DESIGN OF 500kVA, 11/0.415kV SUBSTATION

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CERTIFICATION

This is to certify that this project work, (design of 500kVA 11/0.415kVkV substation) was carried out by **OGUNGBURE, SEMILOGO OLUSOLA** with the matriculation number **EEE/11/5092** of the Department of Electrical and Electronics Engineering, Federal University of Technology, Akure, Ondo State, Nigeria.

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DEDICATION

The author of this report work (OGUNGBURE SEMILOGO OLUSOLA) dedicates it to the Almighty GOD, the GOD of Abraham, Isaac and Jacob, the giver of life, strength, wisdom and inspiration during and after my SIWES.

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ABSTRACT

This research project presents a method of planning for the electrical loads requirements using load estimation method rather than measurement method because of its simplicity, flexibility, sustainability and cost reliability and the recommendation of the appropriate transformer size to avoid incessant blow off and damages to 500kVA 11/0.415kV substation even for other substations with related specifications. The proposed electrical model designs of Emiloro Community ,off Oda road was used to show a typical design with 500kVA implemented using AutoCAD 2012 Version Software. It aims at the design of 500kVA, 11/0.415kV substation with respect to voltage and frequency deviation with maximum efficiency and at moderate running and maintenance cost, the required quantities of the major substation components required for implementation of developed electrical model designs were obtained. A methodology for estimating an adequate transformer capacity with consideration of future expansion in load demand in the nearest future while the same transformer and other substation equipment will still be considered relevant and reliable. Advice on the best equipment and accessories to be used when constructing any distribution substation such as the one I worked on is also given, thus achieving a reliable supply of electricity within our society, which brings about socio-economic development

CHAPTER ONE

1. INTRODUCTION

1.1 Introduction to A Substation

The energy sector of any nation occupies a place of central importance in terms of its relative contribution to the national socio economic goal of raising or elevating the productivity and therefore, higher living standard. Of all the sub-sectors comprising the energy sector, none has a greater impact on the lives of the citizenry than electricity (Abitogun, 2003).

The historic development of electricity supply in Nigeria dates back to 1896 when a bank of two 30kVA generators were installed in Lagos, at the present site of national Electric power Authority (NEPA) headquarters Annex. Later on, electricity supply from the generating sets was extended to some other parts of the country. In 1946, the Nigerian Government Electricity undertaking (NGEU) was established under the then public Works Department (PWD) to handle electricity supply in Lagos environs. Alongside NGEU, there were other electricity supply undertakings owned and managed by local Authorities and private organizations .However, the need to coordinate various electricity supply activities across the country and to facilitate even development culminated in the establishment of Electricity Corporation of Nigeria (ECN) in1950.

The growing need for electricity has necessitated a rise in electrical and electronics installations to meet the growing need. Electrical installation in buildings, factories, village, towns and this was comprised various types of electrical materials, apparatus and equipment interconnected with cables and conductors infixed position and utilization of electrical energy. Transmission and distribution lines are vital links between generation stations and consumers as power from generating stations is transmitted at high voltage over long distances to the major load centers and then the power is distributed to various substations located at various places and localities through distribution lines (Gupta, 2013).Depending upon the availability of resources these sub stations are constructed at different places. These places may not be nearer to load centers where the actual consumption of power takes place. So it is necessary to transmit these huge power blocks from generating station to their load centers.

Power is generated comparatively in low voltage level. It is economical to transmit power at high voltage level to reduce power losses (Ale, 2015). Distribution of electrical power is done at lower voltage levels as required by consumers. For maintaining these voltage levels and for providing greater stability a number of sub stations have to be created in between generating station and consumer ends. These transformation and switching stations are generally known as electrical substations (Ale, 2016).

Plate 1.1: Installation of substation equipment

1.1.1 System of Power Supply

Electric power is normally generated between 11 to 25kV in a power station. To transmit over long distances, it is then stepped-up to 33kV.This power is carried through a primary transmission network of high voltage lines usually; these lines run into hundreds of kilometers and deliver the power into common power pool called the grid. The grid is connected to the load center (cities) through a secondary transmission network of normally 132kVlines. These lines terminate into a 33kV at 132/33KVsubstation; the voltage is step-down to 11kV for power distribution network.

The supply system consists of network conductors and associated equipment through which energy is transmitted from the generating station to the consumer's. Basically, the power system substation consists of generation, Transmission, Distribution and Consumption. The term generation means obtaining electric power by conversion from other forms of power; as of today, the country's bulk of power comes from five thermal stations and three hydro-generating stations. They include Afam thermal power station Delta thermal power station, Ijora thermal power station, Sapele thermal power station and Lagos (Egbin) power station. The hydro stations are located in Kanji, Jebba and shiroro.The power network which generally concerns the common man is the distribution network of 11kVlines. Each 11kVfeeder, which emanates from the 33/11kV substation branches further into several subsidiary 11kV feeder to carry power close to the load point (final consumers).At these load points, a transformer further reduces the voltage from 11kV to 0.415kV to provide the last-mile connection through 415V feeders(low tension feeders) to individual consumers either at 240V (single phase supply) or at 415V (three phase) .In urban areas, owing to the diversity up to 30km.On the other hand, in rural areas, the feeder length is much longer (up to 20km). A 415V feeder should normally be restricted to about 0.5 to 1.0km.Usually long feeders leads to low voltage at consumer ends.

Similarly, consumption means converting power into other forms. Transmission deals with the transfer of electric power in bulk, either by underground cable or overhead lines over a considerable distance; and distribution is the conveyance of power to consumers by means of lower voltage networks. The transmission system is divided into two; primary and secondary transmissions. Distribution is divided into primary, secondary and tertiary distributions.

In power networks, bulk power is subdivided into smaller blocks based on the operating voltage levels and feds into the sub-transmission portions of the power network. Finally, the distribution networks service the individual small consumers. Consumers drawing large amount of power up to 500kVA and above, takes supply from the secondary distribution network. But the bulk of consumers with smaller loads take supply from tertiary distribution.

In an a.c system, there is always a voltage transformation at each point where sub division takes place by means of transformer. Such a place is called a substation.

1.2 Aim and Objectives

1.2.1 Aim

The aim of this project is to design a 500kVA, 11/0.415kV substation and with respect to voltage and frequency deviation with maximum efficiency and at moderate running and maintenance cost.

1.2.2 Objectives of the Project

These are the definite future desirable state or target I intend to achieve. The specific objective of this project is to:

(i) to determine the load requirement.

(ii) to collect data of electrical loads used in the selected buildings so as to determine the power consumption

(iii) to determine the transformer rating for these selected buildings with estimated load.

(iv) to determine the size of the required conductors (cables), earth conductor, circuit breaker panel

(v) to determine the cost implication of running and maintaining a 500kVA,11/0.415kV substation

(vi) to recommend the best transformer for a town or industry from findings

1.3 Scope of Study

This report is limited to the design of 500kVA, 11/0.415kV electric power distribution substation.

1.4 Problem Statement

Most often when efforts are made to increase power generation and expand transmission systems, the power still does not get to the end users as expected. Disruption and technical losses abound. Both the supply authority and its customers suffer the socio-economic challenges, the only thing I think can be done is to critically look into our methods and of designing our substations. The importance of correct substation cannot be over emphasized as most of inhabitants in our society cannot even afford personal generator but rather depend on government supply of electricity in Nigeria.

This issue of incorrect design of distribution substation has caused so many people to look for alternate source of electricity power supply such as the so called “I-better pass my neighbor” which has been polluting our environment with exhausted fumes which is so dangerous and unfriendly to our lives, even this alternate source of electricity is being used in universities and other organizations. Nevertheless, since they need to carry out their day-day activities to fend for their needs, they cannot be banned. Painfully, anyone who cannot afford all these sorts of alternate sources of supply of electricity will unavoidably live in total black out and wallow in darkness, which is very common in Nigeria today.

Now, the only solution and option available for us is to start checking each part that contribute to our stages of supply of electricity step by step where the correct design of distribution substation (500kVA 11/0.415kV) plays a very paramount role hence it cannot be looked down upon.

1.5 Motivation

To ensure an effective electric power distribution to consumers by making proper planning before the establishment of 500kVA 11/0.415kV substation without violating voltage and frequency deviation and to make sure there is a high reliability in power supply according to the international standard.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Literature Review of Substation

In Nigeria, electricity supply and distribution has passed through many stages dating to 1896 when the first set of generators with installed capacity of 30MW, which served Lagos. Thereafter, some native authorities under the colonial rule made efforts to extend electricity supply to other parts of Nigeria.

These isolated power generating stations owned by the native authorities were coordinated operationally by the public works department until 1946 when the Nigerian Government Electricity Undertaking (NGEU) was set up but the financial and management control of the stations remained with the native authorities. The colonial administration therefore passed the ordinance No. 15 of 1950 to establish the Electricity Corporation of Nigeria (ECN) for better management of the fast growing electricity distribution system. This legal instrument brought electricity under a unified control in Nigeria for the first time. Following the discovery/research work on the potentiality of using River Niger for electricity generation and other purposes, the Niger Dam Authority (NDA) was established by an Act of parliament in 1962. Its construction work took off in 1964 with the inaugural ceremony performed by the prime minister of the federation, Sir Alhaji Abubakar Tafawa Belewa.

Both ECN and NDA operated independently for many years before merging together to form National Electric Power Authority (NEPA) through the decree No.24 of 27th June 1972. The merger thus saddled NEPA (presently Power Holding Company of Nigeria, PHCN) with statutory responsibilities of ensuring generation, transmission, distribution and supply of electricity throughout Nigeria. According to Musa (2007). Electric power generation may be through one of the following sources of energy: coal, oil or natural gas, hydro power (water turbine), nuclear power (steam turbine), solar-wind or water-wave turbine, solar thermal generator, solar voltaic generator. Coal, oil, gas and hydro power are abundant in Nigeria. Presently Nigeria mostly employs gas-fired and hydroelectric turbines for bulk generation, oil being too expensive and coal-fired stations having gone moribund, Musa (2007).

Maximum power consumption or peak demand depends on the population and industrialization of a country. If the maximum supply meets the peak demand, there is a surplus otherwise there is a shortfall.

The power industry plays a vital role in determining the quality of life of people. In today's modern economy, power generation and power consumption per person are indices used to determine the level of development and growth of any country.

2.1.1 Substation

A substation is where the transformer, switching and protection equipment (feeder pillar) are installed. It could be an outdoor or indoor type. For electricity projects mainly at distribution level, there are two main types of substation namely: primary injection (33/11kV systems) and distribution (11/0.415kVkV or 11/0.415kV system) substations. A substation is a part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions. Between the generating station and consumer, electric power may flow through several substations at different voltage levels (Donald, 1978).

2.1.2 Selection and Location of Site for a Substation

The following factors are considered while making site selection for a substation (Gupta, 2013).

i) **Type of Substation**: The category of substation is important for its location .For example , a step-up substation, which is generally a point where power from various sources (generating machines or generating stations) is pooled and stepped up for long distance transmission, should be located as close to the generating stations as possible to minimize the transmission losses, also a step-down substation should be located close to the load center to reduce transmission losses, cost of distribution systems and better reliability of supply.

ii) **Availability of suitable and sufficient land**: The land proposed for a substation should be normally level and open from all sides. It should not be water logged particularly in rainy season. The site selected for a substation should be such that approach of transmission lines and their take off can be easily possible without any obstruction.

iii) **Communication Facility**: Suitable communication facility is desirable at a proposed substation both during and after its construction. It is better, therefore, to select the site alongside an existing road to facilitate road an easier and cheaper transportation.

iv) **Atmospheric pollution**: Atmosphere around factories, which, may produce metal corroding gases, air fumes, conductive dust, etc., nearer to sea coasts, where air may be more humid and may be salt loaded ,is detrimental to proper running of power system and therefore substations should not be located near factories or sea coast.

v) **Availability of Essential Amenities to the Staff**: The site should be such where staff can be provided essential amenities like school, hospital, drinking water, housing etc.

2.1.3 Classifications of Substation

(i) **Transformer substations**: Majority of the substations in the power system are classified under this type. They are used to transform power from one voltage level to another voltage level. Transformer is the main component in such substations. Transformer substations are further classified into Step-up substations, Primary grid substations, Secondary substations and Distribution substations.

(ii) **Step-up substations**: These substations are usually located at the generating stations.

Generating voltage of the order of 11kV needs to be stepped up to a primary transmission voltage level of the order of 330kV or 400kV.

(iii) **Primary Grid Substations**: These substations are located at the end of primary transmission lines and the primary voltage is stepped down to suitable secondary voltages of the order of 132kV or 33kV.

(iv) **Secondary Substations**: The voltage is further stepped down to 11kV. Large consumers are supplied power at 11kV.

(v) **Distribution Substations**: These substations are located near the consumer localities to supply power at 415V, three phase or 220V, single phase to the consumers.

(v) **Switching Substations**: These substations are meant for switching operations of power lines without transforming the voltage. Different connections are made between the various transmission lines.

(vi) **Converting Substation:** Such substations are meant for either converting AC to DC or vice versa. Some are used to change the frequency from higher to lower or vice versa for industry utilizations.

According to constructional features substations are classified into Indoor substations, Outdoor substations, Underground substations and Pole mounted substations.

(i) **Indoor Substations**: All equipment of the substation is installed within the station buildings.

(ii) **Outdoor Substations**: All equipment such as transformers, circuit breakers, isolators, etc., is installed outdoors.

(iii) **Underground Substations**: In thickly populated areas where the space is the major constraint, and cost of land is higher, under such situation the substations are laid underground. This is practiced in Qatar

(iv) **Pole mounted substations**: This is an outdoor substation with equipment installed overhead on a H pole or 4 pole structure.

2.1.4 Functions of a Substation

Substations may be owned and operated by an electrical utility, or may be owned by a large industrial or commercial customer (Ale, 2016). Substation serve as sources of an energy supply for the local areas of distribution in which they are located. Their main functions are to receive energy transmitted at high voltage to a value appropriate for local use and to provide facilitates for switching. Substation provides points where safety device may be installed and disconnected circuits or equipment in the event of trouble. Voltage on the outgoing distribution feeders can be regulated at a substation and is also a convenient place to make measurement to check the operation of various parts of the system. Other functions of substation are,

A substation may include transformers to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages.

i. Substation serves as sources of energy supply for the local areas of distribution in which these are located .Their main functions are to receive energy transmitted at high voltage from the generating station, reduce the voltage to a value appropriate for a local distribution and provide facilities for switching.

ii. Some substations are simply switching station where different connections between various transmission lines are made.

iii. They provide points where safety devices may be installed to disconnect equipment or circuit in the event of fault. Voltage on the outgoing distribution feeders can be regulated at a substation.

iv. A substation is a convenient place for installing synchronous condensers at the end of transmission line for the purpose of improving power factor and make measurements to check the operation of the various parts of the power system .Street lighting equipment as well as switching controls for street lights can be installed in a substation.

2.2 Components of 500kVA, 11/0.415kV Distribution Substation

(i) Distribution Transformer

A transformer is a device which will change the voltage and current of AC, but not DC. Power transformers are used for stepping up the voltage for transmission at the generating stations and for stepping down voltage for further distribution at main step-down transformer substations. Usually naturally cooled, oil immersed, known as ON type, two winding, three-phase transformers, are used up to the rating of 10MVA. A transformer, as can be seen in plate 2.1 ,consists of two or more coils of wire wound on an iron core. The winding to which power is applied is called the primary winding and the winding from which the power is taken is called the secondary winding. Many transformers have more than two windings.

Plate 2.6 : A typical 500kVA transformer

To determine quantitatively how the voltage is changed by a transformer we must remember the equation

$$E = Nd\emptyset/dt \quad (1)$$

Where E is the voltage across the coil, N is the number of turns on the coil and $\emptyset$ is the magnetic flux linking the coil. For the two windings of a transformer we can write

$$E_p = N_p \frac{d\emptyset_p}{dt} \quad (2)$$

And

$$E_s = N_s \frac{d\emptyset_s}{dt} \quad (3)$$

In a transformer the magnetic flux is so well confined by the iron core that all of the flux from the primary also links the secondary and vice versa. This means that $\emptyset_p = \emptyset_s$. We can divide equation 2 through by N_p and equation 3 by N_S which solves them for $d\ /\ dt$, set them equal and rearrange terms to obtain the following equation.

$$\frac{E_p}{E_s} = \frac{N_P}{N_s} \quad (4)$$

A transformer which steps up the voltage will step down the current and vice versa. An electric utility uses transformers to step up the voltage to a very high value (as much as 330 kV) to send power over very long distances. When the voltage is stepped up, the current is stepped down. Most of the loss in power transmission lines is due to the resistances of the wires. Making the current as small as possible will minimize the power loss due to I^2R losses (Ale, 2016). The voltage is later stepped down for distribution around cities to be delivered to the final consumers

2.2.1 Types of transformer

(i) **Autotransformer**: An autotransformer (sometimes called auto step down transformer) is an electrical transformer with only one winding. The "auto" (Greek for "self") prefix refers to the single coil acting on itself and not to any kind of automatic mechanism

(ii) **Power transformer**: An iron-core transformer having a primary winding that is connected to an alternating- current power lines and one or more secondary windings that provide different alternating voltage values.

(iii)Potential transformer (voltage transformer):Potential transformer or voltage transformer gets used in electrical power system for stepping down the voltage to a safe value which can be fed to low ratings meters and relays. Commercially available relays and meters used for protection and metering, are designed for low voltage. This is a simplest form of potential transformer definition.

(vii) **Step-down Transformer**

The transformer, easy to recognize by its large canister shape, converts the high primary voltage to the lower voltage needed for home use. Look closely and you'll see that the high voltage transformer terminal is connected to one of the primary phase conducting wires. The transformer case is attached to the ground wire on the pole to prevent dangerous differences in voltage from developing

2.3 Feeder Pillar

Feeder pillar is a cabinet for electrical equipment, mounted in the street and controlling the electrical supply to a number of houses in a neighborhood. Feeder pillar can be described as an electrical enclosure used to provide electrical services for low voltage electrical applications. It is designed as a compact and robust for vandalism protection. It is shown in plate 2.1 below.

Plate 2. 7: Feeder pillar

2.3.1 Transformer and Feeder Pillar Connections

The primary side of the transformer was connected to the high tension lines via a J & P fuse by 50mm^2 (15m) single core PVC conductor while the secondary side of the transformer was connected to the feeder pillar via 1 x 300mm^2 armored copper cables at 10m per phase and neutral. The 95mm^2 S.W.A copper cable used as up risers were connected to the feeder pillar

2.4 Danger Plate

These are safety devices fitted on all the H.T poles to prevent easy access of climbing and to warn unauthorized person of the danger of playing around h.v systems and equipment.

Enameled danger plate of size 200x150mm on top, left hand side of the front door should be provided

Figure 2.20: Danger plate: (Dreams time 2000-2016)

2.5 Pin Insulator and Shackle Insulators

Pin and shackle insulators are respectively used to support high tension and low tension conductors. For any design work, the rating of pin insulator must be consistent with voltage level of the in-coming high tension line (11 or 33 kV line) while the shackle insulator must be of rating consistent with the low tension line. (415 V rating). Also, the number of pin and shackle insulators is dependent on the number of high and low tension poles employed for a given design work. One other important factor that must be considered in determining the total number of disc and pin insulators for a given design work is the tee-off point. At this point, the direction of high tension line usually changed. Depending on whether it is single-channeled or double-channeled, three additional pin insulators are needed if it is single-channeled or three additional pin insulators and disc insulators are needed if it is double-channeled.

2.6 Cross Arms

The cross arms are the supports which carry the components such as pin and disc insulators and all other accessories associated with them. The number of cross arms is usually determined by the number of high tension poles with due consideration of the ones that would carry other accessories at the transformer substation and section poles

2.7 Utility Poles

A terminal pole is an ‘H’ pole with the conductors erected on one side only and made tensioned by disc insulators. From this definition, an 11 kV line requires only three (3) disc insulators at the terminal pole/line arranged one per phase where 33 kV line requires only nine (9) disc insulators at the terminal poles/line arranged three per phase.

A section pole is an ‘H’ pole inserted into the high tension (11 or 33 kV line) where additional strengthen is required, stayed both ways in the direction of the line route and with the conductors tensioned by disc insulators on each side of pole. Therefore, for an 11 kV line, three (3)disc insulators are needed on one side of the pole arranged one per phase whereas 33 kV line requires only nine (9) disc insulators on one side of the pole only arranged three per phase. Hence, for one (1) section pole, an 11 kV line requires a total of six (6) disc insulators whereas 33 kV line requires eighteen (18) disc insulators are required.

A utility pole is a wooden pole used to support overhead power lines and various other public utilities, such as cable, fiber optic cable, and related equipment such as transformers and street lights. It can be referred to as a transmission pole, telephone pole, telecommunication pole, power pole, hydro pole, telegraph pole, or telegraph post, depending on its application. Some poles can be multi-purpose poles; for example stobie pole is a multi-purpose pole made of two steel joists held apart by a slab of concrete in the middle.

Electrical cable is routed overhead on utility poles to keep it insulated from the ground and out of the way of people and vehicles. Utility poles can be made of wood, metal, concrete, or composites like fiberglass. They are used for two different types of power lines; sub transmission lines which carry higher voltage power between substations, and distribution lines which distribute lower voltage power to customers.

(i) Poles range from 20-100 feet tall; the standard pole is 35 feet tall. Popular pole trees include Douglas fir, Southern pine, and Western red cedar.

(ii) Poles are buried about 6 feet in the ground and spaced about 125 feet apart.

(iii) The wood pole's lifespan is about 30-40 years. Sounding, drilling, and coring inspections give information about the pole's condition.

(iv) Attachment weight, moisture content, vibration, and settling add stress to poles. Utility poles may also be made of concrete, steel, or a fiberglass composite.

2.7.1 Pole Materials

Wooden Poles

The wooden pole material provides great flexibility during placement of hardware (up risers, disc insulators) and cable apparatus (Ale, 2016). Holes are easily drilled to fit the exact hardware needs and requirements. In addition, fasteners such as lags and screws are easily applied to wood structures to support Outside Plant (OSP) apparatus. The major disadvantage of the wooden poles is the attack of fungi and insects but this can be prevented by the use of preservatives like creosote, pentachlorophenol, and copper naphthenate.

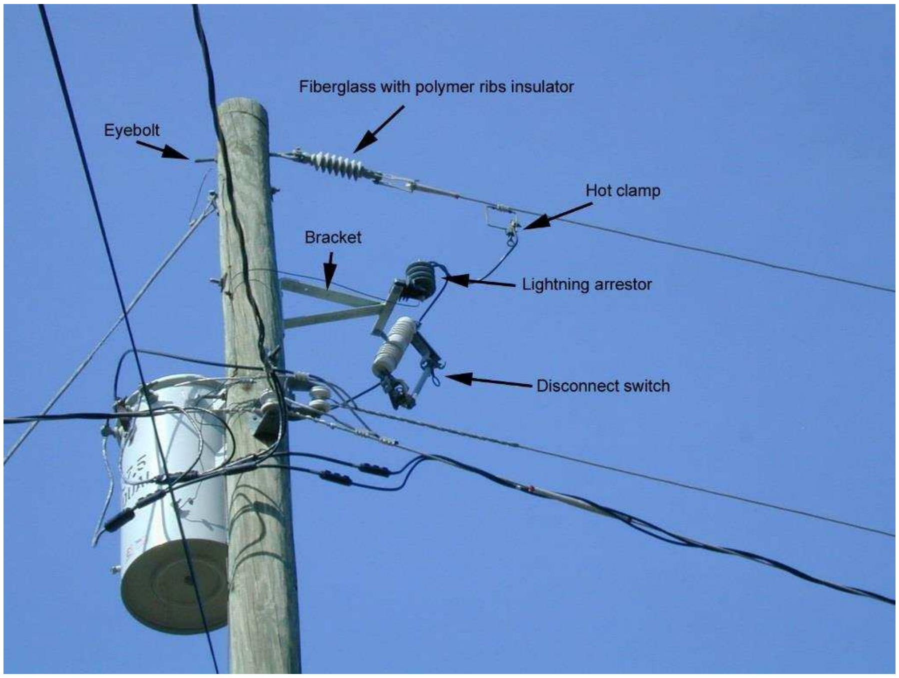

Figure 2.21: Wooden pole: (Pacific star electric, 2013)

2.7.2 Non-Wood Poles

There are three main non-wood pole materials and structures on which the attachment hardware may be mounted: concrete, steel, and Fiber-Reinforced Composite (FRC). Each material has intrinsic characteristics that need to be considered during the design and manufacture of the attachment hardware.

2.7.2.1 Characteristics of Materials We Need to Consider in non-wood Pole

i) Concrete Poles

The most widespread use of concrete poles has occurred in swampy environments and coastal zones where excellent corrosion resistance is required to reduce the impact of sea water, salt fog, and corrosive soil conditions (e.g., marsh). Their heavy weight also helps the concrete poles resist the high winds possible in coastal areas.

ii) **Steel Poles**

Steel poles can provide advantages for high-voltage lines, where taller poles are required for enhanced clearances and longer span requirements. Tubular steel poles are typically made from 11-gauge galvanized steel, with thicker 10- or 7-gauge materials used for some taller poles because of their higher strength and rigidity. For tall tower-type structures, 5-gauge materials are used. Although steel poles can be drilled on-site with a rota broach drill bit or standard twist drill, it is not a recommended practice. As with concrete poles, bolt holes could be built into the steel pole during manufacture for use as general attachment points or places for steps to be bolted into the pole. Welding of attachment hardware or attachment ledges to steel poles may be a feasible alternate approach to help provide reliable attachment points. However, operational and practice hazards of welding in the field may make this process undesirable or uneconomical.

Figure 2.22: Galvanized steel poles (Alibaba Manufacturer Directory, 1999-2016)

Plate 2.8: HT poles and overhead line materials

2.8 Pole Equipment

The basic equipment found on a typical distribution pole are listed below;

i. **Grounding Conductor**: The grounding conductor is a wire that connects the static wire to the ground rod. You can recognize the grounding conductor because this wire runs the entire length of the pole.It limits the voltage upon the circuit that might otherwise occur through exposure to lightning or other voltages higher than that for which the circuit is designed.

ii. **Distribution line**: Distribution lines that distribute power along residential and light commercial feed from the electric substation. The power in distribution lines can be one, two, or all three phases. The primary phase conductors are part of the distribution system wires and carry electricity from the substations at 220-415volts (V). On older poles, you will often see the primary wires supported by the crossbars. This cable brings electricity to the end user. Follow the wire from your home to the utility pole. The two insulated "hot" wires come from the transformer, and the bare neutral wire is connected to the ground wire at the pole.

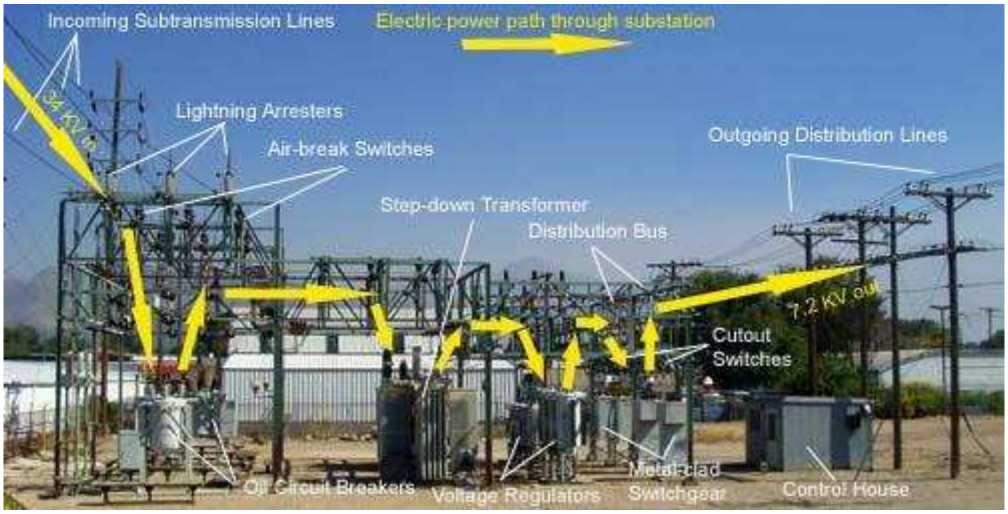

Figure 2.23: Distribution Line, (U.S department of Labor, 2011)

iii. R-Y-B Phase

These transmission wires carry high voltage electricity from the power plants in three phases, usually labeled R, Y and B. The three phase wires carry the power to substations where the voltage is reduced. From the substations, the power is distributed by lines called feeders. 6mm Aluminum is used for servicing from pole to the meter while 6mm copper is used for supplying current into internal / household appliances

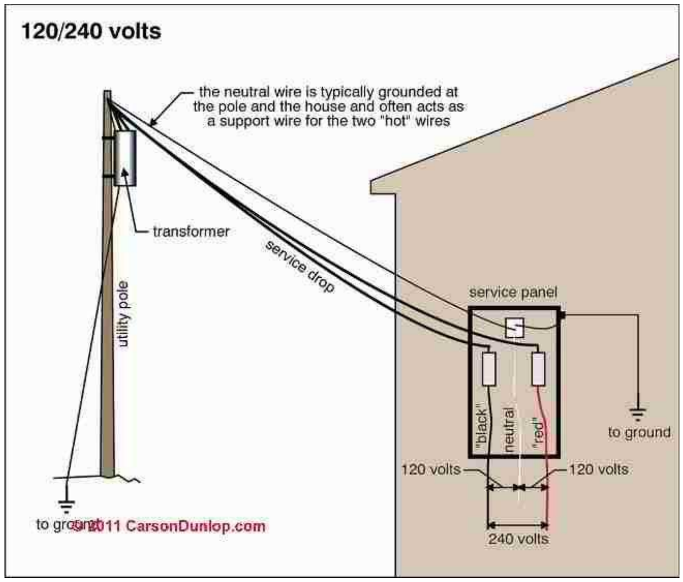

Figure 2.24: Red-yellow-blue phase :(inspectapedia, 2012)

2.9 Ground Rod and Wires that are used in a Substation

The ground rod is buried in the soil near the base of the utility pole. Since the ground rod is connected to the grounding conductor, when lightning strikes a pole or static wire, the high voltage surge travels down the grounding wire to the ground rod and safely into the earth (Oyeleye, 2015).

Armored cables are the most common type of cables used in a substation depending greatly on the capacity of the transformer. The picture below shows a roll of armored cable. Transformer sizes and cables used for incoming (dropper cable) and outgoing (feeder pillar) servicing are:

16mm (Aluminum): it is used for servicing from the pole to the cut-out meter while copper is used for supplying from the meter to the distribution board, 70mm Aluminum is used for servicing low tension while 70mm copper is used for supplying from the up riser to the H.T. pole

(i) **Guy Wire and Stay**

This is a conductor connected to an anchor in the ground to stabilize the pole. Guy and Stays these are usually installed to balance the pole. The theoretical angle between the pole and stay should be 45 degree but in general practice it is not always possible to obtain this and so stay design is generally based on a minimum angle of 30 degree between the stay and pole.Tables showing details about cables for different transformer ratings are shown below in table 2.1 and table 2.2..

(ii) **XLPE/Dropper/Jumper/Armour PVC Cable**: It is used to connect the D fuse to the High voltage terminal of the transformer.

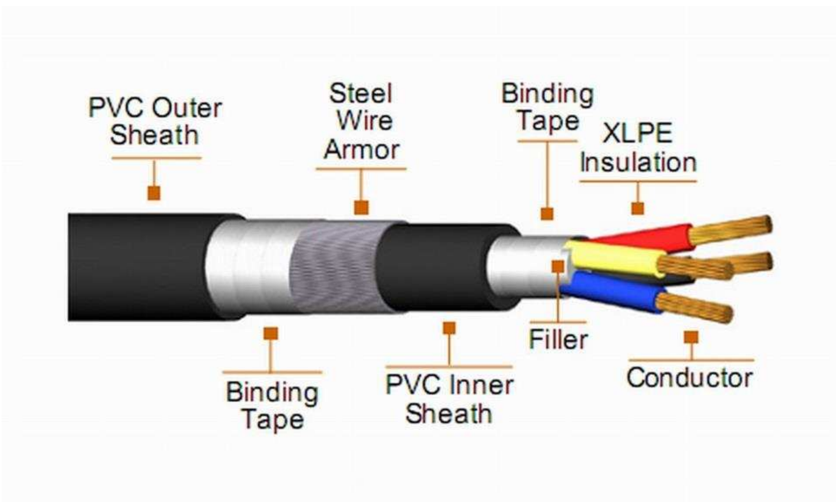

Figure 2.25: XLPE-insulated-steel-Wire-Armored-power-cable

Table 2.1: Transformer sizes and cables used in substation

Transformer size	**Feeder cable(HT)**	**Outgoing cable (LT)**
50Kva	70mm^2	35mm^2
100Kva	70mm^2	35mm^2
200kVA1	150mm^2	70mm^2
300Kva	300mm^2	185mm^2

315kVA	300mm^2	185mm^2
500Kva	500mm^2	300mm^2

Table 2.2: Cables sizes and their current carrying capacity

The cable sizes and their current carrying capacity is shown below:	**Current carrying capacity.**
35mm^2	140A
70mm^2	200A
150mm^2	335A
185mm ^{2}(single core)	380A
185mm ^{2}(3 core or 4 core)	370A
300mm^2	550A
500mm^2	750A

iii) Up riser Armored cable: It is used to connect feeder pillar to the low tension lines

(iii)Incomer armored cable: It is used to connect the low voltage side of the transformer to the feeder pillar

iv) **Transmission Wire**

For further transmission, in some electric poles transmission wires carry electricity at higher voltages of kilovolts (kV) from the generating plants to the next substations

v) **Vegetation**

All plants and trees planted around poles and under wires should be trimmed regularly to avoid interference with the electric system, especially during a storm (Ale, 2016). Utility companies are responsible for pruning vegetation on their easements, and homeowners can plant smaller bushes and trees that will stay below the overhead lines.

2.10 Protective Devices

Protective devices are usually installed to protect the substation components from damage due to faults or surges. The most common protective devices found in transformer substation are J & P fuses and lightning arresters. Another form of protective devices in the transformer substation is gang isolator which is normally being used in breaking the substation from in-coming high tension for the purpose of maintenance. Insulators of different types are also being used for protection of substation components such as overhead conductor apart from supporting them mechanical. The choice of protective devices is usually dependent on the level of voltage used for the design.

2.10.1 Lighting Arrester

A lightning arrester is a device used on electrical power systems and telecommunications systems to protect the insulation and conductors of the system from the damaging effects of lightning (Ale, 2016). By voltage surge is meant any sudden excessive rise in voltage that may be dangerous to the electrical equipment of an installation. Among such surges are those whose values approach the voltage at which the equipment in the installation has been tested. All the electrical equipment must be protected from severe damage due to the lightning strokes .Power stations are usually indoor while substations may be indoor or outdoor. For protection of a structure from direct strokes there are three requirements which are to be fulfilled. These requirements are interception, conduction and dissipation. These requirements involved

(i) an object in good electrical connection with the earth so that the leader stroke may get attracted,

(ii) a low impedance path joining this object to earth so that the discharge follows it in preference to any other path.

(iii) a low resistance connection with the earth body.

For (1), the upper portion of a metal structure may be employed .Alternatively a separate metallic system, often called the shield, either mounted on the structure or near to the and above it may be provided. A particular shield configuration in the form of masts or overhead ground wires is considered to provide good shielding.

For (2), the requirements are:

i) Low resistance (i.e., adequate conductivity and cross section, properly bounded joints; free from possible corrosion),

ii) Low reactance (i.e. absence of sharp bends, or loops and short conductors),

iii) And sufficient clearance from any other conducting object that might provide separate uncontrolled path to ground.

Outdoor substations have much of equipment carried on metal gantries and the interconnection of the upper portion of these will screen the apparatus. Usually, there is suitable grounding provided.

2.10.1.1 Operation of the Arrester

Lightning is a huge spark, which is due to electrical discharge taking place between the clouds, within the same cloud and between the cloud and earth. A lightning arrestor consists of spark gaps in series with nonlinear resistor, the whole assembly housed inside hermitically spaced porcelain bushing and a line lead soldered to the metal cap spun over the phase conductor. The earth terminal at the bottom of the arrester is connected to the group. Earth terminals of all the three lightning arresters are joined together and connected to the earth provided specially for lightning arresters. The lightning arrester discharges down to the earth, a high voltage lightning wave surges while it acts as an insulator for the system voltage.

Thus, the lightning arrester protection results in the maximum continuity of electricity supply to the consumer, low maintenance and greatly reduced distribution operating costs. The lightning arresters are erected on the top of the sectional pole structure for the protection of the transformer against lightning

2.10.2 Fuses

The word fuse is a short form of "fusible link" and it is also protection device capable of protecting a circuit from overload currents and short circuit currents. A fuse is essentially a short piece of wire /metal appropriately rated. This melts when a dangerous high electric current flows through it. This breaks the circuit and isolates the faulty part (overhead circuit) from the power supply system. Thus, the fuse is useful in the detection of fault current (If) .Here, fuse is viewed as part of a switch and hence can be referred to as a fuse switch. A high rupturing capacity (HRC) fuse is a fuse that has a high breaking capacity (higher kA Rating). The minimum fault value for an HRC fuse is 80kA. A general approach is that it should operate at 1.2 times the rated current. A typical fuse is made of silver-coated copper strips and granular quartz (Ale, 2016).

2.10.2.1 High Rupturing Capacity (H.R.C) Fuse

The rewire able fuse has limited breaking capacity and disability of destroying itself in the event of heavy overloading. When the fuse element is replaced with wrong type and rating, the fuse will operate inappropriately and endanger the circuit it is protecting. The HRC fuse was developed to cater for the limitation of the rewritable fuse. The HRC fuse wire are normally enclosed in ceramic cylinder that is caped at both ends (end caps) with appropriate metals to which the wire ends are connected .These end-caps form the terminals of the complete fuse link. When the wire melts or blows, the formation of arc is prevented and/or absorbed by the purified fine sand thus preventing the overheating effect associated with such fuse action.

Plate 2. 9: High Rupture Capacity Fuse

2.10.2.2 Major Factors to be considered for selecting a Proper fuse

i) **Voltage Rating:** The voltage rating of a fuse or circuit breaker must be at least equal to or greater than the voltage of the circuit it is to operate.

ii) **Continuous Current Rating:** This rating of a fuse or circuit breaker should be equal to or marginally greater than the rating of the circuit it is to protect.

iii) Interrupting Rating: This rating is the measure of the ability of fuse or a circuit breaker to break an electric circuit under fault conditions such as overhead, short circuit and ground fault currents without destroying itself.

iv) **Speed of Operation:** The time required for the fuse element to melt and break the circuit it protects varies inversely with the magnitude of the current flowing through the fuse.

2.10.2.3 Fuse Applications

Fuses find application in systems where the load does not vary much above the normal value (overload protection). They also find application in systems where the loads vary considerably (short-circuit protection). These applications include but are not limited to: Transformer circuits, Capacitor banks, Motor circuits, Fluorescent lighting circuits, Control circuits

2.10.2.4 Fuse Characteristics

The inverse time-current characteristic shows the time required melting the fuse and the time required to clear the circuit for any given level of over current load. A simplified, but typical fuse time-current feature is depicted in figure 3 below.

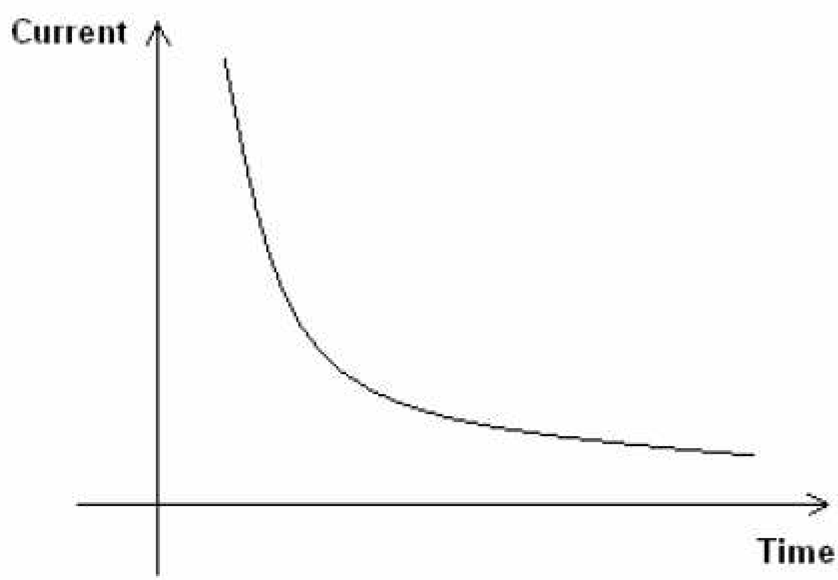

Figure 2.26: Typical time-current feature of a fuse

This curve is very important when determining an application for a fuse as it allows the correct ratings to be chosen.

2.10.2.5 Fuse Operation

When an over current condition occurs in the circuit, the silver-coated metal strip melts. It subsequently melts the surrounding quartz and this combination forms an insulating material called fulgarite. Like any perfect insulator, fulgarite has an infinite resistance and hence it creates an open circuit. This operation is summarized in figure 4 below.

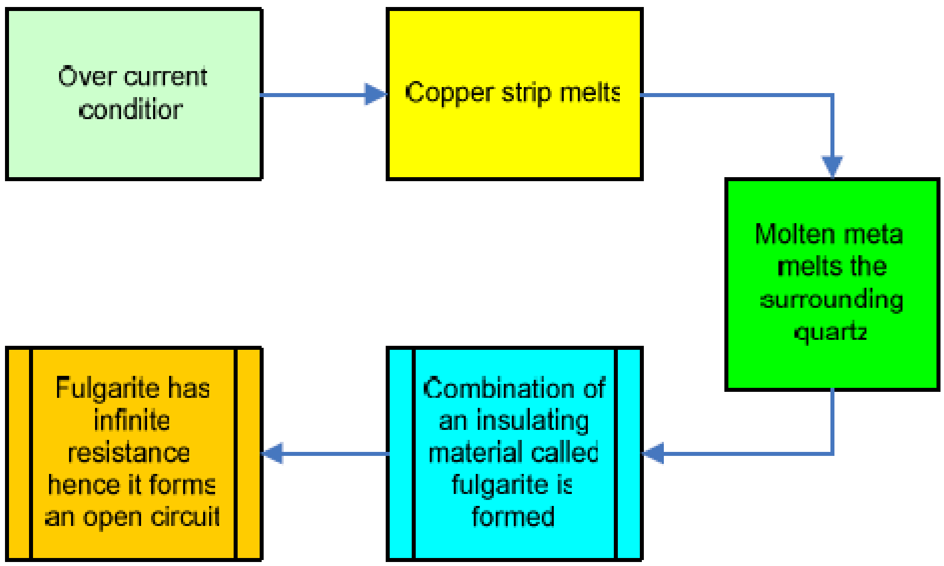

Figure 2.27: The Operation of the Fuse

2. 10.2.6 Fuse Disadvantages

The disadvantages of the fuse can be summarized as follows (Ale, 2016):

(i) The abrupt introduction of high resistance in the circuit by a badly designed and assembled fuse can create unwanted effects while clearing the fault

(ii) Although this is very rare, fuses are likely to produce high peak voltage which is much higher than the system voltage and can puncture the insulation of the rest of the circuit

(iii) A lot of maintenance and replacement costs. Maintenance in the form of continuously monitoring the state of the fuse; and replacement after each and every fault.

(iv) The cut-off current increases with the fuse rating.

(v) Fuse of incorrect ratings can easily be installed in the fuse holders.

(vi) In a three phase power circuit, if one fuse blows, all the fuses must be replaced at the same time.

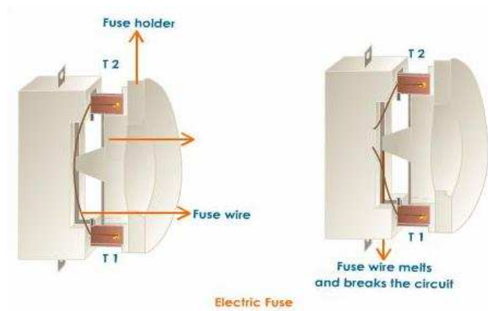

Figure 2.28: Electric fuse (TutorVista.com, 2016)

2.10.3 Isolator

Circuit breaker always trip the circuit but open contacts of breaker cannot be visible physically from outside of the breaker and that is why it is recommended not to touch any electrical circuit just by switching off the circuit breaker. So for better safety there must be some arrangement so that one can see open condition of the section of the circuit before touching it (Gupta,2013).Since isolator (or isolating switches) are employed only for isolating circuit when the current has already been interrupted .they are simple pieces of equipment. They ensure that the current is not switched into the circuit until everything is in order. Isolator or disconnect switches operate under no load condition. They are not equipped with arc-quenched devices. They do not have any specified current breaking capacity or current making capacity. The isolator in some cases are used for breaking charging current of transmission line.

2.10.3.1 Prevention of Maloperation of Isolator

i) Interlocking between three poles for simultaneous operation. ii) Interlocking with circuit breakers: isolator cannot be opened unless b the circuit breaker is opened and circuit breaker cannot be closed unless the isolator is closed.

Plate 2. 10: High Voltage electric Isolator

2.10.3.2 Categorization of Isolator

(i) Bus side Isolator- the isolator is directly connected with the main bus

(ii) Line side isolator- the isolator is situated at line side of any feeder

2.10.3.3 Operation of Electrical Isolator

As no arc quenching technique is provided in isolator it must be operated when there is no chance current flowing through the circuit? No live circuit should be closed or open by isolator operation.

A complete live closed circuit must not be opened by isolator operation and also a live circuit must not be closed and completed by isolator operation to avoid huge arcing in between isolator contacts. That is why isolators must be open after circuit breaker is open and these must be closed before circuit breaker is closed. Isolator can be operated by hand locally as well as by motorized mechanism from remote position. Motorized operation arrangement costs more compared to hand operation; hence decision must be taken before choosing an isolator for 500kVA 11/0.415kVdistribution substation whether hand operated or motor operated economically optimum for the system. For voltages up to 145kVsystem hand operated isolators are used whereas for higher voltage systems like 245kV or 420kV and above motorized isolators are used.

OCB Panel: Operating Circuit Breaker (OCB) panel is sometimes called H.T,it serves as NEPA incomers. It has 3-phase and no neutral. Its major function is to trip off when there is excess current/earth leakage. It is also an interlink between the NEPA incomer and distribution load board or transformer.

2.10.4 Breakers

Everyone is familiar with low voltage switches and rewireable fuses. A switch is used for opening and closing of an electric circuit while a fuse is used for over current protection. Every electric circuit needs a switching device and protective device. Switching and protective devices have been developed in different forms. Switchgear is a general term covering a wide range of equipment concerned with switching and protection.

Circuit breakers are mechanical devices designed to close or open contact members, thus closing or opening of an electrical circuit under normal conditions.

Automatic circuit breakers, which are usually employed for the protection of electrical circuits, are equipped with a trip coil connected to a relay or other means, designed to open the breaker automatically under abnormal conditions, such as overcurrent.

Figure 2.29 : Circuit Breaker; Your electrical home, 2011

2.10.4.1 Operating Principle of Circuit Breaker

A circuit breaker is a switching and current interrupting device. It consists, essentially, of fixed and moving contacts, which are touching each other and carry the current under normal conditions i.e when circuit breaker is closed. When the circuit breaker is closed, the current carrying contacts, called the electrodes, engage each other under the pressure of a spring.

During the normal operating condition the circuit breaker can be opene3d or closed by a station operator for the purpose of switching and maintenance. To open the circuit breaker, only a small pressure is required to be applied on a trigger. Wherever a fault occurs on any part of the power system, the trip coils of the breaker get energized and the moving contacts are pulled apart by some mechanism, thus opening the circuit. The separation of current carrying contacts produces an arc.

The production of arc not only delays the current interruption process but it also generates enormous heat which may cause damage to the system or to the breaker itself. Therefore, the main problem in a circuit breaker is to extinguish the arc within the shortest possible time so that heat generated by it may not reach a dangerous value. The basic construction of a circuit breaker requires the separation of contacts in an insulating fluid which serves two functions

(i) Extinguishes the arc drawn between the contacts when the circuit opens

(ii) Provides insulation between the contacts and from each contact to earth.

2.10.4.2 Basic Duties of Breakers

i) Make or break both normal and abnormal currents

ii) Appropriately manage the high-energy arc associated with current interruption. The problem has become more acute due to the interconnection of power stations resulting in very high faults level.

iii) Effect current interruption only when it is called upon to do so by the relay circuits. In fact, they are required to trip for a minimum of the internal fault current and remain inoperative for a maximum of through fault current

iv) Rapid and successive automatic breaking and making to aid stable system operation

3-pole and single pole auto-reclosing arrangement

In addition to these making and breaking capabilities, circuit breakers are required to do so under the following typical conditions:

i) Short-circuit Interruption

ii) Capacitor Switching

iii) Interruption of small inductive current

iv) Interruption of short-line fault

v) Asynchronous switching

2.10.4.3 Breakers Advantages and Disadvantages

Breakers Advantages over fuses

The advantages of the breakers can be summarized as follows:

Closed overload protection compared to HRC fuses ,stable tripping characteristics ,common tripping of all the phases of a motor ,instant re-closing of the circuit after a fault has been cleared off ,safety disconnect features for circuit isolation ,terminal insulation for operator safety ,ampere ratings that can be fixed and modified compared to the possibility of introducing overrated fuses, it is reusable, hence very little maintenance and replacement costs, lower power losses ,Simplicity of mounting and wiring, lower space requirements, provision of accessories e.g. auxiliary switch ,stable arc interruption, discrimination can be achieved either based on current or based on time

Breaker Disadvantages

The disadvantages of the breakers can be summarized as follows (Oyeleye,2015):More expensive than the fuse, difficult to identify where the fault occurred ,fault can be cleared in any time up to 10 cycles of the current waveform ,large amount of energy “let through” (10 times that released by the fuse)

Plate 2. 11 :D fuse unit

2.10.5 Earthing System

Earthing is the connection of part of an electrical circuit, accessible conductive parts of electrical equipment (exposed conductive parts) or conductive parts in the vicinity of an electrical installation (extraneous conductive parts) are connected to earth (Ale, 2016).

2.10.5.1 Components of earthing system

The earthing system comprises three (3) main components which are

a) Ground conductor

b) Connection between the ground conductor and ground electrode

c) Ground electrode

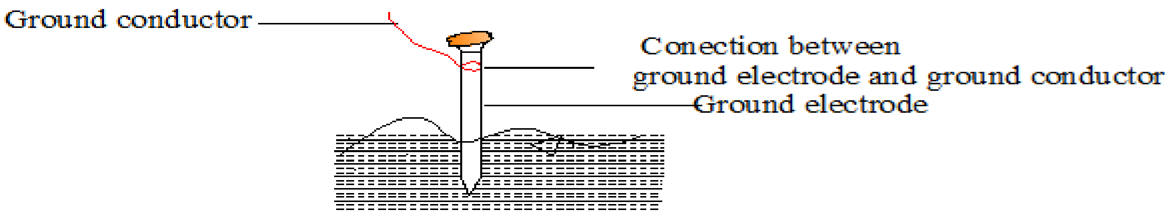

Figure 2.30 : Earthing

2.10.5.2 Types of Earthing

Three are four different types of earthing systems. They differ by the method of connecting the earthing electrode to either the earthing copper rod or the earthing copper plate. They are used depending on the level of earthing resistance we plan to achieve. The types are as follows (Oyeleye, 2015);

(i) Single earthing rod: This is a system whereby the earthing electrode is connected to a single earthing rod which is buried in the ground. Mostly used for Substations, Lightning protection, Standalone structures, Back-up for utility ground

(ii) Multiple earthing electrodes

(iii)Ground plate

2.10.5.3 General Earthing System Requirements and Terms

In order to achieve an effective and reliable earthing system, the following recommendations must be observed:

i) Any pit dug for burying earth grid or rods etc. and cables must be properly refilled and rammed

ii) All joints between the buried strips of steel and electrodes should properly be over-lapped and welded

iii) Joint in the earth bar between the switchgear unit and the cable sheathing should be bolted

iv) All welded and buried joints must be coated with bitumen and covered with bitumen impregnable tape for protection against rusting and /or corrosion

v) All joints to be welded must be properly clamped together to ensure good surface contact

vi) All earthing systems must be done as much as possible in accordance the existing regulations.

2.10.5.4 Terms Used in Earthing System

(i) Earth electrode: Is a metal conductor, or a system of interconnected metal conductors, or other metal parts acting in the same manner, embedded in the ground and electrically connected to it, or embedded in the concrete, which is in contact with the earth over a large area (e.g. foundation of a building).

(ii) Earthing conductor: Is a conductor which connects a part of an electrical installation, exposed conductive parts or extraneous conductive parts to an earth electrode or which interconnects earth electrodes. The earthing conductor is laid above the soil or, if it is buried in the soil, is insulated from it.

(iii) Electrical Shock: Occurs when two portions of a person's body come in contact with electrical conductors of a circuit which is at different potentials, thus potential differential across the body.

(iv) Reference earth: Is that part of the ground, particularly on the earth surface, located outside the sphere of influence of the considered earth electrode, i.e. between two random points at which there is no perceptible voltages resulting from the earthing current flow through this electrode. The potential of reference earth is always assumed to be zero.

(v) Earthing voltage (earthing potential, V_E): Is the voltage occurring between the earthing system distribution substation and reference earth at a given value of the earth current flowing through this earthing system.

(vi) Earth resistivity ρ (specific earth resistance): Is the resistance, measured between two opposite faces, of a one-meter cube of earth (Figure 1). The earth resistivity is expressed in Ωm.

2.10.5.5 Conditions for Efficient Earthing System

i) The resistance of the consumer's earthing system

ii) The soil resistivity,

iii) The resistance of the substation neutral earthing point and,

iv) Moisture condition of the soil

For an effective earthing system, the acceptable earth resistance value as stipulated by the Electricity Act is below 2.0 ohms. The reliability of protective devices especially in power systems largely depends on the state of the earthing system. With a earthing system, correct rating of fuse or earth leakage circuit –breakers are proper lay setting ,insulation breakdown or accidental touching of the live part will cause the fuses to blow or ELCB or relay/circuit breakers to disconnect the affected area. On the other hand, when there is insulation breakdown or accidental touching of a live part, poor earthing system will cause shock, fire or explosion.

2.10.5.6 Electrical Properties of the Earthing System

The electrical properties of earthing depend essentially on two parameters: Earthing resistance, Configuration of the earth electrode.

2.11 Single Line Diagram

Simple and complex power system even though they are three phase circuits, is usually represented by a single line diagram, showing various electrical components of power system and their interconnection. In single line representation of substation the electrical components such as power transformers, incoming and outgoing lines, bus-bars, switching and protecting equipment, are represented by standard symbols and their interconnections between them are shown by lines (Ale ,2016). Some of the standard symbols used to represent substation components are given in Table below.

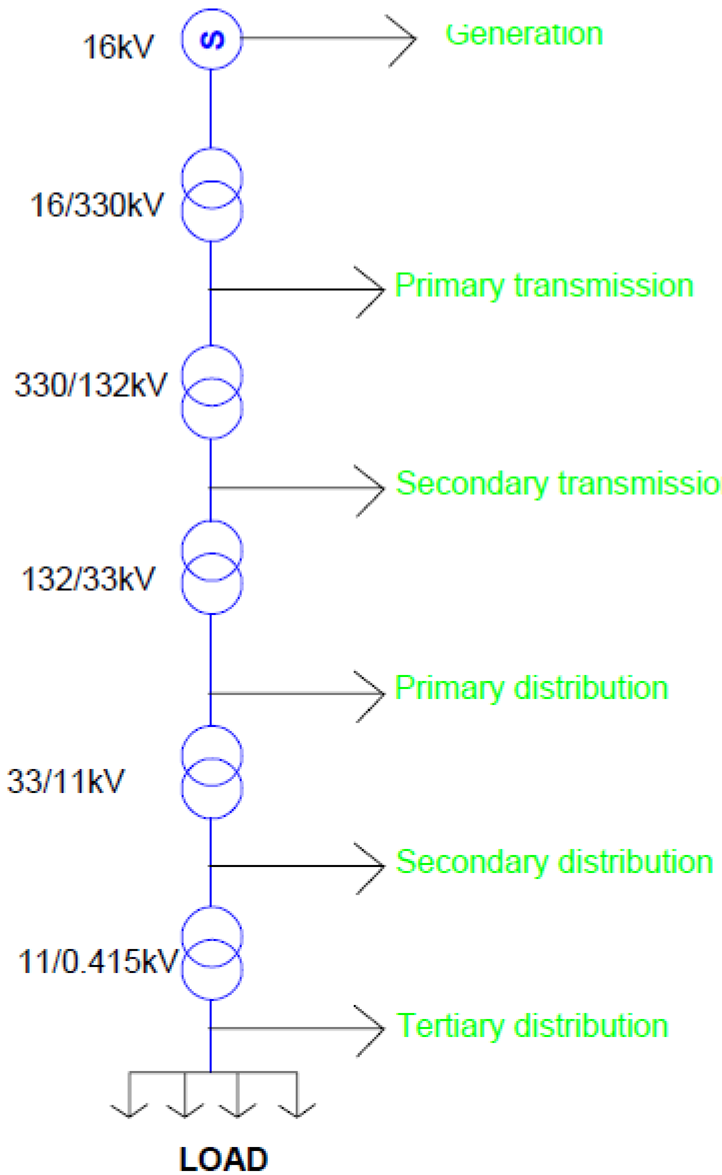

Figure 2.31 : One line diagram of power system in Nigeria

This line diagram above is a representation of a simple distribution sub-station. This starts from the incoming source (generating station or a substation) from the extreme left. The arrow head pointing in the right direction indicates the direction of current. The whole diagram is divided into sections with the introduction of circuit breakers and isolators, during fault or maintenance particular section can be de-energized. This eliminates complete shutdown of the system Also below is the single line diagram of 132kV supply to a town from national control center NCC which is injected into town injection substation at a junction where a double step down is performed on the incoming voltage; the incoming 132kVis stepped down to 33kV and also a further step down is perfumed to 11kV which is distributed to feeder,. Community is fed from the road feeder.

2.12 Fault Overview

When a reliable design is not available, there will be a failed development of the project in view. The normal operation of a power system gets disturbed or disrupted when abnormally high current flows through an abnormal path as a result of partial or complete failure of insulation at one or more points of the 500kVA 11/0.415kV distribution substation. The complete failure of insulation is called “short circuit” or fault (Turan, 2006).A fault is not to be confused with an overload. An overload means that the 500kVA 11/0.415kV distribution substation is loaded above the normal load for which the 500kVA 11/0.415kV distribution substation is designed. The voltage at the overload point may drop to a low value but not zero, as would be the case in the event of a fault.

Substation buses are designed to withstand the maximum expected faults due to extraordinary large mechanical forces produced by heavy short circuit currents. Transformer failures can be due to the insulation deterioration caused by ageing or overloading or over voltage as a result of lightning or switching transients. Most of the on the overload transmission lines are transient in nature, (Turan ,2006).Therefore, a service can be restored by isolating and reclosing the faulty line section very rapidly, allowing only enough time for the air to be deionized after the fault arc has been extinguished so as to prevent restriking. This procedure is called high-speed reclosing.

Fault can be shunt faults (balanced and unbalanced fault), Open line/series fault and Simultaneous faults

CHAPTER THREE

METHODOLOGY

3.1 Steps in Implenting the Design Of 500kVA ,11/0.415kv Substation

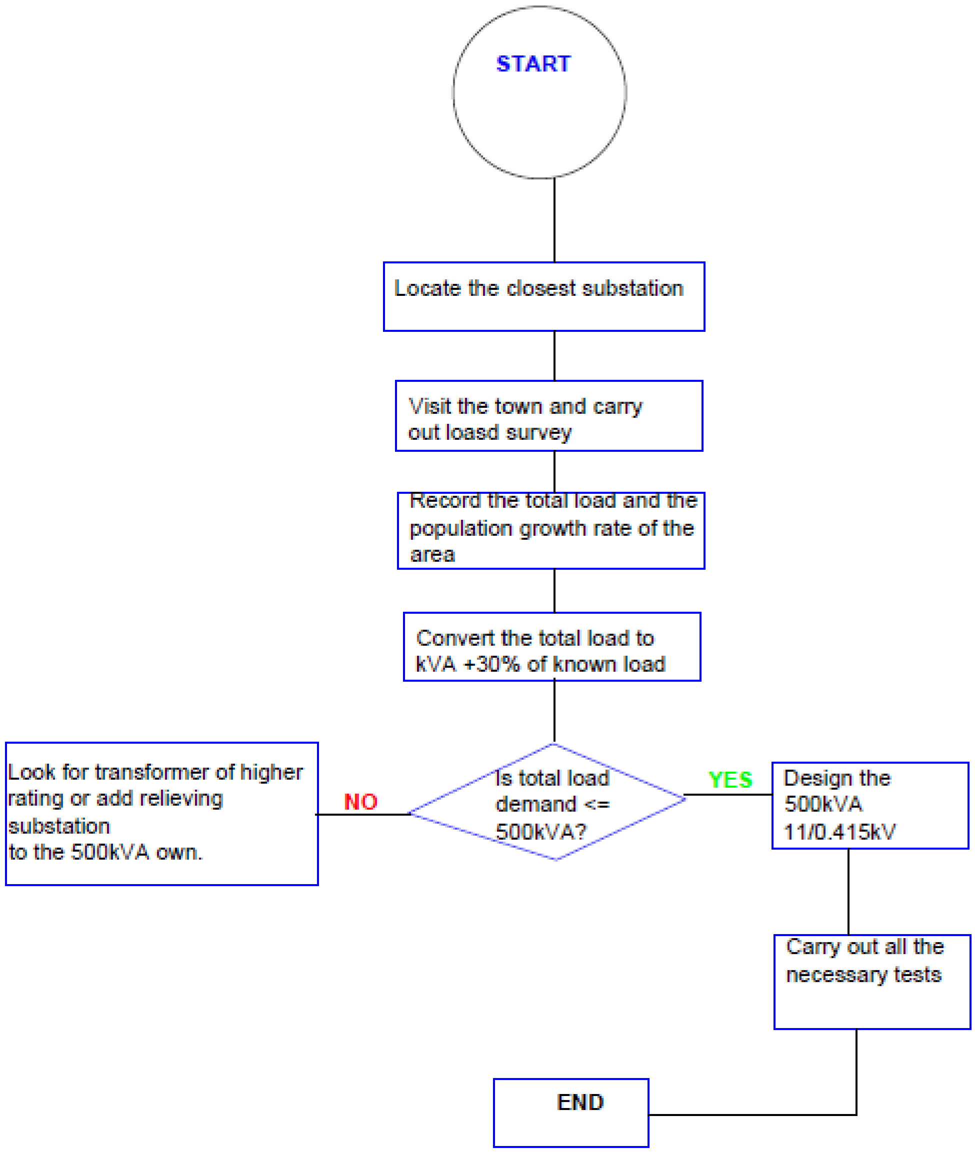

Figure 2.32: Flow chart for procedure

How can I achieve the definite future desirable state or task I intend to achieve at the end of this project work with maximum efficiency and effectiveness ?.The flow Chart in Figure 2.13 answers my question as this helps me not only to achieve my goals but also to have practical realities in Chapter 4.And the various steps to achieve the aim and objectives of the design of 500kVA 11/0.415kV distribution substation, below are the procedure according to the flow chart in Figure 3.0 above.

3.2 Preliminary Information

In most of the cases the project of the design of a substation must be submitted before any further detailed studies to the approval of the utility operating the network that will feed the substation. The list of information to provide for this approval may be the result of preliminary discussions with the utility.

3.2.1 Visit the town to be designed 500kVA 11/0.415kV substation for

This is the starting point of the design. The proposed area is first visited to access the nearest available grid system and identify the voltage level. This is quite important as it is the determining factor for linking the area to the National Grid system .As can be seen in the figure below, a town to be designed 500kVA 11/0.415kV distribution substation for.

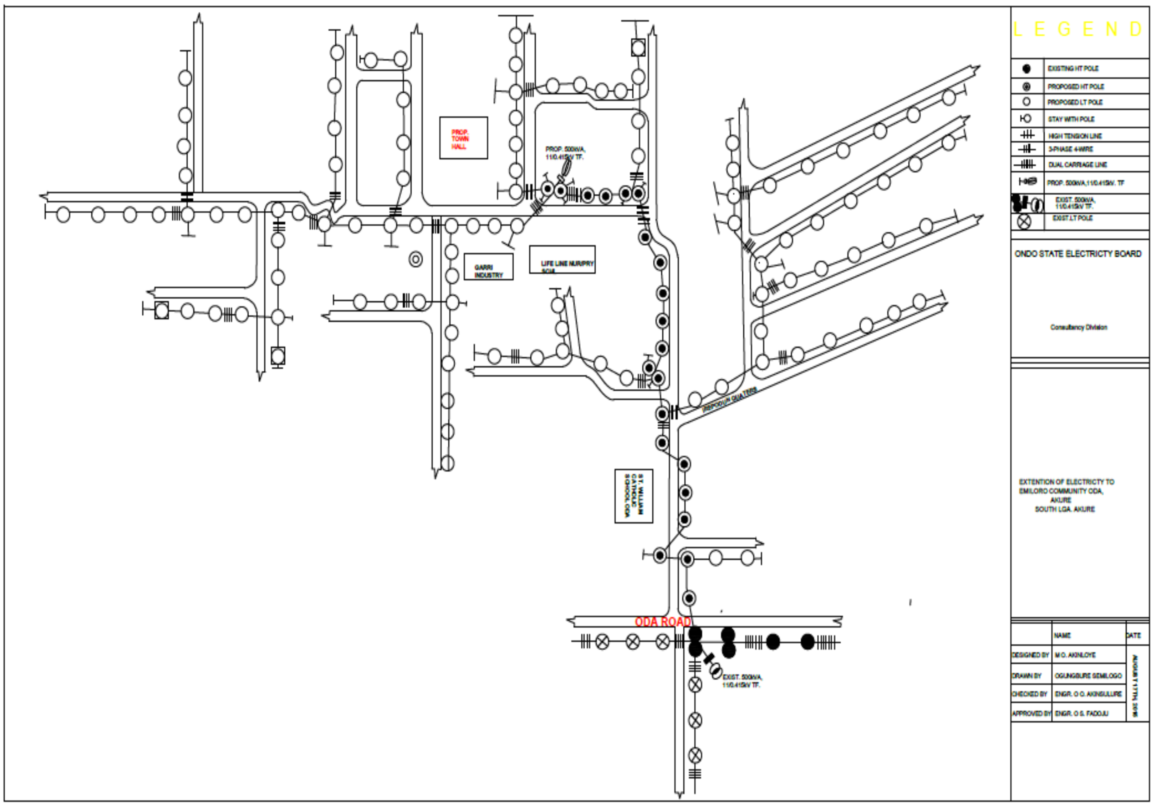

Figure 2.33 :A typical town with proposed 500kVA 11/0.415kV

When designing a new substation, it is important to know the environment, climate and the local government’s longer-range plans for the construction area. For example, when building substations near major roadways with open-air equipment, designers should consider using insulators that are highly resistive to contamination buildup, which can cause electrical tracking, flashovers, equipment degradation and outages. In heavily wooded areas, consider higher-end equipment such as special fencing to keep animal intruders from wandering into the substation, particularly near energized equipment. It is also important to carefully review the spare part needs for new equipment. Not only can this be costly and increase a company’s inventory, but in the event of a premature equipment or component failure, the needed spare parts become critical.

3.2.2 Locate the Closest Available Power Grid System

After visiting the town or the area and the National Grid system has been ascertained with the discovery of the rating of the grid systems that are available (e.g 33kV and 11 KV grid system), the route is surveyed, noting the route nature and terrain. This survey is to determine the actual kilometer coverage between the existing Grid system and the area of interest as well as the kilometer coverage for the township distribution network. Based on the route survey, the preliminary route drawings to scale are produced. The preliminary route drawings form the basis for further design consideration. The drawings make it possible to determine the number of spans involved, poles and poles positions (straight line .angle section, and intermediate) and the required stays.

3.2.3 Maximum Load anticipated power (kVA) demand and future expansion in load demand calculation

For this method, a data sheet is prepared and a field work embarked upon data collection, records of seen appliances would be taken down with their respective power rating as applicable and additional information were also gathered from observations and interaction of the personnel during the field work so as to reduce errors in load estimation to the barest minimum.

Two factors associated to the loads are used in the proposed method by using the formula given below:

$$Power = \sqrt{3}\ \ IVCos\ \Theta \qquad (5)$$

Where I, V and $Cos\ \Theta$ are the current, voltage and the power factor at the primary and the secondary side of transformer

(i) The factor of maximum utilization (ku)

(ii) The diversity factor (ks).

The load requirement for any substation design for electrification scheme is usually analyzed based on the existing dwelling houses, offices hotel premises, hospitals and industries giving room for future expansion, that is, future load demand of 30% of the total known load due to load growth using equation 5. Based on the arrived load in kW, the transforming distribution (feeder), fusing equipment etc. are determined. The total load demand should not exceed 500kVA, otherwise relieving substation will be needed. This will be demonstrated under chapter four.

3.2.4 Load Calculation Analysis

After the collection, the next step is to calculate and analyze these data so as to determine the capacity of the transformer require to supply these buildings. The total load will be derived by balancing each individual loads on the three supply, thus achieving a 'worst case scenario' single phase loading where each phase is assumed to carry equals adding together all individual loads with overall results multiplied by three to obtain the three phase loading and the rating of the transformer. The same unit of load rating is used throughout (kW) ,because of the variation in appliances load ratings, load ratings can be in Ampere (A) ,Horse power (HP),Kilo-Volt-Ampere (kVA),Kilo-Watt (KW), there arises the need to unify all these load ratings by converting to kW and then sum everything up in kVA using equation 6.

Below is the rating conversion

i) $P=IV$ *(6)*

Where I=current in Ampere (A), V is Volts (consumed to be 240V)

ii) Horse Power (H.P) to Kilo-Watt

(KW):0.746*hp *(7)*

iii) Kilo-Volt-Ampere (kVA) to Kilo-Watt (kW):

kVA *P.F *(8)*

Power factor is assumed to be 0.8 in this report

Relating the kW power rating from the load calculation to determine the usually quoted kVA transformer rating, a power factor of 0.8 lagging is assumed since three phase transformer are rated for 0.8 pf loads.

kVA=kW/0.8 + 30% of the total load demand (Transformer selection) *(9)*

A good long-term plan on how the substation is going to be used and how it will fit into the current system not only now but in the future years is the most important thing.

3.3 Layout and arrangement drawing of 500kVA, 11/0.415kV proposed substation

The practical fundamental design on factors such as location of protection, distribution distance to source on the low-voltage side, and other general factors will need to be considered. First, put together a good design that is consistent with good construction practices, including the ground grid and equipment foundations. It is difficult to replace a failed or weak foundation after the equipment has been installed. Verify the credentials of the people doing the work and their safety records and review references. It is good to have a licensed engineer perform the engineering work and be available during construction. Single line diagram and type of protections against phase to phase and phase to earth faults, Main characteristics of electrical equipment, Solution foreseen for the compensation of the reactive energy, Principle of the earthing system all these are take cognizance of.

3.4 Information and Requirements to Be Provided

These include level of voltage supply by overhead line, supply by underground cables

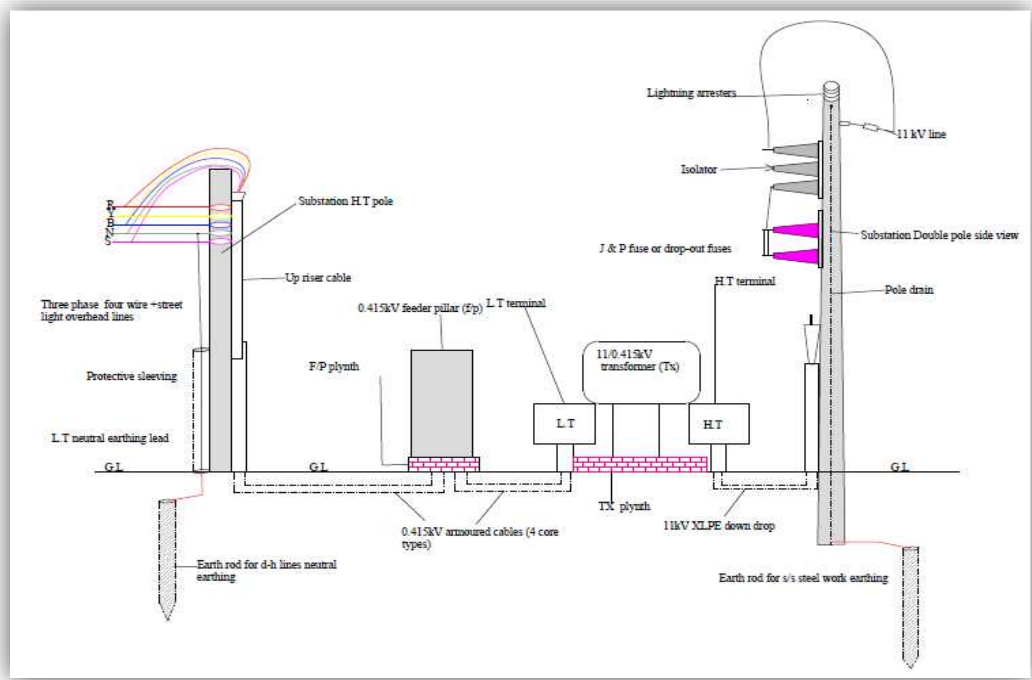

Figure 2.34: Distribution Substation arrangement with H.T down drop and L.T up riser cable

,single-line service, ring type supply, parallel feeders, etc. ,rated values concerning the voltage ,rated value concerning the current ,details concerning the applicable tariff and the billing of the electrical energy ,comments on drawings and information provided by the consumer ,specific requirements applicable to the substation.

The detailed studies of the substation must take all these parameters into account and other requirements.

3.4.1 Commissioning, Testing and Energizing

When required by the local authority, commissioning tests and checking must be successfully completed to get the authorization to energize a new installation. The following tests and checking are generally mandatory and applicable to the whole installation:

A. **Electrical Installation Works**: These include ,Insulation Resistance test ,Verification of polarity Continuity test Ring Circuit Test Effectiveness of earthing test

B. Electricity Projects:

(i) Insulation Resistance Test ,By megger testing ,By pressure testing

(ii) Transformation Ration Test

(iii) Short Circuit test

(iv) Excitation Test

(v) Transformation Oil Dielectric strength Test

(vi) Earth Resistance Test

As soon as the conformity official document is issued, the utility proceeds with the energizing of the installation.

3.4.2 Transformer Tests

On completion of the design of 500kVA 11/0.415kVkV some forms of inspections and testing with suitable instruments by qualified person (installation inspector or engineer or technician) are desirable and necessary. These are to ensure suitability, fitness and the reliability of materials and equipment used for the completed electrical installation and electricity projects before they are commissioned for use. They are also to ensure the safety of operation of the installation or network.

Physical inspections are carried out on such installation prior to actual testing. During such inspections, the fault and or defects that are brought to light must be corrected before the actual testing proceeds in order to save the time of the testing engineer(officer).However, the inspection and testing that are carried out on a completed installation works are not a complete and all time guarantee of the safety and quality of the electrical installation works after the initial testing and commissioning is necessary to maintain the installation in proper and safe times. More importantly, such regular inspection and testing help to ensure as far as practicable that the safety requirements as specified in the regulations have been complied with.

3.4.3 Things to note before carrying out any test.(Ale, 2016)

(i) Ensure the reliability of the measuring instrument.

(ii) Ensure that the three J & P fuses (Drop-out fuses) are isolated from the high tension.

(iii) Ensure that the fuses in the feeder pillar are all deloaded from the circuit unit.

(iv) Avo-meter must be used to check if there is any unidentified source, if there is any returning current.

(v) Test must not be carried out when it is raining and also when there is lightning, because when transformer is wet it gives wrong reading and for lightning for safe working condition.

(vi) The neutral cable must be loose from the secondary side of the transformer before testing.

3.4.4 Open and short circuit testing

These two tests are performed on a transformer to determine;

(i) Equivalent circuit of transformer

(ii) voltage regulation of transformer

(iii) efficiency of transformer

The power required for these Open Circuit test and Short Circuit test on transformer is equal to the power loss occurring in the transformer.

3.4.5 Open Circuit Test on Transformer

A voltmeter, wattmeter, and an ammeter are connected in LV side of the transformer as shown. The voltage at rated frequency is applied to that LV side with the help of a variac of variable ratio auto transformer. The HV side of the transformer is kept open. Now with help of variac applied voltage is slowly increase until the voltmeter gives reading equal to the rated voltage of the LV side (Ale, 2016). After reaching at rated LV side voltage, all three instruments reading (Voltmeter, Ammeter and Wattmeter readings) are recorded.

The ammeter reading gives the no load current i.e. As no load current i.e. is quite small compared to rated current of the transformer, the voltage drops due to this electric current then can be taken as negligible. Since, voltmeter reading V_1 can be considered equal to secondary induced voltage of the transformer. The input power during test is indicated by watt-meter reading. As the transformer is open circuited, there is no output hence the input power here consists of core losses in transformer and copper loss in transformer during no load condition. But as said earlier, the no load current in the transformer is quite small compared to full load current so copper loss due to the small no load current can be neglected. Hence the wattmeter reading can be taken as equal to core losses in transformer.

3.4. 6 Short Circuit (Capacity) Test on Transformer

There is no problem in short-circuiting the transformer secondary once the rated full load current of the secondary of the transformer under test is not exceeded. The impedance of a transformer is usually expressed in percentage (e.g. 2.5%,4%,5% etc.) and is normally found on the name-plate of the transformer.

These values are referred to the HV side of transformer because the test is conducted on HV side of transformer. These values could easily be referred to LV side by dividing these values with square of transformation ratio. Therefore it is seen that the Short Circuit test on transformer is used to determine copper loss in transformer at full load and parameters of approximate equivalent circuit of transformer.

Plate 3. 3: Short circuit test

3.4.7 Continuity Test

Electrical Installation Regulation 203 and IEE Regulation E10 stipulate that a test shall be conducted to verify the continuity of all conductors (including the earth continuity conductor) of every ring circuit. The test could be carried out with insulation megger. Continuity testing is the act of testing the resistance between two points. If there is very low resistance the two points are connected electrically and a tone is emitted. If there is more than a few Ωs of resistance, then the circuit is open and no tone is emitted. This test helps insure that connections aremade correctly between two points. This test also helps us detect if two points are connected that should not be. This feature allows us to test for conductivity of materials and to trace where electrical connections have been made.

The multimeter is set to continuity mode, as the probes are touch together (Ale, 2016). The multimeter should emit a tone. This shows that a very small amount of current is allowed to flow without resistance between probes. These probes are connected to the primary side of the transformer and the secondary. If it does not emit a tone, then you can begin to trace the route the particular terminal takes and tell if it is broken in the coil. Continuity is a great way to test if two terminals are connected without breakage or bridging between the coil turnings. When the transformer coils are all emitting sound it connotes that the coils inside the transformer is bridges at some point inside.

Figure 2.35 :Continuity Tester: (The Toolbox Manchester Ltd, 2016)

The above process can also be performed using a local method the use of a low voltage source connected at the primary terminals and a bulb or a noise-producing component such as an electric speaker is connected at the secondary. If the devices produce the energy they ought to produce with the right output then it shows the continuity is okay for use.

3.4.8 Earth Resistance Test

Earthing is the connection to the general mass of the earth in such manner that will ensure at all times the immediate and safety discharge and flow of fault current to operate protective devices. For the purpose of earthing, the earth electrodes are buried at least 1.2 meters below the ground level with appropriate cable connection to the point of interest in the installation.

Figure 2.36: Digital Earth Resistance Test: (ebay1995-2016)

For good and efficient earthing system, the acceptable earth resistance value as stipulated by the regulation is below 4.0 ohms(Ale, 2016). With good earthing system and current rating of fuses or earth leakage circuit breaker (ELCB) and proper relay setting insulation breakdown of the live part will cause the fuse to blow or trip the ELCB.

To test the entire earth resistance of a substation one of the three terminals of the earth cable of the transformer to be tested while the other are connected to two short earth rods taken away from substation and pegged to the earth tester until a reading is taken in ohms.

3.4. 9 Insulation Test

To understand the essence of the insulation test, a good knowledge of the property of the insulation is required.

Figure 2.37 : Insulation Tester: (frbiz.com. 2016)

3.4. 9.1 The property of Insulation

A pipe of electrical material has two basic parts namely

(i) Where electric current is intended to flow through i.e. through the conductor

(ii) Where the electric current is to be prevented from flowing the later is achieved by good insulation.

Some do so more readily, thus they are called good conductors; some materials resist the passage of electric current very well and they are used to surround conductor to keep the current flowing in the intended area, these material are called insulators. Examples of insulating materials are rubber, ceramics and plastic.

From ohms law

$$V=IR \tag{10}$$

Where V is applied voltage

I is the current flowing in the conductor R is the resistance of the conductor

We deduce that the more the voltage supplied, the more the current flow using equation 10. Hence insulators must have high resistance. This is why insulator used for 11kV line must not be suitable for 33kV. A good insulator should be able to have high resistance and remain so for a very long time. Insulation resistance of a material may however after the influence of some factors such as the effect of moisture, corrosive vapour, mechanical damage, vibration, excessive heat or cold, dirt and changing weather condition.

A good insulator is one having resistance of at least one mega ohm. Good insulation will usually have a resistance measured in mega ohms. For higher voltages, higher insulation resistance is required.

3.4.9 .2 Measurement of Insulation Resistance

Insulation requirements are of paramount and critical importance in the design, construction and commissioning of power systems. Over-voltage occurring in the power supply system's due to switching, lighting stroke etc. are usually far in excess of the operating voltages. Therefore, Insulation is generally designed so that it can withstand voltages far above the normal, so that in the case of transient over-voltage, the insulation will remain uninjured. A megger tester is used to measure insulation resistance. The megger is an essentially high resistance meter (ohm-meter) with in-built A.C generator and AC/DC converters or electronic voltage generator. The instrument's in-built generator produces a high DC voltage which is applied to the insulation under test.

A small current is then caused to flow through and over the surface of the insulator (Ale, 2016). The instrument measures the current and resistance is given on the meter scale in mega ohms. The meter scale is usually non-linear and shows a resistance value from zero to infinity.

Figure 2.38: Insulation resistance tester: (Megger Test Information and Resources, 2015*)*

3.5 Reliability of 500kVA 11/0.415kv Distribution Substation

This is the probability that 500kVA 11/0.415kV distribution substation or equipment will perform its required function under stated conditions, for a stated period of time,(Melodi, 2016).This can as well be defined as the ability of a 500kVA 11/0.415kV distribution substation to maintain its quality under specified conditions, within a specified time; quality and this is associated with manufacturing, while reliability is often used by the consumers. Environmental conditions such as temperature, humidity, vibration, etc. affect the quality and in turn cause failures.

In any project design reliability evaluation is an important and an integral feature of planning, design and operation of all engineering500kVA 11/0.415kV distribution substation which is one of the improving services of achieving reliability through adequate and coordinated planning. The usefulness or value of a 500kVA 11/0.415kV distribution substation therefore is determined by its steady availability and frequency of failures. In power 500kVA 11/0.415kV distribution substation, stability can be measured based on the 500kVA 11/0.415kV distribution substation reliability indices.

Reliability is probability expression, which needs to be quantified to make it suitable for scientific analysis. Introducing performance parameters, which indicates the degree of reliability and are called the indices of reliability, does the quantity. Some of them are expressed below:

This definition is broken into four terms, which are, Probability, Adequate performance, Time, Operation In the first part, probability provides the numerical input for the assessment of reliability and also provides the first index of system adequately. The other three parts are all engineering parameters. And probability theory is of no assistance in this part of the assessment. Components failure rates are stress level of the environment in which they function. The criterion of "adequate performance" is an engineering and managerial problem.

The function of an electric power distribution substation is to satisfy the system load requirement with reasonable assurance of continuity and quality. The ability of the 500kVA 11/0.415kV distribution substation to provide adequate supply of electrical energy designated by the term of reliability.

System adequacy and security: Adequacy related to the existence of sufficient facilities within the substation to satisfy the consumer-load demand. They include the facilities necessary to generate sufficient energy and the associated transmission and distribution facilities required to transport the energy to the actual consumer load point. Security relates to the ability of the 500kVA 11/0.415kV distribution substation to respond to disturbance arising within that 500kVA 11/0.415kV distribution substation. Security is therefore associated with the response of the 500kVA 11/0.415kV distribution substation to perturbations. Mostly of the probability techniques presently available for power-system reliability evaluation are in the domain of adequacy assessment (Peter, 2000)

In summary, high failure rates indicates a low reliability of a system while the longer the Mean Time between Failure the more reliable the 500kVA 11/0.415kV distribution substation. Similarly, the shorter the mean Down Time, the more reliable the 500kVA 11/0.415kV distribution substation is.Finally, considering the probability that the 500kVA 11/0.415kV distribution substation will work without failure in 24hours, the supply reliability is dependent on the value of the percentage value.

3.6 Civil work on Transformer Substation

It is required that 1.2m high transformer plinth and the feeder plinth of 0.6m be constructed to lift the equipment above ground level for protection against creepers (plants and animals) and to prevent the ingress of water in the event of flooding. The mass of the transformer is also another consideration. The fence measuring 5m x 5m x 5m with perforation was constructed to prevent unauthorized access to the substation. The transformer and the feeder pillar were positioned on the plinths. A steel gate was constructed and firmly earthed. The top soil was removed and the substation floor was covered with sand and overlaid with granite chipping.

Plate 3. 4: A typical civil work carried out on a substation

CHAPTER FOUR

4. RESULTS AND DISCUSSION

For the result and discussion, data obtained from load estimation used for this research work for the transformer sizing and evaluation, data a represented in tables, and the results of the various transformer tests that were carried out to know the condition of the transformer to be remarked as either good or bad transformer.

4.1 Result Analysis of Design of 500kVA Substation

In any substation the following constraints must be met:

I. Total load on the substation

II. Transformer sizing

III. I_{pry} side cable

IV. I_{sec} side cable

V. Feeder pillar rating

Transformers which could be step-up or step-down depending on the usage are normally rated in kVA .For our purpose, I will limit the scope of my research to step-down transformers. The 33/11kVtransformer with RMU is equipment used in primary/injection substations while 11/0.415kVkV transformers with the associated feeder pillars are the equipment used for distribution substation. The basic formula and method for determining the current capacities of transformers that are commonly used for primary and distribution substations is as shown hereunder:

a) *Three- phase transformers*

Figure 4.1 :A typical three phase line Life :(United State Department of labor,2016)

Power (P)= $\sqrt{3}\ \ IVCos\ \Theta$ *(11)*

Where I, V and $Cos\ \Theta$ are the current, voltage and the power factor at the primary and the secondary side of the transformer respectively.

Power (P) in

kVA=$\sqrt{3}$ IV *(12)*

Now, considering 500kVA transformer with 33/ 0.415kV

$P\ (kVA) = \sqrt{3}\ \ IV$

$I = \frac{P(kVA)}{\sqrt{3}\ \ IV}$ *(13)*

$$I_p = \frac{500 * 10^3}{\sqrt{3} * 11{,}000}.$$

$=26.24A$

Equation (12) above gives the design value and I need to look for the recommended value which gives me 30A.This the current entering the HRC (High Rupturing Capacity) fuse on the 11kVline. Then, I look for the type of cable and size corresponding to the current on the cable catalogue.

b) For Single-Phase Transformers:

The calculation procedure is the same as for the three phase with the exclusion of the $\sqrt{3}$ from the equation (10) or (11)

For Lv Side of a Transformer:

$$I_s = \frac{500k}{\sqrt{3} * 0.415k} = 695.6A \quad (14)$$

From equation (12) above, the design value for current is approximately 696A, but the recommended value is 700AThen, I look for the type of cable and size corresponding to the current on the cable catalogue.

Therefore, the bus bar rating will also be a minimum of 695.6A.Also the feeder pillar fuse will have a rating of 695.6A.So if the future expansion calculations have not been prior

4.2 TESTING AND RESULTS

4.2.1 Short Circuit Test

Below shows the readings obtained from the short circuit test carried out

TABLE 4. 3: Short Circuit Test Result

	Injected Voltage (V)			Current Measured (A)						Remarks
Connection	R - Y	Y – B	B - R	R	Y	B	r	Y	b	
R – Y	173	86	87	4.7	4.8	—	150	75	75	GOOD
Y- B	85	172	85	—	4.8	4.8	75	150	75	GOOD
B – R	85	85	170	4.8	—	4.8	75	75	150	GOOD

From the table above, the result obtained for connection R – Y, RY = 173, YB = 86, BR= 87 therefore, RY is our nominal voltage and for a good transformer, the sum of YB and BR = RY ± 5.i.e. 86 +87 =173 which is within the range of 173 ± 5. Also, in Y – B connection, RY +BR = YB ± 5, i.e. 85 + 85 = 170 which is within the range of 172 ±5. From the analysis of the result above, it shows that the transformer is okay.

4.2.2 Open Circuit Test

The table below shows the results obtained for the open circuit test

Table 4. 4 : Open Circuit Test result

	Injected Voltage (V)			Current Measured (A)						Remarks
Connection	R - Y	Y – B	B - R	r-y	y-b	b-r	r-n	y-n	b-n	
R – Y	277	240	38	10.9	4.3	6.7	5.9	5.1	0.8	GOOD
Y- B	152	271	120	9.3	8.7	0.7	3.3	5.8	2.6	GOOD
B – R	48	228	275	3.9	10.9	7	0.9	4.9	5.9	GOOD

From the table above, the result obtained for connection R – Y, RY = 277, YB = 240, BR= 38 therefore, RY is our nominal voltage and for a good transformer, the sum of YB and BR = RY ± 5. i.e. 240 +38 =278 which is within the range of 277 ± 5. Also, in Y – B connection, RY +BR = YB ± 5, i.e. 152 + 120 = 272 which is within the range of 271 ±5. From the analysis of the result above, it shows that the transformer is okay.

4.2.3 Continuity Test

All the cables are continuous as indicated by the continuity tester

4.2.4 Earth Resistance Test

For good and efficient earthing system, the acceptable earth resistance value is stipulated by the regulation is 4.0 ohms or below 4.0 ohms.

The result obtained from the earth resistance test carried out on a typical substation is 3.74Ω. Comparing this value to the regulation value, this result is okay for the substation.

4.2.5 Insulation Test

This type of test is carried out to determine the level of insulation of the transformer coil to the ground(Ale, 2016). To know if the level of the insulation can withstand the voltage it was designed for before breaking down. A result of insulation resistance test carried out on 11kV winding 500kVA transformer is as shown below

Red phase to Earth – 2500MΩ

Yellow phase to Earth – 2500MΩ

Blue phase to Earth – 2500MΩ

Neutral to Earth – 2500MΩ

Between phases – zero mega ohms

4.3 Cost Evaluation for Installing a 500kVA 11/0.415kV

A cost benefit evaluation is a normal process of design of any system and the selection of any component.(Gnan, 2010).Procurement costs are widely used as the primary criteria for equipment or system selection based on simple payback period. Some costs such as unit cost of 500kVA transformer, installation cost, maintenance cost and servicing cost, monthly cost are some of the costs that must be incurred in course of designing a 500kVA,11/0.415kV substation.,

The BEME in appendix will enable us to have idea about how much the installation of a 500kVA substation will cost.

4.4 ESTIMATEDLOAD FOR A TYPICAL DWELING PLACE

Table 4.5: A typical estimation for the agro allied and small scale industries

ITEM NUMBER	ITEM DESCRIPTION	RATING HP/KW	TOTAL W
I	30 Nos. lighting point	40W	1,200
ii	6 Nos. Security lighting points	250W	1,500
	3 Nos. Fuel pumps Electric motors	1.5Hp	3,357
iii	2 Nos. Electric tools motor for cassava grinding mills	5HP	7,460
iv	5 Nos. Electric tools motors	1.5kV	7,500
v	Saw mill machines		

	a) 1 No. CDC machine electric motor	1.5kW	18,650
	b) 1 No. Circular machine electric	5HP	3730
	motor	2.5kW	250
	c) Electric shaping machine		
vi	1 No.Rice processing mill electric motor	7.5HP	5595
vii	Bore hole electric motor	5HP	3730
	TOTAL LOAD=55.22kW		

Considering the size of the town and the above estimated loads for dwelling, hospital. Offices, workshops. and agro-allied industries, an allowance of 30% of the total load is allowed for future load demand, say it gives me 90.07kW

4.5 Load Summary and Analysis

1) Dwelling House Load = 180.05W

2) Hospital, offices, and workshop =65kW

3) Agro-allied/small scale industries =55.22kW

4) Future load demand =90.07kW

From the above the town estimated maximum load =390.34kW

Using the formula for power

Power (P)= $\sqrt{3} \quad IVCos\,\Theta$

Where P=Power and $Cos\ \theta$ power factor (P.F), therefore, the kVA rating of the above load is given as

KVA rating=kW/P.F

$$= \frac{3903.34}{0.8}.$$

= 487.92kVA

Thus the approximate kVA load demanded for the town below 500kVAbut 487.92kVA.Hence 500kVA transformer rating can be installed in a substation like this.

1. Expected Result

The accessories rating and other equipment ratings give the result listed below

I. Transformer size = 500kVA

II. I_{pry} side cable =*8.7A* , approximately 10A

III. I_{sec} side cable =695.6A ,approximately 700A

IV. Feeder pillar rating =695.6A , approximately 700A

4.6 General Comment based on the calculation made so far

The values of load demand in kVA imply that one 500kVA transformer would respectively serve community with the above load estimation.

For the sizing of the feeder pillar, equation (13) and the transformer ratings were employed. The rated secondary current which is determinant of the feeder pillar rating for 500 kVA transformer with 11 kV was calculated to be 695.60 A . Usually in practice feeder pillars are available in ratings of 200 A, 400 A and 800 A and based on the calculated rated secondary current of 500 kVA transformer, the appropriate feeder pillar for this work is 800 A, 4-way distribution unit for the transformer types.

For the conductor and cable selection, since the rated secondary current for 500 kVA transformer was calculated to be 695.60 A , the size of the cables that connect the secondary of the transformer type to the feeder pillar was selected as 500 mm squared unit for 500 kVA transformer. Also, for the cables that connect the feeder pillar to the low tension line (up-riser), 4 x 185 mm squared unit insulated PVC sheathed 4 core-armored cable was also selected since the current per functional unit of the feeder pillar for 500 kVA transformer is 174 A. Also, since the rated primary current of the transformer type was calculated as 8.75 A for 500 kVA transformer using equation (4.1), 70 mm squared unit AAC (all aluminum conductor) was selected as the transmission/distribution conductor to reduce losses

The number of high tension poles required are calculated and known using equation (), inter-township connection length of the said town should be known and a condition that at every 400 m, there must be a sectional pole (for strength of the line). The number of low tension poles required should be calculated and township distribution connection length should be computed in km. Also, the conductor length of the high tension line for the community could be calculated in metre and wastage factor of 1.1. Similarly, the conductor length of the low tension for the said area should be calculated in metre and wastage factor of 1.1. The required disc insulators should be found, number of pin insulators and shackle insulators disc. The summary of the few of essential components required for the design of 500kVA 11/0.415 are presented in Tables and respectively.

4.5 Advantages of Choosing the Right Transformer Size

When the right transformer size and other accessories is chosen the following will be checked;

No unexpected system failure, no shutdown due to capacity overload, increased longevity of transformer, guaranteed performance, smoother hassle-free maintenance, increase system life span, assured personnel safety, much smaller chances of asset damage.

CHAPTER FIVE

5. RECOMMENDATION AND CONCLUSION

5.1 Conclusion

Design is defined as a road map, strategic approach for achieving a unique expectation in creating an object, system, network which defines the specifications, parameters, values, cost, activities, processes "how and what " to do within legal, political, social and environmental safety and economic constraints in achieving the goals or objectives (Oyeleye ,2015).It therefore be concluded that the objectives and the aim of this research work were met satisfactory according to the guideline

Firstly, the transformer sizing was carried out using the load estimation method. Through the design and construction of 500kVA sub-station transformers, the little available supply can be enjoyed by the consumers. More so, loss of consumers' properties can be reduced. 500kVA, 11/0.415kVkV can be designed as a relief substation also, since relief sub-station gives a good quality of power supply, and also guarantee the life span of equipment such as transformer. Moreover, it saves life because when the conductors are overloaded, it is prone to sagging which can lead to conductor snap causing electrocution. Losses of power is also reduced which is uneconomical. Good quality supply of electricity improves cash collection of the utility company, also reduces loss of customers properties due to power surge and erratic power supply.

Hence, at the end of this research report the designer of the electricity project with the transformer rating of 500kVA will be guided a lot by this report and as such costly mistake of selecting wrong size of cable and type, feeder pillar, bus bar etc. which will as well lead to a reliable power supply, avoidance of costly maintenance of the project because, the constructor will accurately be guided by this report.

5.2 Recommendation

For the obtained result after various analyses, I hereby recommend the following:

i) The capacity of 500kVA, 11/0.415kV substation is reliable and environmentally friendly with affordable PHCN bill, therefore more attention should be paid to the stage of designing our distribution substation than to the interest of buying personal generators which are not environmentally friendly and much more costly in maintenance than the amount of money we paid for the PHCN bill.

ii) Secondly, I would like to recommend that allowance should be made for easier substation maintenance by using intelligent substation devices .Utilities must continue to explore technology designed to monitor (monitoring devices), measure and trend key substation equipment performance to move toward a more condition-based maintenance program instead of a time-based approach. Time-based maintenance tends to be more intrusive and, at times, not necessary due to the lack of significant equipment issues found during maintenance.

(iii) I suggest that utilities develop a good plan reviewed by experienced substation maintenance engineers who have a thorough understanding of these systems

Also, I recommend the provision of electricity, particularly through off-grid renewable energy technologies, as this will also raise standard of living and enables income generation and serves as an alternative to supply of electricity to the conventionally methods (hydro turbine ,thermal, chemical etc.)

One major limitation of the work presented here is that the effect of voltage drop on the placement of transformer substations was not put into consideration because I only considered short lines and so the effect of voltage drop was neglected. However, further work can be done on this same research work to study the effect of voltage drop on the substation locations other means of generation such as renewable technologies including biomass, small hydropower scheme, solar photovoltaic and wind hybrid for electrifying a communities with load demand like the one in this work and evaluate the cost implication of such electrification and compare with grid-based technology adopted in this work to determine the easier, better and economically more viable means to electrify the two communities.

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APPENDIX

S/N	DESCRIPTION OF MATERIALS	QTY	UNIT	RATE ₦	TOTAL COST ₦
1	10.36m R.C. Poles	2	length	25,000	50,000.00
2	11kV Channel Iron	5	length	7,000	35,000.00
3	11kV Steel cross arm	2	length	6,500	13,000.00
4	11kV pot Insulator complete with spindle	3	no	3,000	9,000.00
5	33kV line Isolator complete	1	set	190,000	190,000.00
6	33kV Tension clamp with J-hook and clevis adaptor	36	no	3,000	108,000.00
7	11kV Tie Strap	1	no	2,500	2,500.00
8	Bracing channel	8	length	2,000	16,000.00
9	11kV Lighting Arrester	1	set	3,500	3,500.00
10	11kV D-fuse with Holder	1	set	40,000	40,000.00
11	1 x 70 PVC Cable	90	m	1,500	135,000.00
12	Washers	50	no	50	2,500.00
13	70mm Bare Copper Conductor	150	m	1,600	240,000.00
14	Galvanized Earth rod	10	length	5,000	50,000.00
15	4 x 120mm SWA Cable	15	m	13,000	195,000.00
16	1 x 500mm^2 SWA Cable	40	m	30,000	1,200,000.00
17	Bolts & Nuts				
	a 5/8 x12	10	no	200	2,000.00
	b 5/8 x 10	10	no	180	1,800.00
	c 5/8 x 8	10	no	150	1,500.00

	d 5/8 x 6 e 5/8 x 2	8 8	no no	120 120	960.00 960.00
18	Substation civil works includinng granite chiping	LS	no	100,000	100,000.00
B	**Pre-Commissioning & Statutory fee**				
1	Pre-Commissioning by FME and BEDC	LS	-	250,000	250,000.00
2	Statutory fee for connection and Materials	LS	-	250,000	250,000.00
	Sub-Total				**2,896,720.00**