UNIVERSITY OF EDUCATION, WINNEBA

CHALLENGES ASSOCIATED WITH ELECTRICAL POWER GENERATION AS WELL AS TRANSMISSION AND DISTRIBUTION USING OVERHEAD AND UNDERGROUND CABLES

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A Dissertation in the Department of **ELECTRICAL AND AUTOMOTIVE TECHNOLOGY EDUCATION,** Faculty of **TECHNICAL AND VOCATIONAL EDUCATION** submitted to the School of Research and Graduate Studies University of Education, Winneba, in partial fulfillment of the award of **MASTER OF TECHNOLOGY EDUCATION (ELECTRICAL AND ELECTRONICS)** degree

AUGUST 2012

DECLARATION

CANDIDATE'S DECLARATION

I JOSEPH KUDJO KPEGLO, DECLARE THAT THIS DISSERTATION, WITH THE EXCEPTION OF QUOTATIONS AND REFERENCES CONTAINED IN PUBLISHED WORKS WHICH HAVE ALL BEEN IDENTIFIED AND ACKNOWLEDGED, IS ENTIRELY MY OWN ORIGINAL WORK, AND IT HAS NOT BEEN SUBMITTED, EITHER IN PART OR WHOLE, FOR ANOTHER DEGREE ELSEWHERE".

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I HEREBY DECLARE THAT THE PREPARATION OF THIS DISSERTATION WAS SUPERVISED IN ACCORDANCE WITH THE GUIDELINES ON SUPERVISION OF THESIS LAID DOWN BY THE UNIVERSITY OF EDUCATION, WINNEBA.

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MR FRANCOIR SEKYERE.

ABSTRACT

Distribution aspect of electrical system has been identified as constituting the greatest risk to realizing uninterrupted power supply. The rate of power outages has been very rampant in recent times. In this regard, this study examined the challenges associated with electrical power generation as well as transmission and distribution using overhead and underground cables within the Northern Electricity Distribution Company (NEDCo). Data for the study was obtained using structured questionnaires and interview guides. In all, 69 respondents participated in the study. This comprised of 65 technical staff and four management staff of NEDCo. Quantitative data analysis was performed using the Statistical Products and Service Solutions (SPSS), version 18. Generally, the study concluded that overhead cables are most effective in the generation, transmission and distribution of electrical power as construction and maintenance of the overhead cables is cheaper than the construction of underground cables. Fault detection and elimination in underground cables consumes a lot of money and time spending as compared to that of overhead cables. The major causes of power outages in NEDCO are external factors such as trees falling on overhead cables and bush fires destroying overhead cables. The study recommends that NEDCo through the Ministry of Energy should provide with appropriate and modern technology for the monitoring of power. Also, the government is encouraged to upgrade the distribution network. There should be rehabilitation of old lines and also injection of new substations which would solve the low voltages and outages in the catchment areas.

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DEDICATION

I dedicated this dissertation to my wife Esther Kpeglo and my daughter Rebecca Kpeglo

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ABREVIATIONS	ACRONYMS
EPT	Electric Power Transmission
SAIDI	System Average Interruption Duration Index
ECG	Electricity Company of Ghana
NEDCo	Northern Electricity Distribution Company
VRA	Volta River Authority
AC	Alternating Current
DC	Direct Current
kV	Kilovolt
Hz	Hertz
ACSR	Aluminum-Conductor Steel-Reinforced
CMOS	Customer Minutes Off-Supply
AAC	All Aluminum Conductor
AAAC	All Aluminum Alloy Conductor
PWD	Public Works Department
NED	Northern Electricity Department
GRIDCo	Ghana Grid Company Limited

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

There is an on-going demand from consumers for more reliable and economic power. Many factors contribute to determining the reliability of a power network: design, construction, operation and maintenance which have their combined input to overall power network reliability. Moreover, deregulation of the electricity sector along with adopting new technology, commercially puts great pressure on electricity utilities to operate not only economically but reliably and securely. A key limitation in the distribution of electric power is that, with minor exceptions, electrical energy cannot be stored, and therefore must be generated as needed.

The transmission system of electrical power acts as an interstate highway that takes electricity to the market. The availability of reliable electric power supplies is an essential precondition for the functioning of modern economies both in developed and developing countries (Literatum, 2012). Substantial expansion in quantity, quality and access to electricity, is fundamental to rapid and sustained economic growth, and poverty reduction. Thus major power system disturbances and outages have a significant economic and social impact and the security of supply becomes a more and more important issue (Coster, 2010).

The fundamental principles of electricity generation were discovered during the 1820s and early 1830s by the British scientist Michael Faraday. His basic method is still used today: electricity is generated by the movement of a loop of wire, or disc of copper between the poles of a magnet (The Institution of Engineering & Technology, 2011).According to Meyer (2011), the electricity supply industry is fundamentally different from most other economic sectors, it is a network industry. Thus, the means for the transportation of electricity power from the point of generation to the points of demand requires an interconnected system of network lines.

Electric Power Transmission (EPT) is one process in the delivery of electrical energy to consumers. EPT is the bulk transfer of electrical energy, from generating power plants to electrical substations located near demand centers. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as electric power distribution. Transmission lines, when interconnected with each other, become transmission networks. In the US, these are typically referred to as "power grids" or just "the grid." In the UK, the network is known as the "National Grid." Additionally, Meyer (2011) noted that power grids for such transmission typically consists of a high-voltage transmission network to cover long distances and a medium and low-voltage distribution network to serve consumers within the region they are located in. Power is usually transmitted through overhead power lines. An overhead power line is an electric power transmission line suspended by towers or utility poles. Since most of the insulation is provided by air, overhead power lines are generally the lowest-cost method of transmission for large quantities of electric energy. A major goal of overhead power line design is to maintain adequate clearance between energized conductors and the ground so as to prevent dangerous contact with the line. Today, overhead lines are routinely operated at voltages exceeding 765,000 volts between conductors, with even higher voltages possible in some cases (Lakervi, 1988).

According to Cowell (2003), underground power transmission has a significantly higher cost and greater operational limitations but is sometimes used in urban areas or sensitive locations. This Electric Power Transmission and Distribution is not limited to: energy storage; transmission and distribution automation and management; renewable energy integration; advanced monitoring and controls; distributed energy resource integration; advanced sensors, devices and systems; demand response and advanced system modeling and applications. Activities include demonstration projects, product development and studies that ensure grid reliability, efficiency, quality, and performance as the delivery network accommodates clean energy technologies such as renewable power generation, electric vehicles, and efficient distributed generation systems

In most countries around the world, the electricity sector has been liberalized forcing the electricity utilities to operate increasingly on commercial terms. Therefore, utilities must develop greater flexibility and security in terms of the supply and distribution of electricity, in the best and in the most effective environmentally-friendly way possible. Currently, due to greater public environmental awareness, restrictions on land usage, and higher demand for reliable and efficient electricity supply, a marked increase in the use of underground cable network is expected (Barber, 2004). Frequent and major power outages cause many concerns. Some of these concerns relate to the security and reliability of the power systems. Ageing assets also play a big role in more frequent outages. According to Mutton (2000), most of the outages and disruptions usually occur on the distribution part of the power network.

The main causes of overhead power transmission and distribution networks interruption are in fact unplanned external causes, like storms, bushfire, lightning, trees, animals, vehicle accidents and vandalism. Interruptions can also be caused by equipment and line or cable failure due to overload and ageing. However, overhead networks are more vulnerable to the external causes, adding to that, in general, the maintenance works required for overhead networks are about twice the number compared to the underground power networks maintenance works.

The System Average Interruption Duration Index (SAIDI, 2012) indicated that 70 percent of outages are attributed to the overhead network and 30 percent to the underground network. The average duration for an overhead fault is 50-55 minutes with an average duration of 65 minutes for an underground fault. The higher duration for the underground network is a reflection of the time it takes to effect repairs. On a per unit basis, an underground fault will take 10 times longer to repair (with a similar cost ratio). For many decades, overhead lines had proven to be a reliable solution, both technically and economically.

According to Karlstrand(2001), back then, no other alternative and competitive system was available and there was little concern for the environmental aspect when planning and constructing new electrical network. However, modern technology with continuous development of manufacturing and installation makes it possible for underground systems to be competitive with overhead lines, technically, environmentally and economically. Whilst most overhead interruptions occur for a short period of time, mainly less than a second due to surge strikes, other permanent interruptions are usually caused by external factors, therefore the surroundings have a big impact on overhead interruptions, unlike underground cables which are insulated from the surrounding conditions.

Many countries, including Ghana, embarked on power sector reforms to migrate from the regulated monopoly structure towards a deregulated competitive market structure. In order to make competitive markets possible, it was necessary to open access to transmission lines to permit new market entrants to buy and sell power. Therefore, it was necessary to functionally "unbundle" generation, transmission, and distribution. With a customer base of approximately 1.4 million, it has been estimated that 45-47 percent of Ghanaians, including 15-17 percent of the rural population, have access to grid electricity with a per capita electricity consumption of 358 kWh. All the regional capitals have been connected to the grid. Fuseni (2011) mentioned that outdated distribution network system, inadequate funding and the dispersed distribution network and maintenance cost, are some of the challenges militating against the growth of the energy sector in Ghana.

Bulk power systems in Ghana, comprise three main sub-systems; generation, transmission and bulk distribution centres. Bulk power is typically generated at very low voltages such as 13 kV to 24 kV at power stations. For example, the bulk power station at Akosombo generates power at 14.4 kV (Volta River Authority, 2010). This bulk power must be transmitted over long distances to bulk load centres such as Accra, Kumasi and Tamale. To minimize transmission losses, the power is transmitted at very high voltages. Therefore, the output from bulk power generators is passed through step-up transformers located at the power station switchyard onto the transmission system. The primary bulk power transmission voltage in Ghana is 161 kV. At the bulk power distribution centre, the power is stepped down through step-down transformers for wholesale power buyers such as ECG and NEDCo for further distribution through their respective distribution networks to their customers (Ghana Wholesale Power Reliability Report, 2010).

The Northern Electricity Distribution Company (NEDCo) of the Volta River Authority (VRA) is responsible for the supply of power to the Northern parts of Ghana. NEDCo operates at 34.5kV, 11kV and 400V voltage levels. The Northern Electricity Distribution Company (NEDCo) since its establishment has been responsible for the supply of electricity to the Northern Sector of the country. Thus NEDCo is responsible for electricity distribution in the northern zone of Ghana (i.e. Brong-Ahafo, Northern, Upper East and Upper West Regions) and serves about 30,000 consumers in its area of operation (Opam & Turkson, 2000). Thus the operational areas of the company are Sunyani, Techiman, Tamale, Bolgatanga and Wa.

1.2 PROBLEM STATEMENT

A sophisticated control system is required to ensure that an electric generation, transmission and distribution system very closely matches the demand. If the demand for power exceeds the supply, generation plants and transmission equipment can shut down which, in the worst cases, can lead to a major regional blackout. Distribution aspect of electricity system had been identified as constituting the greatest risk to realizing uninterrupted power supply. Studies showed that a typical distribution system accounts for 40 percent of cost to deliver power and 80 percent of customer reliability problems. (Karlstrand, 2001).

The energy industry in Ghana is currently going through a period of significant changes resulting in a multi-billion pound investment programme. This will encompass small and large scale electricity generation and substantial investment in energy networks to replace and upgrade ageing assets, construct new infrastructure to connect and efficiently deliver new energy sources, as well as maintaining the levels of safety and reliability to which everyone has become accustomed. Statistics from the Annual Report of NEDCo (2011) indicated that the rate of power outages has been very rampant in recent times. The transmission lines are owned and operated by the larger utilities, but the move toward deregulating the generation sector has opened the transmission lines to greater use. The existing transmission system was not designed to meet today's growing demand for electricity. The reliability of the system is no longer a certainty.

Additionally, empirical work on powered generation, transmission, and distribution in Ghana is scanty. Most of the work in the area has been in identifying the determinants of the investment and not the resulting effects (Haveman, 1976). It is however vital that an empirical study is carried out to identify the challenges associated with the generation, transmission, and distribution of electric power using underground and overhead cables in Ghana with specific reference to NEDCo.

1.3 OBJECTIVE OF THE STUDY

The main objective of this study was to examine the challenges associated with electrical power generation as well as transmission and distribution using overhead and underground cables. Specifically, the study sought to investigate:

1. The extent to which delays in locating faults on the distribution network affect the network as well as the customers;
2. Whether failure rate of electrical joint will increase on underground cables or not;
3. The major cause of power outages in the NEDCo; and

4. Make relevant recommendations to enhance the generation, transmission and distribution of electrical energy in the Northern Sector of the Country and Ghana as a whole?

1.4 RESEACH QUETION

They sought to give answers to the following questions:

1. What are the challenges associated with electrical power generation as well as transmission and distribution using overhead and underground cables in the Northern Sector of the Country?;
2. What is the extent to which delays in locating faults on the distribution network affect the network as well as the customers?;
3. Whether failure rate of electrical joint will increase on underground cables or not?;
4. What are the major causes of power outages in the NEDCo?; and
5. What relevant recommendations can be made to enhance the generation, transmission and distribution of electrical energy in Ghana

1.5 DELIMITATION AND LIMITATIN OF THE STUDY

For the purpose of this study, the focus was scoped to the technical challenges in power generation, transmission and distribution using overhead and underground cables. The environmental impact of both overhead and underground cables is beyond the scope of this study.

Additionally, although electricity supply facilities include power generating stations, electric substations, overhead lines and underground cables. This study only cover overhead and underground lines in power generation, transmitting and distribution because; power generating stations are major territorial facilities requiring special investigations on each project which cannot be covered in such a project due to time constraints and limited resources.

With regards to geographical locations, of the five operational areas of NEDCo (Wa, Bolgatanga, Tamale, Techiman and Sunyani), this study covered only three out of the five operational areas (Wa, Bolgatanga and Tamale). This was basically due to proximity. Even though this may limit the generalization of the research findings for the entire NEDCo, this study highlighted the challenges associated with electrical power generation, transmission and distribution in using overhead and underground cables in the Northern Sector of the Country.

1.6 SIGNIFICANCE OF THE STUDY

Findings from this study brings to light the best approaches for the generation, transmitting and distribution of electrical powers with regards to the use of overhead and underground cables for stakeholders in the energy sector. Additionally, it adds to the body of literature on the generation of electrical power using underground and overhead cables in the academia.

1.7 STRUCTURE OF THE STUDY

The study is structured into five chapters. Chapter one deals with the introduction which covers the background to the study, problem statement, objectives of the study, research questions, scope of the study, and significance of the study. Chapter Two is the review of related literature. Distinctively, the chapter reviews literature on challenges associated with electricity transmission and distribution through underground and overhead cables. Chapter Three presented the research methodology, which details how the study was designed and data was collected and analyzed. Chapter Four presented and discussed the results in relation to the applicable theories and concepts discussed in the review of related literature. Chapter Five summarised the major findings from the study, and made recommendations to stakeholders in electric power transmission, as well as directions for future research.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 INTRDUCTION

The chapter is the review of related literature. It reviews the theoretical and empirical literature on the challenges allied with electrical power generation, transmission and distribution using overhead and underground cables. The literature survey on different dimensions is presented under the following headings:

1 Overview Of electrical power generation, transmission and distribution;

2 Overhead cables;

3 Underground Cables;

4 Challenges involved in using overhead and underground cables

5 Historical overview of electrical power generation, transmission and distribution to Ghana.

6 Background of the Northern Electricity Distribution Company (NEDCo) Of Ghana

2.2 OVERVIEW OF ELECTRICAL POWER GENERATION, TRNSSMMITION AND DISTRIBUTION

According to Al-Khalidi (2009), electricity power generation is the process of generating electric energy from other forms of energy. Central power stations became economically practical with the development of alternating current power transmission, using power transformers to transmit power at high voltage and with low loss. Electricity has been generated at central stations since 1881. The first power plants were run on water power in 1881, under the leadership of Jacob Schoellkopf, after the first hydroelectric generating station was built on Niagara Falls.

Generally, electricity goes through a three-step process before arriving at the end user for consumption. First, power is produced from generators that are usually located far from the load centers. The power is then transported over the transmission grid, which is composed of transmission lines, transformers, and other components, to the bulk load distribution substations. From bulk load distribution substations, power is delivered to the individual customer sites using distribution lines. Since electric power currently cannot be stored easily in large quantities, this process must occur instantaneously in response to demand, for example, to the flick of a light switch.

Electricity generation ranges from 13,000 to 24,000 volts. Transformers increase the voltage to hundreds of thousands of volts for transmission. High voltages provide an economical way of moving large amounts of electricity over the transmission system. Figure 2.1 shows a basic power network plan.

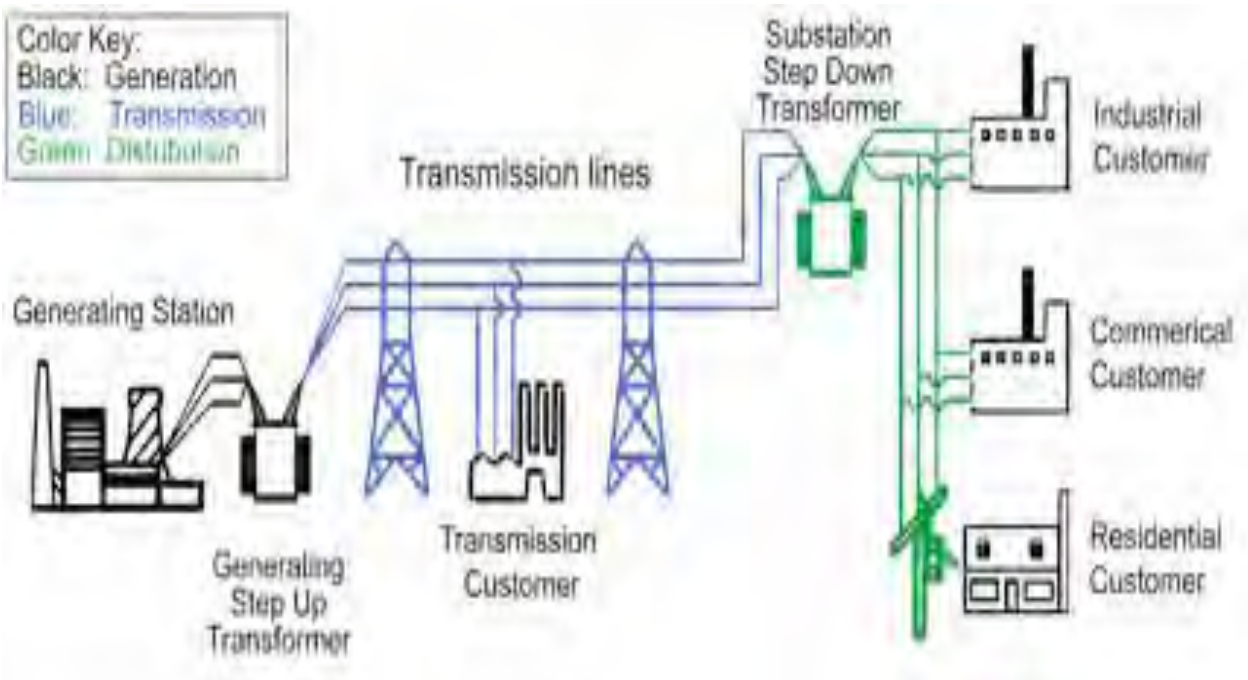

Figure 2.1: Basic Power Network Plan

Source: Ghana Wholesale Power Reliability Assessment, 2010

2.2.1Transmission and Distribution

Once electricity is given enough push (voltage) to travel long distances, it can be moved onto the wires or cables of the transmission system. The transmission system moves large quantities of electricity from the power plant through an interconnected network of transmission lines to many distribution centers called substations. These substations are generally located long distances from the power plant. Electricity is stepped up from lower voltages to higher voltages for transmission (Guide to Electric Power in Ghana, 2005)

High voltage transmission lines are interconnected to form an extensive and multi-path network. If one line fails, another will take over the load. Most transmission systems use overhead lines that carry Alternating Current (AC). There are also overhead Direct Current (DC) lines, underground lines, and even under water lines. All AC transmission lines carry three phase current - three separate streams of electricity travelling along three separate conductors. Lines are designated by the voltage that they can carry. Voltage ratings are usually 345 kilovolt (kV) for primary transmission lines and 138 kV and 69 kV for sub transmission lines.

Even though higher voltages help push along the current, electricity dissipates in the form of heat to the atmosphere along transmission and distribution lines. This loss of electricity is called line loss. The loss will be higher if the lines are not well maintained by the utilities. According to Khalidi (2009), around the world, best utility practices lower the technical line loss during transmission and distribution to 7-8 percent.

Switching stations and substations are used to (1) change the voltage, (2) transfer from one line to another, and (3) redirect power when a fault occurs on a transmission line or other equipment. Circuit breakers are used to disconnect power to prevent damage from overloads. Control centers coordinate the operation of all power system components. One or more utilities can make up a control area. To do its job, the control center receives continuous information on power plant output, transmission lines, ties with other systems, and system conditions.

2.2.2 Transmission constraints

There are some important constraints that affect the transmission system. These include thermal limits, voltage limits, and system operation factors (Lakervi, 2005). Electrical lines resist the flow of electricity and this produces heat. If the current flow is too high for too long, the line can heat up and lose strength. Over time, it can expand and sag between supporting towers. This can lead to power disruption. Transmission lines are rated according to thermal limits as are transformers and other equipment (Edward, 2010). Edward noted that the following variables are key to transmission constraints:

2.2.3 Voltage Limits

Voltage tends to drop from the sending to the receiving end of a transmission line. Equipment (capacitors and inductive reactors) is installed to help control voltage drop. Lakervi (2005) noted that if voltage is too low, customer equipment and motors can be damaged

2.2.4 System operation constraints

Power systems must be secured and reliable. Operating constraints are needed to assure that this is achieved.

2.2.5 Power flows:

Electricity flows over the path of least resistance. Consequently, power flows into other systems' networks when transmission systems are interconnected. This creates what are known as loop flows. Power also flows over parallel lines rather than the lines directly connecting two points-called parallel flows. Both of these flows can limit the ability to make other transmissions or cause too much electricity to flow along transmission lines thus affecting reliability.

2.2.6 Preventive operations:

The primary way of preventing service failures from affecting other areas is through preventive operations. Some standards and guidelines developed by the utility or regulator or another entity are usually desired. Operating requirements include (1) having a sufficient amount of generating capacity available to provide reserves for unanticipated demand and (2) limiting power transfers on the transmission system. It is recommended that operations are able to handle any single contingency and provide for multiple contingencies when practical. Contingencies are identified in the design and analysis of the power system.

2.2.6 System stability

The two types of stability problems are maintaining synchronization of the generators and preventing voltage collapse. Generators operate in unison at a constant frequency of 60 Hz. When this is disturbed by a fault in the transmission system, a generator may accelerate or slow down. Unless returned to normal conditions, the system can become unstable and fail. Voltage instability occurs when the transmission system is not adequate to handle reactive power flows. Reactive power is needed to sustain the electric and magnetic fields in equipment such as motors and transformers, and for voltage control on the transmission network.

2.2.7 Distribution

The distribution system is made up of poles and wire seen in neighborhoods overhead and underground circuits. Distribution substations monitor and adjust circuits within the system. The distribution substations lower the transmission line voltages to 34,500 volts or less. The voltage is then further reduced by distribution transformers (substations) to the utilization voltages of 415 volts three-phase or 230 volts single-phase supply required by most users (Guide to Electric Power in Ghana, 2005).

Substations are fenced yards with switches, transformers and other electrical equipment. Once the voltage has been lowered at the substation, the electricity flows to homes and businesses through the distribution system. Conductors called feeders reach out from the substation to carry electricity to customers. At key locations along the distribution system, voltage is lowered by distribution transformers to the voltage needed by customers or end-users.

Apart from voltage magnitude, distribution systems differ in other ways from transmission networks. The distribution network has more feeders or wires and more sources of power supply than the transmission network. Figure 2.2 shows a basic electric power system.

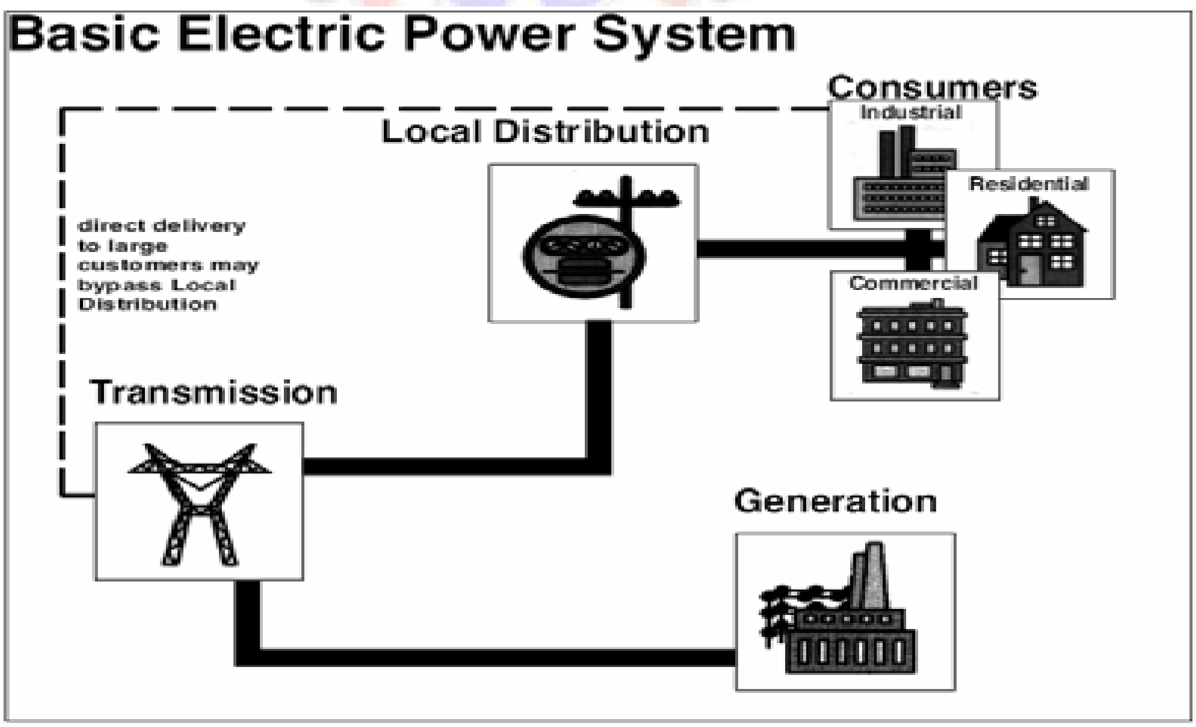

Figure 2.2: Basic electric power system

Source: Guide to Electric Power in Ghana, 2005

The structure or topology of its network is also different: this may be either radial overhead feeder as are often used in rural areas or loop/ring format that are the norm in urban areas. Ring circuits are usually interconnected to form networks used for enhancing reliability of supply to customers. Radial feeders are cheaper than ring or loop circuits but are less reliable as there is only one path between the substation and the customer. A failure of any component along the path results in complete loss of power delivery. Ring systems however provide two paths between the sources of power (substations or service transformers) and every customer. Here, each loop is designed such that service can be maintained regardless of a break at any point on the loop.

The effectiveness of a distribution system is measured in terms of service continuity or reliability, service quality in terms of voltage stability and lowest cost possible. Distribution systems also face similar cost constraints for transmission networks but to a much lesser extent.

2.3 CUSTOMERS AT THE END OF THE LINE

The ultimate customers who consume electricity are generally divided into three categories: industrial, commercial, and residential. The cost of serving customers depends upon a number of factors including the type of service (for example, if service is taken at high or low voltage) and the customer's location with respect to generating and delivery facilities.

2.3.1 INDUSTRIAL

Industrial customers generally use electricity in amounts that are relatively constant throughout the day. They often consume many times more electricity than residential consumers. Most industrial demand is considered to be base load. As such, it is the least expensive load to serve. Industrial loads are expected to remain within certain levels over time with relatively little variation. Major industrial customers may receive electricity directly from the transmission system (rather than from a local distribution system).

2.3.2 COMMERCIAL

Commercial loads are similar to industrial in that they remain within certain levels over intermediate periods of time. Examples of commercial customers are office buildings, warehouses, and shopping centers.

2.3.3 RESIDENTIAL

Residential electrical use is the most difficult to provide because households use much of their electricity in the morning and evening and less at other times of the day (Guide to Electric Power in Ghana, 2005). This is less efficient to provide and therefore a more expensive use of the utility's generators. Over time as homeowners buy new appliances and change lifestyles, the expected loads also change. Examples of residential loads are individual residences.

2.4 OVERHEAD POWER NETWORK CABLES OVERVIEW

Overhead lines employ a free and natural insulation medium - Air - to insulate long exposed conductors. Overhead lines are almost always favored over their much more expensive counterpart, underground cables, due to the unavailability of inexpensive alternatives to supply electricity, especially at high voltage levels (Lakervi, 1988). Overhead conductors are governed by strict rules and regulations, such as clearance from ground and nearby buildings, including easement and impact of Electromotive force (EMF) as well as swing of conductors to allow wind blowing across the lines at specific speeds. Usually, the line height is determined by the maximum conductors 'sag between towers. According to Lakervi (1988), when designing overhead power grids, engineers should consider these factors as well as extreme weather conditions with high current loading in hot temperatures or cold weather conditions with low load and their implication for conductor's stress levels **.**

The common type of overhead line is an Aluminum-Conductor Steel-Reinforced (ACSR) conductor, which is used usually for LV and MV distribution networks that require small conductor sizes This type of overhead line is fabricated by winding Aluminum wires that conduct the current around a core of steel strands in which they enforce the mechanical strength of the entire conductor. Overhead lines require some sort of support to keep them off the ground and have clearance required for their operation. They can be hung on a selection of types of supports: most obvious for LV and MV are wooden, concrete or steel poles; meanwhile for higher voltages, steel towers are the typical construction (Lakervi, 1988)

In addition to double-sided line clearance, many types of insulated overhead lines are commonly used in bushy topography to prevent physical contact with trees or to avoid conductor clashing which leads to a short circuit and can instigate a fault. Therefore, insulated overhead lines are considered safer than exposed lines. Figure 2.3 shows the graphical distribution of an overhead cable.

Figure 2.3: An overhead cable

Source: Furukawa Electric Group, 2012

2.5 RELIABILITY ISSUES OF OVERHEAD CABLES IN POWER NETWORK

The main causes of overhead power transmission and distribution network interruption are in fact unplanned external causes, like storms, bushfires, lightning, trees, animals, vehicle accidents and vandalism. Interruptions can also be caused by equipment and line or cable failure due to overload and ageing (Cowell, 2003). However, overhead networks are more vulnerable to the external causes; adding to that, in general, the maintenance works required for overhead networks are about twice the number compared to the underground power networks maintenance works.

Karlstrand (2001) noted that frequent and major power interruptions cause many concerns. Some of them relate to the power systems 'security and reliability. Ageing assets can play a big role in more frequent power interruptions (most of the outages and disruption usually occur on the distribution part of the power network).

According to Mutton et al. (2000), 85 percent of all Customer Minutes Off-Supply (CMOS) results from faults on the 22kV overhead distribution system. The low voltage network to a consumer's property accounts for only 4 percent and, although faults at zone substations and on sub transmission circuits impact on a large number of customers, they account for only 11 percent of customer minutes off-supply. The top three causes of outages account for 50 percent of all outages (Trees 23%, No Identified Cause 14% and Planned Outages 13%). Lightning, animals or birds and high voltage conductor failures each account for around 7 percent. Al-Khalidi (2009) Figure 2.4, noted that in 1999, trees caused more than 80 percent of faults on the two worst short rural 22kV feeders in Australia.

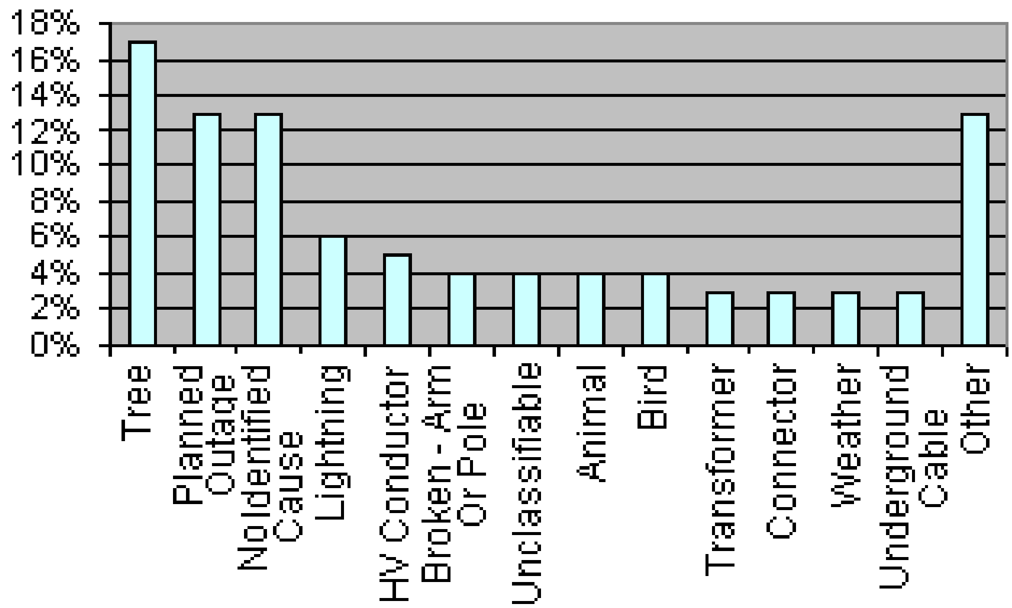

Figure 2.4: Reliability issues of power cables

Source: Al-Khalidi, 2009

2.6 TYPES OF OVERHEAD CABLES CONDUCTORS

Overall, there are a number of different overhead line conductor types which are usually installed by spacing between the individual conductors in order to acquire various voltage ratings. According to Cable (2004), the following are the three major types of overhead cables conductors:

1 AAC - All Aluminum Conductor;

2 AAAC - All Aluminum Alloy Conductor; and

3 ACSR - Aluminum Conductor Steel Reinforced.

Moreover, these features constitute many of the factors that an engineer would have to take into account when determining the type of conductors required for designing an overhead network. A short list, which highlights some of these important factors is as follows:

i Section length

The length of an overhead line can be decided with the following factors taken into account: terrain of line easement, quantity and quality of conductors, local climate conditions, nature of load and the required safety procedures.

ii Degree of sagging

Degree of sagging is determined by measuring the catenaries curve which takes into account the ratio of line span and weight as well as the structure required to support the conductor above the ground.

iii Daily conductor stress

The daily conductor stress is the unit which measures the variation of conductor stress under the normal operation load at or around the mean temperature with minimal or no high demand on existing load.

iv Surrounding environment temperature

Local climate has an explicit impact on the conductor temperature. Thus evaluating the actual operating temperature of a conductor is considered as an essential exercise in order to enhance conductor capacity utilization and mitigate the risk of sagging.

Table 2.1 presents the pros and cons associated with each category of overhead cable conductors.

Table 2.1: Pros and cons of overhead cable conductors

Cable	AAC	ACSR	AAAC
Category	All Aluminum Conductors; comprises a single or multiple strands made of hard drawn 1350 Aluminum Alloy.	Aluminum Conductor Steel Reinforced; comprises a solid or stranded steel core surrounded by one or more layers of strands of 1350 aluminum	A high strength Aluminum-Magnesium-Silicon Alloy cable;
Pros	1. excellent corrosion resistance 2. conductor of choice in coastal areas 3. heavily used in urban areas as spans are short but high conductivity is required	4. Mainly used for overhead ground wires 5. extra-long spans 6. makes the best candidates for river crossing …etc	7. offers excellent electrical characteristics 8. excellent sag tension characteristics 9. superior corrosion resistance
Cons	10. low strength-to weight ratio 11. limited use in transmission lines and rural distribution because of the long spans	12. inner core wires may require zinc coating (galvanized) steel	13. limited use 14. thermal coefficient of expansion is greater ACSR

Source: Al-Khalidi, 2009

2.7 UNDERGROUND CABLE

Undergrounding is no longer perceived as a prohibitively expensive exercise due to the advancement of technology in underground cables (Al-Khalidi, 2009).Figure 2.5

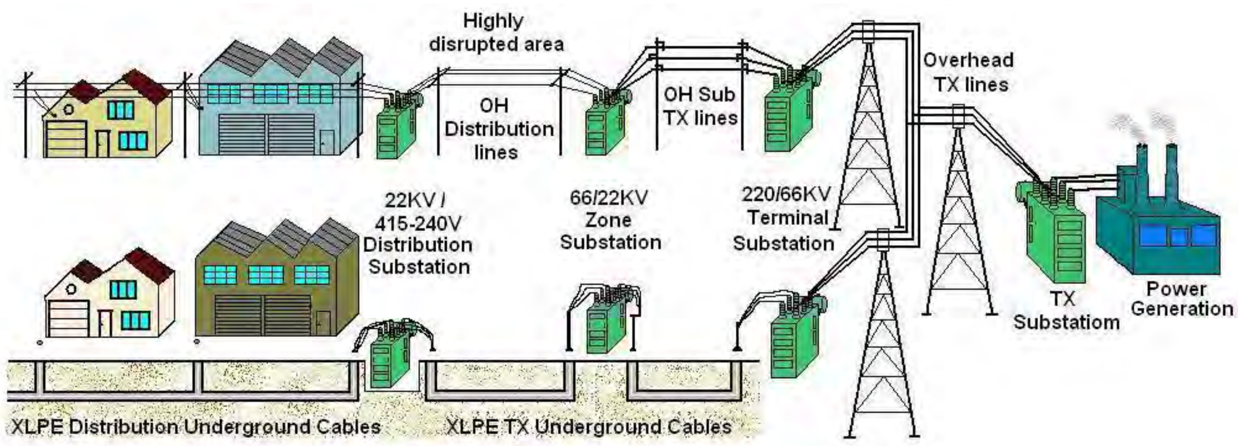

Figure 2.5: Power network with sub-transmission

Source: Al-Khalidi, 2009,

Despite the added reliability that could be gained from undergrounding, it is important to know that fault detection and elimination is much more time and money consuming than its overhead counterpart. Even shorter interruption time in overhead lines, does not hold as a viable discussion point when arguing against installing underground solutions. Furthermore, the total loss of revenues is far less when undergrounding than using overhead and that's primarily due to the significantly decreased fault frequency (Pansini, 1993).

2.8 CHALLENGES INVOLVED IN USING OVERHEAD AND UNDERGROUND CABLES.

Electric energy utilizes overhead and underground means to deliver power. Overhead networks comprise relatively low-cost insulators and conductors mounted on poles made of various materials like wood, steel or concrete. Other overhead equipments are installed on some of these poles which make it more cost effective to repair and maintain. On the other hand, this direct exposure has a down side of being highly susceptible to malfunctioning due to environmental and man-made breakdowns (Pansini, 1993).

2.8.1 Challenges associated with overhead cables

On August 14, 2003, most of Ontario, Canada, and eight north-eastern states of the U.S. experienced the largest power outage in North American history (Task Force, 2004). The blackout was so extensive that it lasted for up to a week in some parts. The investigative reports into the incident revealed that, a major cause of the blackout was trees interfering with overhead power lines causing the affected lines to trip and eventually contribute to the cascading power outage. The report also highlighted that three of the four lines whose tree contact led to the blackout were inspected only two or three months prior to the event (Novembri & Cieslewicz, 2004). It is generally accepted that the single largest cause of electric power outages arises from trees, or portions the trees, that grow or fall into overhead power lines.

2.8.2 Challenges with underground cables

Undergrounding consists of maintenance holes which are commonly referred to as manholes which are tubes used to connect underground utilities to the surface. Manholes are widely used in sewer systems, electrical and communication systems. These manholes are situated at regular intervals along the utility path, to allow easy access to maintenance workers. Rubber and other insulated conductors (cables) are installed and sliced inside these underground cavities. Therefore, fault detection and repairs can be a very costly exercise (Cable, 2004).

Undergrounding used to be implemented in very few cases where it met strict regulatory conditions. This was primarily, due to the high cost involved in undergrounding, for example when utilities and the public dispute over private property for line easement (Jey, 2003). Over the years, various factors have played a significant role in increasing the deployment of undergrounding. Some of these core factors are: the demand for higher power consumption which has led to building more generation sites. Unfortunately, it became ultra-difficult to obtain properties for such purposes (Maney, 1996). Another factor was the need for larger more economical generation units instead of local units. Finally, a more recent factor came into inception which is that health and environmental effects have been pushed quite heavily by industry lobby groups, regulators and more green governments.

The biggest advantage of underground installation is that it is less exposed and susceptible to external factors than overhead. However, somehow or other, this advantage can be offset by the time and effort spent in locating and repairing faults should they take place. The nature of the installation design and the complexity will be determined by the obligatory standards used for the installation.

Chang et al. (2009) argued that although underground cables have continued, up until the present, to be more expensive than overhead lines for the same capacity, a number of

European countries like the Netherlands have had underground cables installed widely since the early 70‘s. The reasons behind their ultimate decisions were based on:

1 Environmental nature of power network reliability;
2 Shortage of land and its utilization;
3 Recent regulation changes and opposition to overhead lines among the public.
4 Areas with historic or environmental values;
5 Crucial sections of the network which have low reliability records; and
6 Areas with a need for extra capacity where constructing a new overhead transmission line is out of question.

Major catastrophic events have normally acted as the mechanism which drives the undergrounding of power lines. In 1974, when Cyclone Tracey hit Darwin, it provided the justification for undergrounding Darwin overhead lines so subsequently by 1980, more than 50 percent of that city was serviced by underground LV and MV cables. Although there was little effort to retrofit existing areas throughout Australian cities since 1980, a steady introduction of underground cables for new residential areas has been undertaken. The bush fire risks in Australia has turned out to be more apparent due to climate change, in many cases these bushfires were results of clashing of bare conductors. Besides, the consumer demand for a more reliable and safer power supply will highlight the necessity of undergrounding the existing power network (Marazzato, 2000).

2.9 HISTORICAL OVERVIEW OF ELECTRICAL POWER GENERATION, TRANSMISSION AND DISTRIBUTION IN GHANA

Akosombo hydroelectric plant, power generation and electricity supply in Ghana was carried out with a number of isolated diesel generators dispersed across the country as well as standalone electricity supply systems. These were owned by industrial establishments such as mines and factories, municipalities and other institutions (e.g. hospitals, schools etc.). The first public electricity supply in the country was established in Sekondi in 1914. The Gold Coast Railway Administration operated the system which was used mainly to support the operations of the railway system and the ancillary facilities which went with its operations such as offices, workshops etc. In 1928, the supply from the system was extended to Takoradi which was less than 10 km away. This system served the needs of railway operations in the Sekondi and Takoradi cities (Guide to Electric Power in Ghana, 2005)

In addition to the Railways Administration, the Public Works Department (PWD) also operated public electricity supply systems and commenced limited direct current supply to Accra in 1922. On November 1, 1924, the PWD commenced Alternating Current supply to Accra. The first major electricity supply in Koforidua commenced on April 1, 1926 and consisted of three horizontal single cylinder oil-powered engines. Other municipalities in the country which were provided with electricity included Kumasi where work on public lighting was commenced. On May 27, 1927, a restricted evening supply arrangement was effected and subsequently, the power station became fully operational on October 1, 1927 (Guide to Electric Power in Ghana, 2005)

The next municipality to be supplied with electricity in 1927 was Winneba where with an initial direct current supply, the service was changed to alternating current (AC) by extending the supply from Swedru. During the 1929-30 time frames, electricity supply of a limited nature was commenced in the Tamale Township. Subsequently in 1938, a power station operating on alternating current was commissioned. In 1932, a power station was established in Cape Coast and subsequently another station was opened at Swedru in 1948. Within the same year, there was a significant expansion of the electricity system and Bolgatanga, Dunkwa and Oda had electricity power stations established.

The first major transmission extension of the electricity network in Ghana is believed to be the 11 kV overhead extensions from Tema to Nsawam which was put into service on May 27, 1949. Subsequently, a power station was commissioned at Keta in 1955. On April 1, 1947, an Electricity Department within the Ministry of Works and Housing was created to take over the operation of public electricity supplies from the PWD and the Railways Administration. One of the major power generation projects undertaken by the Electricity Department was the construction of the Tema Diesel Power Plant. The plant was built in 1956 with an initial capacity of 1.95 MW (3x 650 kW units). This was expanded in 1961-64 to 35 MW with the addition of ten 3 MW diesel generators and other units of smaller sizes. Subsequently, three of the original units were relocated to Tamale and the others used as a source of spare parts for the ten newer units. The plant when completed was the single largest diesel power station in Black Africa and served the Tema Municipality. In addition, through a double circuit 161- kV transmission line from Tema to Accra, the Tema Diesel Plant supplied half of Accra's power demand. The total electricity demand before the construction of Akosombo cannot be accurately determined due to the dispersed nature of the supply resources and the constrained nature of electricity supply. Most of the towns served had supply for only part of the day. In addition to being inadequate, the supply was also very unreliable. There was therefore very little growth in electricity consumption during the period. Total recorded power demand of about 70 MW with the first switch on of the Akosombo station can be used as a proxy for the level of electricity demand in the country just prior to the construction of Akosombo (Guide to Electric Power in Ghana, 2005)

2.9.1 How electric power works in Ghana

Bulk power systems in Ghana, comprise three main sub-systems; generation, transmission and bulk distribution centres. Bulk power is typically generated at very low voltages such as 13 kV to 24 kV at power stations. For example, the bulk power station at Akosombo generates power at 14.4 kV (Volta River Authority, 2010). This bulk power must be transmitted over long distances to bulk load centers such as Accra, Kumasi and Tamale. To minimize transmission losses, the power is transmitted at very high voltages. Therefore, the output from bulk power generators is passed through step-up transformers located at the power station switchyard onto the transmission system. The primary bulk power transmission voltage in Ghana is 161 kV. At the bulk power distribution centre, the power is stepped down through step-down transformers for wholesale power buyers such as ECG and NED for further distribution through their respective distribution networks to their customers (Ghana Wholesale Power Reliability Report, 2010).Figure 2.6

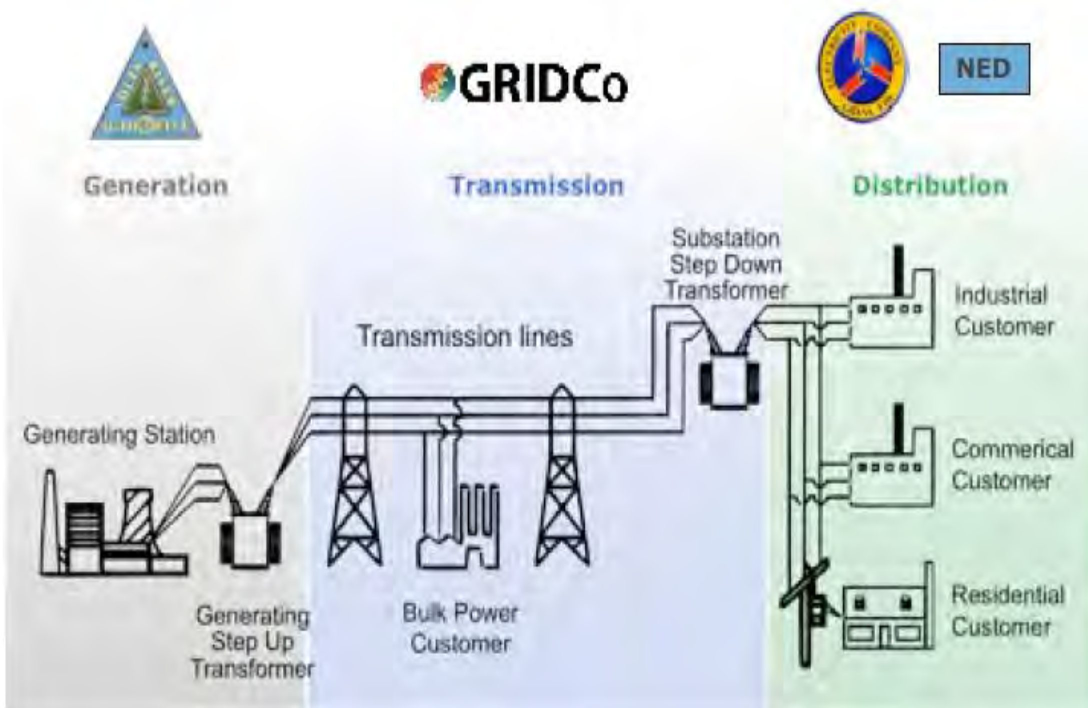

Figure 2.6: Ghana's Power Sector

Source: Ghana Wholesale Power Reliability Report, 2010

Thus, the transmission of power from bulk power generators to bulk power distribution centers is very similar to the haulage of farm produce from commercial farms to bulk market centers. In this case, the farmer who cultivates and harvests the farm produce is analogous to a generation owner such as Volta River Authority (VRA) who generates the power. The trucker who carts the farm produce in a truck from the farm across trunk roads to the bulk market centre is analogous to a transmission company such as Ghana Grid Company Limited (GRIDCo). The marketer who receives the farm produce at the bulk market centre is analogous to a bulk power distribution company such as Electricity Company of Ghana (ECG) or Northern Electricity Department (NED).

2.10 Historical overview of the Northern Electricity Department (NED) of Ghana, now Northern Electricity Distribution Company (NEDCo)

Until July 1987, the responsibility for distributing and supplying power in the country rested on ECG. The Government created the Northern Electricity Department (NED) as a subsidiary of Volta River Authority (VRA) in 1987 which took over from ECG, the responsibility for the running and development of electric power systems in Brong Ahafo, Northern, Upper East and Upper West Regions. Thus as part of the arrangements to expedite the Northern Grid Extension and Systems Reinforcement Project, Act 46 was amended to extend VRA's mandate to distribution of electricity in Ghana and VRA has since created a Northern Electricity Department (NED) to implement the northern distribution zone component of the National Electrification Project. The NED is responsible for electricity distribution in the northern zone of Ghana (i.e. Brong-Ahafo, Northern, Upper East and Upper West Regions) and serves about 30,000 consumers in its area of operation (Opam & Turkson, 2000).

The Northern Electricity Department (NED) of the Volta River Authority (VRA) has now been transformed into an independent liability company known as the Northern Electricity Distribution Company (NEDCo), a subsidiary of the VRA. The Northern Electricity Distribution Company (NEDCo) of the Volta River Authority (VRA) is responsible for the supply of power to the Northern parts of Ghana. NEDCo operates at 34.5kV, 11kV and 400V voltage levels. Since its establishment, the Company has been responsible for the supply of electricity to the Northern Sector of the country.

In view of this development, the VRA has mapped out a 10-year business development programme that would involve an amount of $200 million to improve upon the quality of service in the operational areas of the NEDCo. The programme would also include the establishment of six substations and the construction of a new headquarters building in Tamale. The operational areas of the company are Sunyani, Techiman, Tamale, Bolgatanga and Wa.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This chapter covers the research methodology that was employed for the study. The methodology was carved out to meet the research objectives and address data gathering problems imminent in research. The major components of this chapter are the study design, research population, sampling technique and selection, data sources and research instruments, and method of data analysis.

3.2 STUDY DESIGN

For this study, a survey method was employed. Surveys are a better source of primary data collection. According to Robson (2002), surveys are used in accord with a cross-sectional design, that is, the collection of information from any given sample of the population only once and provide a basis of comparison for case study triangulation. Specifically, the survey involved both the qualitative and quantitative research designs where questionnaires and interview guides are used to collect data to provide a rich resource of data among the respondents both at the staff and management level.

Mertens (2003) and Punch (1998) opined that the mixed method helps in having a better understanding of the research problem by converging numeric trends from quantitative data and specific details from qualitative data.

3.3 TARGET POPULATION

The target population for this study was employees of the Northern Electricity Distribution Company (NEDCo) from the Northern, Upper East and Upper West Regions. However, the unit of analysis included engineers and management of NEDCo. In other words, other employees of NEDCO were exempted from the study. That is to say employees of NEDCo in Brong Ahafo region were exempted from the study based on proximity, limited time, and the lack of available resources.

3.4 SAMPLE AND SAMPLING TECHNIQUES

To effectively sample the target population, the study would employ the simple random and purposive sampling methods. The purposive sampling method was used to sample management of the NEDCo since they are directly involved in the management of the sector. On the other hand, the simple random sampling method was used to sample staff of the engineering department. In this method, staff of the Department were chosen randomly and entirely by chance such that each staff had the same chance of being part of the sample. Additionally, the sampling of consumers was also done randomly across the operational areas (Tamale, Wa, and Bolga). Table 2 shows the distribution of the sample across the operational areas of NEDCo.

Table 3.1: Sample size distribution

Operational Area	Management	Staff
Tamale	2	30
Wa	2	20
Bolgatanga	2	25
Total	4	75

Source: NEDCo Annual Report, 2012

3.5 DATA COLLECTION

3.5.1 Sources of data

Primary data was obtained from the study's unit of analysis using questionnaires and interview guides respectively. On the other hand, secondary data was collected from books, articles, and the internet in exploring the whole range of issues pertaining to underground and overhead power generation, transmitting and distribution.

Two major data collection instruments were employed in the collection of the relevant data for the study in answering the research questions. The questionnaire was responded to by the staff of NEDCo, while the interview guide focused on the management of NEDCo.

Interviews can be a great source of information. Interviews may be structured, semi-structured or open-ended depending on the researchers' familiarity and knowledge about the study and the purpose of the interview, as well as the nature of the study (Drew, Hardman & Hosp, 2008). In this study, the researcher used semi-structured interviews to collect data from the management of NEDCo. This method involves face to face interaction between the interviewer and the participants allowing the researcher to control the process, and allowing freedom for respondents to express their thoughts (O'Leary, 2004). The interview sought to ask questions in relation to the study's topic. The interviews were tape-recorded with the permission of the participants and supported with notes taken by the researcher.

The questionnaire for staff of NEDCo was administered through a self-completion method. In this case, the respondents completed the items on the questionnaire on their own. The following reasons accounted for the choice:

- Respondents are literate and could read to adequately respond to the items;
- The method is relatively inexpensive;
- Obtaining very large samples was feasible, making the results statistically significant; and
- The method eliminates interviewer subjectivity thereby increasing the validity of the results.

Regarding the type of questions, the questionnaire contained both opened and close-ended questions. To make data analysis as easy as possible, majority of the questions were coded. In other words, most of the questions were closed-ended.

To adequately answer the research objectives of the study, the questionnaire was structured in five parts. The first relates to the socio-demographic characteristics of the respondents including age, gender, educational background, number of years of working with NEDCo. The other four sections were designed and structured in relation to each of the study's objective.

3.5.2 Procedure for data collection

To up-hold the principles of ethical consideration which greatly affect research participation, an introductory letter was obtained from the Department of Technology, University of Education, Kumasi Campus. This letter introduced the researcher to the management of NEDCo to grant the permission to conduct the study in the Company.

3.6 PILOT TESTING OF DATA COLLECTION INSTRUMENT

In order to test the reliability, adequacy and suitability of the research survey instruments, the questionnaire and interview guides were pre-tested using 10 staff and two management of NEDCo in the Sunyani operational areas. This operational area was selected for the pilot testing because it has similar characteristics with the other three operational areas.

The pre-testing helped to determine the strengths and weaknesses of the data collection instruments regarding their reliability and validity before proceeding to the actual field work. Few revisions were made to the instruments based on the results of the pre-test.

3.7 METHOD OF DATA ANALYSIS

Before analysing the data from the field, all completed questionnaires and interview guides were adequately checked for completeness. Thus data cleaning and processing was done to identify errors in data recording prior to the data analysis. The quantitative data gathered was coded and entered using the Statistical Products and Service Solutions (SPSS) , version 16. Quantitative analysis involved generating descriptive statistics. Descriptive statistics such as frequencies and percentages in the form of tables and figures were used to present the results. Qualitative analysis also involved the categorization of data from interviews and field notes into common themes.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The results of the data analyzed and the discussion of the findings are presented in this chapter. The discussion involves the possible implications of the findings. In discussing the findings, attempts were made to relate the findings of the study to the pertinent concepts and theories discussed in the review of related literature in Chapter Two.

4.2 RESULTS

The study assessed the challenges associated with electrical power generation as well as transmission and distribution using overhead and underground cables, the extent to which delays in locating faults on the distribution network affect the network as well as the customers and the major causes of power outages in the NEDCo.

The results of the study are presented in five sections. However, the first section presents the findings and discussions on the demographic characteristics of the respondents while the subsequent sections present findings and discussions on the relevant research questions and objectives of the study.

4.3 ANALYSIS AND DISCUSSIONS

4.3.1 Demographic characteristics of the respondents

This section presents the analysis and discussions of respondents' demographic characteristics. In all, there were 69 respondents who participated in the study. This comprised of 65 technical staff of the Northern Electricity Distribution Company (NEDCo) and four management staff of NEDCo. In examining the demographic characteristics of the respondents, the following four variables were analysed: Gender, age, number of years of working with NEDCo and the operational area of the respondents. In examining the gender of the respondents, the study revealed that all (100.0%) the technical staff of NEDCo who participated in the study were males. Thus there were no female respondents among the technical staff of NEDCo who participated in the study. This suggests that females have not been attracted to the electrical engineering profession so much.

In relation to the ages of the respondents, descriptive analysis presented an average age of 40 years with minimum and maximum ages of 26 years and 58 years respectively. In addition, a standard deviation of 7.6 was obtained which gives the indication that the ages of the respondents were uncluttered around the mean age. In exploring the ages of the respondents further, the study re-coded the ages of the respondents into a five consistent age interval as shown in Table 4.1

Table 4.1: Age distribution of respondents

Age (Years)	Frequency	Percent
26-30	11	16.9
31-35	5	7.7
36-40	22	33.8
41-45	12	18.5
46-50	11	16.9
51-55	2	3.1
Above 55	2	3.1
Total	65	100.0

Source: Fieldwork, 2013

It is noted in Table 3 that more than half (58.4%) of the respondents were aged at most 40 years while 41.6 percent were aged above 40 years. It is important to note that none of the respondents was in their retirement age (At least 60 years). Thus the majority of the respondents were made up of relatively young people, which gives an indication that the technical staff of NEDCo is made up young people as compared to the older people.

The study examined the number of years respondents have been working with

NEDCo. Descriptive analysis showed that, averagely, respondents have worked with NEDCo for 10.4 years. In addition, the descriptive analysis showed that the minimum and maximum years respondents have worked with NEDCo were three months and 30 years respectively. Furthermore, Table 4.2 shows the detailed results on the number of years respondents have been working with NEDCo

Table 4.2: Years of working with NEDCo

Years	Frequency	Percent
Less than a year	2	3.1
1-5	12	18.5
6-10	22	33.8
Above 10	29	44.6
Total	65	100.0

Source: Fieldwork, 2013

In Table 4, it is noted that the most prevalent number of years the respondents had worked with NEDCO was above 10 years (44.6%) followed by those who had worked with the company for 6-10 years (33.8%). Further analysis shows that majority (78.4%) of the respondents have worked for at least six years with NEDCO. Generally, it can be deduced that the respondents have worked with NEDCO for a long period. This is relevant for this study as the long number of years of work implies that the respondents could be more experienced in identifying the challenges associated with electrical power generation as well as transmission and distribution using overhead and underground cables. The operational area of the respondents was also studied with the results depicted in Table 4.3.

Table 4.3: Operational area

Area	Frequency	Percent
Wa	14	21.5
Tamale	31	47.7
Bolgatanga	20	30.8
Total	65	100.0

Source: Fieldwork, 2013

It is noted that most (47.7%) of the respondents worked in the Tamale operational area whilst the least proportion was noted for Wa (21.5%) operational area. Further analysis was carried out on the operational area of the respondents across their years of working with NEDCo. All (100.0%) the respondents who have worked with NEDCo in less than a year were all from the Bolgatanga operational area. It is also seen that majority (68.8%) of respondents who have worked with NEDCo for more than 10 years were from the Tamale operational area. Figure 4.1 presents the graphical representation of the results.

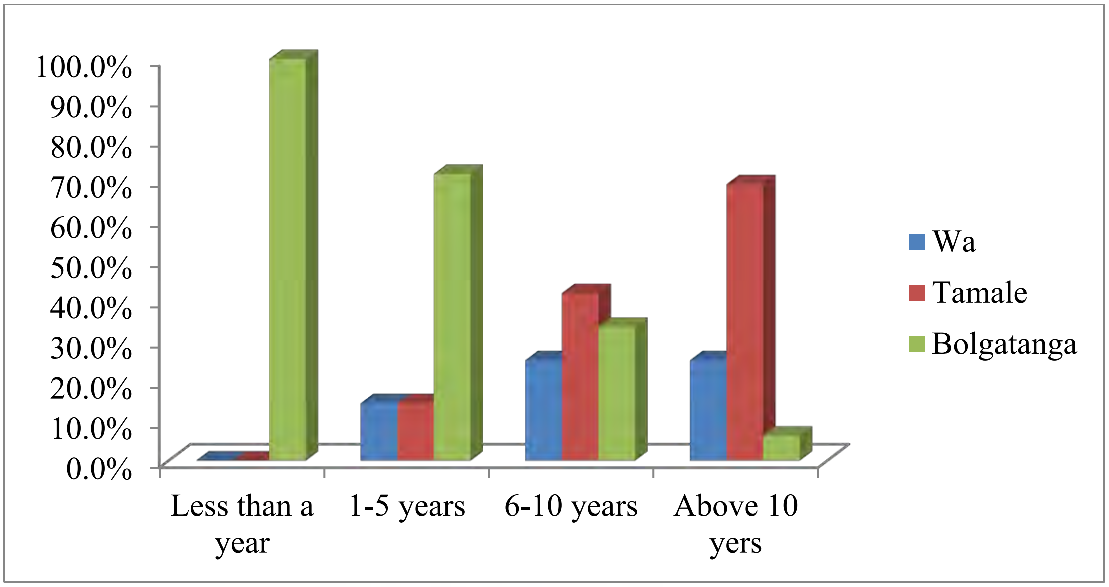

Figure 4.1: Operational area across years of working with NEDCo

Source: Field Work 2913

4.4 CHALLENGES ASSOCIATED WITH ELECTRICAL POWER GENERATION TRANSMISSION AND DISTRIBUTION USING OVERHEAD AND UNDERGROUND CABLES

This section examined the type of cable which is more effective in the generation, transmission and distribution of electrical power in NEDCo. The study further examined the challenges which are most associated with electrical power generation, transmission and distribution using overhead and underground cables.

In this regard, Figure 4.2 shows which type of cable is more effective in the generation, transmission and distribution of electrical power in NEDCo

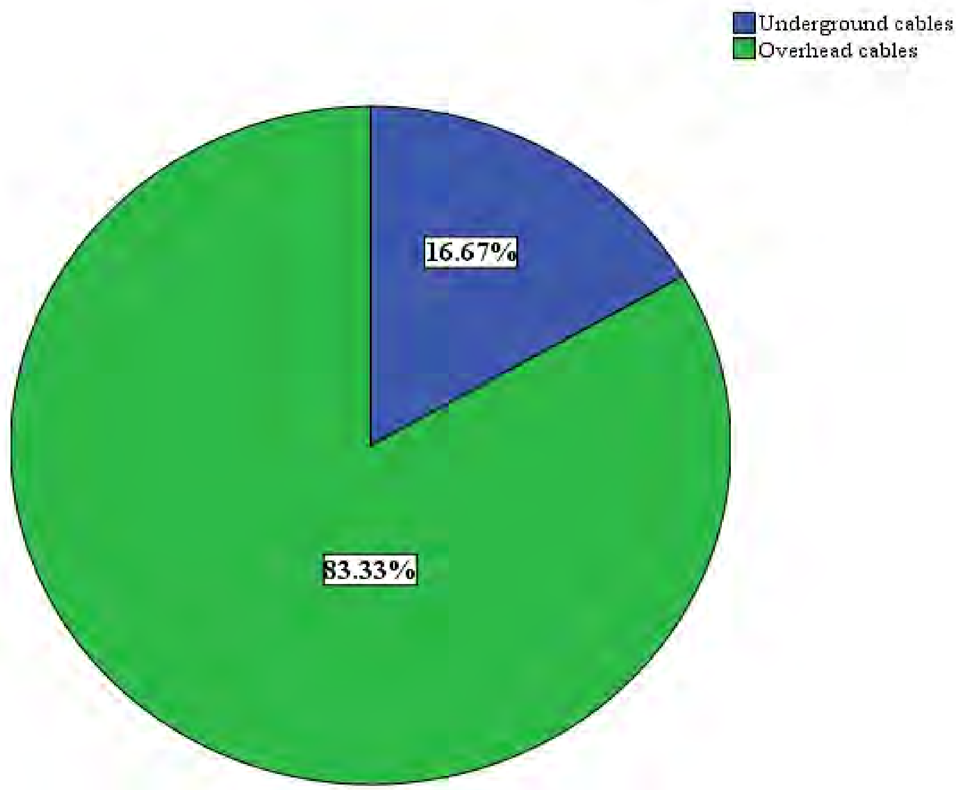

Figure 4.2:Type of electrical cable systems which is more effective for electrical power generation, transmission and distribution using overhead and underground cables

Source: Field Work 2013

In Figure 4.2, it is noted that majority (83.3%) of the respondents were of the view that overhead cables were the most effective for the generation, transmission and distribution of electrical power in NEDCo. Thus the proportion of respondents who indicated that overhead cables were the most effective for the generation, transmission and distribution of electrical power in NEDCO was about 66.6 percent higher than those who indicated that underground cables were more effective. Thus, the result implies that overhead cables were more effective for the generation, transmission and distribution of electrical power in NEDCo.

The respondents who said overhead cables were most effective for the generation, transmission and distribution of electrical power outlined the following reasons for their choice of answer:

i. Construction of the overhead cables is cheaper than the construction of underground cables.

ii. Fault detection and elimination of overhead cables is easier than in underground cables

iii. The cost of maintaining overhead cables is cheaper than the cost of maintaining underground cables

iv. It is easy to detect faulty overhead cables and rectify it.

Regarding the challenges associated with underground and overhead cables for electrical power generation, transmission and distribution, the study identified and examined seven challenges as shown in Table 4.4.

Table 4.4: Overhead power lines are generally the lowest cost method for large quantities for electric energy as compared to underground power lines

Response	Frequency	Percent
Disagree	2	3.2
Agree	32	49.2
Strongly agree	31	47.6
Total	65	100.0

Source: Fieldwork, 2013

A significant proportion of the respondents (96.8%) indicated that overhead power lines were generally the lowest cost method for large quantities for electric energy as compared to underground power lines. This could be explained by the fact that most of the insulation in overhead cables are provided by air, overhead power lines are generally the lowest-cost method of transmission for large quantities of electric energy. This result is in agreement with Cowell (2003) assertion that underground power transmission has a significantly higher cost and greater operational limitations but is sometimes used in urban areas or sensitive locations. Jay (2003) also added that undergrounding used to be implemented in very few cases where it met strict regulatory conditions. This was primarily, due to the high cost involved in undergrounding, for example when utilities and the public dispute over private property for line easement. It can therefore be deduced from the results that overhead cables are generally affordable when it comes to the transmission for large quantities of electric energy.

The study further inquired from the respondents whether or not the maintenance works required for overhead networks are about twice the number compared to the underground power networks.

Table 4.5: Maintenance works required for overhead networks are about twice the number compared to the underground power networks

Response	Frequency	Percent
Strongly disagree	7	10.8
Disagree	6	9.2
Agree	29	44.6
Strongly agree	23	35.4
Total	65	100.0

Source: Fieldwork, 2013

Majority (80%) of the respondents admitted that maintenance works required for overhead networks are about twice the number compared to the underground power networks. This could be explained by Cowell (2003) assertion that overhead networks are more vulnerable to the external causes hence in general; the maintenance works required for overhead networks are about twice the number compared to the underground power networks maintenance works. Additionally, it is against this background that Lakervi (1988) indicated that when designing overhead power grids, engineers should consider factors such as extreme weather conditions with high current loading in hot temperatures or cold weather conditions with low load and their implication for maintenance works on conductor's stress levels

The study also investigated whether or not the surrounding has a big impact on overhead line interruptions.

Table 4.6: Impact of the environment on overhead line interruption

Response	Frequency	Percent
Agree	29	44.6
Strongly agree	36	55.4
Total	65	100.0

Source: Fieldwork, 2013

The result in Table 8 shows that all (100%) the respondents admitted that the surroundings have a big impact on overhead line. The results agrees with Karlstrand(2001) who put to bare that interruptions are usually caused by external factors, therefore the surroundings have a big impact on overhead interruptions, unlike underground cables which are insulated from the surrounding conditions. Additionally, Mutton (2000), mentioned that the main causes of overhead power transmission and distribution networks interruption are in fact unplanned external causes, like storms, bushfire, lightning, trees, animals, vehicle accidents and vandalism. All of these causes of power interruptions are found in the environment. Thus the result implies that overhead line interruptions are largely influenced by the environment.

The study also explored whether or not the designing of overhead power grids is difficult as compared to underground cables as shown in Table 4.7

Table 4.7: Designing of overhead power grids is difficult

Response	Frequency	Percent
Strongly disagree	20	30.8
Disagree	26	40.0
Agree	17	26.1
Strongly agree	2	3.1
Total	65	100.0

Source: Fieldwork, 2013

Majority (70.8%) of the respondents refuted that designing of overhead power grids is difficult as compared to underground cables. In other words, the difficulties in designing underground cables far exceed those of designing overhead cables. The difficulties in designing underground cables could explain why Cowell (2003) was of the view that underground power transmission has a significantly higher cost and greater operational limitations.

The study also examined whether or not physical contact of overhead cables with trees leads to a short circuit and often instigates a fault with the results shown in Table 4.8

Table 4.8: Physical contact of overhead cables with trees leads to a short circuit and often instigates a fault

Response	Frequency	Percent
Agree	23	35.4
Strongly agree	42	64.6
Total	65	100.0

Source: Fieldwork, 2013

All (100%) the respondents admitted that physical contact of overhead cables with trees lead to a short circuit and often instigates a fault. This is consistent with Novembri and Cieslewicz (2004) investigative report which revealed that a major cause of blackout is trees interfering with overhead power lines causing the affected lines to trip and eventually contribute to the cascading power outage.

According to Pansini (1993), fault detection and elimination in underground cables is much more time and money consuming than its overhead counterpart. In this regards, the study investigated whether or not fault detection and elimination is much more time and money consuming in underground cables than its overhead counterpart as shown in Table 4.9

Table 4.9: Fault detection and elimination

Response	Frequency	Percent
Strongly disagree	5	7.7
Disagree	5	7.7
Agree	25	38.5
Strongly agree	30	46.1
Total	65	100.0

Source: Fieldwork, 2013

Over 80 percent of the respondents (84.6%) were of the view that fault detection and elimination is much more time and money consuming in underground cables than its overhead counterpart. Despite the added reliability that could be gained from undergrounding, Pansini (1993) put to bare that fault detection and elimination is much more time and money consuming than its overhead counterpart. Even shorter interruption time in overhead lines, does not hold as a viable discussion point when arguing against installing underground solutions. It can therefore be deduced from the results that much money and time is spent in fault detection and elimination in underground cables than overhead cables. This also gives an indication that fault detection and elimination in underground cables would cause delay since it is time consuming.

The study also investigated whether or not the total loss of revenues is far less when undergrounding than using overhead power lines as shown in Table 4.10

Table 4.10: Total loss of revenue

Response	Frequency	Percent
Strongly disagree	9	13.8
Disagree	16	24.6
Agree	17	26.2
Strongly agree	23	35.4
Total	65	100.0

Source: Fieldwork, 2013

A little over 60 percent (61.6%) of the respondents were of the view that the total loss of revenue is far less when undergrounding than using overhead power lines. The results is in agreement with Pansini (1993) who mentioned that the total loss of revenues is far less when undergrounding than using overhead and that‘s primarily due to the significantly decreased fault frequency. Although majority admitted, the proportion of those who refuted was quite huge (38.4%). It can therefore be deduced from the study that when the power lines are laid underground, NEDCo would not lose much revenue as the underground cables do not have contact with trees, rainstorms, lightening etc. which results in faults and power outages.

The views of the management on the major challenges associated with electrical power generation as well as transmission and distributing using both overheads and underground cables in NEDCO were explored. The following challenges were noted for overhead cables:

i. Frequency of electrical faults
ii. Exposed to accidental contacts and cable thefts
iii. Trees falling on the conductors (wires) if the horizontal clearance is not good

The following major challenges were noted for underground cables:

i. Difficulty in locating fault
ii. Length of time in restoring power when it is faulty is long: Thus there is difficulty in tracing cable faults and cable maintenance

4.5 EXTENT TO WHICH DELAY IN LOCATING FAULT ON THE DISTRIBUTION NETWORK AFFECT THE NETWORK AND THE CUSTOMERS

This section of the chapter examined the delays in locating faults on the distribution network and those who are affected as a result of delays in locating faults on the distribution network. In addition, the study examined the type of cable which detects faults with the minimum speed. In this regard, the study explored how frequent there are delays in locating faults on the distribution network. Figure 4.3 illustrates the findings.

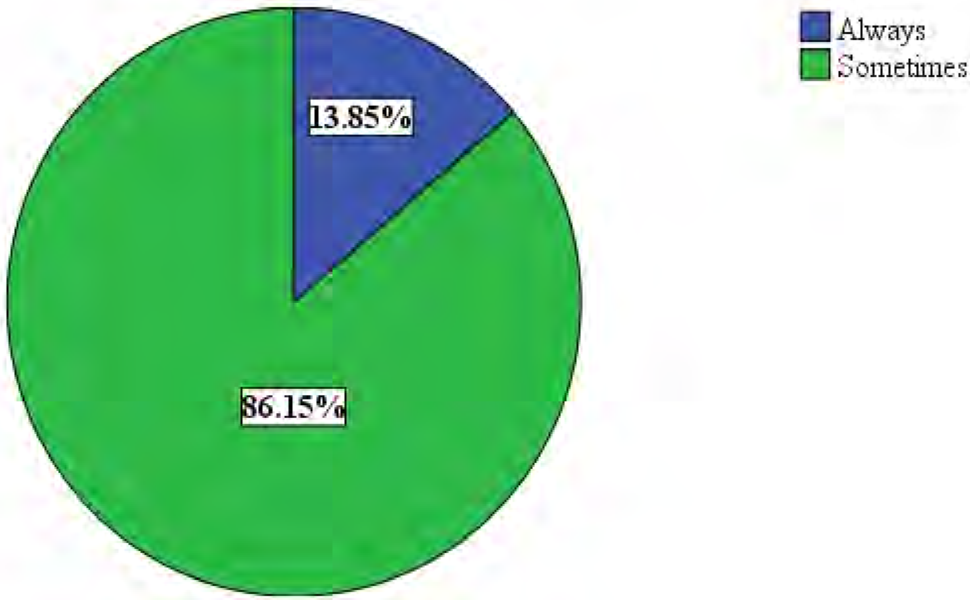

Figure 4.3: Delays in locating faults on the distribution network

Source: Fieldwork, 2013

The results in Figure 9 shows that majority (86.15%) of the respondents indicated that sometimes there are delays in locating faults on the distribution network. It is important to note that none of the respondents was of the view that there had never ben delays in locating faults on the distribution network. Thus, a critical assessment of the results implies that delay in locating faults on the distribution network is bound to occur.

The possibility of faults occurring on the distribution network would mean that power interruptions and outages are bound to occur in the various catchment areas. This has various implications for the economy. According to Literatum (2012), the availability of reliable electric power supplies is an essential precondition for the functioning of modern economies both in developed and developing countries.

Further analysis was carried out to determine the delays in locating faults in the distribution network across the various operational areas. Figure 4.4 shows the graphical view of the findings.

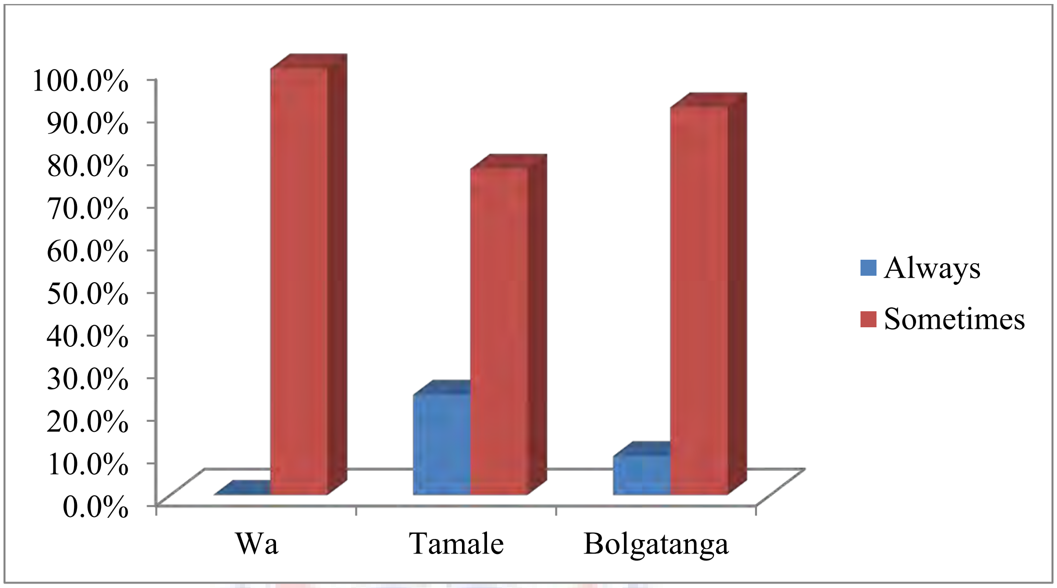

Figure 4.4: Area of operations across delay in locating fault

Source: Field Work 2013

All (100.0%) the respondents who worked under the Wa operational area admitted that the delays in locating faults on the distribution network occur from time to time. Furthermore, majority (90.9) of the respondents who are under the Bolgatanga operational area also admitted that the delays in locating faults on the distribution network occur from time to time. Similar findings were also noted for the respondents who work under the Tamale operational area. Further analysis performed shows that the occurrence of delays in locating faults on the distribution network was independent on the operational area and that all the operational areas sometimes experience delays in locating faults on the distribution networks. This could be explained by Mutton (2000) assertion that most of the outages and disruptions usually occur on the distribution part of the power network.

In this regard, the study investigated the most affected as a result of delays in locating faults on the distribution network. Figure 4.5.

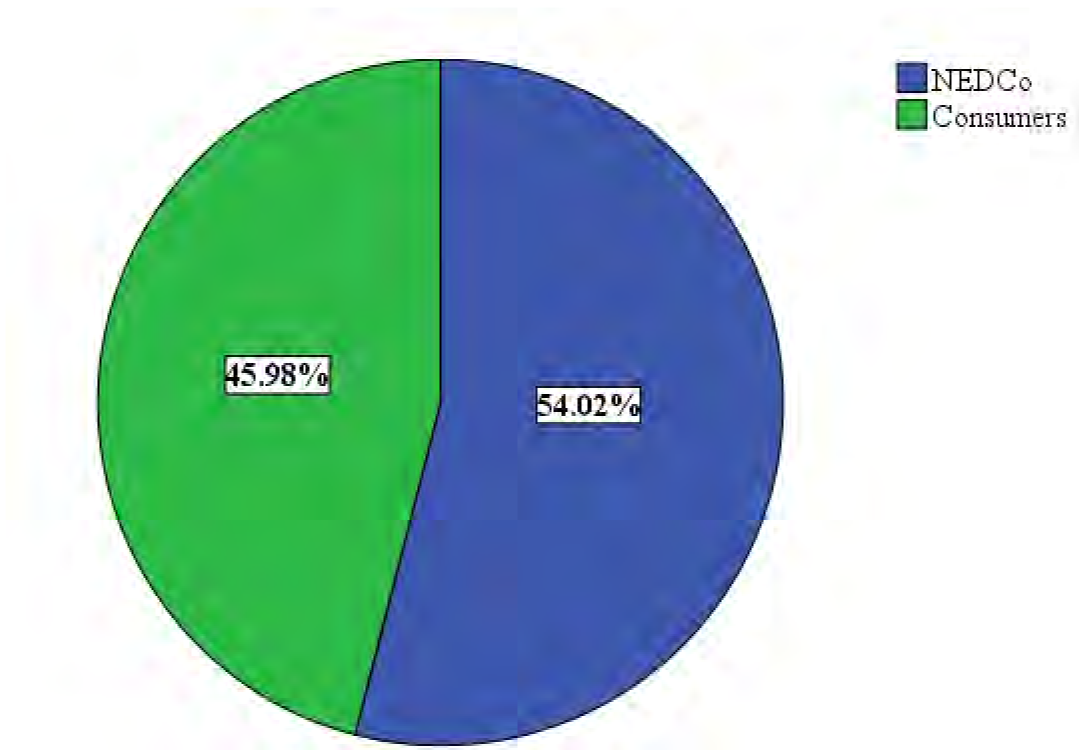

Figure 4.5: Those who are more affected due to delays in locating faults

Source: Field Work 2013

It is noted that more than half (54.0%) of the respondents were of the view that NEDCo is the most affected as a result of delays in locating faults on the distribution network. Although the results showed that NEDCo is more affected as compared to customers, the proportion of respondents who indicated that customers are more affected is significant. Thus, it can be deduced that delays in locating faults on the distribution network has significant effect on both NEDCO and consumers.

The study further examined in what specific ways do delays in locating faults on the distribution network affects NEDCO and the consumers.

4.6 NEDCo:

- There is power outage and the energy meter stops running;
- Down time affect power consumption by the customers as well revenue generation;
- Customers tend to lose trust in the company when there are delays in locating faults on the distribution network. In this regard they refuse to pay their bills; and
- Long period of power outages leads to low revenue in that period. This affects the finances of the company.

Management buttressed the points outlined by the respondents when they also put to bare that the delays in locating faults on the distribution network leads to loss of revenue on the part of the company. One of the management stated:

> Time that could be used by staff to carry out other works is used to locate faults on the distribution network.

4.7 CUSTOMERS

In relation to how the delays in locating faults on the distribution network affect the customers, the following were noted:

i. Customer dissatisfaction as power outages affects their businesses;

ii. Damage to consumers electrical devices through the occurrence of power surge;

iii. Food stuff of consumers going bad; and

iv. Increase in theft and criminal activities in the neighborhood.

One of the management stated during the interviews:

> Our customers become dissatisfied when there are power outages as they cannot do without electricity. They just feel uncomfortable without electricity

Thus the interviews with management also support the views of the technical staff and that the delays in locating faults on the distribution network affected consumers who use power to run their businesses.

Furthermore, the study examined the type of cable which detects faults with the minimum speed. Figure 4.6 shows the results:

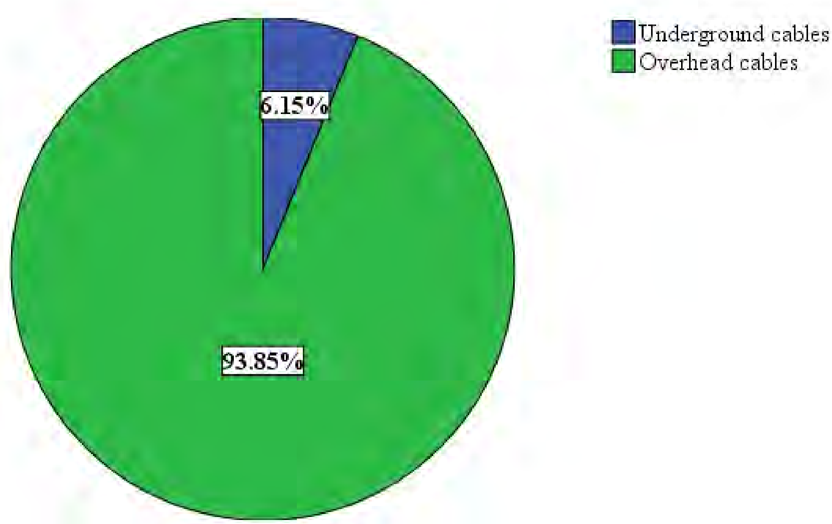

Figure 4.6: Type of cable that detects faults with the minimum speed

Source: Field work, 2013

It is noted in Figure 12 that a significant proportion (93.8%) of the respondents were of the view that overhead cables detect faults with the minimum speed. This was supported by the fact that technicians are able to see abnormalities on the cables since the overhead cables are visible. In this way, faults are detected fast as against underground cables that cannot be seen therefore it takes a long time to determine the fault. The result implies that the rate at which overhead cables detect faults with the minimum speed is higher than that of underground cables. In other words, overhead cables are more effective in detecting faults with the minimum speed.

Management further explained that the delay occurs when the fault is with an underground cable but it is faster to detect when it is an overhead cable.

The study also explored whether or not underground cables or overhead cables experience more failure rate in electrical joints. The results are showed in Figure 4.7.

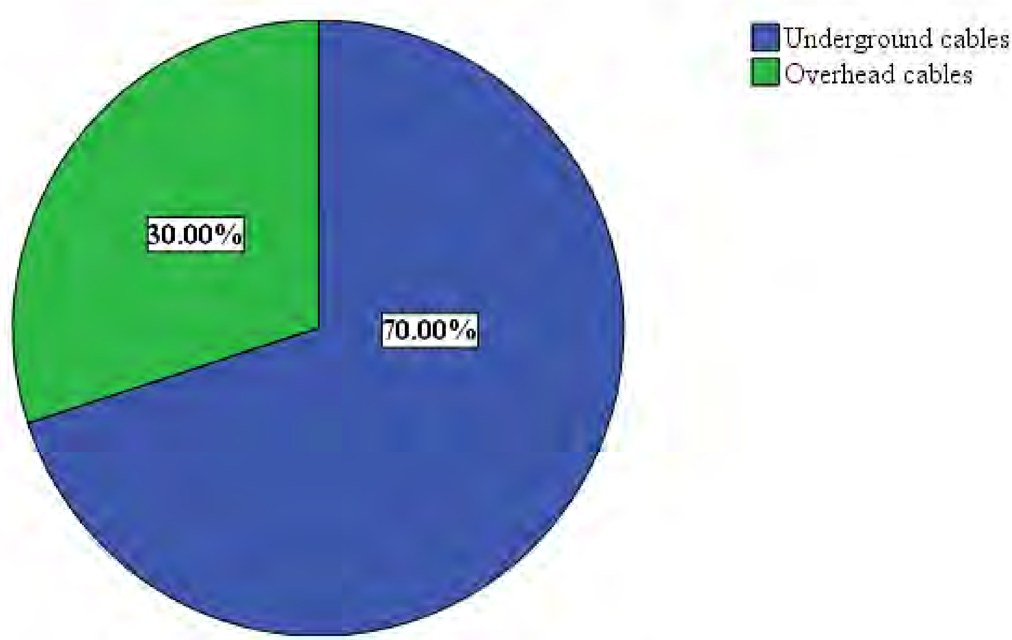

Figure 4.7: Type of cable that experiences more failure rate in electrical joints

Source: Field work, 2013

The results in Figure 13 showed that majority (70.0%) of the respondents stated that underground cables experience more failure rate in electrical joints than overhead cables. The respondents who said underground cables experience more failures explained that the joints are embedded underground where the moist creates corrosion of the materials and insulation around the conducting parts. The wetness has a tendency to breakdown the insulation around the conducting parts. In other words, it can be deduced that underground cables have higher failure rate than overhead cables in electrical joints.

4.8 MAJOR CAUSES OF POWER OUTAGES IN THE NORTHERN ELECTRICITY DISTRIBUTION COMPANY (NEDCo)

This section of the chapter explores the major causes of power outages in NEDCo as well as the how the cables (Overhead or underground) are associated most with power outages. Factors that also cause power outages in NEDCO were also explored.

Table 4.11 shows the rate at which power outages occur in NEDCo's catchment area.

Table 4.11: Rate at which power outages occur in NEDCo's catchment area

Rate	Frequency	Percentage
Very high	2	3.1
High	19	29.2
Low	39	60.0
Very low	5	7.7
Total	65	100.0

Source: Field work, 2013

Majority (67.7%) of the respondents rated the rate at which power outages occur in NEDCo's catchment area as low while 32.3 percent rated the occurrence as high. The result implies that, although power outages in NEDCO's catchment area are not very frequent, the occurrence is quit alarming. Cowell (2003) mentioned that the main causes of overhead power transmission and distribution network interruption are in fact unplanned external causes, like storms, bushfires, lightning, trees, animals, vehicle accidents and vandalism. Cowell (2003) further stated that interruptions can also be caused by equipment and line or cable failure due to overload and ageing. In this regard, NEDCo and its technical staff should put adequate measures in place to make power supply more reliable and stable.

The respondents further outlined major causes of power outages in the Northern Electricity Company (NEDCo) as follows:

- Overloading of transformers;
- Destruction of cables by contractors;
- Bush fires destroying overhead cables;
- Illegal connection of power;
- Natural disasters such as rainstorms and lightening that affect the isolators. One of the respondents said:

  Severe lightening destroys equipment such as lightening arrestors, line insulators and power transformers which in turn cause power outage

- Joint failure of underground cables and overhead line cut
- Falling of trees on overhead cables

Further analysis was carried out to determine the rate of power outages across the operational areas of the respondents. All (100.0%) the respondents in the Wa operational area admitted that the rate of power outages in the Wa catchment area is low. Additionally, majority (72.7%) of respondents in the Bolgatanga catchment admitted also admitted the rate of power outages as low. However, majority (52.9%) of those in the Tamale area described the rate of power outages as high. Further analysis shows that the rate of power outages was independent of the operational areas and that power outages are likely to occur across all the operational areas. Figure 4.8 presents a graphical representation of the results in Table 4.11:

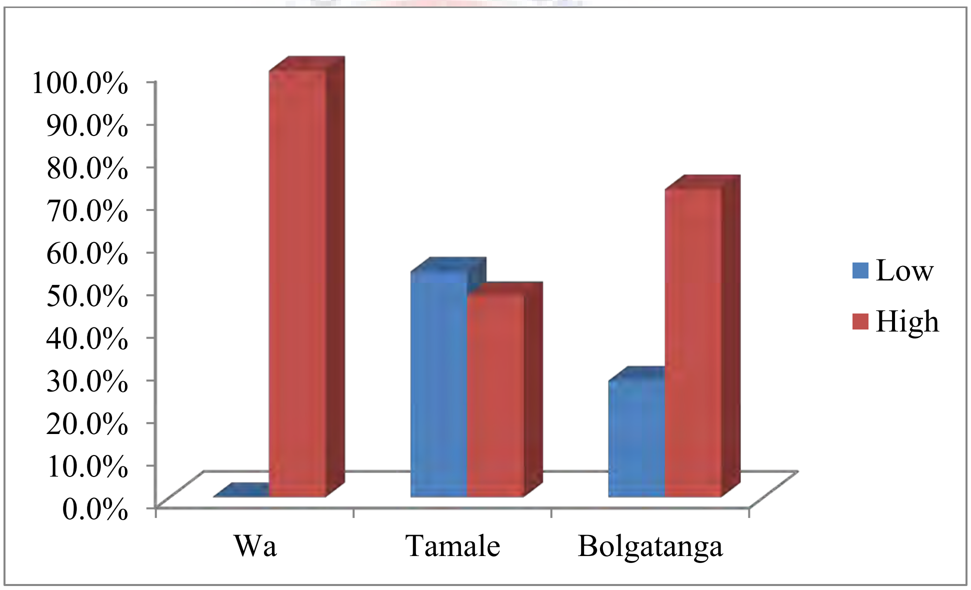

Figure 4.8: Rate of power outages across area of operations

Source: Filed Work 2013

Further investigation was carried out to identify the type of cable which is more associated with power outages. Figure 4.9 shows the results.

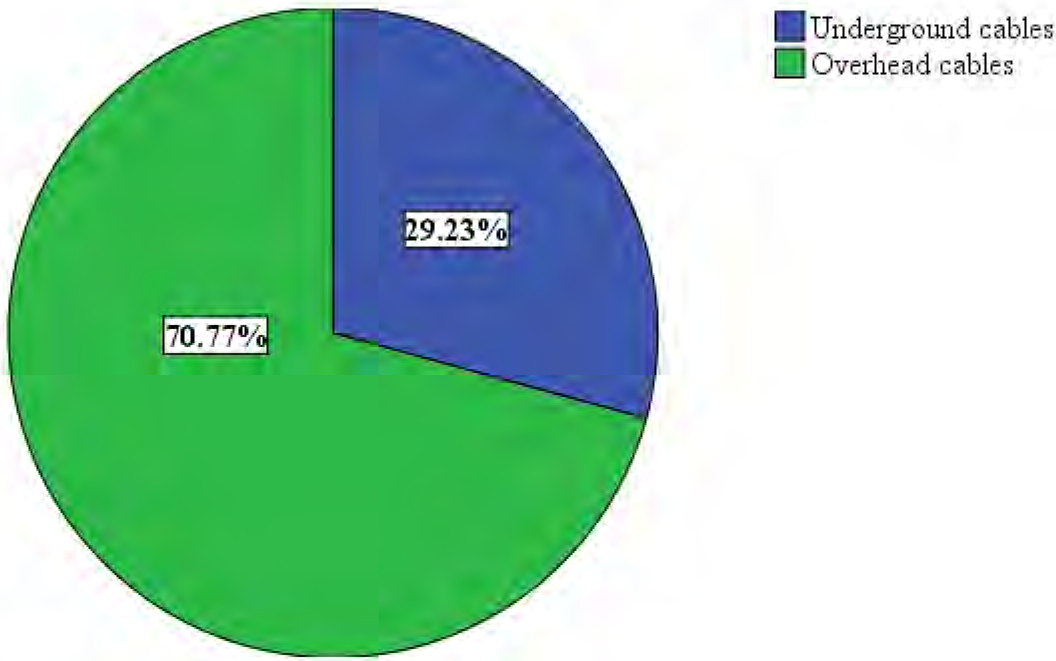

Figure 4.9: Type of cable that is more associated with power outages

Majority (70.8%) of the respondents stated that overhead cables are more associated with power outages as compared to underground cables. This could be explained by Mutton (2000) assertion that overhead networks are more vulnerable to the external causes as compared to underground cables.

Finally, the study investigated the factors that cause power outages in NEDCo. Thus, the causes of power outages in NEDCo are indicated in Table 4.12

Table 4.12: Causes of power outages in NEDCo

Factors	Frequency	Percentage
Ageing assets	40	61.5
Overload	42	64.6
Trees falling on overhead cables	56	86.2
Bush fires destroying overhead cables	44	67.7
Contractors destroying underground cables	12	18.5

Source: Field work, 2013

The results in Table 15 show that trees falling on overhead cables, bush fires destroying overhead cables, overloads and aging assets are major causes of power outages. However, the major cause of power outage in NEDCo is trees falling on overhead cables and bush fires destroying overhead cables. Contractors destroying underground cables had insignificant impact on the cause of power outages. This result is similar to Mutton (2000) that the main causes of power transmission and distribution networks interruption are in fact unplanned external causes, like storms, bushfire, lightning, trees, animals, vehicle accidents and vandalism. In relation to aging assets, the results are also consistent with Karlstrand (2001) who noted that ageing assets play a big role in more frequent power interruptions. Most of the outages and disruption according to Karlstrand (2001) usually occur on the distribution part of the power network.

It is important to note that none of the respondents cited unidentified causes as one of the major causes of power outages in NEDCo. Based on the results, it can be deduced that power outages are caused by external factors (such as bush and trees falling on overhead cables) as well as internal factors (aging assets) but mostly through external factors. Figure 4.10 shows the aggregated results on the major causes of power outages in NEDCo's catchment area.

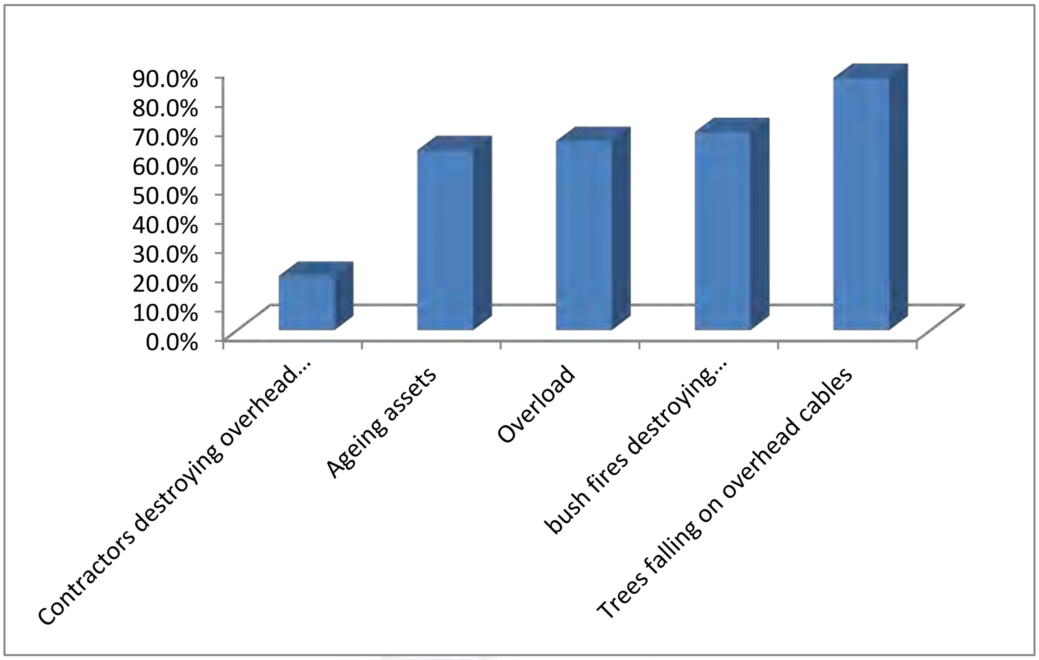

Figure 4.10: Causes of power outages in NEDCo

Source: Field work, 2013

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents a summary of the findings from the study as well as the conclusions, recommendations, and directions for future research. Thus, the chapter focuses on the implications of the findings from the study for policy making and future research. The recommendations are made based on the key findings and major conclusions arising from the study.

5.2 SUMMARY

The study analysed the challenges associated with electrical power generation as well as transmission and distribution using overhead and underground cables with specific focus on the extent to which delays in locating faults on the distribution network affect the network as well as the customers, whether failure rate of electrical joint will increase on underground cables or not and the major causes of power outages in the NEDCo.

In all, there were 69 respondents who participated in the study. This comprised of 65 technical staff of the Northern Electricity Distribution Company (NEDCo) and four management staff of NEDCo. Both questionnaires and interview schedules were used in the collection of data. Data analysis was performed using the Statistic Product and Service Solutions (SPSS), version 18 and Microsoft Excel.

In relation to the first objective of the study which focused on challenges associated with electrical power generation as well as transmission and distribution, the following major findings emerged:

i. Majority of the respondents were of the view that overhead cables are the most effective for the generation, transmission and distribution of electrical power in NEDCo

ii. The major challenges associated with overhead cables for electrical power transmission are that physical contact of overhead cables with trees leads to a short circuit and often instigate a fault, the surroundings have a big impact on overhead line interruptions in NEDCo and that maintenance works required for overhead networks are about twice the number compared to the underground power networks

iii. On the other hand, major challenges associated with underground cables are that fault detection and elimination is much more time and money consuming in underground cables and difficulty in designing of overhead power grids as compared to underground cables

iv. Generally, underground cables experience more failure rate in electrical joints than overhead cables

In relation to the second objective of the study which analysed the extent to which delay in locating fault on the distribution network affect the network as well as the customers, the following major findings emerged:

i. Majority of the respondents indicated that there are delays in locating faults on the distribution network sometimes

ii. NEDCo is the most affected as a result of delays in locating faults on the distribution network.

iii. The delays in locating faults on the distribution network were independent of the operational area of NEDCo and that all the operational areas sometimes experience delays in locating faults on the distribution network

The major causes of power outages in the northern electrical distribution company (NEDCo) were studied in the third objective. The following major findings emerged:

i. The major causes of power outages in NEDCo are external factors such as trees falling on overhead cables and bush fires destroying overhead cables;

ii. Internal factors such as aging and overload were the major internal factors that cause power outages in NEDCO

5.3 CONCLUSION

The study can conclude that overhead cables are most effective in the generation, transmission and distribution of electrical power in NEDCo. This is because, the construction and maintenance of the overhead cables is cheaper than the construction of underground cables. In the transmission of large quantities of electric energy, overhead power lines are low cost as compared to underground power lines. The cost of using overhead power lines is cheaper than using underground power lines.

The study can further conclude that delay in locating faults on the distribution network is a situation that has the possibility of occurring. The delay in locating faults on the distribution network has significant effect on both NEDCo and consumers. The rate at which overhead cables detect faults with the minimum speed is higher than that of underground cables and that underground cables have higher failure rate than overhead cables in electrical joints as the wetness in the ground has a tendency to breakdown the insulation around the conducting parts.

Generally, the rate at which power outages occur in NEDCo's catchment area is low. However, overhead cables are more prone to power outages in the Northern sector of Ghana as compared to underground cables. The major cause of power outages in NEDCO is as a result of trees falling on overhead cables.

5.4 RECOMMENDATIONS

Based on the major findings and conclusions from the study, the following recommendations are formulated:

5.4.1 Frequent maintenance works

The study recommends that maintenance works should be carried out regularly by NEDCo. Since power interruptions and outages are bound to occur in the various catchment areas, it is recommended that maintenance works on the distribution network should be frequent. In this way, faults, power interruptions and power outages that would have occurred could be prevented. A faulty power line for instance should not be left unattended to for a long time. Also staff should endeavor to attend to faults that are reported to them by the customers.

5.4.2 Upgrading and rehabilitation of distribution network

It is also recommended that there should be an upgrading of the distribution network. Single phase transformers in the system should be upgraded to three phases. For example, the 161kv lines should be improved to a loop system. There should also be the rehabilitation of old lines and also injection of new substations which would solve the low voltages and outages in the catchment areas.

5.4.3 Modern technology for power monitoring

The study recommends that government through the Ministry of Energy should provide NEDCo with appropriate and modern technology for the monitoring of power. In this way, NEDCo would be adequately prepared to monitor the electrical power distribution network to know when there would be power interruptions. This would help to rapidly response to power surge to help control the frequent power fluctuations and outages.

5.4.4 Expansion works

The study recommends that there should be expansion in generation, transmission and maintenance of the distribution network. The expansion to other communities should be done in consultation with the technicians and engineers of NEDCo.

5.4.5 Procurement of quality equipment

Quality and durable equipment should be procured by government and installed with strict supervision. The procurement of the equipment should be done in consultation with NEDCo. In this way, NEDCo would ensure that the equipment being bought are right ones needed for the job and are of high quality as anything inferior would go against the supply of efficient and reliable electricity to their customers.

5.4.6 Solar energy and stand by generators

Solar energy should be introduced into the system. It should also be made affordable so customers can patronise as it would reduce the pressure on the distribution network. There should also be stand by generators that would generate electricity when there is a fault on the distribution network.

5.4.7 Frequent training of staff

Staff of NEDCo should be given frequent training especially the maintenance staff. They should be trained on the use of new equipment and new technologies. This would help the staff to be abreast with new ways of going about their job. This would even reduce subletting of contracts where some of the contractors do a shoddy job which in turn affects customers

5.4.8 Suggestion for future research

Based on the key limitations and major findings from this study, and considering the frequent power outages and fluctuations experienced by the residents, it is recommend that a further study be conducted to examine the enhancement of electrical power distribution using phasor measurement units(PMU).

REFERENCES

Al-Khalidi, H. (2009). Technical consideration and impact of converting overhead power lines to underground power cables. PhD thesis. Melbourne: Faculty of health, engineering and science, Victoria University.

Barber, K. (2004). Undergrounding transmission and distribution lines in Australia. Australian Power Transmission & Distribution magazine.

Chang, G.W., Huang, H.M., & Lai, G.G.(2002). A study on controlling electrical stress of underground cable by semi-conductive shielding. Asia Pacific : IEEE/PES.

Coster, J., E., Parabirsing, E,.N & Goerdin, S., A.,V. (2013). Method for determining dynamic short circuit withstands capability of installations in meshed cable mv-networks, during switching on a fault. . Stockhoolm : Centre International de Recherche sur l'Environnement et le Developpement

Cowell, R., (2003). The Scope for Undergrounding Overhead Electricity Lines.2003. *A* report by the UK Centre for Economic and Environmental Development.

Drew, C. J., Hardman, M. L., & Hosp, J. L. (2008). Designing and conducting research in education. LA: Sage Publications.

Ghana Wholesale Power Reliability Report, (2010). Final report. Power Systems Energy Consulting (PSEC) in collaboration with Ghana Grid Company Limited (GRIDCo)

Guide to Electric Power in Ghana, (2005). Guide to Electric Power in Ghana: First edition. Institute of Statistical, Social and Economic Research (ISSER). Accra: University of Ghana.

Havemen, R. (1976). Evaluating the impact of public policies on regional welfare. *Regional Studies,* 449-63

Karlstrand,J., Bergman, J., & Jonsson, H.A. (2001). Cost-efficient XLPE cable system solutions, AC-DC Power Transmission. Seventh International Conference on (Conf. Publ. No. 485).33-38.

Lakervi, E. & Holmes, E.J. (1988). Electricity distribution network design. London: Peter Peregrinus Ltd.

Maney, C.T., (1996). Benefits of urban underground power delivery. Technology and SocietyMagazine, IEEE. 15(1), 12-22.

Marazzato, H. & Barber, K.W. (n.d). *The* challenge for undergrounding electricity supply, Australian Power Transmission & Distribution magazine

Mertens, D. M. (2003). Handbook of mixed methods in social and behavioral research. Thousand Oaks, CA: Sage Publications.

Meyer, R. (2011). Vertical Economies of Scope in Electricity Supply –Analysing the Costs of Ownership Unbundling. PhD thesis in Economics. Bremen: School of Humanities and Social Sciences, Jacob's university

Mutton, S., Tebbs, J., Simpson, S., & Mann, R. (2000). Investigation of low reliability urban and rural feeders phase two of two TXU Networks.

Novembri, R.R. & Cieslewicz, S.R., (2004). Utility vegetation management. Final Report. Valley Ford: CN Utility Consulting.

O'Leary, A. (2004). The essential guide to doing research. London: Sage Publications

Opam, M. A., & Turkson, J. K. (2000). Power sector restructuring in Ghana: Reforms to promote competition and private sector participation. London: Macmillan Press Ltd.

Pansini, A.J. & Smalling, K.D. (1993). Undergrounding electric lines. Lilburn: The Fairmont Press Inc.

Punch, K. F. (1998). Introduction to social research: Quantitative & qualitative approaches. London: Sage Publications.

Robson, C. (2002). Real world research: A resource for social scientists and practitioner researchers. Oxford: Blackwell

Schramm, G. (1990). Electric power in developing countries: Status, problems, prospects. Annual Review Energy. (15) 307-333.

APPENDICES

APPENDIX A

CHALLENGES ASSOCIATED WITH ELECTRICAL POWER GENERATION AS WELL AS TRANSMISSION AND DISTRIBUTION USING OVERHEAD AND UNDERGROUND CABLES

INTERVIEW GUIDE
FOR
MANAGEMENT OF OPERATIONAL AREAS

Introduction

This study is designed for academic purpose. The study seeks to assess the challenges associated with electrical power generation as well as transmission and distribution using overhead and underground cables with specific focus on the extent to which delays in locating faults on the distribution network affect the network as well as the customers, whether failure rate of electrical joint will increase on underground cables or not, and the major causes of power outages in the Northern Electricity Distribution Company (NEDCo).

You are however assured that information provided to complete this study would be treated with the strictest confidentiality.

Part A: Background characteristics

1. Position in NEDCo…………
2. How long have you been working with NEDCo?..

Part B: Challenges associated with electrical power generation as well as transmission and distribution using overhead and underground cables

3. What are the major challenges if any associated with electrical power generation as well as transmission and distribution using

i. Overhead cables in NEDCo?

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ii. Underground cables in NEDCo?

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4. Comparatively, which forms of cable is most effective in the generation, transmission and distribution of electrical powers in NEDCo? Kindly give reasons

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Section C: Extent to which delay in locating fault on the distribution network affect the network as well as the customers

5. How would you describe delays in locating faults on the distribution network?

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6. To what extent do delays in locating fault on the distribution network affect NEDCo?

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7. To what extent do delays in locating faults on the distribution network affect consumers in the Northern Sector of the Country?

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Section D: Failure rate of electrical joint

8. At what rate do cables experience failure rate in electrical joints inNEDCoand what are the possible reasons for the failure rates?

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9. Which cables experience the most failure rate in electrical joints in NEDCo?

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Section E : Major causes of power outages in the Northern Electricity Distribution Company (NEDCo)

10. At what rate do power outages occur in the Northern Electricity Distribution Company (NEDCo)?

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11. What are the major causes of power outages in the Northern Electricity Distribution Company (NEDCo)?

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Section E : Recommendations and suggestions

12. What relevant recommendations can be made to enhance the generation, transmission and distribution of electrical energy in Northern Sector of the Country and Ghana as a whole?

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THANK YOU FOR YOUR TIME AND COOPERATION

APPENDIX B

CHALLENGES ASSOCIATED WITH ELECTRICAL POWER GENERATION AS WELL AS TRANSMISSION AND DISTRIBUTION USING OVERHEAD AND UNDERGROUND CABLES

INTERVIEW GUIDE

FOR

STAFF of NEDCo

Introduction

This study is designed for academic purpose. The study seeks to assess the challenges associated with electrical power generation as well as transmission and distribution using overhead and underground cables with specific focus on the extent to which delay in locating fault on the distribution network affect the network as well as the customers, whether failure rate of electrical joint will increase on underground cables or not, and the major causes of power outages in the Northern Electricity Distribution Company (NEDCo).

You are however assured that information provided to complete this study would be treated with the strictest confidentiality.

Thank you in advance for participating in the study

Instructions: Please tick were applicable

SECTION A: demographic data

1) Gender……Male ☐ Female ☐

2) Age...

3). How long have you been working with NEDCo? ……………………………..

4. Under which operational area do you work?...a. Wa ☐ b. Tamale ☐ c. Bolgatanga ☐

Section B:Challenges associated with electrical power generation as well as transmission and distribution using overhead and underground cables

5. Comparatively, which forms of cable is most effective in the generation, transmission and distribution of electrical powers in NEDCo? You may tick more than one

a. Underground cables ☐
b. Overhead cables ☐

6. Kindly give reasons for your choice of answer in question 5

…………………………………………………………………………………………………

…………………………………………………………………………………………………

7. Kindly indicate your view with regards to the challenges which are most associated with underground and overhead cables for electrical power generation, transmission and distribution where SD= Strongly disagree , D= Disagree, A= Agree and SA= Strongly Agree

Challenges	**SD**	**D**	**A**	**SA**
1. Overhead power lines are generally the lowest-cost method of transmission for large quantities of electric energyas compared to underground power lines				
2. Maintenance works required for overhead networks are about twice the number compared to the underground power networks				
3.The surroundings have a big impact on overhead interruptions				
4.Designing of overhead power grids is difficult as compared to underground cables				
5. Physical contact of overhead cables with trees leads to a short circuit and often instigate a fault				
6. Fault detection and elimination is much more time and money consuming in underground cables than its overhead counterpart.				
7. The total loss of revenues is far less when undergrounding than using overheadpower lines				

Section C: Extent to which delay in locating fault on the distribution network affect the network as well as the customers

8. How frequent are there delays in locating faults on the distribution network?

a. Always ☐
b. Sometimes ☐
c. Never before ☐

9. Which of these categories is most affected as a result of delays in locating faults on the distribution network? You may tick more than one

a. NEDCo ☐
b. Consumers ☐

10. In what ways do delays in locating faults on the distribution network affectNEDCo?

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11.In what ways do delays in locating faults on the distribution network affectconsumers?

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12. In which of these cables are faults detected with the minimum speed?

a. Underground cables ☐

b. Overhead cables ☐

13. What are the possible reasons for your choice of answer in question 12?

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Section D: Failure rate of electrical joints

14. Which cables experience the most failure rate in electrical joints? You may choose more than one

a. Underground cables ☐

b. Overhead cables ☐

15. Kindly give reasons to your choice of answer in question 14

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Section E : Major causes of power outages in the Northern Electricity Distribution Company (NEDCo)

16. At what rate do power outages occur in the Northern Electricity Distribution Catchment Area?

a. Very high ☐
b. High ☐
c. Low ☐
d. Very low ☐

17. What are the major causes of power outages in the Northern Electricity Distribution Company (NEDCo)?

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18. Which of these cables is most associated with power outages in the Northern Sector of the Country?

a. Underground cables ☐
b. Overhead cables ☐

19. Which of these factors is the most major cause of power outages in NEDCo? You may tick more than one

a. Ageing assets ☐

b. Overload ☐

c. Tress falling on overhead cables ☐

d. Bush fires destroying overhead cables ☐

f. Contractors destroying underground cables ☐

g. Unidentified causes ☐

Section E :Recommendation and suggestion

20. Make relevant recommendations to enhance the generation, transmission and distribution of electrical energy in Northern Sector of the Country and Ghana as a whole?

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THANK YOU FOR YOUR TIME AND COOPERATION