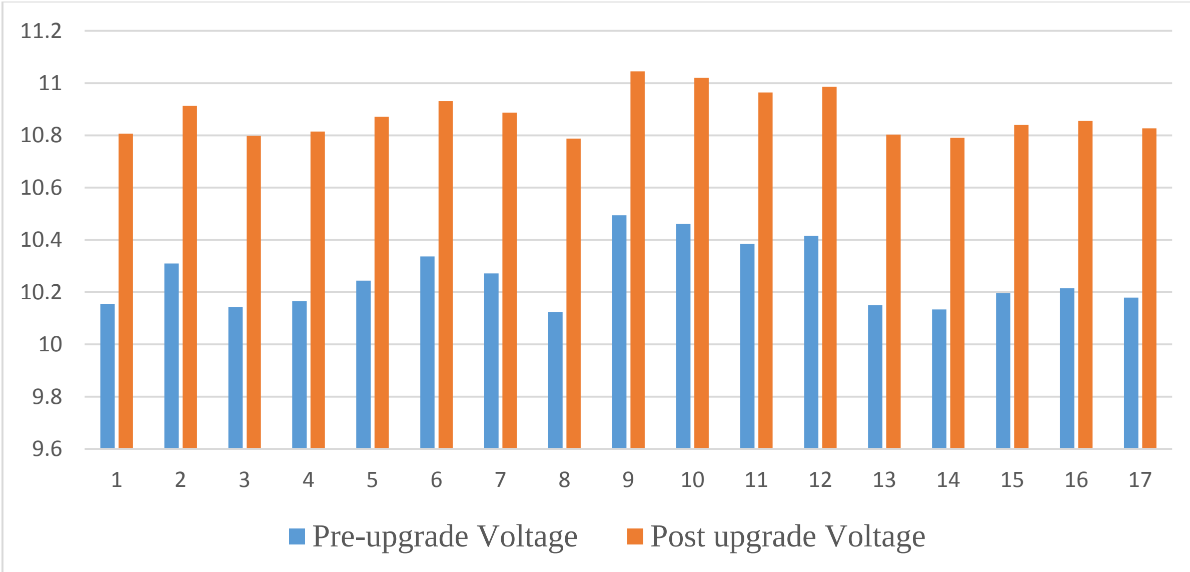

Figure 4.6: The Pre and Post Upgrade of the System on 11/0.415KV distribution Feeder in Buruku, Mamse and Gboko Communities.

5. CONCLUSION

5.1 Conclusion

In conclusion, this research work is to improve 33KV/11KV distribution network at Gboko, Buruku and Guma-Agasha, Apir area in Makodi Local Government Area in Benue State, Nigeria. Newton-Raphson method were used to determine the fault current and line impedance while Microsoft Excel was used to justify the current and Electrical Transient analyzer program (ETAP) was used for the simulation.

the Apparent Power rating at Gbajima and Nyion Village was rated (280.5A) respectively has the highest while the Apparent Power rating at Akaa-Kusugh, Judges Quater, and Wanune has the lowest current rating of 115.72A respectively. The Current Rating at Groma LGA and Tarka has the highest rating of 216A respectively, while the current rating at Akaa-Kusugh, Judges Quater, and Wanune has the lowest value of 115.72A respectively. The Transformer Percentage Loading at location Akaa-Kusugh, Judges quater, and Wanune, has the lowest value of 39% respectively while at location Groma LGA and Tarka has the highest value of 52% respectively. The Active Power on transformer located to Akaa-Kusugh, Judges quater, and Wanune, has the lowest value of 92.58KW respectively while the highest value of 224.56KW was on the active power located at Gbajima and New GRA. The Reactive Power at location Gbajima and New GRA has the highest value of 168.06KVR respectively while the lowest value of 92.58KVR was on transformer located at Akaa-Kusugh, Judges Quater, and Wanune. The value of the Power Factor and the Frequency on all the transformers were all equal in Buruku, Mamse and Gboko Community.

The post upgrade Voltage on 11/0.415KV distribution Feeder in Buruku, Mamse and Gboko Communities was improved upon using Transformer load tap changer was used as optimization technique to improve on the voltage profile of the network.

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