International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 10 Ver I || Oct 2018 || PP 75-130

Integration Of Reactive Power Compensation In A Distribution Network Case Study: Rumuola Injection And Distribution Network Port Harcourt, Nigeria

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Abstract:*This paper will considers the analysis of the voltage regulation techniques to investigate the activities of the system behaviour, voltage profile, power-injected, power received and mismatches. However, the existing data of the case study. Rumuola distribution network were used to compute a load flow with the aid of the electrical transient analyzer tool (E-tap-tool) to verify those areas in the feeder that have critical or marginal problem to be compensated. The automatic capacitor bank was integrated, coupled with the power factor correction controller to preset the existing current for the power factor correction. Thus, the voltage drop techniques was use to verify the existing state of the system, where power losses and mismatches are enormous. Furthermore, the results were obtained via simulation of the excel software programme. And the analysis were also simulated using electrical transient analysis tool (E-tap) to verify the existing state of the system, voltage magnitude, voltage drop and power flows etc. The result obtained via the excel software programme were used to plot graphs showing the voltage drop with respect to substations, power distribution for different stations, power distribution with respect to distances, voltage drop versus percentage voltage regulation for substations, voltage drop, power distribution with respect to load current (I_L).*
Keywords: *Reactive power compensation, voltage drop, voltage regulation, distribution network, load flow, power factor correction*

Date of Submission: 01-10-2018 Date of acceptance: 12-10-2018

I. Introduction

The Fundamental Reason of Electrical Power Supply system is to provide and ensure an adequate electric power supply to all load points of a consumer at an affordable and acceptable rate with reasonable level of reliability. Therefore the distribution of large electricity from the generation station to the utilization point (receiving) involved a tedious arrangement, because the daily needs of electrical energy by different power consuming devices, equipment and facilities are enormous, thus the analysis of these configuration is complex. Therefore, the electricity utilities strongly need to upgraded, and improve the existing system, because the need for energy requirement is constantly on the increase. [1].

Figure 1: Nigeria Power Station
Source: available at (internet): http://bizwatchnigeria.ng./Nigeria-gets-power-plant-training-engineers-renewable-energy

Electricity supply involves a very complex and highly integrated system of generation, transmission, and distribution and utilization. Failures in the part of the sector can evidently cause serious interruptions which may leads to a collapse and system failures.

Electric power distribution is the major component in the delivery of electric power. The main function of the electric power distribution is to provide power to individual consumer's premises which is done with much low voltage level. Distribution of electrical power is usually done by distribution network such as distribution substation, primary distribution feeder, distribution transformer, distributor and service mains [17]. Distribution system can be classified in terms of voltage of primary distribution voltage (11kv), secondary distribution (33kv) and tertiary distribution voltages (415v) between phase or 220/240 between phases and neutral.

The supply of adequate and stable electricity is the basic need for an economic development of any country, because it's determine the level of macro-economic activities and engagement. Availability of electricity has been the most powerful tool of introducing social economic development throughout the world. Inadequate supply due to lack of energy generation of electricity would constitute to the drawback of social, economic and infrastructural development of any nation. The Nigerian power system is suffering from inadequate generation, transmission and distribution capacity. The demand is much higher than the generation and this has led to constant load shedding and erratic power supply. Even by the intervention of federal government, to privatized power holding Company (PHCN), on the view to upgrade and improve the existing state of the system, yet the energy (generation) requirement does not match the energy demand. These have resulted to a decline particularly in the distribution network (receiving end).

Evidently, analysis and statistics, show that most of the distribution network are seriously overstressed, overloaded and currently experiencing excessive line losses which may lead to huge voltage drop, thereby making the power system planning and operation not effective and efficient at all time.

However, the primary reason for study: reactive power compensation in a distribution network, particularly in Rumuola distribution substation, is to ensure that the voltage profile of the distribution network are improve with the integration of reactive power compensation on the view to calculate for the size (capacity) bank that will be required for voltage improvement at the receiving end .

Reactive power compensation is an important issue in electric power system in the case of operation, economic and quality of service. Consumer loads including residential, commercial and industrial loads, seriously impose both active and reactive power demand, depending on their characteristics. Active power is converted into useful energy such as light or heat. Therefore, reactive power must be compensated to guarantee an efficient delivery of active power to loads, thus releasing system and improving system power factor and bus voltage profile. Optimal reactive power compensation can significantly improve the performance of the radial distribution network. Many reactive power compensation techniques or strategies which includes integration of facts device, capacitor or capacitor-bank for compensation are always required for system stability [20].

II. Problem Statement

The declining state in the distribution network in Port Harcourt, particularly in Rumuola area necessitate serious and urgent attention. Because the reliability of electric power is paramount for modern society to function optimally.

Hence, the analysis of load flow problem are conducted in order to evaluate the extend of voltage drop, excessive losses on power line parameters.

This has led to:

Power outage (black-out) in the study area.

Losses in power system network (distribution) due to insufficient supply of power generation via distribution network.

Overload/overdependence of distribution feeder/networks resulted to system collapse.

Lower conductor size (cross-sectional area) resulted to overheating

Low power factor resulted into voltage drop

Hence, the analysis of load flow problems are conducted in order to evaluate the extent of voltage drop, excessive losses on power line parameter.

Objectives of the paper

The objectives of this work will seriously apply the appropriate measures on the view to realize the prevailing condition of the study area, which includes:

Analysis of the numerical data collected from the study area via (PHEDC), with the aim to evaluate the load capacity of the feeders whether overloaded/overstressed

To implement the data collected into voltage drop and voltage regulation equation for analysis and validation (E-tap tool)

Calculation of the size of capacitor, or capacitor-bank as a form of reactive power compensation.

Scope of these Paper

The scope of this paper will conduct the analysis of reactive power compensation in a (11kv) distribution network, particularly at Rumuola with the view to calculate the rating (capacity) of the capacitor or capacitor-bank allocation for associated voltage profile and power loss problems. In order to enhance an effective operation in distribution network.

Significance of these paper

The significance of this paper will seriously improve the active and reactive power flow to the load ends, and therefore will enhance and further improve the bus voltage profile of the distribution feeder in the study area. Evidently, this will be a benefit to the consumer at the receiving end, the [26], TCN provided this contribution is considered. Hence, the reliability of power system will be efficiently be operative provided:

The overloaded grid connected transformers are upgraded or resize for expansion.

Resizing/upgrading the cross-sectional area of the conductor (mm^2)

Resizing/upgrading the injection distribution substation switch-yard.

Adhere strictly to actual design (calculated capacitor-bank for improvement.

Therefore, proper provision of distribution system planning will seriously provide for an orderly development of the system to meet the power requirement; thereby making the system economical, confirming to the electricity rules, and also minimizes losses and maintains regulations within permissible limits.

III. Review of Previous Work

This paper will reviews the important of the paper which includes sources of reactive power in the power system; generators, Synchronous condensers, generating units, onload tap changers phase-shifting transformers, capacitors, reactors and static compensators. It also explains what is reactive power, reactive power reserve, impact of poor reactive power compensation and benefits of reactive power etc.

Reactive power is a subject of great concern for the operation of alternating current (AC) power system. It has always been a challenge to obtain the balance between a minimum amount of reactive power flow (to maximize the capacity for reactive power flow) and a enough amount of reactive power flow to maintain a proper system voltage profile.

However, reactive power is not widely understood outside the power engineering community. It remains one of the most important aspects of AC power system operation. Those involved with maintaining the operating systems most constantly be concerned with the stability between reactive power supply and demand as much as with active supply and demand [24].

The efficient and economic use of electric power depends on the availability of sources for leading and lagging reactive power that can be appropriately dispatched to the system.

Reactive Power in System Analysis

Reactive power compensation in a power distribution networks is used for reducing energy losses, improving voltage profile in medium and low voltages networks and improving reactive power balance in distribution network. [12]. Power factor is defined as the ratio of the real power to apparent power. The definition can be expressed mathematically as KW/KVA, where is the active power (real) and the denominator is the square of active (real) plus square of reactive (apparent power). Furthermore, the definition is very simple but the idea of reactive power is not clearly expressed. Therefore, the explanation for reactive power says that in an alternating current system, the simultaneous flickering of voltage and current triggers only real power to be transmitted and when there is a time shift between the voltage and current, both real and reactive powers are transmitted. Moreover, when the average in time is known, the average active power exists causing a net flow of energy from one point to another, while average reactive power .is zero, irrespective of the network of the system.[3]. In the case of reactive power, the amount of energy coming in one area is equal to the amount of energy flowing in the opposite direction. But in the actual sense we measure reactive power losses, introduced [13]. Many equipments for reactive power compensation are used to compensate for electricity consumption and. cost. Reactive Power (KVAr) is the difference between working (real/power (active power measured in KW) and the total power consumed (apparent power measured in KVA). Some electrical equipment used in industrial and commercial buildings requires certain amount of reactive power with active power in order to work efficiently. Reactive power is very important for the generation of the magnetic fields which are essential for inductive electrical equipment to function, especially transformers and motors. [11]

Therefore, researches on reactive power has been going on, reactive power flows when current leads or lags behind the voltage, especially the current lags because of inductive loads like motors. Reactive power transmits wastes energy, so transmission capacity causes voltage drop. To correct this measure, lagging power flow leading reactive power (current leading voltage) is supplied to bring the current in with voltage [0). Reactive power can be supplied from either static or dynamic VAR sources. Static sources are typically transmission, distribution equipment, such as VAR compensators or capacitors at substations and their cost has historically been included in the revenue requirements of the transmission owner (To), and resolved through cost-of-service rates [32].

However, comparing dynamic sources especially energy producers, addition generators capable of generating both real and reactive power alongside synchronous condensers which produce only reactive power [22]. Now power system is operated closer to its limits than in the past due to the trend of power changes caused by market integration and the effect of renewable, often treated at the remote regions. This shows that the system is operated differently than before and thus leaves less room for reduced measures [15].

This implies that for a reliable and efficient operation of the distribution network, voltages should remain between the expected limits, system stability should be upgraded, the usage of the distribution grid should be increased and losses should be reduced as low as possible. In recent years, a change in the generation dispatch has been effective. Generation and transmission used to be planned and operated in an organized manner together by large vertically integrated utilities.

Reactive power is mainly produced by generating facilities and is very important for a proper operation of the distribution network. When the generation is interchange to production companies, fewer opinions was available for controlling the reactive power output. [31]. Furthermore, the tread towards variable is more, often renewable energy sources, both on a large scale and a small scale residential and other distribution generation [34].

However, conventional dispatch generators is of great importance to reactive power consequent shifts in the generation type because of the effect on the reactive power compensation. Hence, power comprises of two components which is active and reactive power. The computation of active and reactive power is known as apparent power. However, reactive power is that power which supplies the stored or conserved energy in reactive elements. Now, in the AC circuits, the energy stored is temporarily in inductive and capacitive elements which gives a periodic reversal of the direction of flow of energy between the source load. [8]

Moreover, the average power after completion of one whole cycle of AC wave form is the real power and this is the usable power of the system to work and the area in which power flow is temporarily conserved in the form of magnetic or electric fields and flow back forth in the transmission line because of inductive and capacitive network element which is known as reactive power.

Inductors (Reactive) are said to store or absorbed reactive power because they conserve energy in the form of magnetic field which gradually build up, and makes the current lag behind the voltage in phase [16] capacitors also generate reactive power because they store energy inform of electric field.

This project research is about reactive power compensation in. a distribution networks. Effective reactive power compensation is required for an efficient electric power system. The voltages on a bus bar changes according to the loadability, the generation pattern and the topology of the distribution networks [28]. The voltage is varied by the injection and absorption of reactive power. Various sources of reactive power is available for voltage control. For example an improvement an improvement in the distributed generation can be noted by the injection of shunt compensation. Also installing underground high voltage drop in the power distribution network [10]. These trends have an impact on the reactive power compensation of a transmission grid.

Purpose of Reactive Power

Synchronous generators, and various types of other DER (Distributed energy resources) equipment are used to maintain voltages throughout the transmission system. Injecting reactive power into the system raises voltage and absorbing reactive power lower voltages and voltages-support requirement are function of the locations and magnitude of generator output and customer loads [10].

Configuring of the DER transmission system. These requirements can differ substantially from location to location and can change rapidly as the transmission lines act as capacitor and increases voltages. At high levels of load, however transmission lines absorb reactive power and thereby lower voltages. Most transmission system equipment e.g. capacitors, inductors, tap-changing transformers) is static but can be switched to respond to changes in voltages support requirements [19].

IV. MATERIALS AND METHOD

The materials considered and used in this paper work are:

Existing data of the case study, Rumuola distribution network.
Electrical transient analyzer tool (E-tap).

Methods used
Analysis of the voltage drop techniques and voltage regulation, are used in the voltage drop verification of the existing system where power losses &mismatches are enormous.

Determination of per-kilometer resistance, (R_0=R') in (Ω/km)
The line parameters collected in the study case: Rumuola distribution network which includes:
Distribution network – 11KV as the study case
Cross – sectional area, A given as:
A = $182mm^2 = 182\times10^{-6}m^2$
Thus, the per-kilometer resistance, R_0

$$R0 = \frac{Rl}{A(m^2)}\Omega/km \qquad (1)$$

or

$$R_0 = \frac{1000\,\ell}{A(m^2)} \qquad (2)$$

$$R_0 = \frac{1000 \times 2.826 \times 10^{-8}\Omega m}{182 \times 10^{-6} m^2} \qquad (3)$$

$$R_0 = 0.20\,\Omega/km$$

Note:
R = $\ell\times\left(\frac{l}{A}\right)$
Where
ℓ = resistivity for pure aluminum =2.826×10^{-8}
l = length of cable
A = cross-sectional area
d = $150mm^2$
Aluminum conductor, the resistance per-kilometer = 0.1884Ω/Km ACSR = $180mm^2$
Distance between bus 1 – 2 (Rumuola – Nikky feeder) = 2500m = 2.5km = Distance measured between (Bus 1 – 2) with respect to resistance, R in (Ω)

$$R = 0.20\,\Omega/km \times 2.5km$$

$$R = 0.5\Omega$$

ANALYSIS I: (RUMUOLA – NIKKY FEEDER) BUS (1 – 2)
CASE 1:
Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as:

$$X_0 = 0.1445\log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km \qquad (4)$$

Where $DGMD = 1.100m$
R= 0.5Ω
Hence; $X_0 = 0.1445\log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157$

$$X_0 = 0.0652\ \Omega/km$$

CASE 2: For a distance measured of 2.5km,

$$X(bus\ 1-2) = 0.0652\ \Omega/km \times 2.5km = 0.163\Omega$$

CASE 3:
The impendance between (bus 1 – 2) is given as:
Z (bus 1 – 2) = 0.5 + j0.163Ω
Z (bus 1 – 2) = 0.526
Per-kilometer capacitive susceptance (b_0)
The capacitance susceptance is given as:

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{\Omega . kmj} \qquad (5)$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log(144.53)}$$

$$b_0 = \frac{7.58}{2.1599580} \times 10^{-6} = 3.509$$

$$= 3.509 \times 10^{-6} * \frac{1}{\Omega . km}$$

For a distance measured of 2.5km

Bus (1 – 2) = $3.509 \times 10^{-6} \times \frac{1}{\Omega . km} \times 2.5km$

The capacitance susceptance, given as:

Bus (1 – 2) = $8.77259 \times 10^{-6}\left(\frac{1}{\Omega} or\ simens\right)$

CASE 4: Determination of load current (I_L) at Rumuola – Nikky while relying on the following condition.

(i) Power factor of the load (P.f) = 0.08
(ii) Transformer rating in KVA = 100
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation;

$$KVA \times p.f = KW \qquad (6)$$

100×0.80 = 80KW
Active power = 80KW

From the load current equation;

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}} \qquad (7)$$

$$I_L = \frac{80}{1.732 \times 11 \times 0.80}$$

$$I_{L_1} = \frac{80}{1.5.2416}$$

$$I_{L_1} = 5.248792778 \quad \approx 5.2488\ Amps$$

$$\therefore I_{L_1} = 5.2488\ Amps$$

CASE 5:

Determination of the required number of conductor per phase but since $I_{L_1} = 5.2488\ Amps$

$$Number\ \ of\ \ conductor = \frac{Load\ \ current}{Current\ \ carrying\ \ capacity\ of\ conductor}$$

Hence, the number of conductor = $\frac{5.2488}{180} = 0.02916 \approx 0.03$

CASE 6: Determination of the voltage drop between Rumuola – Nikky Feeder

$$V_{d_1} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ \ line\ section}{\# of\ conductor / \ phase \times 100} \qquad (8)$$

Where;

$$V_{d_1} = \frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 6.2488 \times 2.5}{0.03 \times 100}$$

$$\frac{1.732 \times (0.2176 \times 0.8 + 0.6) \times 13.122}{0.03 \times 100}$$

$$\frac{1.732 \times 0.8176 \times 13.122}{3}$$

$$V_{d_1} = \frac{18.58184375}{3}$$

$V_{d_1} = 6.193997917\ V$

CASE 7: Determination of the receiving end voltage at Nikky feeder

$V_{R1} = Sending\ voltage\ (Vs) - Voltage\ drop(V_{d1})$

$V_{R1} = 11000 - 6.093947917 = 10999.94514\ V$

$V_{R1} = 10993.80605\ V$

$V_{R1} = 10993.80605\ V$

CASE 8: Determination of the percentage Voltage regulation between Rumuola – Nikky feeder

% voltage regulation $= \frac{V_S - V_{R1}}{V_{R1}} \times 100\%$ (9)

$= \frac{11000 - 10993.80605}{10993.80605} \times 100\%$

$= \frac{6.19395}{10993.80605} \times 100\%$

% voltage regulation = 0.00049872976 ≈ 0.0005%
= 0.05634036 ≈ 0.06%
= 0.06%

Case 9: Determination of the reactive power of the load
KVA = 100
KW = 80
Applying Pythagoras theorem gives;

$KVAR = \sqrt{(KVA)^2 - (KW)^2}$ (10)

$KVAR = \sqrt{100^2 - 80^2}$

$KVAR = \sqrt{3,600}$

$KVAR = 60$

ANALYSIS 2 (Nikky –Rumuadaolu 1) (Bus 2 – 3)
Calculation of the distance between buses:
Distance between bus 2 – 3
(Nikky – Rumuadaolu I feeder) = $\frac{600m}{100} = 0.6km$

Distance measured between (bus 2 – 3) with respect to resistance, R in (Ω) $0.20\ \Omega/km \times 0.6km$

R = 0.12Ω

CASE I:
Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as**; Recalling Equation(3.4)**

$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$

Where;
$DGMD = 1.100m$
R= 0.5Ω

$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$

$X_0 = 0.1445 \log_{10}(2.2) + 0.0157$

$X_0 = 0.0652 \approx 0.0652\ \Omega/km$

CASE 2: For a distance measured of 0.6km,

$$X(bus\ 2-3) = 0.0652\ \Omega/km \times 0.6km = 0.03912\ \Omega$$

CASE 3:
Hence, the impedance between (bus 2 – 3) gives:
Z (bus 1 – 2) = 0.12 + j0.03912Ω
Per-kilometer capacitive susceptance (b_0)
Then the capacitive susceptance is given as**; Recalling Equation (5)**

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.6KM
bus (2 – 3) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$

Bus (2 – 3) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.6km = 2.1054 \times 10^{-6}\left(\frac{1}{\Omega} or\ simens\right)$

CASE 4: Determination of the load current (I_L) at Nikky – Rumuadaolu while relying on the following condition.
(i) Power factor of the load (P.f) = 0.08
(ii) Transformer rating in KVA = 500
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined
From the power equation**; Recalling Equation (6)**

$$KW = KVA \times p.f$$

KW = 500×0.80
KW = 400
Active power = 400KW.
From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3} \times V \times p.f}$$

$$I_L = \frac{400}{1.732 \times 11 \times 0.80}$$

$$I_{L_1} = \frac{400}{15.2416} = 26.24396389 \approx 26.244 Amps$$

CASE 5: Determination of the required number of conductor per phase but since load current

$$I_{L_1} = 5.2488\ Amps$$

$$Number\ \ of\ \ conductor = \frac{Load\ \ current}{Current\ carrying\ capacity\ of\ conductor}$$

Hence, number of conductor = $\frac{26.244}{180} = 0.1458$

CASE 6: Determination of the voltage drop between Nikky – Rumuola feeder.
Recalling Equation (8)

$$V_{d_2} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ \ line\ section}{Number\ \ of\ conductor/\ phase \times 100}$$

Where;

$$V_{d_2} = \frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 26.244 \times 0.6}{0.1458 \times 100}$$

$$\frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 15.7464}{14.58}$$

$$\frac{1.732 \times 0.8176 \times 15.7464}{14.58} = \frac{22.2982125}{14.58}$$

$V_{d_2} = 1.529369856\ V$

CASE 7: Determine of the receiving end voltage at Nikky – Rumuadaolu feeder

$V_{R_2} = Sending\ voltage\ (Vs) - Voltage\ drop (V_{d2})$

$V_{R_2} = 11000 - 1.529369856 = 10998.47063\, V$

$V_{R_2} = 10998.47063\, V$

CASE 8: Determination of the percentage Voltage regulation (V_R) between Rumuola – Nikky feeder given as;

Recalling Equation (9)

% voltage regulation = $\frac{V_S - V_{R2}}{V_{R2}} \times 100\,\%$

$$= \frac{11000 - 10998.47063}{10998.47063} \times 100\%$$

$$= \frac{1.52937}{10998.47063} \times 100\%$$

% voltage regulation = 0.013905296 ≈ 0.014%

CASE 9: Determination of the reactive power of the load

KVA = 500, KW = 400

Applying Pythagoras theorem gives as; **Recalling Equation (10)**

$$KVAR = \sqrt{(KVA)^2 - (KW)^2}$$

$$KVAR = \sqrt{(500)^2 - (400)^2}$$

$$KVAR = \sqrt{250{,}000 - 160{,}000}$$

$$KVAR = \sqrt{90{,}000} = 300$$

$$KVAR = 300$$

Analysis 3(Rumuadaolu I – Rumuadaolu II) (Bus 3 – 4)

Distance between Bus (3 – 4) = 0.3km

Distance measured between Bus (3 – 4) with respect to resistance, R in (Ω) gives:

R = 0.20Ω/km×0.3km

R_{Bus} (3 – 4) = 0.06Ω

CASE I

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (4)**

$$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$$

Where;

$$DGMD = 1.100m$$

R= 0.5Ω

$$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$$

$$X_0 = 0.1445 \log_{10}(2.2) + 0.0157$$

$$X_0 = 0.0652\ \Omega/km$$

CASE 2: For a distance measured of 0.3km,

$$X_{(Bus\ 3-4)} = 0.0652\ \Omega/km \times 0.3km = 0.01956\ \Omega$$

CASE 3:
Thus, impedance between (Bus 3 – 4) gives:
$Z_{(Bus\ 3-4)} = 0.06 + j0.01956$
Per-kilometer capacitive susceptance (b_0)
Thus, the capacitance susceptance is given as; **Recalling Equation (5)**

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} \cdot \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log(144.53)}$$

$$b_0 = \frac{7.58}{2.1599580} \times 10^{-6} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.3KM

Bus (3 – 4) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.3 = 1.0527 \times 10^{-6}\left(\frac{1}{\Omega} \text{or simene}\right)$

CASE 4: Determination of load current (I_L) at Rumuadaolu I – Rumuadaolu 2 while relying on the following condition.

(i) Power factor of the load (P.f) = 0.08
(ii) Transformer rating in KVA = 500
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation; **Recalling Equation (6)**

$$KW = KVA \times p.f$$

KW = 500×0.80
KW = 400
∴ Active power = 400KW.

From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3} \times V \times p.f}$$

$$I_L = \frac{400}{1.732 \times 11 \times 0.80}$$

$$I_{L_1} = \frac{400}{15.2416} = 26.24396389 \approx 26.244 Amps$$

CASE 5: Determination of the required number of conductor per phase but since $I_{L_3} = 26.244\ Amps$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Hence, number of conductor = $\frac{26.244}{180} = 0.1458$

CASE 6: Determination of the voltage drop between Rumuadaolu I – Rumuadaolu 2
Recalling Equation (8)

$$V_{d_3} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{Number\ of\ conductor/\ phase \times 100}$$

$$V_{d_3} = \frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 26.244 \times 0.3}{0.1458 \times 100}$$

$V_{d_3} = V_{d_3} \times Length\ of\ the\ line\ section$

$V_{d_3} = 0.764684928$ Where: length of the line section = 0.3km

CASE 7: Determine of the receiving end voltage at Rumuadaolu I – Rumuadaolu 2 feeder

$V_{R3} = Sending\ voltage\ (Vs) - Voltage\ drop(V_{d3})$

$V_{R3} = 11000 - 764684928$

$V_{R3} = 10999.23532\ V$

CASE 8: Determination of the percentage Voltage regulation between Rumuadaolu I – Rumuadaolu 2 feeder given as;**Recalling Equation (9)**

% voltage regulation $= \frac{V_S - V_{R3}}{V_{R3}} \times 100\%$

$= \frac{11000 - 10999.23532}{10999.23532} \times 100\%$

$= \frac{0.76468}{10999.23532} \times 100\%$

% voltage regulation = 0.00695211965 ≈ 0.007%

CASE 9: Determination of the reactive power of the load

KVA = 500, KW = 400

Applying Pythagoras theorem gives; **Recalling equation (3.10)**

$KVAR = \sqrt{(KVA)^2 - (KW)^2} = 300$

$KVAR = 300$

ANALYSIS 4: (Rumuadaolu 2 – Lulu Shopping Centre)

Bus parameter between Bus (4 – 5)

Distance between Bus (4 – 5) = 0.4km

Distance measured between Bus (4 – 5) with respect to resistance, R in (Ω) gives;

R = 0.20Ω/km×0.4km = 0.8Ω

CASE 1:

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (3.4)**

$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$

$X_0 = 0.1445 \log_{10}(2.2) + 0.0157$

$X_0 = 0.0652\ \Omega/km$

$X_0 = 0.0652\ \Omega/km$

CASE 2: For a distance measured of 0.4km,

$X(Bus\ 4-5) = 0.0652\ \Omega/km \times 0.4km = 0.02608\ \Omega$

CASE 3:

Hence, impendance between (Bus 4 – 5) (Rumuadaolu 2 – Lulu Shipping Centre) gives:

Z (Bus 4 – 5) = 0.08 + j0.02608Ω

Per-kilometer capacitive susceptance (b_0)

Thus, the capacitive susceptance is given as; **Recalling Equation (5)**

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.4KM

Bus (4 – 5) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$

Bus (4 – 5) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.4km = 1.4036 \times 10^{-6}\left(\frac{1}{\Omega} or\ Simens\right)$

CASE 4: Determination of the load current (I_L) at Rumuadaolu 2 – Lulu Shipping Centre while relying on the following condition.

(i) Power factor of the load (P.f) = 0.80
(ii) Transformer rating in KVA = 500
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation; **Recalling Equation (6)**

$$KVA \times p.f = KW$$

500×0.80 = 400
KW = 400
∴ Active power = 400KW

From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3} \times V \times p.f}$$

$$I_L = \frac{400}{1.732 \times 11 \times 0.80}$$

$$I_{L_1} = \frac{400}{15.2416} = 26.24396389 \approx 26.244 Amps$$

CASE 5: Determination of the required number of conductor per phase but since $I_{L_1} = 26.244\,Amps$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Hence, number of conductor = $\frac{26.244}{180} = 0.1458$

CASE 6: Determination of the voltage drop between Rumuadaolu 2 – Lulu Shipping Centre.

Recalling Equation (8)

$$V_{d_4} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{Number\ of\ conductor/phase \times 100}$$

$$V_{d_4} = \frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 26.244 \times 0.4}{0.1458 \times 100}$$

$$\frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 15.7464}{14.58}$$

$$\frac{1.732 \times (0.8176) \times 10.4976}{14.58} = \frac{14.865475}{14.58}$$

$$V_{d_4} = 1.1019579904$$

Where;

Length of the line section = 0.4km $V_{d_4} = 1.1019579904$

CASE 7: Determine of the receiving end voltage at Rumuadaolu 2 – Lulu Shipping Centre feeder.

$V_{R4} = Sending\ end\ voltage\ (Vs) - Voltage\ drop(V_{d4})$

$V_{R4} = 11000 - 1.019579904$

$V_{R4} = 10998.98042\,V$

$V_{R4} = 10998.98042\,V$

CASE 8: Determination of the percentage Voltage regulation between Rumuadaolu 2 – Lulu Shipping Centre feeder.

Recalling Equation (9)

% voltage regulation $= \frac{V_S - V_{R4}}{V_{R4}} \times 100\,\%$

$= \frac{11000 - 10998.98042}{10998.98042} \times 100\%$

$= \frac{1.01958}{10998.98042} \times 100\%$

% voltage regulation = 0.009269768297 ≈ 0.0093%

CASE 9: Determination of the reactive power of the load

KVA = 500, KW = 400

$\therefore$ KVAR = 300

Applying Pythagoras theorem

Analysis 5 (Bus 5 – 6) Lulu Shopping Centre - Chief Benson Street

CASE I:

Calculation of the distance between buses:

(Lulu Shopping Centre - Chief Benson Street feeder) = 0.5km

$\therefore$ Distance between (Bus 5 – 6) = 0.5km

Distance measured between (bus 5 – 6) with respect to resistance,

R in (Ω)

R = $0.20\,\Omega/km \times 0.5km$ R = 0.1Ω

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (3.4)**

$$X_0 = 0.1445\,\log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$$X_0 = 0.1445\,\log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$$

$$X_0 = 0.1445\,\log_{10}(2.2) + 0.0157$$

$$X_0 = 0.0652\ \Omega/km$$

CASE 2: For a distance measured of 0.5km,

$$X(Bus\ 5-6) = 0.0652\ \Omega/km \times 0.5km = 0.0326\,\Omega$$

CASE 3:

Hence, impendance between (bus 5 – 6) gives:

Z (bus 5 – 6) = (0.1 + j0.0326)Ω

Per-kilometer capacitive susceptance (b_0)

Then the capacitive susceptance is given as; **Recalling Equation (5)**

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} \cdot \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.5KM

Bus (5 – 6) = 3.509 $\times 10^{-6} \times \frac{1}{\Omega.km} \times 0.5 \left(\frac{1}{\Omega} or\ Simens\right)$

CASE 4: Determination of the load current (I_L) at Lulu Shopping Centre - Chief Benson Street feeder, while relying on the following condition.

(i) Power factor of the load (P.f) = 0.80
(ii) Transformer rating in KVA = 500
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation; **Recalling Equation (6)**

$$KVA \times p.f = KW$$

500×0.80 = 400. Active power = 400KW

From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}} = \frac{400}{1.732 \times 11 \times 0.80}$$

$$I_{L5} = \frac{400}{15.2416} = 26.24396389 \approx 26.244 Amps$$

CASE 5: Determination of the required number of conductor per phase but since load current; $I_{L5} = 5.2488\ Amps$

$$Number\ \ of\ \ conductor = \frac{Load\ \ current}{Current\ carrying\ capacity\ of\ conductor}$$

Thus, number of conductor = $\frac{26.244}{180} = 0.1458$

CASE 6: Determination of the voltage drop between Lulu Shopping Centre - Chief Benson Street.

Recalling Equation (8)

$$V_{d_5} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ \ line\ \text{section}}{Number\ of\ conductor / \ phase \times 100}$$

$$V_{d_5} = \frac{1.732 \times (0.8176) \times 26.244 \times 0.5}{0.1458 \times 100}$$

$$\frac{1.732 \times (0.8176) \times 13.122}{14.58}$$

$$\frac{18.58184375}{14.58}$$

$$V_{d_5} = 1.27497488\ \ V$$

Where;

Length of the line section = 0.5km

$$V_{d_5} = 1.27447488\ \ V$$

CASE 7: Determine of the receiving end voltage at Lulu Shopping Centre - Chief Benson Street feeder

$$V_{R5} = Sending\ end\ voltage\,(Vs) - Voltage\ drop\left(V_{d5}\right)$$

$$V_{R5} = 11000\ \ - 1.27447488$$

$$V_{R5} = 109998\ \ .72553\,V$$

CASE 8: Determination of the percentage Voltage regulation between Lulu Shopping Centre - Chief Benson Street feeder.

Recalling Equation (9)

% voltage regulation $= \frac{V_S - V_{R5}}{V_{R5}} \times 100\%$

$= \frac{11000 - 10998.72553}{10998.72553} \times 100\%$

$= \frac{1.27447}{10998.72553} \times 100\%$

% voltage regulation $= 0.011587433 \approx 0.012\%$

CASE 9: Determination of the reactive power of the load

KVA = 500, KW = 400

Applying Pythagoras theorem gives; **Recalling Equation (10)**

$KVAR = \sqrt{(KVA)^2 - (KW)^2} = 300$

$\text{Re}active\ power = 300KVAR$

ANALYSIS 6 (Bus 6 - 7) Chief Benson Street – MTN feeder

Calculation of the distance between buses:

(Chief Benson Street – MTN feeder) = 0.25km

Distance measured between (Bus 6 – 7) with resistance, R in (Ω) gives;

R = 0.20Ω/km × 0.25km = 0.05Ω

R = 0.05Ω

CASE 1:

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (4)**

$$X_0 = 0.1445\ \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$$X_0 = 0.1445\ \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$$

$$X_0 = 0.1445\ \log_{10}(2.2) + 0.0157$$

$$X_0 = 0.0652\ \Omega/km$$

CASE 2: For a distance measured of 0.25km,

$$X(Bus\ 6-7) = 0.0652\ \Omega/km \times 0.25km = 0.0163\,\Omega$$

CASE 3: Hence, impedance between (bus6 – 7) gives;

Z (Bus 6 – 7) = Z (Bus 6 – 7) (0.05 + j0.01603)Ω

Per-kilometer capacitive susceptance (b_0), thus, the capacitive susceptance is given as;

Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}\ b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

Bus (4 – 5) $= 3.509\times10^{-6}\times\dfrac{1}{\Omega.km}$

For distance measured of 0.25km

Bus (6 – 7) = $3.509\times10^{-6}\times\dfrac{1}{\Omega.km}\times0.25km=$

$0.87725\times10^{-6}\left(\dfrac{1}{\Omega} or\ Simens\right)$

CASE 4: Determination of the load current (I_L) at Chief Benson Street – MTN feeder Centre while relying on the following condition.

(i) Power factor of the load (P.f) = 0.80
(ii) Transformer rating in KVA = 100
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation; **Recalling Equation (6)**

$KVA\times p.f = KW$

100×0.80 = KW

KW = 400

∴ Active power = 80KW

From the load equation; **Recalling Equation (6)**

$I_L = \dfrac{KW}{\sqrt{3\times V\times p.f}} = \dfrac{400}{1.732\times11\times0.80} =$ \

$\dfrac{400}{15.2416} = 26.24396389 \approx 26.244 Amps$

$I_L = 26.244\,Amps$

CASE 5: Determination of the required number of conductor per phase but since $I_{L_6} = 26.244\,Amps$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Thus, number of conductor = $\dfrac{26.244}{180} = 0.1458 \approx 0.15$

CASE 6: Determination of the voltage drop between Chief Benson Street – MTN feeder. **Recalling Equation (8)**

$$V_{d_6} = \frac{\sqrt{3}\times(RCos\phi + \sin\phi)\times I_L\times length\ of\ line\ section}{\#of\ conductor/phase\times100}$$

$$V_{d_6} = \frac{1.732\times(0.272\times0.8+0.6)\times26.244\times0.25}{0.1458\times100}$$

$$\frac{9.290921875}{14.58}$$

$V_{d_6} = 0.0063723744\ \ V$

Where;

Length of the line section = 0.25km

$V_{d_6} = 0.0063723744$

CASE 7: Determine of the receiving end voltage at Chief Benson Street – MTN feeder

$V_{R6} = Sending\ voltage\ (Vs) - Voltage\ drop(V_{d6})$

$V_{R6} = 11000 - 0.0063723744$

$V_{R6} = 10999.99363\,V$

$V_{R6} = 10999.99363\,V$

CASE 8: Determination of the percentage Voltage regulation between Chief Benson Street – MTN feeder. **Recalling Equation (9)**

%voltage regulation $= \frac{V_S - V_{R6}}{V_{R6}} \times 100\%$

$= \frac{11000 - 10999.99363}{10999.99363} \times 100\%$

$= \frac{0.00637}{10999.99363} \times 100\%$

%voltage regulation = 0.00005790912444 ≈ 0.00006%

CASE 9: Determination of the reactive power of the load

KVA = 100, KW = 80

Recalling Equation (10)

$KVAR = \sqrt{(KVA)^2 - (KW)^2}$

$= \sqrt{(100)^2 - (80)^2} = \sqrt{10{,}000 - 6{,}400}$

$KVAR = \sqrt{3600} = 60$

$\therefore KVAR = 60$

Analysis 7: (Bus 7 – 8) (MTN - SBS Relief Feeder)

Calculation of the distance between buses:

(MTN - SBS Relief Feeder) = 0.5km

Distance between bus (7 – 8) = 0.5km

Distance measured between (bus 7 – 8) with respect to resistance, R in (Ω)

R $= 0.20\ \Omega/km \times 0.5km = 0.1$

R = 0.1Ω

CASE I:

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (4)**

$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$

$X_0 = 0.1445 \log_{10}(2.2) + 0.0157$

$X_0 = 0.0652\ \Omega/km$

CASE 2: For a distance measured of 0.5km,

$X(Bus\ 7-8) = 0.0652\ \Omega/km \times 0.5km = 0.0326\ \Omega$

CASE 3: Hence, impendance between (bus7 – 8) gives;

Z (Bus 7 – 8) = (0.1 + j0.0326)Ω

Per-kilometer capacitive susceptance (b_0), thus the capacitive susceptance is given as;

Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.5KM

Bus (7 – 8) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.5km$

Bus (7 – 8) = $1.7545 \left(\frac{1}{\Omega} or\ Simens \right)$

CASE 4: Determination of the load current (I_L) at MTN - SBS Relief Feeder, while relying on the following condition.

(i) Power factor of the load (P.f) = 0.80
(ii) Transformer rating in KVA = 500
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation; **Recalling Equation (6)**

$$KVA \times p.f = KW$$

500×0.80 = 400

∴ Active power = 400KW

From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}} = \frac{400}{1.732 \times 11 \times 0.80} =$$

$$\frac{400}{15.2416} = 26.24396389 \approx 26.244 Amps$$

$$I_{L7} = 26.244\ Amps$$

CASE 5: Determination of the required No. of conductor per phase but since $I_{L7} = 26.244\ Amps$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Thus, number of conductor = $\frac{26.244}{180} = 0.1458 \approx 0.15$

CASE 6: Determination of the voltage drop between MTN - SBS Relief Feeder.

Recalling Equation (8)

$$V_{d_7} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{Number\ of\ conductor/\ phase \times 100}$$

$$V_{d_7} = \frac{1.732 \times (0.8176) \times 26.244 \times 0.5}{0.1458 \times 100}$$

$$\frac{1.732 \times (0.8176) \times 13.122}{14.58}$$

Where;

Length of the line section = 0.5km

$$V_{d_7} = 1.27447488\ \ V$$

CASE 7: Determine of the receiving end voltage at MTN - SBS Relief Feeder

$$V_{R7} = Sending\ voltage\ (Vs) - Voltage\ drop (V_{d7})$$

$$V_{R7} = 11000\ - 0.010972735\ \ = 10998\ .72553\ V$$

$$V_{R7} = 10998\ .72553\ V$$

CASE 8: Determination of the percentage Voltage regulation between MTN - SBS Relief Feeder.

Recalling Equation (9)

% voltage regulation $= \frac{V_S - V_{R7}}{V_{R7}} \times 100\%$

$= \frac{11000 - 10998.72553}{10998.72553} \times 100\%$

$= \frac{1.27447}{10998.72553} \times 100\%$

%voltage regulation = 0.011587433 ≈ 0.012%

CASE 9: Determination of the reactive power of the load

KVA = 500, KW = 400

Applying Pythagoras theorem gives; **Recalling Equation (10)**

$$KVAR = \sqrt{(KVA)^2 - (KW)^2}$$

$$KVAR = \sqrt{(500)^2 - (400)^2}$$

$$KVAR = \sqrt{250{,}000 - 160{,}000} = \sqrt{90{,}000}$$

$$KVAR = 300$$

ANALYSIS 8 (Bus 8 – 9) SBS Relief – SBS Feeder

Calculation of the distance between buses:

(SBS Relief – SBS Feeder) = 0.57km

∴ Distance bus (8 – 9) = 0.57km

Distance measured between (bus 8 – 9) with respect to resistance,

R in (Ω)

R = $0.20\ \Omega/km \times 0.57\ km = 0.114$ ∴ R = 0.114Ω

CASE 1:

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation(4)**

$$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157 \approx 1km$$

$$X_0 = 0.1445 \log_{10}(2.2) + 0.0157$$

$$X_0 = 0.0652\ \Omega/km$$

CASE 2: For a distance measured of 0.57km,

$$X(Bus\ 8-9) = 0.0652\ \Omega/km \times 0.57\ km = 0.037164\ \Omega$$

$$X(Bus\ 8-9) = 0.037164\ \Omega$$

CASE 3:

The impedance between (bus8 – 9) gives;

Z (Bus 8 – 9) = (0.114 + j0.03716)Ω

Per-kilometer capacitive susceptance (b_0), thus the capacitance susceptance is given as;

Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{\Omega.kmj}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log(144.53)}$$

$$b_0 = \frac{7.58}{2.1599580} \times 10^{-6} = 3.509$$

$$= 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.57km

Bus (8 – 9) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.57km$

= $2.00013 \times 10^{-6}\left(\frac{1}{\Omega} or\ simens\right)$

CASE 4: Determination of load current (I_L) at SBS Relief – SBS Feeder while relying on the following condition.

(i) Power factor of the load (P.f) = 0.08
(ii) Transformer rating in KVA = 500
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation; **Recalling Equation (6)**

$$KVA \times p.f = KW$$

500×0.80 = 400KW

∴ Active power = 400KW

From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}}$$

$$I_L = \frac{400}{1.732 \times 11 \times 0.80}$$

$$I_L = \frac{400}{15.2416}$$

$$I_L = 26.24396389 \approx 26.244\ Amps$$

$$\therefore I_L = 26.244\ Amps$$

CASE 5:

Determination of the required number of conductor per phase but since $I_{L_8} = 26.244\ Amps$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Hence, number of conductor = $\frac{26.244}{180} = 0.1458 \approx 0.15$

CASE 6: Determination of the voltage drop between SBS Relief – SBS Feeder.

Recalling Equation (3.8)

$$V_{d_8} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{\#of\ conductor/phase \times 100}$$

$$V_{d_8} = \frac{1.732 \times (0.272 \times 0.8 \times 0.6) \times 26.244 \times 0.5}{0.1458 \times 100}$$

$$\frac{1.732 \times 0.81176 \times 14.95908}{14.58}$$

$$\frac{21.18330188}{14.58}$$

Where;

Length of the line section = 0.57km

$V_{d_8} = 1.452901364 \ V$

$V_{d_8} = 1.452901364 \ V$

CASE 7: Determination of the receiving end voltage at SBS Relief – SBS Feeder

$V_{R8} = Sending\ voltage\ (Vs) - Voltage\ drop(V_{d8})$

$V_{R8} = 11000 - 1.452901364 = 10998.5471V$

$V_{R8} = 10998.5471V$

CASE 8: Determination of the percentage Voltage regulation between SBS Relief – SBS Feeder.

Recalling Equation (9)

%voltage regulation = $\frac{V_S - V_{R8}}{V_{R8}} \times 100\%$

$= \frac{11000 - 10998.5471}{10998.5471} \times 100\%$

$= \frac{1.4529}{10998.5471} \times 100\%$

%voltage regulation = 0.013209926 ≈ 0.013%
= 0.013%

Case 9: Determination of the reactive power of the load

KVA = 500, KW = 400

Applying Pythagoras theorem gives; **Recalling Equation (10)**

$KVAR = \sqrt{(KVA)^2 - (KW)^2}$

$KVAR = \sqrt{500^2 - 400^2}$

$KVAR = 300$

ANALYSIS 9 (Bus 9 – 10) SBS – Zenith Bank

Calculation of the distance between buses:

(SBS – Zenith Bankfeeder) = $0.06km$

Distance (Bus 9 – 10) = 0.06km

Distance measured between (Bus 9 – 10) with respect to resistance,

R in (Ω)

R_{Bus}(Bus 9 – 10) = $0.20\ \Omega/km \times 0.06km = 0.012\ \Omega$

R_{Bus}(Bus 9 – 10) = 0.012Ω

CASE I:

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (4)**

$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$

$X_0 = 0.1445 \log_{10}(2.2) + 0.0157$

$X_0 = 0.0652 \approx 0.0652\ \Omega/km$

CASE 2: For a distance measured of 0.6km,

$X(Bus\ 9-10) = 0.0652\ \Omega/km \times 0.6km = 0.03912\ \Omega$

CASE 3:

Hence, impedance between (bus9 – 10) gives;

Z (Bus 9 – 10) = (0.12 + j0.03912Ω)
Per-kilometer capacitive susceptance (b_0), thus the capacitive susceptance is given as;
Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.6km

Bus (2 – 3) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$

Bus (9 – 10) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.6km = 2.1054 \times 10^{-6}\left(\frac{1}{\Omega} or\ Simens\right)$

Bus (9 – 10) = $2.1054 \times 10^{-6}\left(\frac{1}{\Omega} or\ Simens\right)$

CASE 4: Determination of the load current (I_L) at SBS – Zenith Bank while relying on the following condition.
(i) Power factor of the load (P.f) = 0.08
(ii) Transformer rating in KVA = 200
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From power equation; **Recalling Equation (6)**

$$KW = KVA \times p.f$$

KW = 200×0.80
KW = 160
∴ Active power = 160KW

From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}}$$

$$I_L = \frac{200}{1.732 \times 11 \times 0.80}$$

$$I_L = \frac{200}{15.2416} = 10.49758556 \approx 10.498 Amps$$

$$I_L = 10.498\ Amps$$

CASE 5: Determination of the required number of conductor per phase but since $I_{L_9} = 10.498\ Amps$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Hence, number of conductor = $\frac{10.498}{180} = 0.058322222 \approx 0.05832$

CASE 6: Determination of the voltage drop between SBS – Zenith Bank.
Recalling Equation (8)

$$V_{d_9} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{Number\ of\ conductor / phase \times 100}$$

$$V_{d_9} = \frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 10.498 \times 0.06}{0.25832 \times 100}$$

$$=\frac{1.732\times 0.8176\times 0.62988}{5.832}$$

$$=0.152942813V$$

Where;

Length of the line section = 0.06km

$$V_{d_9}=0.152942813\ V$$

$$V_{d_9}=0.152942813\ V$$

CASE 7: Determine of the receiving end voltage at SBS – Zenith Bank feeder

$$V_{R9}=Sending\ voltage\ (Vs)-Voltage\ drop\left(V_{d9}\right)$$

$$V_{R9}=11000-1.52942813=10999.84706\ V$$

$$V_{R9}=10999.84706\ V$$

CASE 8: Determination of the percentage Voltage regulation between SBS – Zenith Bank feeder.

Recalling Equation (9)

% voltage regulation= $\frac{V_S-V_{R9}}{V_{R9}}\times 100\%$

$$=\frac{11000-10999.84706}{10999.84706}\times 100\%$$

$$=\frac{0.15294}{10999.84706}\times 100\%$$

% voltage regulation = 0.01390382968 ≈ 0.0014%

CASE 9: Determination of the reactive power of the load

KVA = 200, KW = 400

Applying Pythagoras theorem; **Recalling Equation (10)**

$$KVAR=\sqrt{(KVA)^2-(KW)^2}$$

$$KVAR=\sqrt{(200)^2-(160)^2}$$

$$KVAR=\sqrt{40,000-25,600}$$

$$KVAR=\sqrt{14,400}=120$$

$$KVAR=120$$

Analysis 10 (Bus 10 – 11) Zenith – First Bank

Calculation of the distance between Buses:

(Zenith Bank– First Bank) = $0.04km$

∴ Distance (Bus 10 – 11) = 0.04km

Distance measured between (bus 10 – 11) $0.20\ \Omega/km\times 0.04km=0.0008\ \Omega$

CASE I

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (4)**

$$X_0=0.1445\log_{10}\left(\frac{DGMD}{R}\right)+0.0157\ \Omega/km$$

Where:

$$DGMD=1.100m$$

R= 0.5Ω

$$X_0=0.1445\log_{10}\left(\frac{1.100}{0.5}\right)+0.0157\ \Omega/km$$

$$X_0=0.1445\log_{10}(2.2)+0.0157$$

$$X_0=0.0652\ \Omega/km$$

CASE 2: For a distance measured of 0.04km,

$$X\left(Bus10-11\right)=0.0652\ \Omega/km\times 0.3km=0.002608\ \Omega$$

CASE 3:

Hence, impendance between (Bus 10 – 11) gives;

Z (Bus 10 – 11) = (0.0008+j0.002608)Ω

Per-kilometer capacitive susceptance (b_0), thus, the capacitance susceptance is given as;

Recalling Equation (5)

$$b_0=\frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)}\times 10^{-6}\cdot\frac{1}{(\Omega.km)}$$

$$b_0=\frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)}\times 10^{-6}=\frac{7.58}{\log(144.53)}$$

$$b_0=\frac{7.58}{2.1599580}\times 10^{-6}=3.509$$

$$b_0=3.509\times 10^{-6}\times\frac{1}{\Omega.km}$$

For a distance measured of 0.04km

Bus (10 – 11) = $3.509\times 10^{-6}\times\frac{1}{\Omega.km}\times 0.04km=0.14036\times 10^{-6}\left(\frac{1}{\Omega}or\ simene\right)$

CASE 4: Determination of load current (I_L) at Zenith – First Bank while relying on the following condition.

(i) Power factor of the load (P.f) = 0.08
(ii) Transformer rating in KVA = 200
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation; **Recalling Equation (6)**

$$KW=KVA\times p.f$$

KW = 200×0.80

KW = 160

∴ Active power = 160KW

From the load current equation; **Recalling Equation (7)**

$$I_L=\frac{KW}{\sqrt{3}\times V\times p.f}$$

$$I_L=\frac{160}{1.732\times 11\times 0.80}$$

$$I_{L_1}=\frac{160}{15.2416}=10.49758556\approx 10.498Amps$$

CASE 5: Determination of the required number of conductor per phase but since $I_{L_{10}}=10.498\,Amp$

$$Number\ of\ conductor=\frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Hence, number of conductor = $\frac{10.498}{180}=0.058322222\approx 0.058$

CASE 6: Determination of the voltage drop between Zenith – First Bank

Recalling Equation (3.8)

$$V_{d_{10}}=\frac{\sqrt{3}\times(RCos\phi+\sin\phi)\times I_L\times length\ of\ line\ section}{Number\ of\ conductor/phase\times 100}$$

$$V_{d_{10}}=\frac{1.732\times(0.272\times 0.8+0.6)\times 10.298\times 0.04}{0.058\times 100}$$

$$=\frac{0.41021793}{5.8}=0.070726343V$$

Where: length of the line section = 0.04km

$V_{d_{10}}=0.070726343\ V$

CASE 7: Determine of the receiving end voltage at Zenith – First Bank feeder

$V_{R10} = Sending\ voltage\ (Vs) - Voltage\ drop(V_{d10})$

$V_{R10} = 11000 - 070726343 = 90999.92927\,V$

$V_{R10} = 90999.92927\,V$

CASE 8: Determination of the percentage Voltage regulation between Zenith – First Bank feeder.

Recalling Equation (9)

% voltage regulation = $\frac{V_S - V_{R10}}{V_{R10}} \times 100\,\%$

$= \frac{11000 - 10999.92927}{10999.92927} \times 100\%$

$= \frac{0.07073}{10999.929217} \times 100\%$

%voltage regulation = 0.0000064300045 ≈ 0.0006%

CASE 9: Determination of the reactive power of the load

KVA = 200, KW = 160

Applying Pythagoras theorem gives; **Recalling Equation (10)**

$KVAR = \sqrt{(KVA)^2 - (KW)^2}$

$KVAR = \sqrt{(200)^2 - (160)^2}$

$KVAR = 120$

ANALYSIS 11 (Bus 11 - 12) First Bank – Sterling Bank

Calculation of the distance between Buses:

(First Bank – Sterling Bank) = $0.2km$

∴ Distance (Bus 11– 12) = 0.2km

Distance measured between (bus 11 – 12) with respect to the resistance, R in(Ω)

$R_{Bus}(11-12) = 0.20\,\Omega/km \times 0.2km = 0.04\Omega$

$\therefore R_{Bus}(11-12) = 0.04\Omega$

CASE 1:

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as: **Recalling Equation (4)**

$X_0 = 0.1445\,\log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\,\Omega/km$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$X_0 = 0.1445\,\log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\,\Omega/km$

$X_0 = 0.1445\,\log_{10}(2.2) + 0.0157$

$X_0 = 0.0652\,\Omega/km$

CASE 2: For a distance measured of 0.6km,

$X(Bus\ 11-12) = 0.0652\,\Omega/km \times 0.2km = 0.0130\,\Omega$

CASE 3:

Hence, impedance between (Bus 11 – 12) (First Bank – Sterling Bank) gives:

Z (Bus 11 – 12) = (0.04 + j0.01304)Ω

Per-kilometer capacitive susceptance (b_0), hence the capacitive susceptance is given as:

Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.2km

Bus (11 – 12) $= 3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.2km$

$= 0.7018 \times 10^{-6}\left(\frac{1}{\Omega} or\ Simens\right)$

CASE 4: Determination of the load current (I_L) at First Bank – Sterling Bank while relying on the following condition.

(i) Power factor of the load (P.f) = 0.80
(ii) Transformer rating in KVA = 100
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation; **Recalling Equation (6)**

$$KVA \times p.f = KW$$

100×0.80 = 80

∴ Active power = 80KW

From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}} = \frac{80}{1.732 \times 11 \times 0.80} = \frac{80}{15.2416}$$

$$I_L = 5.248792778 \quad \approx 5.249\ Amps$$

CASE 5: Determination of the required number of conductor per phase but since $I_{L_{11}} = 5.249\ Amps$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Thus, number of conductor = $\frac{5.249}{180} = 0.029161111 \approx 0.0292$

CASE 6: Determination of the voltage drop between First Bank – Sterling Bank.

Recalling Equation (3.8)

$$V_{d_{11}} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{Number\ of\ conductor / phase \times 100}$$

$$V_{d_{11}} = \frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 5.249 \times 0.2}{0.0292 \times 100}$$

$$= \frac{1.025531983}{2.92}$$

Where;

Length of the line section = 0.2km

$$V_{d_{11}} = 0.351209583\ V$$

$$V_{d_{11}} = 0.351209583\ V$$

CASE 7: Determine of the receiving end voltage at First Bank – Sterling Bank

$$V_{R11} = Sending\ voltage\ (Vs) - Voltage\ drop(V_{d11})$$

$$V_{R11} = 11000 - 0.351209583$$

$$V_{R11} = 10999.64879\ V$$

CASE 8: Determination of the percentage Voltage regulation between First Bank – Sterling Bank feeder. **Recalling Equation (3.9)**

%voltage regulation $= \frac{V_S - V_{R11}}{V_{R11}} \times 100\,\%$

$= \frac{11000 - 10999.64879}{10999.64879} \times 100\%$

$= \frac{0.35121}{10999.64879} \times 100\%$

%voltage regulation = 0.003192920126 ≈ 0.0032%

CASE 9: Determination of the reactive power of the load

KVA = 100, KW = 80

Applying Pythagoras theorem; **Recalling Equation (10)**

$KVAR = \sqrt{(KVA)^2 - (KW)^2}$ $KVAR = \sqrt{(100)^2 - (80)^2}$

$KVAR = \sqrt{10000 - 6400}$

$KVAR = \sqrt{3,600} = 60$

$\therefore$ Active power = 60KVAR

Analysis 12 (Bus 12 – 13) Sterling Bank - Ebony Junction

CASE I:

Calculation of the distance between buses:

(Sterling Bank - Ebony Junction) = 0.3km

Distance between bus (12 – 13) = 0.3km

Distance measured between (bus 12 – 13) with respect to resistance, R in (Ω)

R = $0.20\,\Omega/km \times 0.3km$

R = 0.3Ω

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (4)**

$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$

$X_0 = 0.1445 \log_{10}(2.2) + 0.0157$

$X_0 = 0.0652\ \Omega/km$

CASE 2: For a distance measured of 0.3km,

$X(Bus\ 12 - 13) = 0.0652\ \Omega/km \times 0.3km = 0.01956\ \Omega$

CASE 3:

Hence, impedance between (Bus 12 – 13) gives;

Z (Bus 12 – 13) = (0.1 + j0.01956)Ω

Per-kilometer capacitive susceptance (b_0), thus the capacitive susceptance gives;

Recalling Equation (5)

$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.3km

Bus (12 – 13) $= 3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.3km \left(\frac{1}{\Omega} or\ Simens\right)$

$= 1.0527 \times 10^{-6} \left(\frac{1}{\Omega} or\ Simens\right)$

CASE 4: Determination of the load current (I_L) at Sterling Bank - Ebony Junction feeder, while relying on the following condition.

(i) Power factor of the load (P.f) = 0.80
(ii) Transformer rating in KVA = 500
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined?

From the power equation; **Recalling Equation (6)**

$$KVA \times p.f = KW$$

500×0.80 = 400

∴ Active power = 400KW

From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}} = \frac{400}{1.732 \times 11 \times 0.80}$$

$$I_L = \frac{400}{15.2416} = 26.24396389 \approx 26.244 Amps$$

CASE 5: Determination of the required number of conductor per phase but since

$$I_{L12} = 5.2488\ Amps$$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Thus, number of conductor $= \frac{26.244}{180} = 0.1458$

CASE 6: Determination of the voltage drop between Sterling Bank - Ebony Junction.

Recalling Equation (3.8)

$$V_{d_{12}} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{Number\ of\ conductor / phase \times 100}$$

$$V_{d_{12}} = \frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 26.244 \times 0.3}{0.1458 \times 100}$$

$$V_{d_{12}} = \frac{1.732 \times 0.8176 \times 7.8732}{14.58}$$

$$V_{d_{12}} = 0.764684928\ V$$

Where;

Length of the line section = 0.3km

$$V_{d_{12}} = 0.764684928\ V$$

CASE 7: Determine of the receiving end voltage at Sterling Bank - Ebony Junction feeder

$$V_{R12} = Sending\ voltage\ (Vs) - Voltage\ drop (V_{d12})$$

$$V_{R12} = 11000 - 0.764684928$$

$$V_{R12} = 10999.23532\ V$$

CASE 8: Determination of the percentage Voltage regulation between Sterling Bank - Ebony Junction feeder. **Recalling Equation (3.9)**

%voltage regulation $= \frac{V_S - V_{R12}}{V_{R12}} \times 100\,\%$

$$= \frac{11000 - 10999.23532}{10999.23532} \times 100\%$$

$$= \frac{0.76468}{10999.23532} \times 100\%$$

%voltage regulation = 0.00695211965 ≈ 0.007%

CASE 9: Determination of the reactive power of the load
KVA = 500, KW = 400
Applying Pythagoras theorem gives; **Recalling Equation (10)**

$$KVAR = \sqrt{(KVA)^2 - (KW)^2} = 300$$

$$\therefore \text{Re}\,active\ power = 300KVAR$$

ANALYSIS 13 (Bus 13 - 14) Ebony Junction – Eco Bank Feeder
CASE 1: Calculation of the distance between buses:
(Ebony Junction – Eco Bank Feeder) = 0.45km
Distance measured between Bus (13 – 14) with respect to resistance, R in (Ω) gives;
R_{Bus} (13-14) = 0.20Ω/km × 0.45km = 0.09Ω
Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (4)**

$$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$$

Where;

$DGMD = 1.100m$, R= 0.5Ω

$$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$$

$$X_0 = 0.1445 \log_{10}(2.2) + 0.0157$$

$$X_0 =$$

CASE 2: For a distance measured of 0.3km,

$$X(Bus\ 13 - 14) = 0.0652\ \Omega/km \times 0.45km = 0.02934\ \Omega$$

CASE 3:
Hence, impendance between (Bus 13 – 14) gives;
Z (bus 13 – 14) = (0.09 + j0.02934)Ω
Per-kilometer capacitive susceptance (b_0), thus, the capacitive susceptance is given as;
Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

$b_0 = 3.509\times10^{-6}\times\frac{1}{\Omega.km}$

For distance measured of 0.45km

Bus (13 – 14) = $3.509\times10^{-6}\times\frac{1}{\Omega.km}\times0.25km = 0.87725\ \times10^{-6}\left(\frac{1}{\Omega} or\ Simens\right)$

CASE 4: Determination of the load current (I_L) at Ebony Junction – Eco Bank Feeder while relying on the following condition.

(i) Power factor of the load (P.f) = 0.80
(ii) Transformer rating in KVA = 200
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation; **Recalling Equation (6)**

$KVA\times p.f = KW$

200×0.80 = 160

Active power = 160KW

From the load equation; **Recalling Equation (7)**

$I_L = \frac{KW}{\sqrt{3\times V\times p.f}}$

$I_L = \frac{160}{1.732\times11\times0.80}$

$I_L\ \frac{160}{15.2416}$

$I_L = 10.49758556\ \approx 10.498\ Amps$

$I_L = 10.498\ Amps$

CASE 5: Determination of the required number of conductor per phase but since $I_{L_{13}} = 10.498\ Amps$

$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$

Thus, number of conductor = $\frac{210.498}{180} = 0.058322222 \approx 0.0583$

CASE 6: Determination of the voltage drop between Ebony Junction – Eco Bank Feeder. **Recalling Equation (8)**

$V_{d_{13}} = \frac{\sqrt{3}\times(RCos\phi+\sin\phi)\times I_L\times length\ of\ line\ section}{Number\ of\ conductor/phase\times100}$

$V_{d_{13}} = \frac{1.732\times(0.272\times0.8+0.6)\times10.498\times0.95}{0.0583\times100}$

$V_{d_{13}} = \frac{1.732\times0.8176\times4.7241}{5.83}$

$\frac{6.689718645}{5.83}$

$V_{d_{13}} = 0.0009875461\ \ 5V$

CASE 7: Determine of the receiving end voltage at Ebony Junction – Eco Bank Feeder

$V_{R13} = Sending\ voltage\ (Vs) - Voltage\ drop(V_{d13})$

$V_{R13} = 11000\ -1.197464605$

$V_{R13} = 10998\ .85254\ V$

CASE 8: Determination of the percentage Voltage regulation between Ebony Junction – Eco Bank Feeder. **Recalling Equation (9)**

%voltage regulation = $\frac{V_S - V_{R13}}{V_{R13}}\times100\%$

= $\frac{11000-10998.85254}{10998.85254}\times100\%$

$$= \frac{1.14746}{10998.85254} \times 100\%$$

%voltage regulation = 0.010432542 ≈ 0.01%

CASE 9: Determination of the reactive power of the load

KVA = 200, KW = 160

Applying Pythagoras theorem; **Recalling Equation (10)**

$$KVAR = \sqrt{(KVA)^2 - (KW)^2}$$

$$\sqrt{(200)^2 - (160)^2} = \sqrt{40,000 - 25,600} \; . \; KVAR = \sqrt{14400} = 120$$

Reactive power $= 120KVAR$

Analysis 14 (Bus 14 –15) Eco Bank - The Promise Feeder

CASE I:

Calculation of the distance between Buses:

(Eco Bank - The Promise) = 0.2km

Distance between bus (14 – 15) = 0.2km

Distance measured between (bus 14 – 15) with respect to resistance, R in (Ω)

R_{Bus} (14 - 15) = $0.20\,\Omega/km \times 0.2km = 0.04\Omega$

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (4)**

$$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157 \; \Omega/km$$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157 \; \Omega/km$$

$$X_0 = 0.1445 \log_{10}(2.2) + 0.0157$$

$$X_0 = 0.0652 \; \Omega/km$$

CASE 2: For a distance measured of 0.2km,

$$X(Bus\ 14 - 15) = 0.0652 \; \Omega/km \times 0.2km = 0.01304 \; \Omega$$

CASE 3:

Hence, impendance between (Bus 14 – 15) gives;

Z (Bus 14 – 15) = (0.04 + j0.01304)Ω

Per-kilometer capacitive susceptance (b_0), thus the capacitive susceptance gives ;

Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega . km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega . km}$$

For a distance measured of 0.2km

Bus (14 – 15) $= 3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.2km$

$$= 0.7018 \times 10^{-6} \left(\frac{1}{\Omega} or\ Simens \right)$$

CASE 4: Determination of the load current (I_L) at Eco Bank - The Promise Feeder, while relying on the following condition.

(i) Power factor of the load (P.f) = 0.80
(ii) Transformer rating in KVA = 200
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation; **Recalling Equation (6)**

$KVA \times p.f = KW$

200×0.80 = 160

∴ Active power = 160KW

$I_L = 10.498\ Amps$

CASE 5: Determination of the required number of conductor per phase but since $I_{L14} = 10.498\ Amps$

Number of conductor = 0.0583

CASE 6: Determination of the voltage drop between Eco Bank - The Promise.

Recalling Equation (8)

$$V_{d_{14}} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{Number\ of\ conductor / phase \times 100}$$

$$V_{d_{14}} = \frac{1.732 \times 0.8176 \times 2.0996}{0.0583}$$

$$\frac{2.51063964}{5.83}$$

$V_{d_{14}} = 0.351812001\ V$

Where: $V_{d_{14}} = 0.351812001 V$

Length of the line section = 0.2km

$V_{d_{14}} = 0.351812001\ V$

CASE 7: Determine of the receiving end voltage at Eco Bank - The Promise Feeder

$V_{R14} = Sending\ voltage\ (Vs) - Voltage\ drop (V_{d4})$

$V_{R14} = 11000 - 0.31812001 = 10999.64819\, V$

$V_{R14} = 10999.64819\, V$

CASE 8: Determination of the percentage Voltage regulation between Eco Bank - The Promise Feeder. **Recalling Equation (9)**

%voltage regulation $= \frac{V_S - V_{R14}}{V_{R14}} \times 100\%$

$$= \frac{11000 - 10999.64819}{10999.64819} \times 100\%$$

$$= \frac{0.35181}{10999.64819} \times 100\%$$

%voltage regulation = 0.00319837502 ≈ 0.0032%

CASE 9: Determination of the reactive power of the load

KVA = 500, KW = 400

Applying Pythagoras theorem gives; **Recalling Equation (10)**

$KVAR = \sqrt{(KVA)^2 - (KW)^2}$

$KVAR = \sqrt{(200)^2 - (160)^2} = 120$

∴Reactive power = 120KVAR

ANALYSIS 15 BUS (15 – 16) The Promise – Fidelity Bank Feeder

CASE I:

Calculation of the distance between Buses:
(The Promise – Fidelity Bank Feeder) = 0.1km
Distance measured between (Bus 15 – 16) with respect to resistance, R in (Ω)
R_{Bus} (15 - 16) = $0.20\,\Omega/km \times 0.1km = 0.02\Omega$

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (3.4)**

$$X_0 = 0.1445\,\log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$$

Where;

$$DGMD = 1.100m$$

R= 0.5Ω

$$X_0 = 0.1445\,\log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157$$

$$X_0 = 0.1445\,\log_{10}(2.2) + 0.0157$$

$$X_0 = 0.0652\ \Omega/km$$

CASE 2: For a distance measured of 0.1km,

$$X(Bus\ 15-16) = 0.0652\ \Omega/km \times 0.1km = 0.163\Omega$$

$$X(Bus\ 15-16) = 0.0652\Omega$$

CASE 3:
The impedance between (bus 15 – 16) gives;
Z (bus 15 – 16) = (0.02 + j0.00652)Ω
Per-kilometer capacitive susceptance (b_0), thus the capacitance susceptance is given as;
Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} \cdot \frac{1}{\Omega.kmj}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log(144.53)}$$

$$b_0 = \frac{7.58}{2.1599580} \times 10^{-6} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.1km

Bus (15 – 16) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.1km$

$$= 3.509 \times 10^{-6} \times \left(\frac{1}{\Omega} or\ Simens\right)$$

CASE 4: Determination of load current (I_L) at The Promise – Fidelity Bank Feeder while relying on the following condition.
(i) Power factor of the load (pf) = 0.08
(ii) Transformer rating in KVA = 100
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined?
From the power equation; **Recalling Equation (6)**

$$KVA \times p.f = KW$$

100×0.80 = 80KW
Active power = 80KW
From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}} = \frac{80}{1.732 \times 11 \times 0.80} = \frac{80}{1.5.2416}$$

$$I_L = 5.248792778 \approx 5.249\ Amps$$

CASE 5:

Determination of the required number of conductor per phase but since $I_{L_{15}} = 5.249\ Amps$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Hence, number of conductor = $\frac{5.249}{180} = 0.029161111 \approx 0.0292$

CASE 6: Determination of the voltage drop between The Promise – Fidelity Bank Feeder. **Recalling Equation (8)**

$$V_{d_{15}} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{Number\ of\ conductor / phase \times 100}$$

$$V_{d_{15}} = \frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 5.249 \times 0.1}{0.0292 \times 100}$$

$$V_{d_{15}} = \frac{0.512765991}{2.92}$$

$$V_{d_{15}} = 0.175604791$$

CASE 7: Determination of the receiving end voltage at The Promise – Fidelity Bank Feeder

$$V_{R15} = Sending\ voltage\ (Vs) - Voltage\ drop\ (V_{d15})$$

$$V_{R15} = 11000 - 0.175604791 = 10999.97805$$

$$V_{R15} = 10999.97805\ V$$

CASE 8: Determination of the percentage Voltage regulation between The Promise – Fidelity Bank Feeder.
Recalling Equation (9)

%voltage regulation = $\frac{V_S - V_{R15}}{V_{R15}} \times 100\%$

= $\frac{11000 - 10999.8244}{10999.8244} \times 100\%$

= $\frac{0.1756}{10999.8244} \times 100\%$

%voltage regulation = 0.00159689121 ≈ 0.0002%

= 0.02%

Case 9: Determination of the reactive power of the load

KVA = 100, KW = 80

Applying Pythagoras theorem; **Recalling Equation (10)**

$$KVAR = \sqrt{(KVA)^2 - (KW)^2}$$

$$KVAR = \sqrt{100^2 - 80^2}$$

$$KVAR = \sqrt{3,600}$$

∴ Reactive power = $60KVAR$

ANALYSIS 16 (Bus 16 – 17) Fidelity Bank – Rumuokwuta I Feeder

CASE I:

Calculation of the distance between buses;

(Fidelity Bank – Rumuokwuta I feeder) = 0.75km

Distance between bus (16 – 17) with respect to the resistance, R in (Ω)

= $R_{Bus} = (16 - 17) =$

$$0.20\ \Omega/km \times 0.75\ km = 0.15\Omega$$

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is thus; **Recalling Equation (4)**

$$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$$

Where;

$$DGMD = 1.100m$$

R= 0.5Ω

$$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$$

$$X_0 = 0.1445 \log_{10}(2.2) + 0.0157$$

$$X_0 = 0.0652 \approx 0.0652\ \Omega/km$$

CASE 2: For a distance measured of 0.75km,

$$X(bus\ 16-17) = 0.0652\ \Omega/km \times 0.75km = 0.0489\,\Omega$$

CASE 3:

Hence, impedance between (Bus 16 – 17) gives;

Z (Bus 16 – 17) = 0.12 + j0.0489Ω

Per-kilometer capacitive susceptance (b_0), thus the capacitive susceptance is given as;

Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.75km

Bus (16 – 17) $= 3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.75km$

$= 0.263175 \times 10^{-6}\left(\frac{1}{\Omega} or\ simens\right)$ **CASE 4:** Determination of the load current (I_L) at Fidelity Bank – Rumuokwuta I,while relying on the following condition.

(i) Power factor of the load (P.f) = 0.08
(ii) Transformer rating in KVA = 500
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined

From the power equation; **Recalling Equation (6)**

$$KVA \times p.f = KW$$

500×0.80 = 400

∴ Active power = 400KW

From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}} = \frac{400}{1.732 \times 11 \times 0.80} = \frac{400}{15.2416}$$

$$I_L = 26.24396389 \approx 26.244\ Amps$$

CASE 5: Determination of the required number of conductor per phase but since $I_{L_{16}} = 26.244\, Amps$

$$Number\ of\ \ conductor = \frac{Load\ \ current}{Current\ \ carrying\ \ capacity\ of\ conductor}$$

Hence, number of conductor = $\frac{26.244}{180} = 0.1458$

CASE 6: Determination of the voltage drop between Fidelity Bank – Rumuokwuta I

Recalling Equation (8)

$$V_{d_{16}} = \frac{\sqrt{3}\times(RCos\phi + \sin\phi)\times I_L \times length\ of\ \ line\ section}{Number\ of\ conductor/\ phase\times 100}$$

$$V_{d_{16}} = \frac{1.732\times(0.272\times 0.8 + 0.6)\times 26.244\times 0.75}{0.1458\times 100}$$

$$= \frac{27.87276563}{14.58}$$

$$V_{d_{16}} = 1.91171232\ \ V$$

Where: Length of the line section = 0.75km

$V_{d_{16}} = 1.91171232\ \ V$

CASE 7: Determine of the receiving end voltage at Fidelity Bank – Rumuokwuta Ifeeder.

$$V_{R16} = Sending\ voltage\ (Vs) - Voltage\ drop(V_{d16})$$

$$V_{R16} = 11000\ - 1.91171232\ \ = 10998\ .08829\, V$$

CASE 8: Determination of the percentage Voltage regulation between Fidelity Bank – Rumuokwuta I.

Recalling Equation (3.9)

%voltage regulation $= \frac{V_S - V_{R16}}{V_{R16}} \times 100\,\%$

$$= \frac{11000 - 10998.08829}{10998.08829}\times 100\%$$

$$= \frac{1.9117}{10998.08829}\times 100\%$$

%voltage regulation = 0.001496365875≈ 0.0174%

CASE 9: Determination of the reactive power of the load

KVA = 500, KW = 400

Applying Pythagoras theorem; **Recalling Equation (10)**

$$KVAR = \sqrt{(KVA)^2 - (KW)^2}$$

$$KVAR = \sqrt{(500)^2 - (400)^2}$$

$$KVAR = \sqrt{250{,}000 - 160{,}000}$$

$$KVAR = \sqrt{90{,}000} = 300$$

$$KVAR = 300$$

Analysis 17 (Bus 17 – 18) Rumuokwuta I – Multi-net

CASE I

Calculation of the distance between buses;

(Rumuokwuta I – Multi-net feeder) = 1.05km

Distance between (Bus 17 – 18) with respect to the resistance, R in (Ω)

$R_{Bus} = (17 - 18) = 0.20\ \Omega/km \times 1.05\ km = 0.21\Omega$

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; Recalling Equation (4)

$$X_0 = 0.1445\ \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$

$X_0 = 0.1445 \log_{10}(2.2) + 0.0157$

$X_0 = 0.0652\ \Omega/km$

CASE 2: For a distance measured of 0.105km,

$X(Bus17-18) = 0.0652\ \Omega/km \times 0.105\,km = 0.006846\ \Omega$

$X(Bus17-18) = 0.006846\ \Omega$

CASE 3: Hence,impedance between (Bus 17 – 18) gives;

Z (Bus 17 – 18) = (0.21+j0.006846)Ω

Per-kilometer capacitive susceptance (b_0), thus the capacitance susceptance;

Recalling Equation (3.5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} \cdot \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log(144.53)}$$

$$b_0 = \frac{7.58}{2.1599580} \times 10^{-6} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

for a distance measured of 0.105km

Bus (17 – 18) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.105km$

$= 0.368445\ \times 10^{-6}\left(\frac{1}{\Omega} or\, simens\right)$

CASE 4: Determination of load current (I_L) at Rumuokwuta I – Multi-net Feeder while relying on the following condition.

(i) Power factor of the load (P.f) = 0.08
(ii) Transformer rating in KVA = 500
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined?

From the power Equation; **Recalling Equation (6)**

$KVA \times p.f = KW$

500×0.80 = 80

Active power = 80KW.

From the load current Equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3} \times V \times p.f} = \frac{80}{1.732 \times 11 \times 0.80} =$$

$$\frac{400}{15.2416} = 5.248792778$$

$I_L = \approx 5.249\ Amps$

CASE 5: Determination of the required number of conductor per phase but since $I_{L_{17}} = 26.244\ Amps$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Thus, number of conductor = $\frac{26.244}{180} = 0.1458$

CASE 6: Determination of the voltage drop between Rumuokwuta I – Multi-net Feeder. **Recalling Equation (8)**

$$V_{d_{17}} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ \ line\ section}{Number\ of\ conductor /\ phase \times 100}$$

$$V_{d_{17}} = \frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 26.244 \times 1.05}{0.1458 \times 100}$$

$$V_{d_{17}} = \frac{1.732 \times 0.8176 \times 27.5562}{14.58}$$

$$V_{d_{17}} = \frac{39.02187188}{14.58}$$

$V_{d_{17}} = 2.676397248\ \ V$

CASE 7: Determine of the receiving end voltage at Rumuokwuta I – Multi-net feeder

$V_{R17} = Sending\ voltage\ (Vs) - Voltage\ drop(V_{d17})$

$V_{R17} = 11000\ - 2.676397248\ \ = 10997\ .3236\ V$

$V_{R17} = 10997\ .3236\ V$

CASE 8: Determination of the percentage Voltage regulation between Rumuokwuta I – Multi-net feeder. **Recalling Equation (9)**

%voltage regulation = $\frac{V_S - V_{R17}}{V_{R17}} \times 100\%$

= $\frac{11000 - 10997.3236}{10997.3236} \times 100\%$

= $\frac{2.6764}{10997.3236} \times 100\%$

%voltage regulation = 0.02433683≈ 0.02%

CASE 9: Determination of the reactive power of the load

KVA = 100, KW = 80

Applying Pythagoras theorem; **Recalling Equation (10)**

$$KVAR = \sqrt{(KVA)^2 - (KW)^2}$$

$$KVAR = \sqrt{(100)^2 - (80)^2}$$

$$KVAR = \sqrt{10{,}000 - 6{,}400}$$

$$KVAR = \sqrt{36{,}000} = 60$$

Reactive power = 60KVAR

ANALYSIS 18 (Bus 18 – 19) Multi-Net – Ejorr Ville Estate Feeder

CASE 1:

Calculation of the distance between buses;

(Multi-Net – Ejorr Ville Estate feeder) = 0.7km

Distance between bus (18 – 19) with respect to the resistance, R in (Ω)

$R_{Bus} = (18 - 19) = 0.20\ \Omega/km \times 0.7\ km = 0.14\Omega$

Per – Kilometer reactance (X_0) in (Ω/km)

The Per – Kilometer reactance, X_0 is given as; **Recalling Equation (4)**

$$X_0 = 0.1445\ \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$

$X_0 = 0.0652\ \Omega/km$

CASE 2: For a distance measured of 0.7km,

$X(Bus\ 18-19) = 0.0652\ \Omega/km \times 0.7km = 0.04564\ \Omega$

CASE 3:
Hence, impedance between (Bus 18 – 19) gives;
Z (Bus 18 – 19) = 0.14 + j0.04564Ω
Per-kilometer capacitive susceptance (b_0), thus the capacitive susceptance;
Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.7km

Bus (18 – 19) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.7km$

$= 2.4563 \times 10^{-6}\left(\frac{1}{\Omega} or\ Simens\right)$

CASE 4: Determination of the load current (I_L) at Multi-Net – Ejorr Ville Estate while relying on the following condition.
(i) Power factor of the load (P.f) = 0.80
(ii) Transformer rating in KVA = 500
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined?
From the power equation; **Recalling Equation (6)**

$KVA \times p.f = KVA$

500×0.80 = 400
Active power = 400KW.
From the load current equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}} = \frac{400}{1.732 \times 11 \times 0.80} = \frac{400}{15.2416}$$

$I_L = 26.244 Amps$

CASE 5: Determination of the required number of conductor per phase but since $I_{L_{18}} = 26.244\ Amps$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Hence, number of conductor = $\frac{26.244}{180} = 0.1458$

CASE 6: Determination of the voltage drop between Multi-Net – Ejorr Ville Estate;
Recalling Equation (8)

$$V_{d_{18}} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{Number\ of\ conductor / phase \times 100}$$

$$V_{d_{18}} = \frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 26.244 \times 0.4}{0.1458 \times 100}$$

$$V_{d_{18}} = \frac{1.732 \times 0.8176 \times 18.3705}{14.5}$$

$$V_{d_{18}} = \frac{26.01415643}{14.58} = 1.794079753$$

$$V_{d_{18}} = 1.794079753 \quad V$$

CASE 7: Determine of the receiving end voltage at Multi-Net – Ejorr Ville Estate feeder.

$V_{R18} = Sending\ voltage\ (Vs) - Voltage\ drop (V_{d18})$

$V_{R18} = 11000 - 1.794079753$

$V_{R18} = 10998.20592\ V$

CASE 8: Determination of the percentage Voltage regulation between Multi-Net – Ejorr Ville Estate feeder.

Recalling Equation (9)

%voltage regulation = $\frac{V_S - V_{R18}}{V_{R18}} \times 100\%$

$= \frac{11000 - 10998.20592}{10998.20592} \times 100\%$

$= \frac{1.79408}{10998.20592} \times 100\%$

%voltage regulation = 0.016312478 ≈ 0.02%

CASE 9: Determination of the reactive power of the load

KVA = 500, KW = 400

Applying Pythagoras theorem; **Recalling Equation (10)**

$KVAR = \sqrt{(KVA)^2 - (KW)^2} = 400$

$KVAR = 400$

Reactive power = 400KVAR

Analysis 19(Bus 19 – 20) Multi-Net - Sobaz filling Station

CASE I:

Calculation of the distance between buses:

(Multi-Net - Sobaz filling Stationfeeder) = 0.3km

Distance measured between Bus (19 – 20) with respect to resistance, R in (Ω)

R_{Bus} (19 – 20) R = $0.20\ \Omega/km \times 0.3km = 0.06\Omega$

Per – Kilometer reactance (X_0) is thus; **Recalling Equation (4)**

$$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$$

Where;

$DGMD = 1.100m$

R= 0.5Ω

$$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$$

$X_0 = 0.0652\ \Omega/km$

CASE 2: For a distance measured of 0.3km,

$X(Bus\ 19 - 20) = 0.0652\ \Omega/km \times 0.3km = 0.01956\ \Omega/km$

$X(Bus\ 19 - 20) = 0.01956\ \Omega/km$

CASE 3:

Hence, impendance between (Bus 19 – 20) gives;

Z (Bus 19 – 20) = (0.06 + j0.01956)Ω

Per-kilometer capacitive susceptance (b_0), thus the capacitive susceptance;

Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For a distance measured of 0.3km

Bus (19 – 20) = $3.509 \times 10^{-6} \times \frac{1}{\Omega.km} \times 0.3km$

Bus (19 – 20) = $1.0527 \times 10^{-6} \quad \left(\frac{1}{\Omega} or\ Simens\right)$

CASE 4: Determination of the load current (I_L) at Multi-Net - Sobaz filling Stationfeeder, while relying on the following condition.

(i) Power factor of the load (P.f) = 0.80
(ii) Transformer rating in KVA = 200
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined?

From the power equation; **Recalling Equation (6)**

$$KVA \times p.f = KW$$

200×0.80 = 160

∴ Active power = 160KW.

From the load current equation, **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}} = \frac{160}{1.732 \times 11 \times 0.80} = \frac{160}{15.2416}$$

$$\therefore I_L = 10.49758556 \quad \approx 10.498\ Amps$$

CASE 5: Determination of the required number of conductor per phase but since

$$I_{L19} = 10.498\ Amps$$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

Thus, number of conductor = $\frac{10.294}{180} = 0.058322222 \approx 0.0583$

CASE 6: Determination of the voltage drop between Multi-Net - Sobaz filling Station.

Recalling Equation (3.8)

$$V_{d_{19}} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{Number\ of\ conductor / phase \times 100}$$

$$V_{d_{19}} = \frac{1.732 \times (0.272) \times 10.498 \times 0.3}{0.05832 \times 100}$$

$$\frac{1.732 \times 0.8176 \times 3.1494}{5832}$$

$$\frac{4.45981243}{5.832}$$

$$V_{d_{19}} = 0.764714065\ V$$

CASE 7: Determine of the receiving end voltage at Multi-Net - Sobaz filling Stationfeeder.

$$V_{R19} = Sending\ voltage\ (Vs) - Voltage\ drop\ (V_{d19})$$

$$V_{R19} = 11000 - 0.764714065$$

$$V_{R19} = 10999.23529\ V$$

CASE 8: Determination of the percentage Voltage regulation between Multi-Net - Sobaz filling Stationfeeder.

Recalling Equation (9)

%voltage regulation $= \frac{V_S - V_{R19}}{V_{R19}} \times 100\%$

$$= \frac{11000 - 10999.23529}{10999.23529} \times 100\%$$

$$= \frac{0.76471}{10999.23529} \times 100\%$$

%voltage regulation= 0.06952392415≈ 0.007%

CASE 9: Determination of the reactive power of the load

KVA = 200, KW = 160

Applying Pythagoras theorem; **Recalling Equation (10)**

$$KVAR = \sqrt{(KVA)^2 - (KW)^2}$$

$$KVAR = \sqrt{(200)^2 - (160)^2}$$

$$KVAR = \sqrt{25{,}000 - 25{,}600}$$

$$KVAR = \sqrt{36{,}000} = 60$$

∴ Reactive power = $120KVAR$

ANALYSIS 20 (Bus 20 - 21) Sobaz filling Station - Dimarine Nigeria Ltd. feeder

CASE 1:

Calculation of the distance between buses:

(Sobaz filling Station - Dimarine Nigeria Ltd.) = 0.45km

Distance measured between Bus (20 – 21) with respect to resistance, R in (Ω) gives;

R_{Bus}(20 - 21) = 0.20Ω/km × 0.45km = 0.09Ω

Per – Kilometer reactance (X_0) in thus; **Recalling Equation (4)**

$$X_0 = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\ \Omega/km$$

Where;

$$DGMD = 1.100m$$

R= 0.5Ω

$$X_0 = 0.1445 \log_{10}\left(\frac{1.100}{0.5}\right) + 0.0157\ \Omega/km$$

$$X_0 = 0.0652\ \Omega/km$$

CASE 2: For a distance measured of 0.45km,

$$X(Bus\,20 - 21) = 0.0652\ \Omega/km \times 0.45km$$

$$X(Bus\,20 - 21) = 0.02934\Omega$$

CASE 3:

Hence, impedance between (Bus 20 – 21) gives;

Z (Bus 20 – 21) = (0.09 + j0.02934)Ω

Per-kilometer capacitive susceptance (b_0), thus, the capacitive susceptance;

Recalling Equation (5)

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6} . \frac{1}{(\Omega.km)}$$

$$b_0 = \frac{7.58}{\log_{10}\left(\frac{1.100}{0.0076108}\right)} \times 10^{-6} = \frac{7.58}{\log_{10}(144.53)}$$

$$b_0 = \frac{7.58 \times 10^{-6}}{2.1599580} = 3.509$$

$$b_0 = 3.509 \times 10^{-6} \times \frac{1}{\Omega.km}$$

For distance measured of 0.45km

Bus (20 – 21) = 3.509 $\times 10^{-6} \times \frac{1}{\Omega.km} \times 0.45km$

$$= 1.57905 \times 10^{-6}\left(\frac{1}{\Omega} or\ Simens\right)$$

CASE 4: Determination of the load current (I_L) at Sobaz filling Station - Dimarine Nigeria Ltd. Feeder, while relying on the following condition.

(i) Power factor of the load (P.f) = 0.80
(ii) Transformer rating in KVA = 300
(iii) Distribution voltage (V) = 11,000 (11KV)
(iv) Active power (KW) to be determined?

From the power equation; **Recalling Equation (3.6)**

$$KVA \times p.f = KW$$

300×0.80 = 240

∴ Active power = 240KW

From the load equation; **Recalling Equation (7)**

$$I_L = \frac{KW}{\sqrt{3 \times V \times p.f}} = \frac{240}{1.732 \times 11 \times 0.80} =$$

$$\frac{240}{15.2416} = 15.74637833 \approx 15.7464 Amps$$

$$I_{L_1} = 15.7464\ Amps$$

CASE 5: Determination of conductor per phase but since $I_{L_{20}} = 15.7464\ Amps$

$$Number\ of\ conductor = \frac{Load\ current}{Current\ carrying\ capacity\ of\ conductor}$$

$$= \frac{15.7464}{180} = 0.08748 \approx 0.0875$$

CASE 6: Determination of the voltage drop between Sobaz filling Station - Dimarine Nigeria Ltd. Feeder.

Recalling Equation (8)

$$V_{d_{20}} = \frac{\sqrt{3} \times (RCos\phi + \sin\phi) \times I_L \times length\ of\ line\ section}{Number\ of\ conductor/phase \times 100}$$

$$V_{d_{20}} = \frac{1.732 \times (0.272 \times 0.8 + 0.6) \times 15.7464 \times 0.45}{0.0875 \times 100}$$

$$V_{d_{20}} = \frac{1.732 \times 0.8176 \times 7.08585}{8.75}$$

$$\frac{10.03419563}{8.78}$$

$$V_{d_{20}} = 1.146765214\ V$$

Where;

Length of the line section = 0.45km

CASE 7: Determine of the receiving end voltage at Sobaz filling Station - Dimarine Nigeria Ltd. Feeder.

$$V_{R20} = Sending\ voltage\ (Vs) - Voltage\ drop(V_{d20})$$

$$V_{R20} = 11000 - 1.146765214$$

$$V_{R20} = 10998.895323\ V$$

CASE 8: Determination of the percentage Voltage regulation between Sobaz filling Station - Dimarine Nigeria Ltd. Feeder.

Recalling Equation (9)

%voltage regulation = $\frac{V_S - V_{R20}}{V_{R20}} \times 100\%$

$$= \frac{11000 - 10998.85323}{10998.85323} \times 100\%$$

$$= \frac{1.14677}{10998.85323} \times 100\%$$

%voltage regulation = 0.010426268≈ 0.01%

CASE 9: Determination of the reactive power of the load

KVA = 300, KW = 240

Applying Pythagoras theorem; **Recalling Equation (3.10)**

$$KVAR = \sqrt{(KVA)^2 - (KW)^2}$$

$$KVAR = \sqrt{(300)^2 - (240)^2} = \sqrt{90{,}000 - 57{,}600}$$

$$KVAR = \sqrt{32{,}400} = 180$$

∴ Reactive Power = 180KVAR

This is applied to other respective bus cases including:
Analysis 21 (Bus 21 – 22) Dimarine Nigeria Ltd. – FCMB Feeder
Analysis 22 (Bus 22 – 23) Rumuokwuta I – SDA Feeder
Analysis 23 (Bus 23 – 24) SDA – Obiwali Feeder
Analysis 24(Bus 24 – 25) Obiwali - The Promise Feeder
ANALYSIS 25 (Bus 25 – 26) The Promise – Daniel Okocha Street Feeder
Analysis 26 (Bus 26 – 27) Daniel Okocha - Daveanges Feeder
Analysis 27 (Bus 27 – 28) Daniel Okocha - Psychiatric Hospital I Feeder
Analysis 28 (Bus 28) Psychiatric Hospital I – Psychiatric Hospital Relief Feeder

Integration of power factor improvement techniques

Reactive power compensation and voltage profile problems is an important factor to be considered in electric power system. The application of reactive power compensation devices (power electronics device) via the use of capacitor or banks of capacitors on the view to improve power factor improvement which will strongly make the electric power system to be more effective and viable for system reliability. The determination of the size of capacity of a capacitor to a distribution system will seriously improve and provide better voltage profile;this is because it will act as the reactive power generation to be distribution network making the provision of the needed reactive power (KVAR) to accomplish active power (KW).

Analysis of capacity of capacitor sizing for power factor improvement

The analysis and the extent of power losses on power distribution cannot be totally ignored owing to the degree of energy demand at the receiving end on daily basis. Therefore, it is important to determine the accurate sizing of the capacitor or capacitor bank.

Analysis of capacitor addition

Analysis 1: Analysis demonstrating the calculations of sizing the capacity of a capacitor

(i) Installed capacity of the transformer (TX) at the base case is given as:
500 KVA
(ii) Existing power factor = 0.70
(iii) Proposed/desired power factor for correction = 0.88
(iv) Total active power load (KW)
(v) Design calculation of capacity for capacitor rating,

The equation for capacitor rating for compensation is given as:

$$Qc = \frac{p}{pf_1} \times \sin\phi_1 - \frac{p}{pf_2} \times \sin\phi_2 \quad (3.11)$$

Where;

Qc= Reactive power factor correction (KVAR)

p = The total active power load (KW)

pf_1 = Existing power factor of the load

pf_2 = proposed/desired power factor to be used for correction

$$\phi_1 = \cos^{-1}(pf_1)$$

$\phi_2 = \cos^{-1}(pf_2)$

$$Qc = \frac{p}{pf_1}\sin\left(\cos^{-1}(pf_1) - \frac{p}{pf_2}\sin(\cos^{-1}(pf_2))\right)$$

The power components can be represented into power triangle as shown in fig. 3.1.

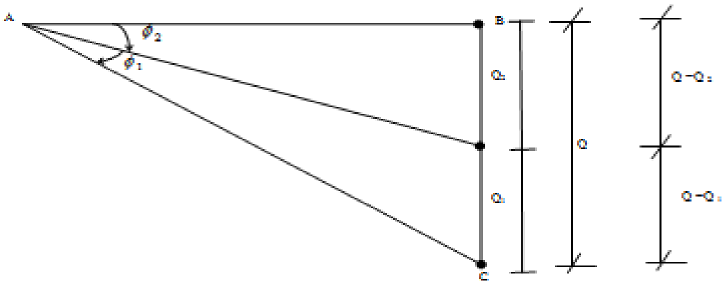


Fig 2: Components of power triangle

From our power equation connecting, active power, power factor and apparent power is given as: $KVA \times pf = KW$

Thus,

$$Qc = \frac{p}{pf_1}\sin\left(\cos^{-1}(pf_1) - \frac{p}{pf_2}\sin(\cos^{-1}(pf_2))\right)$$

P_{AC} = to be determined

P_{AP} = 500KVA (Apparent power)

Pf_1 = 0.70

Pf_2 = 0.88

But P_{AC} = 350KW

$KVA \times Pf = \text{KW}, \quad 500 \times 0.70 = \text{KW}. \quad KW = 350$

$$Qc = \left(\frac{350}{0.70}\sin(\cos^{-1}(0.70)) - \frac{350}{0.88}\sin(\cos^{-1}(0.88))\right)$$

$$Qc = (500 \times \sin(45.57.29) - 397.7272 \times \sin(28.3576))$$

$$Qc = (500 \times \sin(45.57.29) - 397.7272 \times \sin(28.3576))$$

$$Qc = 500 \times (0.71414) - 397.7272 \times (0.474973)$$

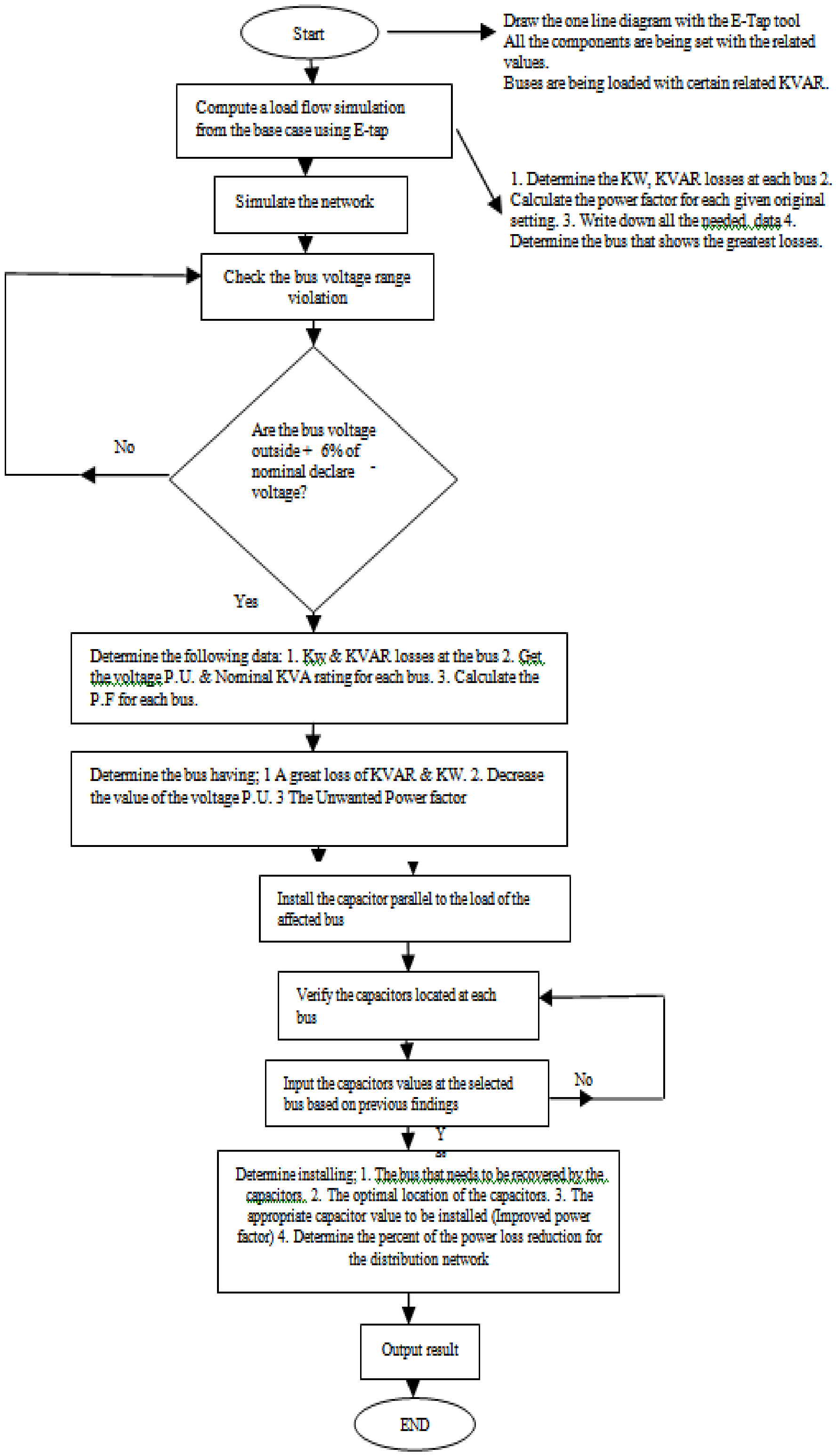
$$Qc = 357.07 - 188.9096814$$

$$Qc = 168.160 KVAR$$

This is the required size of the capacitor that is adequate to suppress the voltage profile atstudy case. This is applied to any other cases in the feeder or buses of the distribution network analysis.

FLOW CHART SHOWING THE ANALYSIS OF THE CAPACITOR BANK COMPENSATION.

HUH


Start
Draw the one line diagram with the E-Tap tool
All the components are being set with the related values.
Buses are being loaded with certain related KVAR.
Compute a load flow simulation from the base case using E-tap
1. Determine the KW, KVAR losses at each bus 2. Calculate the power factor for each given original setting. 3. Write down all the needed data 4. Determine the bus that shows the greatest losses.
Simulate the network
Check the bus voltage range violation
Are the bus voltage outside + - 6% of nominal declare voltage?
No
Yes
Determine the following data: 1. Kw & KVAR losses at the bus 2. Get the voltage P.U. & Nominal KVA rating for each bus. 3. Calculate the P.F for each bus.
Determine the bus having; 1 A great loss of KVAR & KW. 2. Decrease the value of the voltage P.U. 3 The Unwanted Power factor
Install the capacitor parallel to the load of the affected bus
Verify the capacitors located at each bus
Input the capacitors values at the selected bus based on previous findings
No
Determine installing; 1. The bus that needs to be recovered by the capacitors. 2. The optimal location of the capacitors. 3. The appropriate capacitor value to be installed (Improved power factor) 4. Determine the percent of the power loss reduction for the distribution network
Output result
END

V. Results and Discussions

The results obtained about the voltage profile voltage drop etc. are presented in table 4.1 - figure 4.11, from the supply grid network at Rumuola-golden Lilly substation. The calculation and analysis are conducted numerically using voltage-drop, voltage regulation equations. the activities and performance of the activities and performance of the line parameters are carried out the electrical transient analyzer tool (E-tap), in order to simulate the voltage profile, active& reactive power.

Table 4.1:- Analysis of feeder: power, Voltage drop, load current and receiving end voltage.

Feeder Name	**Transformation Ratio(V_1/V_2)**	**Power (KVA)**	**Power (KW)**	**KVAR**	**Length (KM)**	**Voltage drop (V_d)**	**% Voltage (vol %)**	**Load current (I_L)**	**Receiving end voltage (V_R)**	**Sending end voltage (V_S)**	**% Voltage regulation**
Rumuola – Nikky	11/0.415	100	80	60	2.5	6.193947917	619.395	5.2488	10993.80605	11,000	0.06%
Nikky – Rumuadaolu 1	11/0.415	500	400	300	0.6	1.529369856	152.937	26.244	10998.47063	11,000	0.014%
Rumuadaolu 1 – Rumuadaolu 2	11/0.415	500	400	300	0.3	0.764684928	76.468	26.244	10999.23532	11,000	0.007%
Rumuadaolu 2 – Lulu shopping centre	11/0.415	500	400	300	0.4	1.019579904	101.958	26.244	10998.98042	11,000	0.0093%
Lulu shopping centre – Chief Benson Str.	11/0.415	500	400	300	0.5	1.27444488	127.447	26.244	10998.72553	11,000	0.012%
Chief Benson Str. – MTN	11/0.415	100	80	60	0.25	0.0063723744	0.637	26.244	10999.99363	11,000	0.00006%
MTN - SBS Relief	11/0.415	500	400	300	0.5	1.27447488	127.447	26.244	10998.72553	11,000	0.012%
SBS Relief – SBS	11/0.415	500	400	300	0.57	1.452901364	145.290	26.244	10998.5471	11,000	0.013%
SBS – Zenith Bank	11/0.415	200	160	120	0.06	0.152942813	15.294	10.498	10999.84706	11,000	0.014%
Zenith Bank – First bank	11/0.415	200	160	120	0.04	0.070726343	7.073	10.498	10999.92927	11,000	0.0006%
First bank – Sterling	11/0.415	100	80	60	0.2	0.351209583	35.121	5.249	10999.64879	11,000	0.0032%
Sterling – Ebony Junction	11/0.415	500	400	300	0.3	0.764634928	76.468	26.244	10999.23532	11,000	0.007%
Ebony Junction – Ecobank	11/0.415	200	160	120	0.43	1.147464605	147.465	10.498	10998.85254	11,000	0.01%

Table 4.2:- Analysis of feeder:power, Voltage drop, load current and receiving end voltage.

Feeder Name	**Transformation Ratio(V_1/V_2)**	**Power (KVA)**	**Power (KW)**	**KVAR**	**Length (KM)**	**Voltage drop (V_d)**	**% Voltage (vol %)**	**Load current (I_L)**	**Receiving end voltage (V_R)**	**Sending end voltage (V_S)**	**% Voltage regulation**
Ecobank – The promise	11/0.415	200	160	120	0.2	0.351812001	35.181	10.498	10999.64899	11,000	0.0032%
The promise – Fidelity bank	11/0.415	100	80	60	0.1	0.175604791	17.560	5.249	10999.8244	11,000	0.002%
Fidelity bank – Rumuokwuta I	11/0.415	500	400	300	0.75	1.91171232	191.171	26.244	10998.08829	11,000	0.0174%
Rumuokwuta I – Multi-Net	11/0.415	100	80	60	0.105	2.676397248	267.640	5.249	10997.3236	11,000	0.02%
Multi-Net – Ejoor ville Estate	11/0.415	500	400	300		1.794079753	179.408	26.244	10998.20592	11,000	0.02%

Ejoor ville Estate – Sobaz filling station	11/0.415	200	160	120		0.7647140657	79.471	10.498	10999.23529	11,000	0.007%
Sobaz filling station – Dimarine Nig. Ltd	11/0.415	300	240	180		1.146763214	144.677	15.7464	10998.85323	11,000	0.016%
Dimarine Nig. Ltd – FCMB	11/0.415	200	160	120		0.764714065	76.471	10.498	10999.23529	11,000	0.007%
Rumuokwuta I – SDA	11/0.415	500	400	300		1.784264832	178.426	26.244	10998.21574	11,000	0.02%
SDA – Obiwali	11/0.415	500	400	300		1.784264832	178.426	26.244	10998.21574	11,000	0.02%
Obiwali – The Promise	11/0.415	100	80	60		2.036444032	203.644	5.249	10997.96356	11,000	0.02%
The Promise – Daniel Okocha str.	11/0.415	500	400	300	0.25	0.637140315	63.714	26.244	10999.36286	11,000	0.006%
Daniel Okocha – Daveanges	11/0.415	200	160	120	0.25	0.637480335	63.714	10.498	10999.36252	11,000	0.006%
Daniel Okocha – Psychiatric Hospital I	11/0.415	500	400	300	0.3	0.764684928	76.468	26.244	10999.23532	11,000	0.007%
Psychiatric Hospital I - Psychiatric Hospital Relief	11/0.415	500	400	300	0.3	0.764684928	76.468	26.244	10999.23532	11,000	0.007%

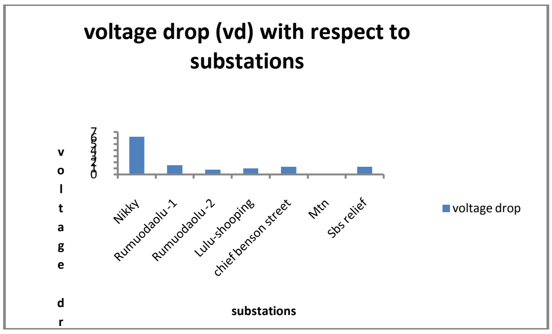


Figure 3: voltage drop with substations

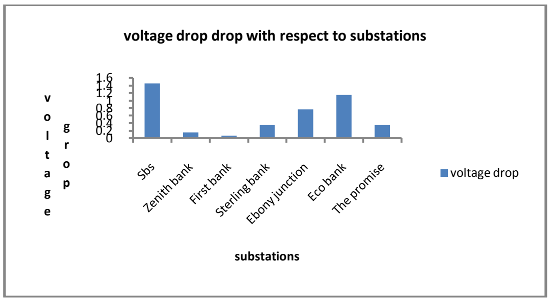


Figure 4: voltage drop with substations

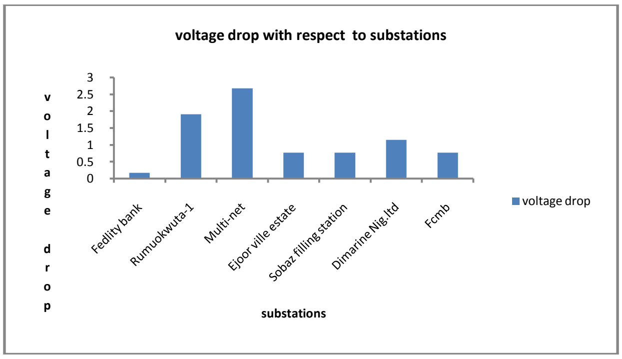


Figure 5: voltage drop with substations

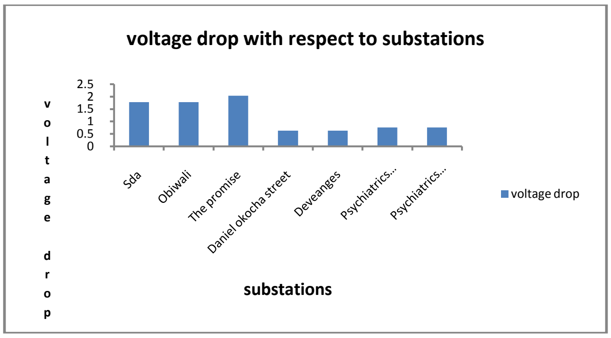


Figure 6: voltage drop with substations

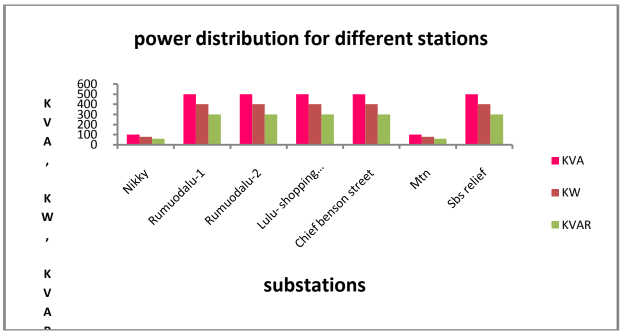


Figure 7: Power distribution for substations

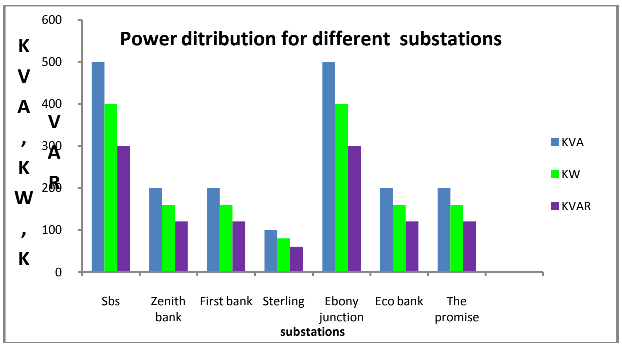


Figure 8: Power distribution for substations

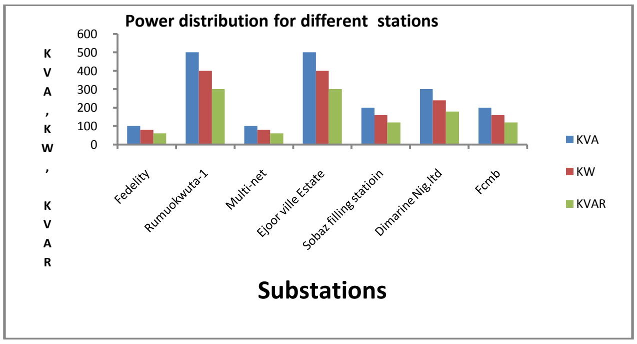


Figure 9: Power distribution with substations

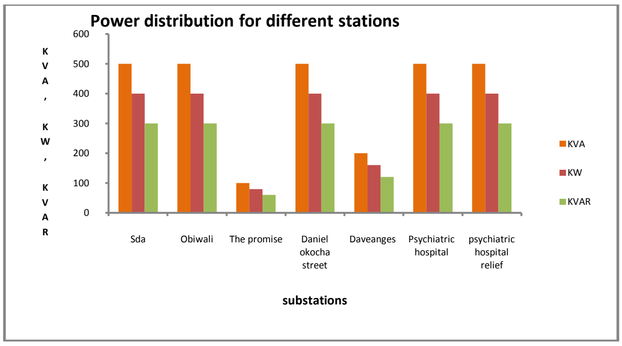


Figure 10: Power distribution with substations

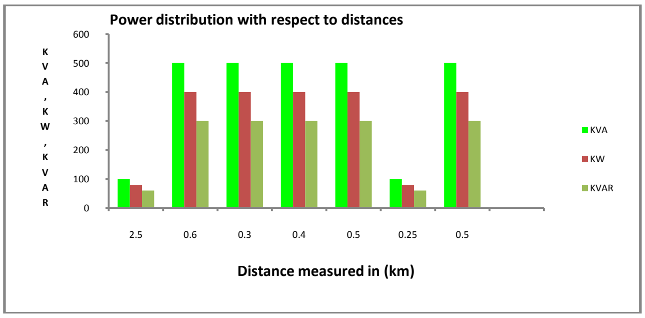


Figure 11: Power distribution with respect to distances

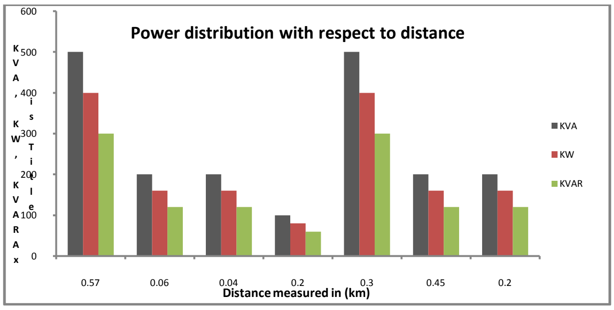


Figure 12: Power distribution with distance

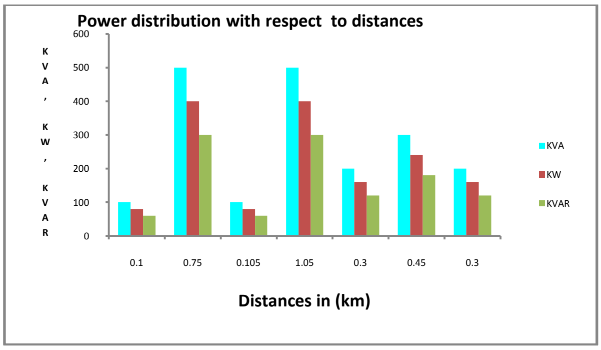


Figure 13: Power distribution with respect to distances

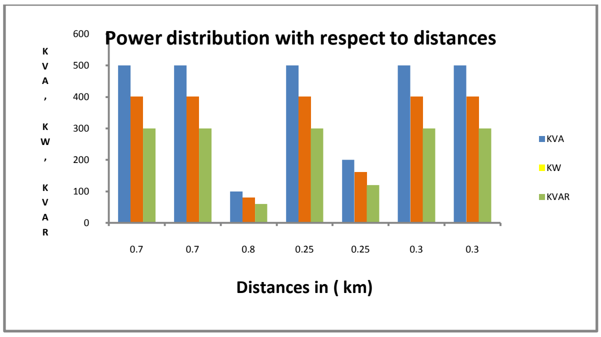


Figure 4.12: Power distribution with distances

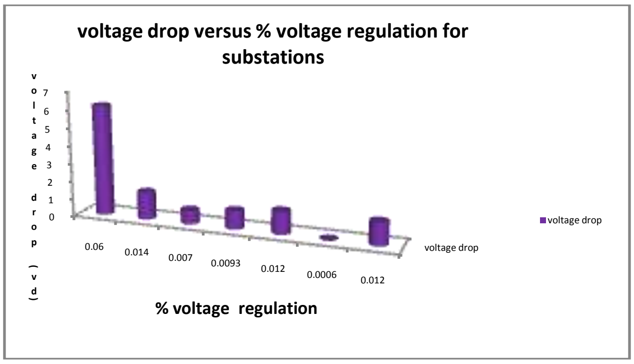


Figure 14: Voltage drop with voltage regulation

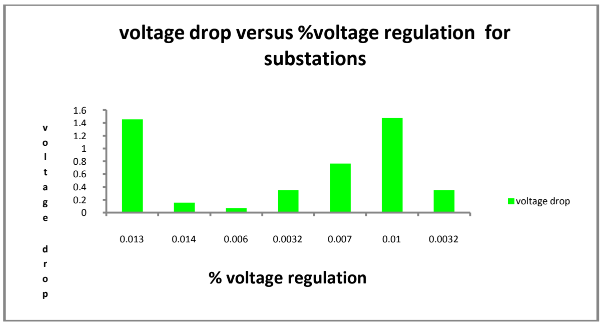


Figure 15: Voltage drop with voltage regulation

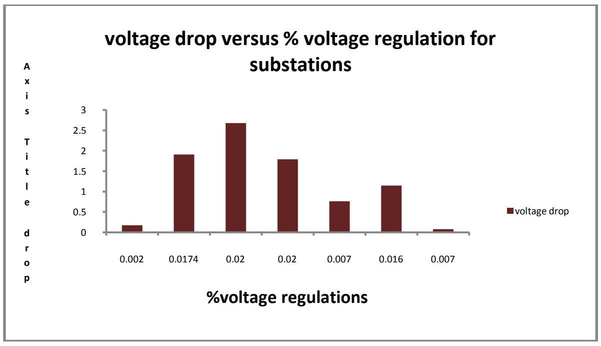


Figure 16: Voltage drop with voltage regulation

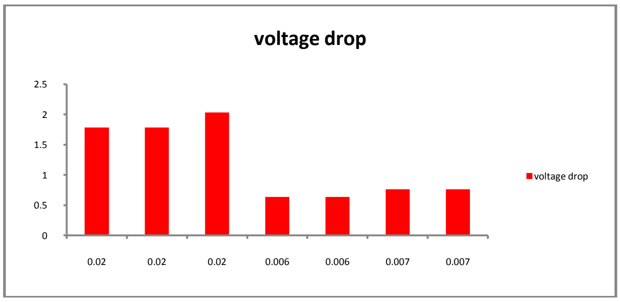


Figure 17: Voltage drop with voltage regulation

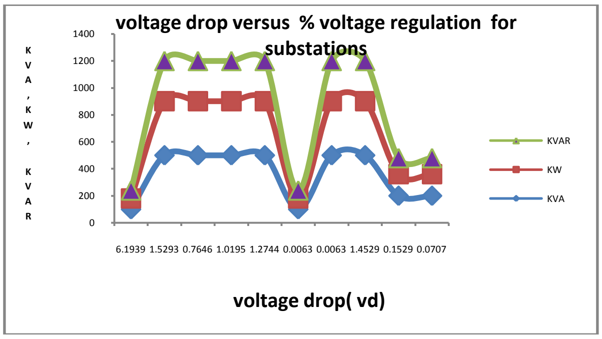


Figure 18: Voltage drop with voltage regulation

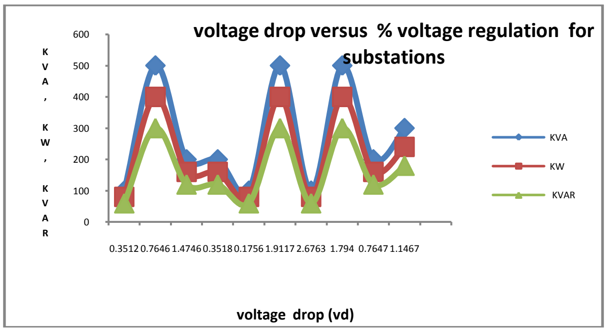


Figure 19: Voltage drop with voltage regulation

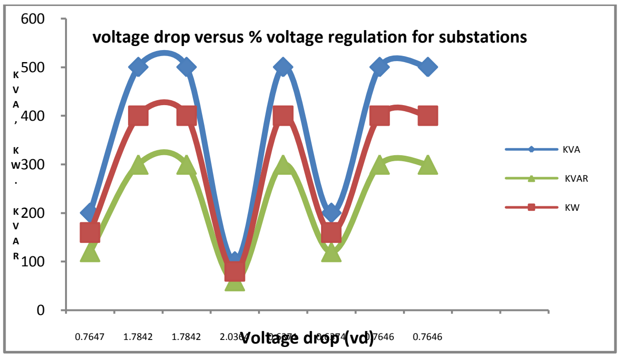


Figure 20: Voltage drop with voltage regulation

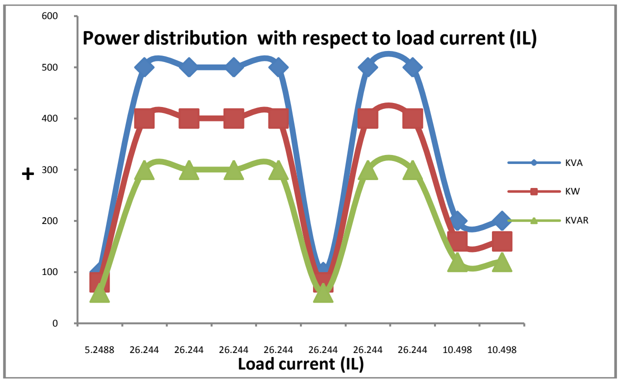


Figure 21: Power distribution with load current

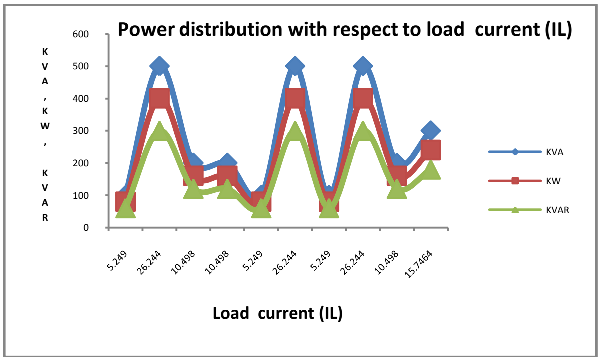


Figure 22: Power distribution with load current

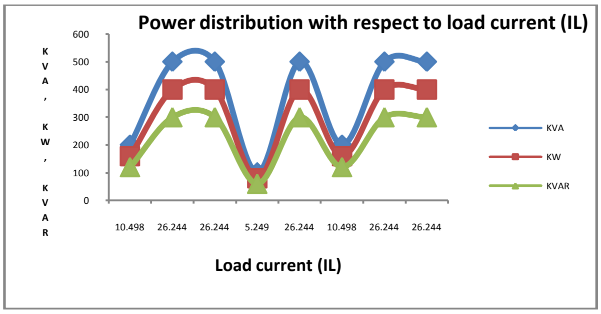


Figure 23: Power distribution with load current

Analysis of the Existing Case without Capacitor Addition

The results of the existing voltage profile of the 11KV distribution feeder is conducted via simulation of excel (software programme) which are presented in figure 4.1 to 4.22 the supply power system is taken from Rumuola-injection substation(Golden-lilly). The analysis were also simulated using electrical transient analyzer tool (E-tap) on the view to examine the existing state of the system: voltage magnitude, voltage drop and power-flows etc.

The voltage drop in each substation are grossly inadequate due to overload problems which is needed to be compensated using appropriate size of capacitor bank in order to suppress the voltage problems. The results also revealed that the actual voltage magnitude received at each bus is below the acceptable range of (0.95 - 1.05pu), that is the voltage drop at each terminal point (or bus) shall not be less than (±6%) of the declared statutory limit according to IEE regulation.

Graph Discussion

Figure 4.1 shows that Nikky substation have the critical voltage problem as compared to other related substation. This is as a result of overload in that feeder, because of the voltage drop in that feeders.

Figure 4.2 shows the relationship between voltage drop with respective substations as shown, the voltage drop is high in 'Sbs', followed by Eco bank, Ebony etc. The voltage drops is critical due to overload problem in that feeders.

Figure 4.3 shows that the voltage drop is high 'multi-net' followed by Rumuokwuta - 1 etc. this is as a result of overdependence of critical load on multi-net feeders.

Figure 4.4 shows the level of voltage drop between related substation. 'The promise' substation indicate more voltage-drop followed by 'Sda and Obiwali'feeder. This is as a result of associated activities in that area of Port Harcourt.

Figure 4.5 shows the distribution of power: (500KVA, 400KW, 300KVAR) 'Lulu-shiping' centre, 'Chief Benson street', and 'Sbs-Relief', while 'Nikky and MTN' are (100KVA, 80kW, 70KVAR) respectively.

Figure 4.6 shows that power distribution are 500KVA, 400KW and 300 KVAR for 'Sbs', while Ebony junction have power distribution capacity of 500KVA, 400KW and 300KVAR capacity respectively. 'Zenith bank', 'First bank', 'Sterling bank', 'Eco bank' and 'The promise' have capacity of 200KVA, 180KW and 150KVAR capacity respectively.

Figure 4.7 shows, the power composite capacity distribution of 500KVA, 400KW and 300KVAR for 'Rumuokwuta - 1','Ejoor Ville' estate also have the same capacity distribution of 500KVA, 400KW and 300KVAR respectively in that area.

Figure 4.8, show that power distribution composite capacity of 'Sda', 'Obiwali','Daniel''Okocha', 'Psychiatric hospital', 'Psychiatric hospital-relief' to be 500KVA, 400KW, and 300 KVAR respectively.

Figure 4.9 shows the power distribution with respect to distances measured in (Km). That is composite power of 500KVA, 400KW and 300KVAR to respective distances of 2.5km, 0.6km, 0.3km, 0.4km, 0.5km, 0.25km and 0.5km respectively.

Figure 4.10 shows that power distribution of 500KVA, 400KW and 300KVAR with respective distances of 0.57KW, 0.06KW, 0.04KW, 0.2KW, 0.3KW, 0.45KW and 0.2KW.

Figure 4.11 shows the power distribution of composite capacity 500KVA, 400KW, 300KVAR as against 0.75km, 1.05km.

Figure 4.12 shows the power distribution of composite capacity: 500KVA, 400KW and 300KVAR as against respective distances of 0.7km, 0.8km, 0.25km, 0.3km respectively.

Figure 4.13 shows the relationship between voltage drop with respect to percentage (%) voltage regulation.

Figure 4.14 shows the relationship between percentage voltage drop and percentage regulation.

Figure 4.15 shows the unequal distributive relationship between voltage drop and percentage voltage regulation.

Figure 4.16 shows an unequal distributive relationship between voltage drop and percentage voltage regulation.

Figure 4.17 shows an unequal distribution of power-line with respect to voltage drop with capacity combination of 500KVA, 400KW and 300KVAR respectively.

Figure 4.18 shows power line distribution of 500KVA, 400KW, 300 KVAR with respect to substation voltage drop.

Figure 4.19 shows that the composite apparent power (KVA), active power (KW) and reactive power (KVAR) with respect to voltage drop.

Figure 4.20 shows thecomposite power distribution of: 500KVA, 400KW and 300KVAR with respect to voltage drop.

Figure 4.21 shows the power distribution of: 500KVA, 400KW and 300KVAR with respect to voltage drop.

Figure 4.22 shows the power distribution with respect to voltage drop.

VI. Conclusion And Recommen-Dation

Conclusion

The distribution of bulk electricity from generating station to the consumer at the receiving end, is a rigorous process. That is, the needed electrical energy consumption is ever on the increase on regular basis.

Hence, system upgrade and expansion is required to meet the demand increase. Consequently, the generation of power do not match power demand and therefore the primary and secondary distribution sections are not delivery enough power as expected, leading to low voltage profile, load shedding, poor energy management system etc.

Consumer is always worried about the constant deviation of the sending-end power at the receiving end, which has always put the consumer at black-out making the energy demand (load) not effectively utilized as a requirement for the use of power.

The work considered the application of voltage regulation/voltage-drop to measure the existing behaviour of the 11KV,(Rumuola distribution network) on the view to compensate or suppress the critical voltage profile on the feeder line. the existing system are simulated with E-tap tool and excel program.

Evidently, reactive power compensation device (capacitor bank) are integrated into the 11KV distribution system in the form of series compensation, shunt compensation or the combination of the two, depending on the nature of the line, this will enhance the performance of the distribution line.

The addition of reactive compensation device (capacitor) will modifies the electrical impedence of the line and therefore increase the power flow across the line. This is an effective and economic means of increasing distribution line nature not loaded to their thermal limits.

Recommendation

The following recommendations are strongly considered via the investigation of the existing IIkv distribution network:-

I recommend the installation of a new distribution network for expansion required a distribution line to deliver the needed amount of power to the respective consumer, in order to alleviate overloading.

I recommend the improvement of the voltage upgrade, which will increase the operating voltage of the distribution line with the capacitor device i.e. capacitor bank.

I recommend the application of the phase – shifting device in the line to help regulate and enhance a better control of the power flows on the system to optimized the existing distribution capacity.

I recommend the integration of the automatic capacitor bank to overload buses with the help of power factor connection controller.

1 recommend the integration of the distribution generation (DG), which can be used to solve the problem of power supply inadequacy in Port Harcourt

Contribution to Knowledge

The rate at which power supply fails particularly in Nigeria has reached an unpresented level such that management of reactive power and voltage control constitute part of the major challenge in power transmission distribution network in order to guarantee transmission distribution efficiency and system stability.

Evidently inductive load used in residential, commercial and industry deal with the problem of power factor improvement.

Therefore, the integration of capacitor bank connected in shunt help in maintaining the pure factor closer to unity, that is they improve the electric power supply quality and increase the efficiency of the system.

The major contribution to this work, is the integration of automatic capacitor bank which should be installed at the control centre at the service entrance. The capacitor bank will be closely maintain a pre-selected value of the power factor. This is achieved by having a controller switch steps of Kvar on, or a controller switch step of KVAR off as needed, that is automatic switching ensures exact current of power factor correction. Using automation capacitor bank is shown in Fig.5.1

Automatic capacitor bank installation

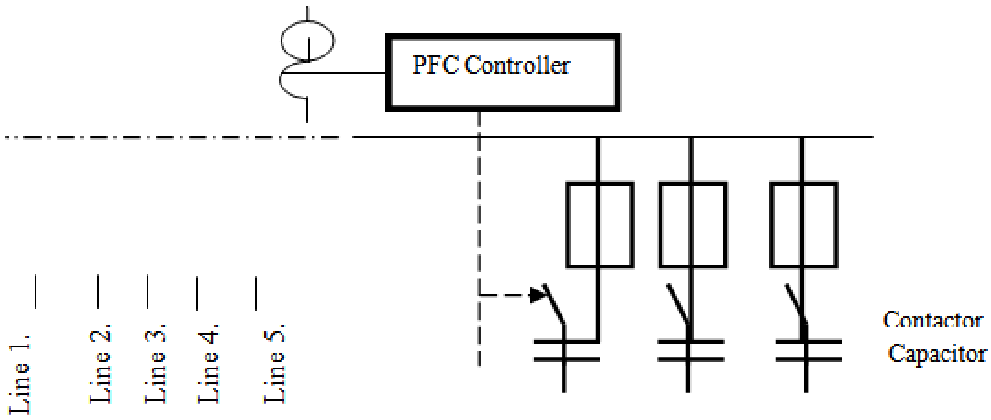


Fig.4: Standard power factor correction

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D.C. Idoniboye-Obu "Integration Of Reactive Power Compensation In A Distribution Network Case Study: Rumuola Injection And Distribution Network Port Harcourt, Nigeria "International Journal of Engineering Science Invention (IJESI), vol. 07, no. 10, 2018, pp 75-130