UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

AN ANALYSIS OF DISTRIBUTION LOSSES IN ELECTRIC POWER SYSTEM IN GHANA: A CASE STUDY OF THE BRONG AHAFO REGION

OPOKU ISAAC BOAKYE

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A Dissertation in the Department of ELECTRICAL AND ELECTRONIC TECHNOLOGY EDUCATION, Faculty of TECHNICAL EDUCATION, submitted to the School of Graduate Studies, University of Education, Winneba, in partial fulfillment of the requirements for award of the Master of Technology (Electrical and Electronic Technology) degree

DECEMBER, 2018

DECLARATION

STUDENT'S DECLARATION

I, OPOKU ISAAC BOAKYE, declare that this Dissertation, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for an-other degree elsewhere.

SIGNATURE: ....……….

DATE: ………………..............................

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of Dissertation as laid down by the University of Education, Winneba.

SUPERVISOR"S NAME: **DR. ALBERT AWOPONE**

SIGNATURE: ....…………..

DATE ………………..................................

DEDICATION

This project work is dedicated to my lovely wife and children Naomi Boamah Boakye, Holiness Pokua Boakye, Benedicta Gyamfuaa Boakye and Isaac Opoku Boaky Junior and of my parents; Madam Dina Opoku and the late Op. Kwadwo Opoku. Though you are no longer with me, papa you will forever be remembered.

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My ultimate thanks go to God, the Creator of Heaven and Earth for His endless mercy and grace bestowed on me throughout my education. He has been my source of strength, hope and understanding. To God be the glory Amen. I would also like to express my sincere thanks to my supervisor, Dr. Albert Awopone for his excellent supervision. In fact, I am most grateful for his encouragement, motivation, guide lines and readiness to open his doors for me anytime I needed his assistance. God richly bless you.

Special thanks goes to my Brothers Mr. Isaac Opoku Junior, Mr. Opoku Gyamfi Kwame and Mr. Opoku Peprah Emmanuel for their assistance and support. I would also appreciate of prove reading and diverse contributions made by Mr. Asare Banasco towards the success of this work.

I finally wish to express my gratitude to all family and friends who contributed to the success of this project work one way or the other, moral and financial supports that have brought me this far, I say may the good God richly bless you all Amen.

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LIST OF ACRONYMS

GWh	Giga Watt Hour
M	Mega
MW	Mega Watt
PURC	Public Utilities Regulatory Commission
SHEP	Self Help Electrification Program
TICO	Takoradi International Company
VRA	Volta River Authority
ECG	Electricity Company of Ghana
NED	Northern Electricity Department
NEDCo	Northern Electricity Distribution Company
PSR	Power Sector Reform
AC	Alternating Current
DC	Direct Current
HV	High Voltage
EHV	Extra High Voltage
MWh	Mega Watts Hour
T&D	Transmission and Distribution
TL	Technical Losses
NTL	Non-Technical Losses
KWh	Kilowatts Hour
OHL	Over Head Lines

ABSTRACT

Market-driven economies and deregulated electricity industry environments have stimulated minimization of the distribution losses even though they do not constitute major operational or quality of supply problems. This research discusses a method for evaluation of distribution losses and an effective management approach to loss minimization and revenue collection. In this research the contribution of other authors was sought on the distribution losses, their analysis and the various ways of minimizing them was discussed. To get the opinion of the public and the workers on the situation of the distribution losses in the Northern Electricity Distribution Company (NEDCo) of Brong Ahafo region simple random sampling was used to get respondents. Interviews conducted with some workers and management revealed that distribution losses have categorized into two thus technical and non-technical losses. An analysis of the distribution losses in Brong Ahafo region revealed that about 30% constitute 94.25 GWh of the power is lost from monthly power purchase from VRA. The study recommends the introduction of prudent measures including electricity theft, monitoring device and private partnership in the management of distribution system.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Electricity is the most important blessings that science has given to mankind. It has also become a part of modern life and one cannot think of the world without it. Electricity has many uses in our day to day life. It is used for domestic, commercial, as well as industrial purposes (All India Electricity Statistics, 2005).

According to Danny (2007), Electric power supply system in a country comprises of generating unit that produce electricity, high voltage transmission lines that transport electricity over long distances, distribution lines that deliver the electricity to consumers, substations that connect the pieces to each other and energy control centres to coordinate the operation of the components. Power losses can be broadly defined as the difference between the amount of electricity entering the transmission system and the aggregated consumption registered at the end-user meter points. From an operational point of view, electricity losses are unavoidable cost of the transfer of energy across electricity transmission and distribution networks which need to be appropriately tackled, as they impose an additional demand and energy load on the system.

Losses result in considerable financial and environmental costs. It should be noted that power losses in transmission and distribution networks may account for up to 15%-25% of the total amount of electricity produced (Chembe 2015). The costs related to these losses are borne by final customers, as they are obliged to pay for an energy supply that includes the load of energy that is „lost" and therefore, not consumed (Singh (2009).

The environmental impact of losses is borne by society as a whole, as a result of the emission of air pollutants associated with the additional generation that needed to cover losses. Therefore, the objective of the regulatory treatment of losses is in two fold; to protect the interest of customers and on the other hand, to promote the efficiency of the network system (Celli, Pilo & Abur, 2005).

According to Frau, Arcos, Ruiz, and Ramis (2005), in order to keep losses at a low and reasonable level, regulators have designed incentive mechanisms which deliver rewards (or penalties) for network operators whenever losses are below (or above) a pre-set target level. These mechanisms are justified by the fact that network operators have, to some extent, the ability to control losses since they are responsible for several activities such as network design, maintenance and investment decision regarding the installation of grid elements that play a significant role in the determination of losses.

Therefore, it is important to ensure that network operators face adequate incentives so that they make an appropriate effort on evaluating the costs and benefits of reducing losses and hence, optimize the level of losses in most efficient way. By contrast, there are a number of external factors with significant influence on the level of losses. In particular, the geographical size of the market as well as the number and degree of dispersion of customers connected to distribution networks are important driving factors which cannot be modified.

Due to its complexity, the treatment of losses is also deeply related to other regulatory and operational issues, such as energy efficiency schemes, infrastructure planning and network reconfiguration, that are far beyond the scope of this document. Generally, it should be stated that losses are proportional to the amount of energy that is delivered, the distance between generation and consumption, and inversely related to the voltage of the network. Consequently, any measures or actions focused on reducing or smoothing the demand for energy, relocating generation plants closer to demand, and upgrading the voltage level of the network, will have a positive impact on losses (Danny, 2007).

The Ghana power system network, like all other power system, waves about the entire country and it is by far the largest interconnections of a dynamic system in existence to date. No matter how careful the system is designed, losses are present. Electrical power losses are wasteful energy caused by external or internal factors and energy dissipated in the system. These include losses due to resistance, atmospheric conditions, theft, miscalculations, etc. and losses incurred between sources of supply to load centres (or consumers). Losses minimization and quantification is very vital in all human endeavors. In power system, it can lead to more economic operation of the system. If we know how the losses occur we can take steps to limit and minimized the losses. (Fourie & Calmeter 2004) There are technical losses, the Non-technical losses and the Administrative losses.

Technical losses on distribution systems are primarily due to heat dissipation resulting from current passing through conductors and from magnetic losses in transformers. Technical losses occur during transmission and distribution and involve substation, transformer, and line losses. These include resistive losses of the primary feeders, the distribution transformer losses (resistive losses in windings and the core losses), resistive losses in secondary network, resistive losses in service drop and losses in KWh meter. These losses are inherent to the distribution of electricity and cannot be eliminated (Fourie & Calmeter2014).

Non-Technical losses, on the other hand, are caused by actions external to the power system or are caused by loads and condition that the Technical losses computation failed to take into account. Non-Technical losses are more difficult to measure because these losses are often unaccounted for by the system operators and thus have no recorded information. Non-technical losses (NTL), on the other hand, occur as a result of theft, metering inaccuracies and unmetered energy. NTLs, by contrast, relate mainly to power theft in one form or another (Chembe 2000).

Administration losses include the component of distribution network losses that accounts for the electric energy used by the distribution utility in the proper operation of the distribution network. Substations, offices, warehouses and workshops, and other essential electrical loads are usually considered as part of the administrative loss (Malovic, Grenard & Stabac 2003).

The previous researchers dealt with the causes of technical and non-technical losses in electrical power system without considering the economic effects on consumers. Hence the researcher seeks to analyze economic impact of technical and non-technical losses in electrical power system on consumers.

1.2 Statement of the Problem

Power losses are one of the major problems facing the utilities companies in the world. Electricity system losses affect the operations of every network operator and supply business, and in extreme cases can threaten the very financial sustainability of companies. When a power generating company produces a unit of energy, not all of this will arrive at the consumer‟s premises. This is because, power networks inherently consumed and lose a proportion of the energy transported. In addition, no power utility in the world has perfect commercial processes, so 100% of billing of electrical power that has been used by consumer just does not happen.

This research seeks to analyses these losses and qualitatively and quantitatively finds out the effects of these losses on consumers and the system itself. The high rise of technical and non-technical losses may be due to the following;

1. Unnecessary rise in the tariff can cause the problem of the payment of bill
2. Expansion of the national grid putting pressure on the old and outdated machines and equipment.
3. Inability to change the equipment and use the right type of cables.

1.3 Purpose of the Study

This research work aims at analyzing the various losses in the power system and its economic consequences in the power systems in NEDCo and consumers. It is aimed at finding all the losses of the system and find out if the losses affect in the billing of the consumers. The main purpose of the research is to;

1. Examine the various losses in the electric power system.
2. Identify the causes of the losses.
3. Analyze the effect of these losses.

1.4 Research Questions

To be able to analyses the technical, administrative and non-technical losses and its economic effect on the power systems, it is important to make certain research questions to help come face to face with the various problems. The areas from which theories can be formulated include the power system, technical losses and the administrative losses and their effects on tariff. The following are some of the assumptions;

1. What is the nature and types of distribution losses in the electrical power distribution system?
2. To what extent do distribution losses in electrical power system bring about an increase in high tariffs?
3. To what extent do these losses in power system affect the economy?

1.5 Significant of the Study

The significant of this research work is to do the following;

1. To help the utility companies to know that there are various losses in their systems from the generation to the customer point.
2. To come out of the various ways to reduce the distribution losses.
3. To find out whether the distribution losses have effect on the tariff of consumers.

1.6 Scope (delimitation) of Study

This study seeks to identify the various losses of the Utilities companies and its economic consequences in the system and consumers. The study was limited to Volta River Authority Northern Electricity Distribution Company (NEDCo) in Brong Ahafo since they are the only utility company in the Northern sector of Ghana who distributes electricity. PURC will help the researcher to know how the tariff of consumers is calculated and whether they take into account losses before they set tariff.

Finally, NEDCo who is responsible for the distribution will help the researcher with factors that accounts for distribution losses and what they are doing to reduce them. The author would solicit the opinions of the workers of these companies and customers to find out more on losses and effect tariffs.

1.7 Organization

This project report consists of five chapters. The first chapter gives the background of the study. It dis cusses the objectives of the study and give the background to the nature of the analysis of technical and non-technical losses in electrical power system of NEDCo at Sunyani in Brong Ahafo Region.

Chapter Two presents a summary of literature that gives the theoretical basics for this study. In this chapter, concepts such as the technical and non-technical losses, as well as the economic impact on consumers are discussed.

The methodological approaches and techniques used in the process of data gathering for the research are explained together with their theoretical underpinning in chapter Three. Both qualitative and quantitative approaches, given practical details encounter in the field are presented here. The sub topics threated here include sampling frame, sampling method, data collection tools, and method of data analysis.

In chapter four, the findings are presented alongside with the analysis of those findings. The findings are divided into the various methods by which the data was collected, namely, Surveys, Focus Group Discussions and Individual in-depth interviews. The analyses are related to the objectives of the study in order to make them more focused and relevant. Where applicable, references are made to the literature where it confirms some of the findings or whether there is a divergence.

The last chapter is the summary of findings, conclusions and recommendations. This chapter highlights some of key findings in relation to the objectives. The references are presented at the end of this chapter. The appendices of data sampled appear after the references.

CHAPTER TWO

LITERATURE REVIEW

For nearly half a century, the Volta River Authority (VRA) has been the principal agency for the generation and transmission of electrical power in Ghana. Within this period, the VRA has harnessed the resources of the Lake Volta, the largest man-made lake in the world to provide Ghana‟s electricity needs. However, as hydro resources can no longer meet the demand in full, the VRA has begun to inject thermal generation capacity into its operations. Apart from its core functions of producing and supplying reliable electricity to customers‟ demand and stakeholders‟ expectations for the socio-economic development of Ghana and West Africa sub-region, the VRA is invariably playing major tourism functions which are strategic for the country.

2.1 The Structure of VRA

The VRA currently operates a total installed capacity of 4,310MW as at the end of 2017. This made up of three hydro plants with installed capacity of 1,020MW 160MW and 400MW at the Akosombo, Kpong and Bui Generating Stations respectively; one 330MW combined cycle thermal plant at Aboadze, near Takoradi and a further 340MW simple cycle thermal plant, the Takoradi International Company (TICO) owned jointly by VRA and TAQA from Abu Dhabi in the United Arab Emirates. There plans to add an 110MW steam component to convert it to 330MW combined cycle. As a short medium term strategy for energy sufficiency, the VRA is developing a number of plants in Tema. These includes: a 110MW Tema Thermal Power Plant commissioned 1 in 2008, a 80MW Tema Thermal Plant commissioned in 2009 and a 220MW Kpong Thermal Plant completed in 2010. In addition to its primary responsibility to meet Ghana‟s power needs, the VRA‟s mandate includes the socio-economic development of the Volta basin, especially for fishing, transportation and tourism. Subsequently, the Authority has established the Volta Lake Transport Company (1970) and Akosombo Hotels Limited (1990) as subsidiaries to exploit the non-power related potentials of the Volta Lake. But that was not all, planning for the future for increased power generating capacity was paramount, hence the commissioning of a 330Mw combined cycle Thermal Plant at Aboadze near Takoradi, in the western Region in 1999. It was followed in 2000, by the addition of further 220MW simple cycle thermal plant at the same site, developed through a joint-venture partnership between VRA and CMS Energy of Michigan, USA. An 110MW steam to be added to the 220MW thermal power plant to bring the total installed thermal generation to 660MW. With other additional interventions over the years with the view to increase power generation capacity (Volta River Authority [VRA], 2018).

The authority currently operates a total installed electricity generation capacity of 4,758.5MW as at the year 2018. This made up of three hydro power plants with installed capacity of 1,020MW, 160MW and 400MW at the Akosombo, Kpong and Bui generating stations respectively; and other power plants including, Takoradi Power Company TAPCO (T1) of 330MW, Takoradi Inter Company TICO (T2) of 340MW, Tema Thermal Plant1 (TT1PP) of 110MW, Tema Thermal Plant2 (TT2PP) of 80MW, Kpone Thermal Power Plant (KTPP) of 220MW, Sunon-Asogli (SAPP) of 200MW, Sunon-Asogli (SAPP2) of 360MW, CENIT of 110MW, AMERI of 250MW, Karpower of 470MW, AKASA of 260MW, CENPOWER of 340MW and some sub-transmission level including, VRA solar of 2.5MW, BXC solar of 20MW, Trojan of 44MW, Meinergy solar of 20MW and Genser of 22MW (Ofosu-Ahenkora, 2018).

2.2 Northern Electricity Department (NED)

In 1987, as part of the arrangements to expedite the Northern Grid Extension and System Reinforcement Project, Act 46 was amended to extend VRA"s mandate to distribute 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 (Northern Electricity Department [NED], 2018). 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 customers in its area of operation.

2.3 Northern Electricity Distribution Company (NEDCo)

The Northern Electricity Distribution Company (NEDCo) of the Volta River Authority (VRA) was established in 1987 to distribute electricity in the Brong-Ahafo, Northern, Upper East and Upper West Regions of Ghana as part of VRA's 161kV transmission grid extension to the northern part of Ghana. In June 1994, the Government of Ghana (GoG) initiated the Power Sector Reform (PSR) program aimed at bringing efficiency and managerial effectiveness in the Energy Sector in order to improve service delivery to all consumers (Northern Electricity Distribution Company [NEDCo], 2018).

In pursuant of the PSR, VRA Management, in 1997, registered the Northern Electricity Distribution Company (NEDCo) as a wholly owned VRA subsidiary, with a

Board of Directors, to take over the operations of NEDCo. In May 2012, the VRA Management operationalized NEDCo as a wholly-owned subsidiary.

NEDCo's current operations cover about 64% of the geographical area of Ghana and include the northern part of Volta, Ashanti and Western regions. However the customer density of the operating area is low with access to electricity estimated at 44%. The Ghana Government, in line with its vision of making electricity available to all has undertaken power extension over the years to new towns and communities that were hitherto not served by NEDCo. Customer population has, therefore, grown at an average customer growth rate of about 13% per annum from less than 20,000 in 1987 to 698,353 at the end of 2015 (NEDCo, 2018).

Our mission is to supply safe and reliable electric power to homes and businesses in northern Ghana and neighbouring countries. NEDCo started with an initial load of about 10MW with a customer population of about 18,000. The Network has grown extensively over the years mainly as a result of the various Electrification programs particularly the Self Help Electrification Programs (SHEP) implemented by the Government of Ghana with support from World Bank and other international donor agencies. Before the power sector reforms begun in Ghana in the 80s, the then Electricity Corporation of Ghana (ECG) was responsible for the distribution of power in the whole of the country. Even though the National grid had not reached the current operational area of NEDCo, ECG was operating isolated diesel generating plants in Brong-Ahafo, Northern Region and the then Upper Region (now Upper East and West Regions), (NEDCo, 2018).

In 1987, as part of the arrangements to expedite the Northern Grid Extension and System Reinforcement Project, Act 46 was amended to extend VRA‟s mandate to distribute electricity in Ghana and VRA has since created a Northern Electricity Distribution Company (NEDCo) to implement the northern distribution zone component of the National Electrification Project. The 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 70,000 customers in its area of operation (NEDCo, 2018).

2.4 Electric Power System

Electric power supply system in a country comprises of generating units that produce electricity, high voltage transmission lines that transport electricity over long distances, distribution lines that deliver the electricity to consumers, substations that connect the pieces to each other, and the energy control centres to coordinate the operations of the components (Beggs, 2012).

An example of an electric power system is the network that supplies a region‟s homes and industries with power for sizable regions, this power system is known as the grid and can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centres to the load centres and the distribution system that feeds the power to nearby homes and industries. Smaller power systems are also found in industries, hospitals, commercial buildings, and homes. The majority of these systems rely upon three-phase AC power – the standard for large-scale power transmission and distribution across the modern world (Hussain, 2017).

2.4.1 Generation

Electric power plants use coal, natural gas, light crude oil and uranium to produce electricity. Additionally, other sources including hydro (water), solar, wind, geothermal sources and biomass. The type of fuel used, it‟s cost and generating plant efficiency can determine the type of plant to be used. For example, a natural gas generator has a high marginal cost but can be brought on-line as quickly as possible.

Coal, lignite and nuclear units have lower marginal cost but cannot be brought on-line as quickly as the former. They are used primarily to provide the base load of electricity. The cost for fuel used, their construction, operations and maintenance vary greatly from one type of power plant to the other. For example, renewable generation plants such as solar panels or windmills have virtually no fuel cost but are expensive to manufacture and install. Nuclear and coal power plants have low fuel costs but can be more expensive to construct and maintain. Coal and lignite units also incur additional cost for meeting air quality standard. Natural gas plants have a higher fuel cost than coal or nuclear, but have lower initial construction costs (Anand, 2010).

Ghana‟s electrical generating plants have an installed capacity of about 4,758.5MW as at the end of the year 2018. That is about 1,580MW is hydroelectric and 3,178.5MW is thermal power plants (Ofosu-Ahenkora, 2018).

Unlike hydro (water) and natural gas, electricity cannot be easily stored. This is a fundamental challenge of the electric power system. There is no accumulator “battery” that can store electricity for indefinite periods. Energy for the matter is stored in the fuel itself before it is converted to electricity. Once converted, it has to be transferred to the power transmission lines.

2.4.2 Transmission System

The power plants typically produce 50 cycle/second (Hertz), alternating-current (AC) electricity with voltages between 11KV and 33KV. At the power plant site, the 3-phase voltage is stepped up to a higher voltage for transmission on cables strung on cross-country towers.

High voltage (HV) and extra high voltage (EHV) transmission is the next stage from power plant to transport AC power over distances at voltages like; 220KV and 400KV. Where transmission is over 1000KM, high voltage direct current (DC) transmission is also favoured to minimize the losses.

Sub-transmission network at 132KV, 110KV, 66KV or 33KV constitute the next link towards the end user. Distribution at 11KV/66KV/33KV constitute the last link to the consumer, who is connected directly or through transformers depending upon the drawn level of service. The transmission and distribution network include sub-stations, lines and distribution transformers. High voltage transmission is used so that smaller, more economical wire sizes can be employed to carry the lower current and to reduce losses. Sub-stations, containing step-down transformers, reduce the voltage for distribution to industrial users. The voltage is further reduced for commercial facilities. Electricity must be generated, as and when it is needed since electricity cannot be stored virtually in the system.

According to Moshin, Shivan and Gopa (2014), there is no different between a transmission line and a distribution line except for the voltage level and power handling capability. Transmission lines are usually capable of transmitting large quantities of electric energy over long distances. They operate at high voltages. Distribution lines carry limited quantities of power over shorter distances. Voltage drops in line are in relation to the resistance and reactance of line, length and the current drawn. For the same quantity of power handled, the high the current drawn, and the high the voltage drops. The current drawn is inversely proportional to the voltage level for the same quantity of power handled.

The power loss in line is proportional to resistance and square of current (i.e.$P_{loss} = I^2R$). Higher voltage transmission and distribution thus would help to minimize the line voltage drop in the ratio of voltages, and the line power loss in the ratio of square of voltages. For instance, if distribution of power is raised from 11KV to 33KV, the voltage drop would be lower by a factor of $1/3$ and the line loss would be lower by a factor of $(1/3)^2$ i.e. $1/9$. Lower voltage transmission and distribution also calls for bigger size conductor on account of current handling capacity needed (Moshin et al, 2014).

2.4.3 Local Distribution System

According to Singh (2009), most homes and businesses use 240V electric power while industries often use much higher voltages. Large commercial and industrial customers may ignore the local distribution system and receive electricity at high voltage directly from the transmission system. Substations on transmission system receive power at higher voltages and step them down to 24,900 volts or less to feed the distribution systems**.**

The distribution system consists of the poles and wires commonly seen neighborhoods. At key locations, voltage is further reduced by step-down transformers to meet customer needs. Customer on the distribution system is categorized as industrial, commercial and residential. Industrial use is fairly constant, both over the day and over seasons. Commercial use is less constant and varies over seasons. Residential and commercial use is more variable, sometimes changing rapidly over the day in responds to consumer‟s needs, appliance use and weather events (Moshin et al, 2014).

2.5 General Consideration about Losses

According to Singh (2009), Power losses can be broadly defined as the difference between the amount of electricity entering the transmission system and the aggregated consumption registered at the end-user meter points. From an operational point of view, electricity losses are unavoidable due to the cost of the transfer of energy across electricity transmission and distribution networks which need to be appropriately tackled, as they impose an additional demand and energy load on the system.

Singh (2009), further stated that, Losses result in considerable financial and environmental costs. It should be noted that power losses in transmission and distribution networks may account for up to 15% - 25% of the total amount of electricity produced. The costs related to these losses are borne by final customers, as they are obliged to pay for an energy supply that includes the load of energy that is „lost‟ and therefore, not consumed.

According to Mehebub, Yasin, and Mandela (2014), the environmental impact of losses is borne by society as a whole, as a result of the emission of air pollutants associated with the additional generation that needed to cover losses. Therefore, the objective of the regulatory treatment of losses is in two fold; to protect the interest of customers and on the other hand, to promote the efficiency of the network system.

Mehebub et al (2014) further stated that, in order to keep losses at a low and reasonable level, regulators have to designed incentive mechanisms which deliver rewards (or penalties) for network operators whenever losses are below (or above) a pre-set target level. These mechanisms are justified by the fact network operators have to some extent, the ability to control losses since they are responsible for several activities such as network design, maintenance and investment decision regarding the installation of grid elements that play a significant role in the determination of losses.

According to Pankaj, (2014), it is important to ensure that network operators face adequate incentives so that they make an appropriate effort on evaluating the costs and benefits of reducing losses and hence, optimize the level of losses in most efficient way. By contrast, there are a number of external factors with significant influence on the level of losses. In particular, the geographical size of the market as well as the number and degree of dispersion of customers connected to distribution networks are important driving factors which cannot be modified.

Due to its complexity, the treatment of losses is also deeply related to other regulatory and operational issues, such as energy efficiency schemes, infrastructure planning and network reconfiguration, that are far beyond the scope of this document. Generally, it should be stated that losses are proportional to the amount of energy that is delivered, the distance between generation and consumption, and inversely related to the voltage of the network. Consequently, any measures or actions focused on reducing or smoothing the demand for energy, relocating generation plants closer to demand, and upgrading the voltage level of the network, will have a positive impact on losses (Pankaj, 2014),

2.5.1 Losses in Electrical Power System

According to Jordanger (2014), the problem of losses may be illustrated as shown in Figure 2.1 that explains the functional process and the losses generated at each stage of the technical and commercial management of a distribution company.

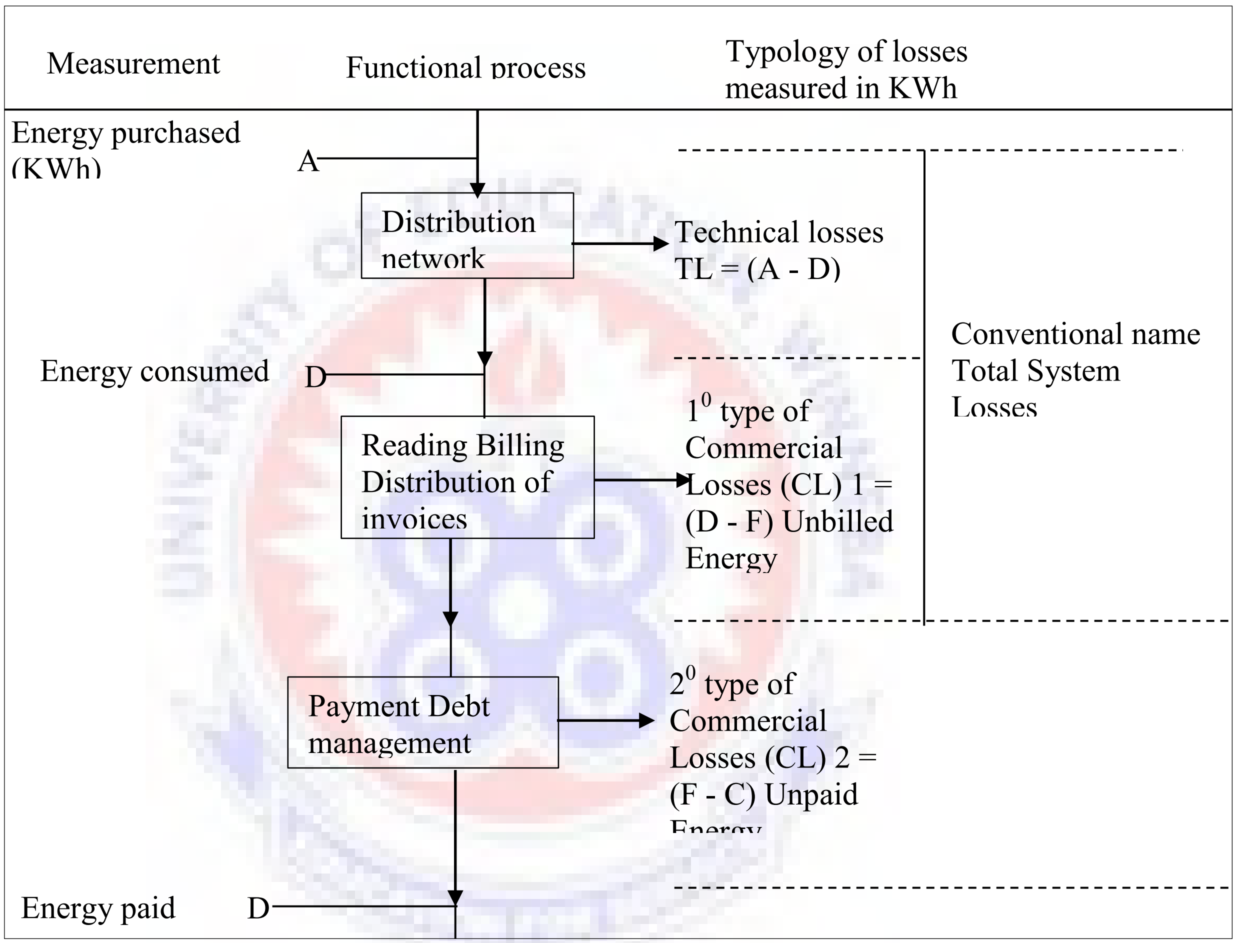

Figure 2.1: Losses in Electrical Power System

The operator of a power distribution system receives or purchases the amount of energy (*A*) needed to meet the customers demand (*D*). His task is to manage this energy and see that it is conveyed to each customer. The financial resources of the operator come from the energy billed (*F*) to each customer (i.e. the product actually sold) and the effective payment of the invoices which is the amount of energy (*C*) indicated in the invoices collected. The ideal situation would be for the quantities *AFC* to be equal. However, energy *F* billed to customers, itself higher than energy *C* which is effectively paid.

The interest of any operator is therefore to reduce system losses. To do so, he has three main actions;

1. Buy the amount (*A*) strictly necessary to meet demand (*D*)**: -** to achieve this, he must design and operate the power network in a technically optimum way to reduce the losses to a minimum natural level, linked to physical phenomena.
2. Minimize billed energy (*F*): - the operator must design and operate a customer management system enabling him to assess the energy consumed by customers and to invoices it accurately and then add up the total amount. A customer who has been „forgotten" or „not billed" means the loss of merchandise and consequently a financial loss.
3. Maximize paid energy (*C*): - one therefore has to monitor the payment of invoices conduct actions to compel defaulters to pay as quickly as possible, manage accounts receivable so as to reduce unpaid energy to a minimum.

Some countries, many had been written, usually to resume the actions to reduce these kinds of losses, but it is necessary also to identify the technical losses in order to deduce the terms of the well-known equation;

Non-Technical Losses = Energy to the network – energy in meters* - Technical Losses.

In order to ease the analysis and properly account for the different sources of this phenomenon, power losses in electrical systems are conventionally broken down into two categories (Ruiz, 2005).

1. Technical losses
2. Nontechnical losses.

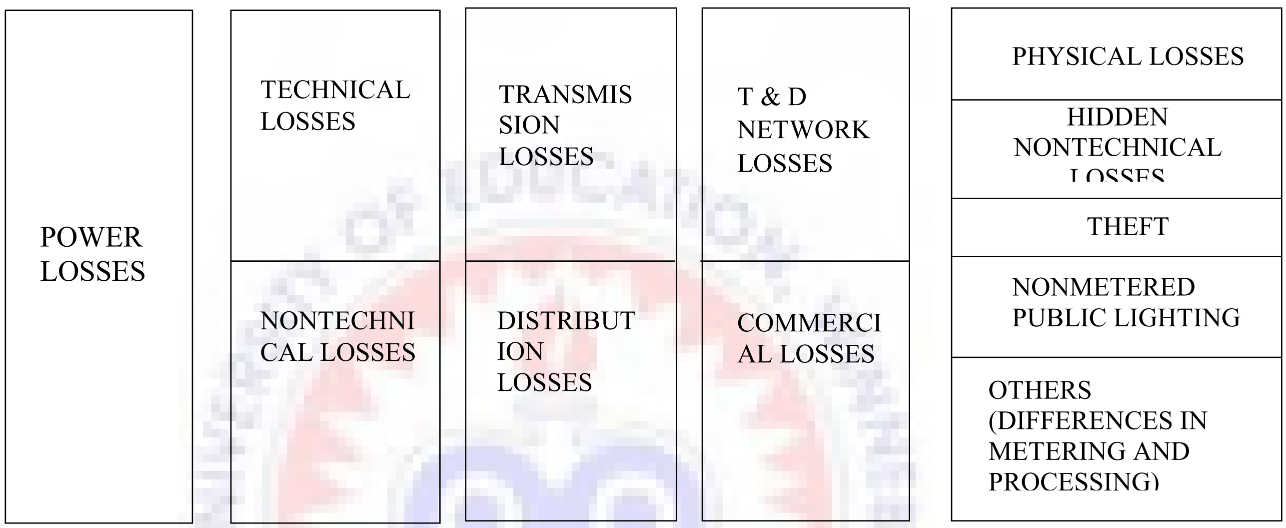

Figure 2.2: Technical operations and Commercial Management of a System Loss.

As a consequence of the wide range of sources of power losses, current regulatory definitions of this term vary significantly from country to country. For benchmarking purposes, this circumstance seriously hinders the analysis of percentages of losses across countries.

According to Hodgkins & Tyler, (2014), for the sake of comparability, power losses are divided into the following five classes. Thus,

1. Physical losses in transportation and distribution of electricity.
2. "Hidden" nontechnical losses (e.g. in-house consumption).
3. Thefts
4. Non-metered public lighting
5. Others (e.g. metering errors) as shown in figure. 2.2

Remarkably, most countries show certain symmetry within their definitions for transmission and distribution losses. In addition, the whole set of countries under analysis agrees to accounts for physical losses. However, regarding nontechnical losses the excessive exercise reveals a noteworthy heterogeneity in definitions. Overall, the vast majority of the countries considered broadly account of physical losses, thefts and metering errors in their regulation, since there is no remedy to prevent it.

Losses can be subdivided according to whether or not they depend on power flow. The „iron" losses in transformers do not vary with power flow, so are considered as „fixed" for a given network. Non-technical losses are likely to be relatively insensitive to total power or energy demands, so can also be classed as „fixed". In contrast, the resistive losses vary as the square of the power flow. Thus, electricity transmission and distribution at peak time"s lead to a greater loss of power and over time contribute disproportionately to the variable component of energy losses (Hodgkins & Tyler, 2014).

2.5.2 Technical Losses of Power System

Technical losses on distribution systems are primarily due to heat dissipation resulting from current passing through conductors and from magnetic losses in transformers. Technical losses occur during transmission and distribution and involve substation, transformer, and line losses. These include resistive losses of the primary feeders, the distribution transformer losses (resistive losses in windings and the core losses), resistive losses in secondary network, resistive losses in service drop and losses in KWh meter. Losses are inherent to the distribution of electricity and cannot be eliminated (Fourie & Calmeter, 2004).

The component of distribution network losses that is inherent in the physical delivery of electric energy. It includes; conductor loss, transformer core loss, and potential/current coil in metering equipment. Technical loss is calculated as the sum of the hourly load loss and non-load (or fixed) loss in all distribution equipment, devices and conductors for a specific billing period. Technical losses mean losses that happen because of the physical nature of the equipment and infrastructure of the power system, i.e. I^2R loss - or copper loss in the conductor cables, transformers, switches and generators. Loads are not included in the losses because they are actually intended to receive as much energy as possible (Fritz & Russ, 2013).

Technical losses are due to current flowing in the electrical network and generate the following types of losses:

1. Copper losses are those due to I^2R losses that are inherent in all inductors because of the finite resistance of conductors.
2. Dielectric losses that are losses that result from the heating effect on the dielectric material between conductors.
3. Induction and radiation losses that are produced by the electromagnetic field surrounding conductors.

The following are the causes of technical losses: Harmonics distortion

4. Improper earthing at consumer end
5. Long single phase lines
6. Unbalanced loading
7. Losses due to overloading and low voltage
8. Losses due to poor standard of equipment.

It is possible to compute and control technical losses, provided the power system in question consists of known quantities of loads. Technical losses are naturally occurring losses (caused by actions inherent to the power system) and consist of mainly power dissipation in electrical system components such as transmission lines, power transformers, measurement systems etc. Technical losses are possible to compute and control, provided the power system in question consists of known quantities of loads (Singh, 2009).

According to Firtz and Rus, (2013) Technical losses can be calculated based on the natural properties of components in the power system: resistance, reactance, capacitance, voltage, current and power is routinely calculated by utility companies as a way to specify what components will be added to the systems. Though the data and tools needed for calculating losses in power systems are available, current techniques have drawbacks regarding such calculations.

Firtz & Russ (2013), further stated that, technical losses in power systems mean power losses incurred by physical properties of components in the power systems infrastructure. Common example of such losses is the power loss caused by resistance of transmission lines. The average power loss in a transmission line can be expressed as in equation (1) as

$$P_{loss} = P_{source} - P_{load} \qquad (1)$$

Where P_{source} means the average power that the source is injecting into the transmission lines and P_{load} is the power consumed by the load at the other end of the transmission lines.

This is simple enough calculation, except that power and current are both time dependent functions and that energy – not power – is the quantity that gets both translated into money. Energy is power accumulated over time, or as in equation (2)

$$W_{loss} = \int_a^b P_{loss}(t)\, dt \quad \text{...} (2)$$

With, a, and b as the starting and ending point of the time interval being evaluated respectively. As a result, we need a fairly accurate description of P_{loss} as a function of time to make a reliable prediction of energy loss (W_{loss}). And power, in a single – phase case, with sinusoidal current and voltage can be represented by equation (3)

$$PI - \varphi = IVcos\Theta \quad \text{..} (3)$$

With P, V and I being the average power, rms voltage and rms current of the element in question respectively. The term cosΘ is the power factor of the element in question, while Θ is the phase difference between the voltage and the current waveforms. From the above equation, it can be summarized that the information needed to calculate the average power loss sampled at an instant of time in a transmission line or an arbitrary element in a power system has to be one of the following sets (all variables are single – phase, rms values and average power);

1. Voltage across the element and resistance, or $P = {V^2}/{R}$
2. Current and resistance, or $P = I^2R$
3. Voltage, current and phase difference between the two, or $P = IVcos\Theta$

These sets of data and choices of calculations are options that an engineer will have for computing power losses in a load – flow analysis. But in order to gain V or I both rms values, the voltage must be known at two ends of the element that is evaluated, at all times or as averages. This means the terminals that feed consumer loads must be appropriately monitored at all times using some of the more sophisticated meters that could store and compute average and instantaneous values that the load – flow analyst is interested in.

The information about the power sources and loads listed above are needed to determine expected losses in the power system using l0ad – flow analysis software. The actual losses are the difference between outgoing energy recorded by the source (e.g. at a substation) and energy consumed by the consumers, which is shown on the bills. The discrepancy between expected losses and actual losses would yield the extent of non-technical losses in that system.

For the simulations undertaken for this research, the voltage, current, power and power factor of the generator have known values at the same time intervals, and consequently, the current going through the transmission lines. The losses in the transmission line are easily computed using the current and transmission line resistance values. Information of the load‟s power and power factor are unknown, but at this point the information at the generator is sufficient to determine what‟s happening to the transmission line using simple calculation shown in equations 4 and 5

$$I^* = \frac{S_{load}}{V_{load}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4), and}$$

$$P_{loss} = (V)I^* \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where $S_{load}, V_{load}, P_{loss}, I \; and \; R$ are the load apparent power, load voltage, power loss in the transmission line, current in the transmission line, and transmission line resistance, respectively (all values are complex values), while $I*$ is the complex conjugate of the current.

The same relationships hold when analyzing these quantities as phasors or rms values. Any major calculations become unnecessary when ***I*** can be measured directly and the transmission line properties are known, which is never true for practical power systems.

Companies that generate and distribute electricity usually measure currents that enter and leave their facilities in order to measure the energy that is bought or sold. For areas outside the company‟s facilities, i.e., residential or business consumer areas, only peak power and accumulated energy are usually measured. However, the low voltage transmission systems (below 24,000 volt or 24 KV) are not as thoroughly measured because of the costs of the added metering. This is the reason power flows solutions are used to estimate the state the various point in the system. Power flows analysis is generally used for specifying equipment rating after estimating the worst-case loading scenarios.

Finding the current in the bus going out of a metered generator is simple, but in reality there are often many interconnected buses and many more elements in the system. Just expanding the two-bus characterization by one step would yield a three-bus system shown in Figure (2.3). Using Kirchhoff‟s Current Law in Equation (6) to solve for the current at the bus where the two transmission line meet,

$$I_1 = I_2 + I_3 \text{...} \quad (6)$$

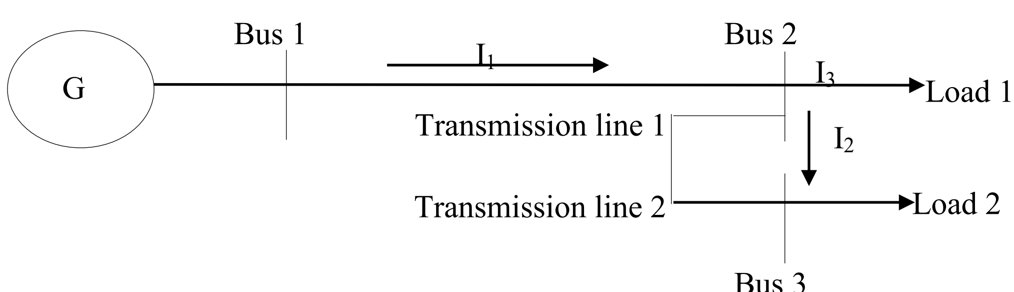

Figure 2.3: Three Bus Bar

As in the three bus-bar case shown in figure 2-3, the current in Transmission Line 1 is measured. To determine the current in transmission Line 2 (I_2), however, the current going into Load 1 must be known. This means there to be a meter at load 1 with the same capabilities as the meter at the generator in order to compute I_2 at desired times. (Jordanger, 2014).

2.5.3 Administrative Losses

Administration losses include the component of distribution network losses that accounts for the electric energy used by the distribution utility in the proper operation of the distribution network. Substations, offices, warehouses and workshops, and other essential electrical loads are usually considered as part of the administrative loss. (Malovic et al, 2016).

2.5.4 Non–Technical Losses (NTL) of Power Systems

According to Pankaj (2014), non-technical losses are caused by actions external to the power system or are caused by loads and condition that the Technical losses .computation failed to take into account. Non-Technical losses are more difficult to measure because these losses are often unaccounted for by the system operators and thus have no recorded information.

Pankaj (2014) further stated that, non-technical losses (NTL), on the other occur as a result of theft, metering inaccuracies and unmetered energy. NTLs relate mainly to power theft in one form or another. Theft of power is energy delivered to customers that is not measured by the energy meter for the customer. This can happen as a result of meter tampering or by bypassing the meter. Losses due to metering inaccuracies are defined as the difference between the amount of energy actually delivered through the meters and the amount registered by the meters. The most probable causes of Non-Technical Losses (Pankaj, 2014) are:

1. Tampering with meters to ensure the meter recorded a lower consumption reading
2. Errors in technical losses computation
3. Tapping (hooking) on LT lines
4. Arranging false readings by bribing meter readers
5. Stealing by bypassing the meter or otherwise making illegal connections
6. By just ignoring unpaid bills
7. Faulty energy meters or un-metered supply
8. Errors and delay in meter reading and billing
9. Non-payment by customers.
10. Fixed rate charge

The aim in this paper work is to first compute the technical losses and then impact of non-technical losses on them is shown. Technical losses will be simply calculated using load flow method of power system. This will be done because non-technical losses are more difficult to measure. As NTL cannot be computed and measured easily, but it can be estimated from preliminary results, i.e. the result of technical losses are first computed and subtracted from the total losses to obtain the balance as NTL. The technical losses are computed using appropriate load-flow studies simulated under MAT LAB environment. Although some electrical power loss is inevitable, steps can be taken to ensure that it is minimized. Several measures have been applied to this end, including those based on technology and those that rely on human effort and ingenuity. (Chembe, 2014).

By their nature, NTL can only be estimated by subtracting technical losses from overall total system losses (Lacus, 2013). He further stated that, losses that are independent of technical losses in the power system. Two common examples of sources of such losses are component break downs that drastically increase losses before they are replaced and electricity theft. Losses incurred by equipment breakdown are quite rare. These include losses for equipment strike by lighting, equipment damaged by time and neglect. Most power components do not allow equipment to breakdown in such a way and virtually all components maintain some form of maintenance policies. Other probable causes of non-technical losses are as follows,

1. Nonpayment of bills by customers.
2. In accurate or missing inventories of data on customers.
3. Errors in accounting and records keeping that distort technical information.
4. Errors in technical losses computation.
5. Power theft.

The most common forms of non-technical losses in Ghana are Power theft and non-payment of bills refers to cases where customers refuse or are unable to pay for the electricity used. However, the other forms are not analyzed thoroughly in this project. Non-technical losses are very difficult to quantify or detect and are more problematic than the other losses.

Non-technical losses can also be viewed as undetected load, customers that the utilities do not know exist. When an undetected load is attached to the system, the actual losses increase while the losses expected by the utilities remains the same. The increased losses will show on the utilities accounts, and the cost will be passed to customers as transmission and distribution charges (Nunoo, 2012).

According to Emad (2010), non-technical losses are not inevitable. They must be identified and fought with eradication objective by all electricity distribution companies concerned about sound management. Table 2.1 shows the main causes of non-technical losses, which can be classified into three major groups.

Table 2.1: Causes of non-technical losses

Non-metered energy (consumption losses)	**Unbilled energy (invoicing error)**	**Unbilled energy (collection losses)**
Illegal connections	(A) Incorrect customer file	(A) Unpaid invoice
1. Delay in the installation of meters	1. Insufficient or erroneous contractual information.	1. Non-distributed invoices.
2. Metering equipment tempered with.	2. None conform metering coefficients.	2. Customer‟s payment difficulties.
3. Faulty meters	3. Faulty updating of the file.	3. Un-adapted collection procedure.
4. Estimates of effective consumption too low	(B) Incorrect invoicing	4. Poor management of unpaid invoice.
5. Faulty connections	1. Customers not billed because of lack knowledge and follow up.	
6. Un adapted metering equipment	2. Absence of follow up of customers who benefit from special or free tariffs	(B) Payment management
7. Customers not taken into account	3. Absence of follow up and to reports on invoicing incidence	1. Misappropriations of payment
8. Meter reading errors at the reading level or erroneous index transfers.	4. Absence of check of rectified invoices.	2. Payment loss.

Reasons behind Distribution Losses

According to Moshin et al (2014), the following are the major reasons for high distribution losses:

1. Inadequate investment on transmission and distribution, particularly in sub-transmission and distribution. While the desired investment ratio between generation and T&D should be 1:1, it has decreased to 1:0.45. Low investment has resulted in overloading of the distribution system without commensurate strengthening and augmentation.
2. Haphazard growths of sub-transmission and distribution system.
3. Short-term objective of extension of power supply to new areas.
4. Large scale rural electrification through long 11kV and LT lines.
5. Too many stage of transformations, improper load management and inadequate VAR compensation
6. Poor quality of equipment used in agricultural pumping in rural areas,
7. Cooler air-conditioners and industrial loads in urban areas.
8. Theft and pilferage account for a substantial part of the high transmission and distribution losses, the theft / pilferage of energy is mainly committed by two categories of consumers i.e. non-consumers and bona fide consumers. Some of the modes for illegal abstraction or consumption of electricity are given below:
9. Making unauthorized extensions of loads, especially those having “H.P.” tariff
10. Tampering the meter readings by mechanical jerks, placement of powerful magnets or disturbing the disc rotation with foreign matters.
11. Stopping the meters by remote control and bypassing the meter.

12. Changing the sequence of terminal wiring.
13. Errors in meter reading and recording and improper testing of calibration of meters.

2.6 Losses Reduction Gains

According to Emad, (2010), the high rate of technical and nontechnical loss generates the following.

1. A reduction in revenue resulting in cash difficulties, with all the ensuring economic consequences.
2. Costly, useless or premature investments.
3. Poor quality of service offered to customers.

Major losses drive the authorities to subsidize the company thus, increasing the state"s financial load. Reducing the losses and reaching an acceptable level will restore the confidence of leaders and private investors to encourage them to participate financially in the development of the power sector. The gains resulting from loss reduction can be classified into economic, financial gains and institutional benefits.

2.6.1 Economic and Financial Gains

Emad, (2010) further gave the economic and financial gains which can be classified into two kinds, thus,

1. With constant consumption, the reduction of technical losses make it possible to cut down generation and therefore save on investment and fuel (with constant generation).

2. With constant generation and consumption. The reduction of nontechnical losses helps increase the sales revenue. Thus, the reduction of technical losses leads to a real gain in energy and reduced capital intensive investment. It therefore benefits the country economy. The reduction of nontechnical losses not only improves the financial balance of the company concerned, but also the load curve by subjecting consumption to the tariff regulation.

Another way of stating the main benefits may be as follows,

1. Reduction of cost prices (with regards to the Kwh sold operating costs), improvement of accounting results on financial stability of electrical utilities.
2. Improvement of the quality of supply and service offered to customers.
3. Optimization of investments and improvement of the environment (reduction of the pollution of power plants, more efficient use of financial resources, rational use of energy and tracking down customers waste of energy).
4. It should also be noted that when a company has stringent management, it can legitimately require stringency of its customers.

2.6.2 Institutional Benefits

Excessive losses are synthetic indicator of more or serious dysfunctions in the distribution company, affecting in particular organization, management and skills. When the loss reduction project is a success and losses have been brought down to a reasonable value, the success is therefore the proof that the actions for reorganization, managerial change, training and motivation of the personnel have been efficient at menthe same time as the technical actions themselves. Not only must one therefore seek to reduce the losses, but also the endeavor to teach the company to continuously struggle to reduce losses

A distribution company that succeeds in controlling its losses may be used by the Public Authorities as a model to be followed for the other infrastructure departments; water, post, telephone etc. A successful loss reduction project is a factor for progress in the country"s infrastructures. (Emad, 2010).

2.6.3 Loss Reduction Strategies

There are several potential ways for network operators to reduce losses. These include changes to the network design, such as specifying larger assets to reduce resistance and low-loss transformers. (Melovic et al, 2016). Utility companies can also reduce non-technical losses by investing in detecting theft and improving data accuracy. These latter measures do not change the level of technical losses, but they do promote economic efficiency. (Celli et al, 2015).

2.7 Synthesis of Lterature Review

This study is conducted to analyze distribution losses in electric power system and find out the effects of these on consumers and the system itself. The study mainly looked at the various losses in the power system and its economic consequences in the power system in NEDCo and consumers.

On the various losses in the electric power system and its causes, it was found out that, power losses were the difference between the amount of electricity entering the transmission system and the aggregated consumption registered at the end-user meter points.

Some of the various losses found in the study included technical and non-technical losses which were considered as the main power losses in system. Also some of the economic consequences in the power system included, cutting down generation and enhancing investment and fuel and increment in the sales revenue. Again other benefits include, reduction of cost prices, improvement of quality of supply and services offered to customers, optimization of investment, improvement of the environment and stringency of customers.

Furthermore, the study brought to light whether or not the losses were causing high increase in tariff. Losses led to reduction in revenue resulting in cash difficulties, useless or premature investment and poor quality of services offered to customers. Therefore, distribution losses in the system caused high increase in tariffs which needs to be looked at.

CHAPTER THREE

RESEARCH METHODOLOGY

In this chapter, the methodology and the approaches to data collection are presented and discussed. The methodology is very important in research because it provides the avenue for anyone interested in the research to judge the validity and reliability of the approach used which has a direct effect on how the findings and conclusions are accepted.

The chapter therefore includes the research design, sampling techniques, sources of data, population and methods of data analysis.

3.1 Research Design

A research design is the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure. In fact, the research design is the conceptual structure within which the research is conducted; it constitutes the blueprint for the collection, measurement and analysis of data. The main aim of the study was to analyze the effects of distribution losses in electrical power system on consumers in Ghana specifically Sunyani. The study was done with the use of survey method. Research design as defined by Cooper & Schindler (2003) is the plan and structure of investigation so conceived as to obtain answer to research questions. This study adopted a descriptive research design, which according to Cooper and Schindler (2003) involves surveying people and recording their responses for analysis.

Hussain (2017), used the survey method in his research work on “Analysis of Non-Technical Electrical power losses and their Economic Impact on Pakistan.” Again, Mohammad and Mandala (2014) used the survey method in their work on “A review of losses in distribution section and minimization techniques in India”. Not only that, Beggs (2012) also used the survey method in his research work on “Loss reduction and efficiency improvement: A critical appraisal of power distribution in India. For this reason, a survey was selected with questionnaires as the research instrument.

Questionnaires, interviews, observations and review of documents were used as the main instruments for the relevant data. Some advantages and disadvantages enumerated by Stefan (2018) on Survey for using survey for data gathering are as follows:

Surveys provide a high level of general capability in representing a large population. Due to the usual huge number of people who answer survey, the data being gathered possess a better description of the relative characteristics of the general population involved in the study as compared to other methods of data gathering, surveys are able to extract data that are near to the exact attributes of the larger population.

When conducting surveys, you only need to pay for the production of survey questionnaires. Surveys can be administered to the participants through a variety of ways. The questionnaires can simply be sent via e-mail or fax, or can be administered through the Internet. Nowadays, the online survey method has been the most popular way of gathering data from target participants.

Aside from the convenience of data gathering, researchers are able to collect data from people around the globe. Because of the high representativeness brought about by the survey method, it is often easier to find statistically significant results than other data gathering methods. Multiple variables can also be effectively analyzed using surveys. Surveys are ideal for scientific research studies because they provide all the participants with a standardized stimulus. With such high reliability obtained, the researcher‟s own biases are eliminated.

Notwithstanding the numerous advantages in using survey for data gathering, surveys have their disadvantages and weak points that must be considered. Among such disadvantages and weak points discussed by (Stefan, 2018).

Questions in surveys are always standardized before administering them to the subjects. The researcher is therefore forced to create questions that are general enough to accommodate the general population. However, these general may not be as appropriate for the participants as they should be.

Questions that bear controversies may not be precisely answered by the participant because of the probably difficulty of recalling the information related to them. The truth behind these controversies may not be relieved as accurately as when using alternative data gathering methods such as face-to-face interviews and focus groups. The survey that was used by the researcher from the very beginning, as well as the method of administering it cannot be changed all throughout the process of data gathering.

3.2 Population

According to Cooper & Schindler (2003), populations consists of the people who wish to describe using our sample. In this study the population target was Domestic, Commercial and Industrial consumers and workers of NEDCo of Brong Ahafo Region.

The research was confined to Brong-Ahafo to look at the losses by the main distributer of electricity in region of the NEDCo. This is because, NEDCo covers four regions in the Northern part of Ghana namely Brong Ahafo, Northern, Upper East and Upper West. Brong Ahafo has the largest population among these four regions. Hence the researcher used the Brong Ahafo region to represent the four regions. The researcher looked at the Bulk unit sold to NEDCo by VRA and the measurements of the various losses i.e. technical and non-technical losses in the regions with particular reference to the Brong-Ahafo Region.

3.3 Sampling Procedure

The sample selection process is continued until the required sample size has been reached (Saunders, Lewis & Thornhill 2009). Under convenience sampling respondents are selected on the basis of proximity, ease of access and willingness to participate (Timothy, 2005). A number of consumers complained of high electricity tariffs and power theft, and Brong Ahafo Region was selected among the four regions. Time and money was saved by selecting a sample to be studied rather than attempting to study the entire population of consumers who complained of high tariffs and power theft. Obtaining data from the population of consumers as well as analyzing and interpreting vast amounts of data would have been impossible to accomplish within the time constraints and with the limited financial resources which were available for conducting this research.

The target population consisted of seven hundred and fifty (750) consumers of electricity and NEDCo workers thus, domestic, industrial and commercial consumers in the region. The sampled three hundred and eight (308) are domestic consumers, one hundred and eighty (180) are commercial consumers while the remaining twelve (12) are industrial consumers. One hundred and thirty (130) questionnaires were distributed to the workers in seven (7) districts and one officer of the region of NEDCo.

The Regional Director of NEDCo in the region and two Regional Engineers. Thus, the substantive Regional Engineer and the assistant Regional Engineer were interviewed to ascertain the knowledge of the distribution Losses in electrical power system in the Brong-Ahafo Region precisely. In all six hundred and thirty (630) questionnaires were distributed to sampled consumers and workers of NEDCo in the region of Brong-Ahafo.

Table 3.1: Distribution of questionnaire to workers and consumers.

Region (Districts)	Population
District Engineers	12
District Technicians	20
District Foremen	26
District Artisans	52
Regional Engineers	4
Regional Technicians	4
Regional Foremen	6
Regional Artisans	6
Commercial consumers	180
Domestic Consumers	308
Industrial Consumers	12
Total	**630**

Source: Field Survey, 2018

The breakdowns of the district distribution of the questionnaires are shown in table 3 – 2 below.

Table 3.2: Distribution of questionnaires to Brong-Ahafo Region of NEDCo.

Districts	Engineers	Techni-cians	Artisans	Foremen	Industrial consumers	Domestic consumers	Commercial consumers	Total
Sunyani	3	4	10	6	2	50	30	105
Bechem	2	4	8	4	0	40	25	83
Brekum	2	3	7	4	1	44	25	86
Domaa Ahenkro	2	4	8	4	0	44	25	87
Wenchi	2	3	7	4	0	40	25	81
Tachiman	3	4	10	6	5	50	30	108
Mim	2	2	8	4	4	40	20	80
Total	**16**	**24**	**58**	**32**	**12**	**308**	**180**	**630**

Source: Field Survey, 2018

With the above sampling, the researcher was quite sure that it represented the population adequately and could therefore reflect a true picture of the distribution losses of electricity in Brong-Ahafo.

3.4 Instruments

A questionnaire was developed and used in the study. The questionnaire was made for electrical power consumers including domestic, commercial and industrial consumers and workers of NEDCo. The questionnaire response format is a four point Likert-type scale from "strongly agree", "agree", "strongly disagree", and "disagree" and were assigned a value of 4 down to 1 respectively. The questionnaire consists of a total number of 46 items, 7 items on the characteristics and statistics of respondents, 4 items on acquisition of meter, 20 items on payment of bills and 15 items for NEDCo workers.

According to Robson, Haugh & Obeng, (2002), a research instrument is any type of written or physical device which is purported to measure variables. The type of instrument used for data collection depends on the type of data to be collected. A choice of instrument will depend on many factors including validity and reliability, ease of administering, ease of acquisition of response and ease of interpretation (Robson, 2002).

The study having taken the above factors into consideration used a questionnaire with both closed and open ended questions. The close-ended questions were relevant for the reason that they were easy to ask and quick to answer. This is significant since data had to be collected quickly to meet the time frame for the research. Another reason was that analysis of closed-ended questions was easy and straight forward. However, the potential for the closed ended questions to introduce bias was duly recognized. The open-ended questions therefore provided the respondents the opportunity to express their views freely and spontaneously. Further, the open-ended questions offered the researcher the opportunity to probe respondents further if answers provided were unclear. However, the open-ended questions were difficult to answer and more difficult to analyze. The questionnaires were self-administered. The questionnaires were administered to 593 consumers of electricity and NEDCo workers. There were 130 NEDCo staff and 463 consumer of electricity selected for the study.

Non-response factors such as content, anonymity and complexity of questions were addressed during the pilot studies. This resulted in refinements to the format of the questionnaire. All respondents were assured of anonymity. A semi-structured interview was also conducted with the selected managers of the NEDCo. The interview enabled the researcher to obtain large and detailed amount of data within a short time.

3.5 Ethical Considerations

The privacy and confidentiality of the respondents was protected by keeping in secrecy the information collected. Deception was avoided by informing construction companies about the purpose of the research and its implications on the respondents. This helped the respondents to make informed decisions with respect to the questions asked. All sources of information were duly acknowledged (Ofori, 2014).

3.6 Validity and Reliability of Instrument

The drafts of the questionnaires were subjected to expert scrutiny, refined and pre-tested in other district in Brong Ahafo Region The pre - tested questionnaires were analyzed to ensure that the questions were understood by the respondents and that there were no ambiguities.

Cohen, Manion and Morrison (2011), argued that it is impossible for a research to be 100 percent valid; that is the optimism of perfection. In view of this, effort was made to sought advice and suggestions from experts during the designing of the instrument, this to a large extend made the instrument valid and reliable for the study.

The two questionnaires were of the survey type. In all thirty and forty items for users and employees respectively were designed. A pre-testing item was carried out which entailed checking the reliability of the questionnaires and whether the questionnaires are easy to understand especially for respondents to whom it would be delivered to.

3.6.1 Data Collection Procedures

The questionnaires were distributed to the consumers, Engineers, Technicians, Foremen and Artisans by hand to avoid delay that could be caused by mailing and sometimes they could get lost on the way before reaching them. The administration and collection of the questionnaires covered a period of four months. It was done through personal visits to the various selected districts where the workers and consumers are found. Upon gaining access to a participant, the instrument was given out and the participants were left to complete the instrument and come back for it after two weeks.

3.6.2 Data Analysis

The data were analyzed using frequency tables and percentages. Johnson and Christensen, (2008), explain that quantitative research attempts precise measurement of something and it also determines facts and figures.

The findings from the in-depth interviews were analyzed using the techniques of descriptive analyses. The findings from the quantitative survey were analyzed using Microsoft Excel. The data was analyzed to assess the distribution losses and to determine the optimal improvement of distribution losses so that customers will be free from paying unnecessary bills. Data entry lasted for three weeks. To ensure high quality, the researcher supervised data entry, cleaning and analysis. A number coding was adapted based on the final questionnaire; this was designed by the researcher. Coherence and precision were achieved in the process. To ensure reliability, the researcher carefully did the coding of questionnaires himself to minimize coding errors.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION

The aim of the study was to analyze the effect of the distribution losses in electrical power system on consumers in Brong Ahafo Region. This chapter therefore reports the finding and discussions under the two research questions. The analyzed and discussed data in this chapter was derived from records of results obtained from the consumers and workers of NEDCo in Brong Ahafo Region.

4.1 Research Findings

The information presented here is deduced from the responses from questionnaires received from sampled commercial, industrial and domestic users of electricity and also workers made up of managers and other workers of NEDCo. Interviews were also conducted with managers made up of the Regional Director and their Engineers of the NEDCo in Brong Ahafo Region.

The results of the study would be treated under the following: responses from domestic users, responses from commercial users, industrial users, responses from workers of NEDCo and interview with Regional Director of Brong-Ahafo and general observations.

In all, seven hundred and thirty (710) questionnaires were distributed to consumers of electricity in Brong-Ahafo respondents were commercial users, industrial users, domestic users and workers of the company.

Table 4.1: Summary data of respondents

Respondents	No. Administered	No. Received	Return Rate (%)
Domestic Users	350	308	88.0
Commercial Users	200	180	90.0
Industrial Users	15	12	80.0
NEDCo Workers	145	130	89.65
Total	**710**	**630**	**88.73**

Source: ***Field Survey, 2018***

With this, it shows that eighty (80) making 11.26% of the questionnaires were not returned. This large number of the questionnaires not returned may be due to large number of population selected and the use of too many districts. With the six hundred and thirty (630) returned questionnaires making up of 88.73%, five hundred and ninety-three (593) of them making 94.12% of the total number received were validated and used for the research.

4.2 Personal Data of Consumers and Employees in the Districts Under Consideration of NEDCo

4.2.1 Consumers Respondents

In all five hundred and ninety-three (593) questionnaires were distributed sampled domestic, industrial and commercial users of electricity in Brong Ahafo Region. Out of the four hundred and sixty-three (463) consumers users were returned making 78.07% of the number.

Table 4.2: Personal data of consumers

Gender of respondents	**Frequency**	**Percentage (%)**
Female	123	26.56
Male	340	73.44
Total	**463**	**100.0**
Age of respondents		
Under 20 Years	6	1.29
21 – 25 years	48	10.36
26 – 30 years	50	10.79
31 – 35 years	110	23.75
36 – 40 years	102	22.03
41 years and above	147	31.74
Total	**463**	**100.00**
Marital status		
Married	340	73.43
Single	105	22.67
Divorce	8	1.72
Widows	10	2.75
Total	**463**	**100**
Highest education of respondents		
BASIC	40	8.63
Secondary/Technical/Commercial	236	50.97
Tertiary	87	18.79
Others	100	21.59
Total	**463**	**100**
Profession of respondents		
Teachers	120	25.91
Soldiers/Mods	40	8.63
Polices	38	8.20
Traders	159	34.34
Farmers	96	20.73
Others	10	2.73
Total	**463**	**100**
Status in the house		
Landlords	106	22.89
Tenants	346	74.73
Caretakers	11	3.7
Total	**463**	**100**
Place of residence		
Barracks	29	6.26
Government Bungalows	36	7.77
Private Residence	50	10.79
Public Residence	348	75.16
Total	**463**	**100**

Source: ***Field Survey, 2018***

Results in table 4.2 shows that out of the 463 consumers respondents who constituted the sample size, 123 (26.56%) of them were female and 340 males (73.44%) of the total sample size.

Regarding the ages of respondents, 6 (1.29%) of them are under 20years, 48 (10.36%) were between ages 21 and 25, 50 (10.79%) fell between ages 26 and 30, 110 (23.75%) were between the ages 31 and 35, 102 (22.03%) were between ages 36 and 40 and 147 (31.74%) were above 41years.

On the marital status of the consumers of electricity, out of the 463 respondents, 340 (73.43%) of the total respondents are married. Also, 105 (22.67%) of the total respondents are single, 8 (1.72%) are divorced and 10 (2.15%) are widows.

On the educational background of the respondents, 40 (8.63%) of the total respondents had Basic Education as their highest education. 236 (50.97%) said they have Secondary, Technical and Commercial as their highest education. 87 (187.9%) completed Tertiary levels and the remaining 100 (21.59%) selected others are either HND or no education.

The profession of the respondents was analyzed and the results showed that one 120 (25.91%) out of the total respondents of the commercial, industrial and domestic users of the electricity were teachers. It came out that 40 (8.63%) and 38 (8.20%) were Soldiers/MOD and Police respectively. Traders being the bulk number of the respondents represented 159 (34.34%). Farmers and others were 96 (20.73%) and 10 (2.15%) respectively.

The status of the respondents in the house was asked and the results showed that 346 (74.73%) of the respondents were tenants. Also, 106 (22.89%) and 11 (2.37%) were landlords and caretakers respectively.

The places of residence of the respondents were enquired and it came out that 29 (6.26%) were living in Military, Police and Prison Officers Barracks. Furthermore, 16 (7.77%) were residing in the Government Bungalows. Also, 50 (10.79%) said they were in their own private residences. The remaining 348 (75.16%) respondents lived in public residences.

From table 4.2, the study shows that an average majority (73.44%) of the respondents are females and are marriage people. They are always at home using the energy both off-peak and on-peak section which incur high consumption that leads to deploying the services of unscrupulous workers of NEDCo to adjust the meter for low records or consumption and that cause distribution loss in the system. The results in collaboration with the findings of Hodgkins & Tyler (2014), which states that electricity transmission and distribution at peak time"s lead to a greater loss of power and over time contribute disproportionately to the variable component of energy losses.

The study further reviews that an average majority of 74.75% of respondents are tenant and are in public houses they are all connected to a single meter which leads to power theft. Hence losses can also occur in the system as a result of on-selling where multiple customers are connected to a single meter. Again the study show that irrespective of the education background of the consumers they have less knowledge about their consumption and its effects so they do not know the current rating of their appliances hence they buy high rating appliance and used them frequently. Electrical gadgets such as, water heater, rice cooker, kettle, air condition and secondhand electrical gadgets which leads to losses in the system by mean of deploying the services of unscrupulous workers of NEDCo to adjust their meter for low records of consumption and also consumers in Barracks and Government Bungalows constitute an average of 14.03% are not paying for their consumption and for that matter they use high rating gadgets both off-peak and on-peak section which inject losses in the system.

The results are in collaboration with the findings of Hodgkins & Tyler (2014), divided into five classes. Thus physical losses in transportation and distribution of electricity, hidden non-technical losses (e.g. in-house consumption) theft, Non-metered public lighting and others e.g. Non-payment of bills.

4.2.2 Employees Responses

In all, 150 questionnaires were distributed to sampled workers of electricity in Brong-Ahafo Region of NEDCo. Out of the 150 questionnaires administered, 141 (94%) were returned and 130 (86.66%) of the number were validated and used for the analysis. These workers are made up of Engineers, Technicians, Foremen and Artisans and those in the managerial positions.

Table 4.3: Personal Data of Employees

Gender of respondents	Frequency	Percentage (%)
Female	10	7.69
Male	120	92.31
Total	**130**	**100.0**
Age of respondents		
Under 20 years	6	1.29
21 – 25 years	15	11.53
26 – 30 years	20	15.38
31 – 35 years	40	30.76
36 – 40 years	35	26.92
41 years and above	20	51.38
Total	**130**	**100.00**
Marital status		
Married	78	60
Single	50	53.84
Divorce	2	1.53
Widows	-	-
Total	**130**	**100**
Highest education of respondents		
Secondary/Technical/Commercial	70	53.84
Tertiary	45	34.61
Others	15	11.53
Total	**130**	**100**
Profession of respondents		
Engineers	16	12.30
Technicians	24	18.46
Foremen and Artisans	68	52.30
Managerial positions	4	3.07
Others	18	13.84
Total	**130**	**100**

Source: Field Survey, 2018

The gender of the respondents revealed that only ten (10) making 7.69% of the total one hundred and fifteen (130) questionnaires returned and validated are female while the rest being one hundred and ten (120) making 92.31% are male.

The respondents of the workers of Brong-Ahafo Region of NEDCo shows that fifteen (15) of the making 11.53% are below 25years, twenty (20) making 15.38% are between the ages 26 and 30 years. Forty (40) of the respondents making 30.76% are between the ages 31 and 35 years while thirty-five (35) of them making 26.92% are between the ages of 36 and 40, twenty (20) of the NEDCo workers sampled making 15.38% are above 41 years.

The marital status of the respondents shows that seventy-eight (78) of them making 60.0% are married, fifty (50) of them making 38.46% are single and two (2) of them making 1.53% are divorced.

The highest education of the technical staff of the respondents revealed that forty-five (45) of the respondents making 34.61% are tertiary, seventy (70) of them making 53.84% are Secondary/Technical/Commercial leavers and the rest of the fifteen (15) being (11) making 28.7% are other qualifications.

The professional/occupation was sought and it came to light that sixteen (16) making 12.30% of the workers" respondents are engineers of the various districts in the Brong Ahafo region twenty-four (24) of the respondents making 18.46% are Technicians, sixty-eight (68) making 52.3% are Artisans and foremen, four (4) of them making 3.07 are managers The rest of the fifteen (15) of the respondents making 11.53% are other workers in the company.

Table 4.3.1: Acquisition of meter

Question	Yes	No	Total
1. Do you have meter in your house?	442 (95.46%)	21 (4.5)	463 (100.0)
2. Do you have any knowledge of wattage(s) of your electrical gadgets?	15 (3.23)	451 (96.77)	463 (100.0)
3. Do you use air-condition(s) in your house?	15 (3.23)	451 (96.77)	463 (100.0)
4. Do your bill payment matches with your consumption?	150 (32.39)	313 (67.60)	463 (100.0)
5. Do your think people use electricity without paying?	150 (32.39)	313 (67.60)	463 (100.0)

Source: Field Survey, 2018

Respondents were asked to state whether they have meters in their houses. 442 (95.46%) of them answered in affirmative while the remaining 21 (4.5%) said they do not have meter. The results indicate that some customers are charged on fixed rate charge which lead to power losses because they do not pay for energy consumed accordingly. This result is in collaboration with the findings Pankaj, (2014), which stated that, losses on the other hand, occur as a result of theft, metering inaccuracies and unmetered energy. Losses, by contrast, relate mainly to power theft in one form or another. Theft of power is energy delivered to customers that is not measured by the energy meter for the customer.

Also, the respondents were asked to state whether they have any knowledge of wattage(s) of their electrical gadgets and whether they use air-condition(s) in your house. The results revealed that 451 (96.77%) respondents do not know or have any idea while the remaining 15 (3.23%) said yes. On the question of whether the bill matches with their income and do they think people use electricity without paying bills, 315 (67.60%) said no while 150 (32.39%) answered in affirmative.

The results in Table 4.31 with reference to item 5 indicate that 32.39% of the respondents have ideas of some customers who do not pay for the energy used with the fact that some are not receiving bills, meters are not reading and others are unwilling to pay for their bills but yet used the energy so it causes high tariff for those who pay for their consumption at the expense of those who do not pay for consumption.

As indicated the results of the study, the study findings collaborates with the findings of Pankaj (2014), which states that, losses occur as a result of theft, metering inaccuracies and unmetered energy. Losses, by contrast, relate mainly to power theft in one form or another. This is an indication that since customers have no in-depth knowledge of wattages of gadgets their using in the various residences, there is power theft leading to distribution losses.

4.3 Management of NEDCo Views on Causes of Distribution Losses in Electric Power System

According to Mr. Alex Boamah, the Brong-Ahafo Regional Engineer, system loss is made up of Technical and Commercial or Non-Technical losses. He said that, Technical losses results from inefficiencies in the distribution networks during the distribution process and Commercial or Non-Technical losses results from illegal connections, inefficiencies in metering, meter reading, accounting, invoicing and collection of electricity bills consumed by consumers.

He moved on further to say that Commercial losses represent unbilled electricity consumed by consumers.

He gave four causes of commercial losses namely; Consumption losses, invoicing errors, Collection losses and External forces.

He said that the first three causes are internal and the external losses may result from; Legal suit, Political environment, Purchasing power, Social obligations etc.

On the part of Mr. Abdulai Kurah the Brong-Ahafo Regional Director of NEDCo, the consumption losses represent actual electricity consumed but nut recorded in NEDCo‟s billing system. They are caused by the following factors: Illegal connections, Faulty meters, Faulty connections, Meter tempering, Delays is meter installation, Underestimation, Unadapt metering equipment‟s, Customers not taking into account on the billing register and Meter reading errors at the various reading and data-entry levels.

He further defined invoicing losses/errors as due to lapses in NEDCo billing system represented as unbilled energy arising from incorrect billing.

He gave the causes as; Insufficient/ erroneous contractual information, Improper updating of customer database, Unknown consumers of electricity, Lack of follow-up actions on customers benefiting from special tariffs such as customers without meters and on flat billing rates, Lack of follow-up actions on reporting detailing billing problems, and Lack of follow-up actions on collected invoices or adjustments.

He further elaborated that collection loses are loses that results from problems with payments emanating from non-payments or delay in payments of billing issued. He mentioned some of the causes earlier stated by the Sunyani Engineer to be; Poor management of unpaid bills, Bills not distributed, Misappropriation of loss payments, Customer difficulties with payment of bills and Non-flexible collection procedures.

On the question of technical losses and its causes, the Regional Director of Brong Ahafo region Ing. Jones Ofori Addo said, Technical losses results from inefficiencies in the distribution networks during the distribution process and it is caused by the following; Overloaded primary transformers, Undersized conductors, Long Low voltage networks, Unbalanced loads on distribution transformers, Lack of OHL connectors for service connections, Lack of routine inspections on OHL and substations, Lack of proper monitoring on distribution transformers and Unsealed meters etc.

He continued to say that apart from the technical and non-technical losses, there is operational wastes which are caused by; Frequent network outages, Poor implementation of optimum network designs, Low revenue collection, Staff overtime, Staff attitude to work, Insufficient use of logistics and Inadequate staff supervision.

According to Mr. Stephen Ayittey, the acting Brong-Ahafo regional Engineer of NEDCo, technical losses which increase slightly with time but more stable than non-technical losses can be measured with meters at vantage points of the bus bars to get differences of drops of each point. The same watt the technical losses can be calculated if the various parameters are known. The levels of technical losses vary from one utility company to another and from one location to another depending on the type and sizes of cable used, the type and sizes of transformers used, how old the equipment are, the distance the power travel to the end users.

Below are the formulae that can be used to calculate the losses from one point of the bus bar to another.

$R = \frac{\rho l}{A}$ And $P = I^2R$.. (7) Where

R represents the resistance of the cable,

P represents the resistivity of the cable

I represents the length of the cable

A represents the cross-sectional area of the cable

P represents the power dissipation

I represent the current through the cable.

"According to the Acting Regional Engineer, the Bulk power purchased from VRA always experience a shortfall at the NEDCo end because of technical losses through the lines and transformers in between VRA and NEDCo".

"According to Mr. Stephen Ballali, the Manager in charge of information systems, the technical losses can be measured but NEDCo does not have the means to do that now.

NEDCo does calculate and estimate it and also conform to the World Bank global standard of Technical losses of 6% - 10%".

The variation of the Technical losses is due to obsolete equipment if all other standards are maintained and adhere to. Table 4.4 below shoes the system losses, Technical losses (Estimated to 10%) and the Non-technical losses.

Table 4.4: Quantity of Technical and Non-Technical losses

Month	System Losses (%)	Technical Losses (%) Estimated	Non-Technical Losses
Jan	14.6	10	4.6
Feb	27.6	10	17.6
Mar	35.7	10	25.7
Apr	30.9	10	20.9
May	17.2	10	7.2
Jun	42.9	10	32.9
Jul	30.8	10	20.8
Aug	30.4	10	20.4
Sept	26.4	10	16.4
Oct	29.2	10	19.2
Nov	29.5	10	19.5
Dec	28.2	10	18.2
AVER	28.62	10	18.62

Source: Field Survey, 2018

The results of the study indicated that there were 28.62% representing system losses, 10% also representing technical losses, and 18.62% representing non-technical losses in the system. This result is in collaboration with the findings of Hodgkins & Tyler, (2014), which states that, for the sake of comparability, power losses are divided into the following five classes. Thus, physical losses in transportation and distribution of electricity, "hidden" nontechnical losses (e.g. in-house consumption), thefts, and non-metered public lighting. Also, the results of the study confirm that, losses are inherent to the distribution of electricity and cannot be eliminated (Fourier & Calmeter, 2014).

"According to acting regional engineer, the type of material for cable is a distributary factor of the technical loss in the system". Copper has a lower resistivity than aluminum and as resistivity is proportional to resistance which is intern proportional to power dissipation. (Equation 6), copper will give lower losses than aluminum when both have the same thickness. The problem NEDCo was facing some time ago before thy change to the use of aluminum is the stealing of copper by thieves. Table 4.5 shows Brong Ahafo global purchase and sales of power and the losses as given by Mr. Stephen Ballali, the manager in charge of management information system in Brong Ahafo region of NEDCo. Mr. Ballali, attributed the high system loss to the following factors which they are putting measures in place to reduce them.

Government influence: - The government under the SHEP program towards contract for the expansion of electrification to rural areas for the ministry of energy to contractors without the knowledge of the region at which they are coming to work.

Table 4.5: Brong Ahafo Global Purchase and Sales Trend 2016 in GWh

Month	Purchase (GWh)	Sales (GWh)	Loss (GWh)	% loss
January	96.4301	81.8426	14.5875	14.6
February	87.2472	63.1072	24.14	27.6
March	97.6875	62.625	35.0625	35.7
April	96.887	66.8992	29.9878	30.9
May	98.8743	81.8794	16.9949	17.2
June	91.154	51.8386	39.3154	42.9
July	91.1045	63.396	27.7085	30.8
August	92.0426	64.238	27.8046	30.4
September	90.8027	67.2261	23.5766	26.4
October	95. 6423	68.4519	27.1904	29.2
November	95.0153	66.6559	28.3594	29.5
December	98.0871	70.4265	27.6606	28.2
Total	**1130.9746**	**808.5864**	**322.3882**	**28.62**

Source: Field Survey, 2018

4.3.1 Percentage system loss formulae

$$\% \text{ system loss} = \frac{\left\{\text{Energy}.\frac{\text{Purchased}}{\text{generated}}(\text{KWh})\right\} - \{\text{Energy sold (KWh)} - \text{companyused (KWh)}\}}{\{\text{Energy}.\frac{\text{Purchased}}{\text{generated}}(\text{KWh})\}} \ldots\ldots (8)$$

4.3.2 Causes of Distribution Losses in Power System – Customers View

On the question of whether high electricity tariff encourages electricity theft, 463 respondents were interviewed. Out of the 463 respondents, 185 commercial consumers were interviewed. Among the 185 interviewed respondents, 150 (32.5%) agreed in affirmative while 30 (6.5%) disagreed and the remaining 5 (1%) said they are not sure. Also, 265 domestic consumers were interviewed. Out the interviewed respondents, 205 (44.4%) agreed in affirmative and 50 (10.8%) disagreed while the remaining 10 (2.2%) respondents interviewed were not sure. Furthermore, 12 industrial consumers were interviewed. Out of the 12 industrial consumers interviewed, 8 (1.7%) agreed in affirmative and 2 (0.43%) disagreed while the remaining 3 (0.64%) were not sure. Table 4.6 depicts the data gathered from the field of study.

Table 4.6: Data of customers responds

Customers	Agreed	Disagreed	Not sure	Total
Commercial	150	30	5	185
Domestic	205	50	10	265
Industrial	8	2	3	13
Total	**363**	**82**	**18**	**463**

Source: Field Survey, 2018

Types of Meter

Concerning the type of meters 315 (68.03%) was using post-paid meters while the rest 148 (31.97%) said they used pre-paid meters. The results indicate that majority of the consumers are using post-paid meters which make it easier for consumers to connive with some workers to bypass or tamper with meters to ensure the meter recorded a lower consumption reading which may increase tariff as a results of increasing distribution losses in the system. This result is in collaboration with the findings of Pankaj, (2014), which states that, losses on the other hand, occur as a result of theft, metering inaccuracies and unmetered energy. Losses, by contrast, relate mainly to power theft in one form or another. Theft of power is energy delivered to customers that is not measured by the energy meter for the customer. The figure 1 shows the data of responses.

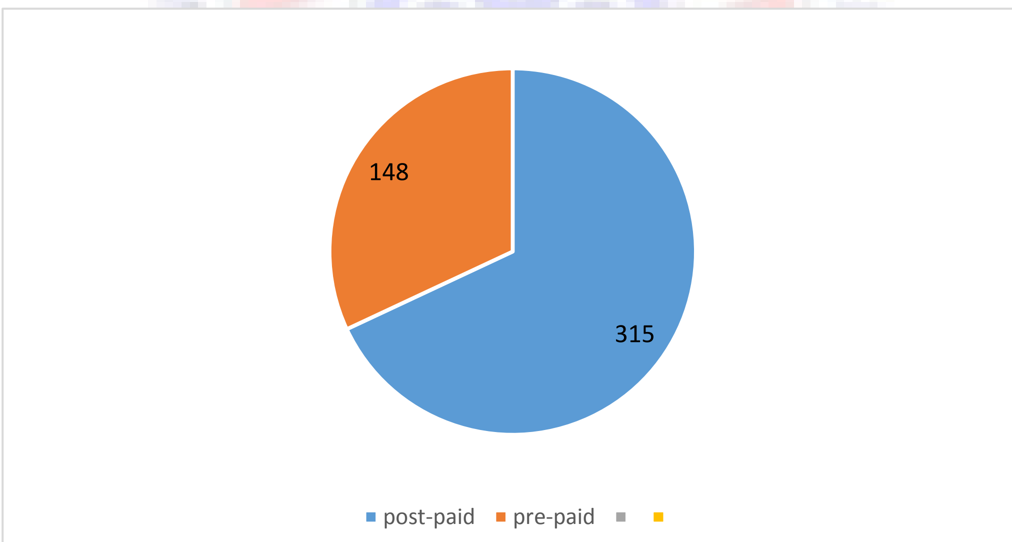

Figure 4.1: Types of Meter

Source: Field Survey, 2018

4.4 Acquisition of Meter

On the whether the meters were acquired through a mediator or self, 105 (22.68%) respondents passed through the formalities themselves while the rest being the majority 358 (77.32%) processed the meter acquisition through a mediator. The study shows that, majority of the consumers acquired their meter through a mediator which as a results of that some customers are unable to capture on the utility data base and some are also have advantage to connive with some workers to bypass or tamper with meters to ensure the meter recorded a lower consumption reading before they captured on the database which make it difficult to trace them This result is in collaboration with the findings of Pankaj, (2014), which states that, it is important to ensure that network operators face adequate incentives so that they make an appropriate effort on evaluating the costs and benefits of reducing losses and hence, optimize the level of losses in most efficient way. By contrast, there are a number of external factors with significant influence on the level of losses. In particular, the geographical size of the market as well as the number and degree of dispersion of customers connected to distribution networks are important driving factors which cannot be modified. Figure 4.2 represent the data of the responses on the pi-chart.

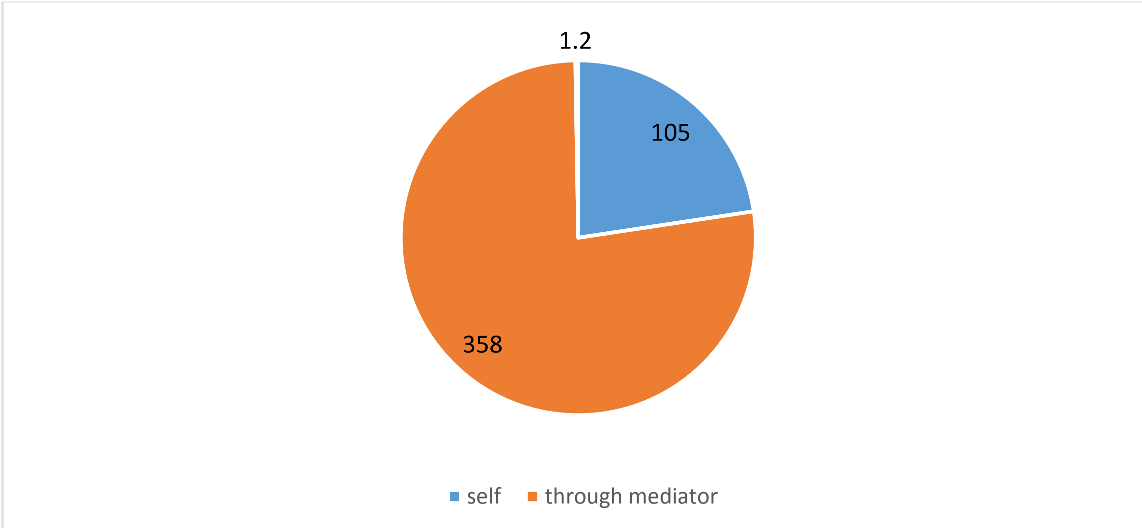

Figure 4.2: Acquisition of Meter

Source: Field Survey, 2018

4.5 Meter Acquisition Time

It took 30 (6.47%) of the respondents less than one week to acquire their meter. It took 31 (6.66%) of the respondents between one to two weeks period to acquire their meter, and it took 52 (11.23%) respondents between three weeks and one month duration to acquire the meter from NEDCo in Brong Ahafo region. Also, 80 (6.6%) respondents said they acquired their meters between two to three weeks, between one month to two months 250 (53.99 %) respondents said they acquired their meters and 20 (4.31%) respondents said they cannot remember the duration. Figure 4.3 gives the data distribution. The study revealed that customers who acquired their meter less than a period of one month passed through mediator commonly called “connection man” and for that matter, they acquired their meter undue process in view of that the network operators are unable to capture them in their database and also it takes some of the customers longer period to receive their bills.

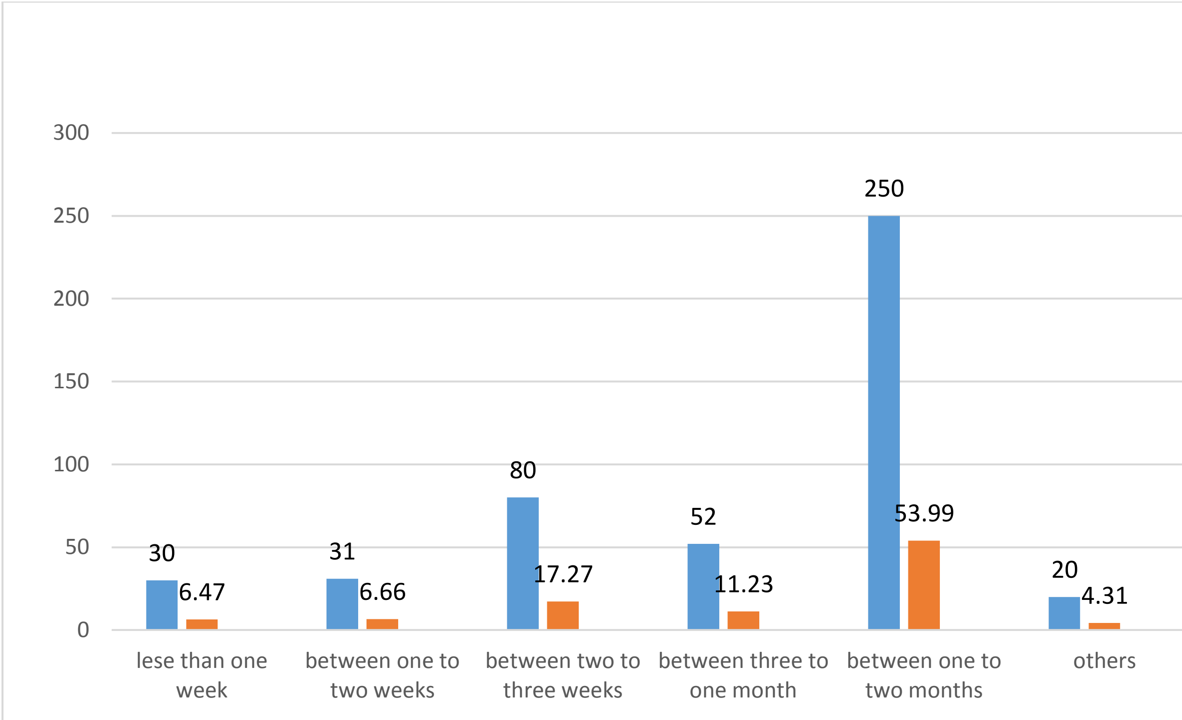

Figure 4.3: Meter Acquisition Time

Source: Field Survey, 2018

4.6 Monthly Income of Customers

Respondents were asked about their monthly electricity bills. From the respondents selected for the study, 11 (2.37%) said they pay less than 10.00 GH cedi‟s while 115 (24.83%) said they pay 11 to 20 GH cedi‟s. Also, 198 (42.76%) respondents said they pay between 21.00 to 30.00 GH cedi‟s a month, 95 (20.51%) of the respondents pay a bill of between 31.00 to 40.00 while 32 (6.91%) respondents pay between 41.00 cedi‟s a month. Finally, 12 (2.59%) paid more than 50.00 GH cedi‟s a month. Figure 5 shows the outcome of the respondents.

On the issue of the monthly income of the respondents, 54 (10.5%) said their monthly income is below 200.00 GH cedi‵‵s, while 106 respondents said their income was between 201.00 and 400.00 GH cedi‵‵s. Also, 144 (28%) respondents received between 401.00 to 600.00 GH cedi‵‵s a month while 70 (13.6%) respondents said their monthly salary received is 601.0 to 800.0 GH cedi‵‵s a month. Furthermore, 59 (11.5%) respondents said their monthly income was above 801.00 GH cedis, and 62 (12%) respondents did not provide their monthly income.

Figure 4 shows the outcome of the responses. Determining the income levels of consumers helped in identify the rate at which customers are able to service their bills and also acquire meters in order to reduce distribution losses in the system.

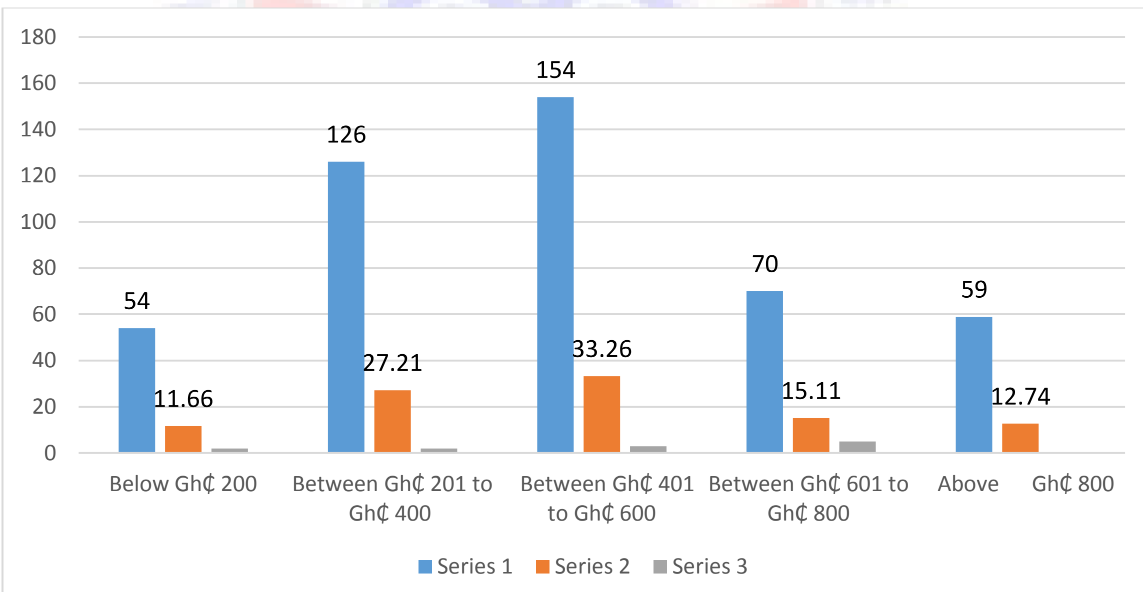

Figure 4.4: Monthly Income of customers

Source: Field Survey, 2018

4.7 Economic Effect of Distribution Losses on Electric Tariff

The study revealed that, losses at high level reduce revenue to extend that it affects infrastructural development. With these old and obsolete equipment cannot be replaced so it continues to increase the system losses.

Moreover system losses at high will make the managers not able to pay mare to the workers so this will make the workers connive with customers to cheat. These workers collect some money from customers and temper with meters. Workers at times collect a little money from customers who will be caught of stealing electricity. When this happen revenue will be low. Respondents were asked whether distribution losses have an effect on tariff. Both customers and workers of NEDCo were queried to share their views on it.

Table 4.7: Economic Effects of Distribution Losses in the Power System Costumers View

Statement	Strongly Agree	Agree	Strongly Disagree	Disagree	Don't know	Total
18. NEDCo offers good services	120	236	95	7	5	463
	(25.91)	(50.97)	(20.51)	(1.51)	(1.07)	(100.0)
19. NEDCo tariff is not fair	245	135	76	4	3	463
	(52.91)	(29.15)	(16.41)	(0.86)	(0.64)	(100.0)
20. NEDCo workers connive with consumers to cheat	120	236	95	7	5	463
	(25.91)	(50.97)	(20.51)	(1.51)	(1.07)	(100.0)
21. Distribution losses are passed on to consumers to pay	200	230	25	5	3	463
	(43.19)	(49.67)	(5.38)	(1.07)	(0.64)	(100.0)
22. Government should subsidized electricity for every one	195	262	2	4	-	463
	(42.11)	(56.58)	(0.43)	(0.86)	-	(100.0)
23. NEDCo putting measures to reduce distribution losses	80	100	90	150	43	463
	(17.27)	(21.59)	(19.43)	(32.39)	(9.28)	(100.0)

Source: Field Survey, 2018

On the issue of whether NEDCo offers good services to the consumers, 120 (25.91%) strongly agreed, while 236 (50.97%) agreed, 95 (20.51%), 7 (1.51%) and 5 (1.07%) respondents strongly disagreed and do not know to that assertion respectively.

On the question of whether the tariff of NEDCo is not fair, 245 (52.91%) respondents strongly agreed while 105 (29.15%) also agreed to that assertion. Also, 76 (16.41%) and 4 (0.86%) disagreed and strongly agreed respectively and 3 (0.64%) of the respondents do not know anything to that effect.

On the issue of whether NEDCo workers connive with consumers to cheat, 120 (25.91%) strongly agreed, while 236 (50.97%) respondents agreed the workers connived with consumers and 95 (20.51%), 7 (1.51%) and 5 (1.07%) of the respondents strongly disagreed and do not know to that assertion respectively.

Also, the respondents were asked whether distribution losses are passed on to consumers to pay. Responses gathered indicated that 200 (43.19%) respondents strongly agreed while 230 agreed, 25 (5.38%) strongly disagreed, 5 (1.07%) disagreed and 4 (0.36%) said they do not know.

Furthermore, on the question of whether Government should subsidized electricity for everyone, 195 (42.11%) respondents strongly agreed while 265 (56.58%) also agreed to that assertion. Also, 2 (16.41%), 4 (0.43%) respondents disagreed and strongly agreed respectively and 4 (0.86%) of the respondents do not know.

On the question of whether NEDCo is putting measures in place to reduce distribution losses, 80 (17.27%) respondents strongly agreed while 100 (21.59%) respondents agreed to that assertion. Also, 90 (19.43%) strongly agreed and 150 (32.39%) disagreed and 43 (9.28%) said they do not have idea of that assertion.

The results of the study above is in collaboration with the findings of Emad, M (2010), which gives the economic and financial gains which can be classified into two kinds, thus,

1. With constant consumption, the reduction of technical losses make it possible to cut down generation and therefore save on investment and fuel (with constant generation)
2. With constant generation and consumption. The reduction of nontechnical losses helps increase the sales revenue. Thus, the reduction of technical losses leads to a real gain in energy and reduced capital intensive investment. It therefore benefits the country economy. The reduction of nontechnical losses not only improves the financial balance of the company concerned, but also the load curve by subjecting consumption to the tariff regulation.

4.8 How to Minimize Distribution Losses

The research has shown that there is a unit in Brong Ahafo Region which mandate is to do monitoring of physical facilities and inconsistency of input of data in the database to sense fraudulent activity of customers. The uses of informants are also helping NEDCo decrease losses. Informant of theft cases are giving 10% of the total money accrued from the defaulter. This is not so effective because of the technicalities involved to identify these culprits.

NEDCo in Brong Ahafo dealing with non-technical losses is not as easy as solving for the technical ones as analyzed in the research findings. Legal and judiciary sectors are always involved in setting pilferage and other matters relating to it. Nevertheless, they too are a factor that raises the level of system‟s loss in every utility by setting an accused free and even they also owe.

Loss reduction does not only mean putting up necessary equipment or upgrading existing configurations in order to achieve such goal. Careful planning and strategic actions must be taken into consideration in order to be more effective in doing the job. We all know the means money savings but it also goes in hand that reducing losses will also mean spending money for capital cost in installing necessary actions as shown in Appendix D and E by the Brong Ahafo Region NEDCo to reduce loses to the target 24%. Determine the extended of losses should be first be achieved before going to the next step in loss reduction.

Different questionnaires were used to consumers, workers and employees to come out with the various ways losses can be minimized. The next sections give respondents views on how to minimize losses.

Table 4.8: How to minimize losses of Distribution system customers view

	Statement	Strongly Agree	Agree	Strongly Disagree	Disagree	Don't know	Total
24	Rewards of informant of electricity theft can help reduce loss	236 (50.97)	120 (25.91)	95 (20.51)	5 (1.07)	7 (1.51)	463 (100.0)
25	Losses control unit (LCU) is helping to reduce losses	120 (25.91)	95 (20.51)	236 (50.97)	7 (1.51)	5 (1.07)	463 (100.0)
26	High system loss is as a result of inadequate investment and preventive maintenance	252 (54.42)	195 (42.11)	7 (1.51)	5 (1.07)	4 (0.86)	463 (100.0)
27	Metering of all customers and installation of pre – paid meters will help to reduce losses	252 (54.42)	195 (42.11)	7 (1.51)	5 (1.07)	4 (0.86)	463 (100.0)

Source: ***Field Survey, 2018***

On the question of whether the use of informants by NEDCo is helping to reduce losses of electricity, 236 (50.97%) strongly agreed that if informants who lives with customers reports of stealing and they are paid, the public will be afraid of doing that.

Also, 120 (25.91%) agreed, 95 (20.51%) respondents strongly disagreed, 5 (1.07%) respondents disagreed, and 7 (1.51%) said they do not know.

On the question of whether losses control unit (LCU) is helping to reduce distribution losses, 120 (25.91%) respondents strongly agreed that if informants who lives with customers reports of stealing and they are paid, the public will be afraid of doing that., 95 (20.51%) agreed, 236 (50.97%) strongly agreed, 7 (1.51%) disagreed and 5 (1.07%) said they do not know.

The respondents were asked whether high system loss is as a result of inadequate investment and preventive maintenance of machines and equipment of NEDCo and metering of all houses and the use of prepaid meters by commercial and domestic consumers help to reduce system losses. Of all the 463 respondents, 252 (54.42%) strongly agreed that they are helping to reduce losses, 195 (42.11%) agreed to the assertion, 7 (1.57%) strongly disagreed, 5 (1.07%) disagreed and 4 (0.86%) respondents said they do not know.

The study results confirm the findings of Melovic et al., (2013) that, there are several potential ways for network operators to reduce losses. These include changes to the network design, such as specifying larger assets to reduce resistance and low-loss transformers. Also, utility companies can also reduce non-technical losses by investing in detecting theft and improving data accuracy. These latter measures do not change the level of technical losses, but they do promote economic efficiency (Celli et al., 2015).

Table 4.9: Causes of Distribution Losses in Power System, Workers of NEDCo and Consumers View

Statement	Strongly Agree	Agree	Strongly Disagree	Disagree	Don't know	Total
6. NEDCo putting measures to reduce distribution losses	70 (53.84)	40 (30.76)	5 (3.84)	15 (11.53)	- -	130 (100.0)
7. Non-technical losses result illegal connections, inefficiencies in metering etc.	80 (61.53)	50 (38.46)	- -	- -	- -	130 (100.0)
8. Technical losses result from inefficiencies in the distribution networks during distribution process	65 (50.0)	30 (23.07)	20 (15.38)	5 (3.84)	10 (7.69)	130 (100.0)
9. Faulty meter can cause losses in NEDCo	70 (53.84)	40 (30.76)	5 (3.84)	10 (7.69)	5 (3.84)	130 (100.0)
10. Losses can be causes by underestimation of consumption	70 (53.84)	40 (30.76)	5 (3.84)	10 (7.69)	5 (3.84)	130 (100.0)
28. Reducing losses of electricity can bring massive infrastructure development to the country	236 (50.97)	120 (25.91)	95 (20.51)	7 (1.51)	5 (1.07)	463 (100.0)
29. High tariff can cause theft of electricity	252 (54.42)	195 (42.11)	7 (1.51)	5 (1.07)	4 (0.86)	463 (100.0)
30. Faulty wiring of houses can cause system losses	236 (50.97)	120 (25.91)	95 (20.51)	7 (1.51)	5 (1.07)	463 (100.0)
31. The position of the meter can contributes to system losses	120 (25.91)	236 (50.97)	95 (20.51)	7 (1.51)	5 (1.07)	463 (100.0)

Source: ***Field Survey, 2018***

Respondents were queried on whether NEDCo is putting measures to reduce distribution losses, 70 (53.84%) strongly agreed, 40 (36.76%) agreed, 5 (3.84%) strongly disagreed and 15 disagreed to that assertion.

On the issue of whether Non-technical losses result from illegal connections, inefficiencies in metering etc., 80 (61.53%) strongly agreed while 50 (38.46%) agreed.

Respondents were asked whether Technical losses result from inefficiencies in the distribution networks during distribution process, 65 (50.0%) strongly agreed, 30 (23.07%) agreed, 20 (15.38%) strongly disagreed and 5 (3.84%) disagreed and 10 (7.69%) respondents said they do not know to that assertion.

The workers were further queried of whether faulty meter san cause losses of electricity to NEDCo and system losses can be caused by under estimation of consumption of users who are yet to be supplied with meter. The study revealed that 70 (61.53%) respondent strongly agreed, 40 (30.76%) agreed, 5 (3.84%) strongly disagreed, 10 (7.69%) disagreed and 5 (3.84%) respondents said they do not know to that assertion.

The results of the study collaborate with the findings of Emad, M. (2010), which states that, non-technical losses are not inevitable. They must be identified and fought with eradication objective by all electricity distribution companies concerned about sound management.

On the issue of whether reducing losses of electricity can bring massive infrastructural development to the country, 236 (50.97%) strongly agreed to that assertion, 120 (25.91%) agreed, 95 (20.51%) strongly disagreed, 7 (1.51%) disagreed, and 5 (1.07%) said they do not know.

On the question of whether high electricity tariff encourages electricity theft, 252 (54.42%) strongly agreed that they are helping to reduce losses, 195 (42.11%) agreed to the assertion, 7 (1.57%) strongly disagreed, 5 (1.07%) disagreed and 4 (0.86%) said they do not know.

On the question of whether faulty wiring of the house can cause system losses, 236 (50.97%) strongly agreed to that assertion, 120 (25.91%) agreed, 95 (20.51%) strongly disagreed, 7 (1.51%) disagreed, and 5 (1.07%) respondents said they do not know.

On the question of whether the position of meter in the house of consumer can contribute to system, 120 (25.91%) strongly agreed to that assertion, 236 (50.97%)

agreed, 95 (20.51%) strongly disagreed, 7 (1.51%) disagreed, and 5 (1.07%) respondents said they do not know.

The result of the study is in tune with the study findings of Hodgkins & Tyler, (2014), which states that, for the sake of comparability, power losses are divided into the following five classes. Thus;

1. Physical losses in transportation and distribution of electricity.
2. "Hidden" nontechnical losses (e.g. in-house consumption).
3. Thefts
4. Non-metered public lighting
5. Others (e.g. metering errors).

Table 4.10: Causes of Distribution Losses in Power System, Employers View

Statement	Strongly Agree	Agree	Strongly Disagree	Disagree	Don't know	Total
11. Faulty transformer can cause Losses	65 (50.0)	30 (23.07)	5 (3.84)	10 (7.69)	20 (15.38)	130 (100.0)
12. System losses causes frequent network outages	70 (53.84)	40 (30.76)	5 (3.84)	10 (7.69)	5 (3.84)	130 (100.0)
13. Bills to Factories are too huge so they connive to cheat	40 (30.76)	65 (50.0)	5 (3.84)	15 11.53)	5 (3.84)	130 (100.0)
14. Increase in losses calls for tariff increase	70 (53.84)	40 (30.76)	5 (3.84)	10 (7.69)	5 (3.84)	130 (100.0)
15. System losses causes low revenue collection	70 (53.84)	40 (30.76)	5 (3.84)	10 (7.69)	5 (3.84)	130 (100.0)

Source: *Field Survey, 2018*

Respondents were asked whether faulty transformers can cause system losses, 65 (50.0%) respondents strongly agreed, 30 (23.07%) agreed, 5 (3.84%) strongly disagreed, 10 (7.69%) disagreed and 20 (15.38%) respondents said they do not know to that assertion.

On the question of whether distribution losses causes frequent network outages and huge bill of the factories is the cause of them conniving with the customers to steal power from NEDCo, 70 (61.53%) strongly agreed, 40 (30.76%) agreed, 5 (3.84%) strongly disagreed, 10 (7.69%) disagreed and 5 (3.84%) respondents said they do not know to that assertion.

On the question of whether increase in losses causes increase in tariff, 80 (61.53%) strongly agreed while 50 (38.46%) agreed to that assertion. The sampled workers of the NEDCo were asked if distribution losses cause low revenue to the company, 70 (61.53%) respondents strongly agreed, 40 (30.76%) agreed, 5 (3.84%) strongly disagreed, 10 (7.69%) disagreed and 5 (3.84%) respondents said they do not know to that assertion.

4.9 Causes of Distribution Losses to Sunyani of NEDCo

The outcome of the research shows that, major non-technical losses to NEDCo are through pilferage and meter reading error. The research revealed that pilferage in distribution is unaccounted (unmetered) uses of electricity is most intentionally done. This like stealing electricity from the through many different means.

Another contributor to non-technical losses to NEDCo is by meter reading errors. Defective meters are either be beneficial to the utility or to the consumers that is why if it is beneficial to the consumers will mean losses to the utility and vice versa. The research has proved that losses of power can be due to customer‟s un-willingness to pay. The un-willingness to pay for the electricity can be caused by a number of different parameters. Among the strongest argument are:

1. Low generating capacity is resulting in a lot of outage.
2. The voltage level is too low and destroying household equipment and machinery
3. Low income of the customers.
4. High tariff of consumers.
5. My neighbors are paying so why shall I pay?
6. My government is giving me work, so at least they can give me free electricity" etc.

Table 4.11: Brong Ahafo losses trend 2013 – 2017

Year	December 2013	December 2014	December 2015	December 2016	December 2017
% Losses	28.98	32.81	30.70	28.28	28.62

Source: *Field Survey, 2018*

From the trend of the system losses shown in table there is indication that the technical losses from January 2013 – December 2017 on the average is 29.88% of the total power purchased from VRA. From the table 8, the power purchased from VRA for the year of 2017 is 1130.9746GWh, this figure multiply by five roughly gives 5654.873GWh so 29.88% of this gives 1633.13GWh which is on the high side and is 149.4% of the January – December 2017 total power purchased by NEDCo from VRA.

"According to Ing. Jones Ofori-Addo the Regional director of Brong Ahafo, 1% reduction of system losses will increase revenue by 11m GH cedis. He also said that NEDCo has a target of reducing system losses to 21% every year but they are finding it difficult to get to the target due to obsolete equipment they are still using which increase technical losses, non-payment of bills and stealing of power".

With this target of 24% which the Brong Ahafo are finding it difficult to achieve will for the five years gives (29.88% - 24%) x 5 = 29.4%. if 1% loss gives an additional revenue of 11.00m GH cedis then if the NEDCo is meet the target of 24% they can get 323.40m GH cedis increase in revenue within the five years. This amount can go a long way for NEDCo to replace all obsolete equipment and to invest to reduce both technical and non with this analysis; the region is putting on measures to reduce losses as shown in Appendix D.

4.10 Effect of Distribution Losses on the Power System

The research revealed that, distribution losses at high level reduce revenue to extend that it affects infrastructural development. With these old and obsolete equipment cannot be replaced so it continues to increase the system losses.

Moreover system losses at high will make the managers not able to pay mare to the workers so this will make the workers connive with customers to cheat. These workers collect some money from customers and temper with meters. Workers at times collect a little money from customers who will be caught of stealing electricity. When this happen revenue will be low.

4.11 Tariff of Consumers

According to the information systems manager of NEDCo in Sunyani electricity tariffs are set by Public Utility and Regulatory Commission (PURC) upon consideration of a numbers of indicators. These indicators are average inflation rate, average exchange rate, and generation mix and light crude oil price. The above parameters are used in what determined automatic tariff adjustment formulae showed in appendix F of PURC. The

Manager said that losses of the company is not pass onto the consumers directly as a tariff increase but rather, the world market price of the crude oil and the cost and percentage of the parameters and the production cost.

CHAPTER FIVE

SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

This chpater presents the summary of major findings of the study. It also concludes the study and provide recommendations to help improve the status quo. Furthemore, reocmmendation for furhter study is profered.

5.1 Summary of Findings

There are two main types of distribution losses. These are technical and non-technical losses (commercial losses). Technical losses are cause by losses due to inefficiency distribution network or physical component of the system while non-technical losses are due to activities of human that can be control such stealing, inefficiencies of metering, illegal connection, faulty meters, meter tampering, meter reading error, under invoicing, under estimation of consumption etc.

Technical losses can be easily be calculated, measured or estimated and can be controlled easily. Non-technical losses are difficult to measure, calculated or estimated and it difficult to controlled. The study results collaborates with the findings of (Fourie & Calmeter, 2004) which state that losses are inherent to the distribution of electricity and cannot be eliminated.

The study revealed that there were various forms of distribution losses. From the analysis it came to light that, 1% reduction of system loss will increase revenue by GH¢11million. With this even with the Region hitting their target they will get an increase of GH¢60.96million which is enough to bring infrastructural development to the Region which will subsequently reduce system losses. In reality, if the Region hitting their target of 24% do not need Government assistance to bring infrastructural development but with prudent management decision they can change all their obsolete transformers, get capacitor bank, change all post meters to prepaid meters, give prepaid meters to all customers and finally change cables. With these measures and with prudent management measures the target can even brought down to between 15 to 20%.

Results of the study indicated that Government agencies, Barracks of military, police and prison officers do not pay for what they consume. Because they don"t pay, they don"t economize the usage of electricity. They use electricity to prepare so many things to sell.

The study findings brought to light that workers of the NEDCo are one of the contributory factors in system losses. They connive with consumers with consumption to tamper with meter or bypass the meter. They collect a percentage of the amount they have to pay and keep it for themselves.

5.2 Conclusion

The reduction of losses will demand an increase of the cost and or of investment which should be compared with the benefits derived from that reduction. It should also be noted that a reduction on non-technical losses does not lead to an energy efficiency improvement. However, it would lead to a higher degree of equity in the treatment of customers and shareholders. In fact, if nontechnical losses are passed through to customers on the corresponding tariffs, the existence of these losses will mean that some customers are paying for others. On other hand, if non-technical losses are not passed through in full to customers, the losses „RETAINED" by the distribution operator are paid by shareholders instead. Reductions of non-technical losses may be possible provided significant additional investment and cost are secured; improved and more accurate metering, data management systems supporting it and more field inspectors. It should be noticed that the potential for further reductions of nontechnical losses may limited given the levels of efficiency already attained. Technical losses are essentially associated with energy and environmental efficiency. This type of losses mainly driven by investment in network assets. Reducing these losses requires fundamental changes in the design and in.

5.3 Recommendations

A good strategy in minimizing losses is to segregate first various aspects of system losses. Segregation on the electrical contest is the process of sorting and identifying the contributions of each part of the power system to the over-all losses. Giving weight (usual in percentage) to the different areas of the system with regards to the losses it contributes is known to be more effective in trying to reduce the system‟s losses that are present. There are known system components that are identified to produce losses during operation namely; transmission lines, substation transformers, distribution/primary lines, distribution transformers, secondary lines, and voltage regulators. Losses can be best segregated using the stated different kinds of system components. The following are the various recommendations made by the researcher to help minimize distribution losses experienced;

1. True loss segregation, electric companies strategically analyzed the present situation and can help them decide which course of action to take. NEDCo must therefore strategically analyze distribution losses and take corrective measures to minimize all forms of distribution losses in the system.

2. NEDCo should contract companies with the sole aim of tracking those who steel power with the aim of bringing the total loss down. They should go into terms to purge the loss at agreeable percentage.
3. To help minimize all forms of distribution losses in the system, private entrepreneurs can be invited to invest in buying efficient pre-paid meters to replace all post-paid meters and also get enough meters to those with flat rates, buying energy efficient transformers to replace all obsolete transformers etc. Upon agreement, they may purge the system losses to an appreciable point and if they are able to reduce the losses, all these money should be given to these companies to share based on the quantum of investment (partnership/ privatization).
4. More so government influences at the energy sector should be ceased completely and the occupants at the military, police and prison services barracks should pay as any other person consuming electricity. NEDCo should invest in buying capacitors to correct power factor problems at the various substations.
5. NEDCo should get electricity theft monitoring devices which can track illegal connection. There should be a devise connected at a point far away from the consumer which can read the same unit as that of the consumer meter. Thus to compare the unit entering the consumer premises and that of the device. If the device reads more than what the meter reads, then it means that, the meter have been tempered with. There should be an improvement in reactive power compensation at distant located by providing capacitor.

6. It has been observed that transformers draw considerable current, through it disconnects from the load side. It is therefore recommended that there should be proper balance of transformer by providing high reactive power and low power factor.

5.4 Suggestion for Further Research

Use of statistical analysis methods for detecting electricity theft by analyzing utility billing information should be considered. Specific issues could include the optimal methods for analyzing the information and cost of related operations.

Per the findings of the study, cost analysis for utilities" theft detection and prevention efforts compared to the recouped revenues, as well as cost analysis for effort to measure nontechnical losses accurately needs to be examined.

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APPENDDIX A

QUESTIONNAIRES

UNIVERSITY OF EDUTION, WINNEBA- KUMASI

SCHOOLOF RESEARCH AND GRADUATE STUDIES

DEPARTMENT OF AUTO AND ELECTRICAL AND ELECTRONICS TECHNOLOGY

This questionnaire is design to elicit information on the losses of electrical power distribution in NEDCo and how the losses affect tariff on the consumers. This research work is being carried out by an M.TECH student of the above department and institution.

NEDCo in Brong Ahafo region has been selected for the study and you are kindly requested to provide responses to the questions to enable the researcher to contribute his knowledge in field of study.

Please all information‟s given will be treated with outmost confidentiality

Pease tick in the appropriate box below.

Section A. Bio – Data

3. Gender

A [ ] Female

B [ ] Male

4. Age

A [ ] Under 20 years

B [ ] 21- 25 years

C [ ] 26-30 years

D [ ] 31-35 years

E [ ] 36-40 years

F [ ] 41 years and above

5. Marital status

A [ ] Married

B [ ] Single

C [ ] Divorced

D [ ] Widow/widower

6. Highest Education

A [ ] Basic

B [ ] Secondary/Technical/Commercial

C [ ] Tertiary

D [ ] Others

Specify……………………………………………...……………………………….

7. Profession/Occupation

A [ ] Teacher

B [ ] Engineer

C [ ] Technician/Artisan/Foremen

D [ ] Soldier/MOD/Police

E [ ] Trader

F [ ] Farmer

G [ ] Others

Specify…………………………………………………………………………..

8. What is your status in the house?

A [ ] Landlord

B [ ] Care taker

C [ ] Tenant

D [ ] Others

Specify…………………………………………………………………………………

9. Place of residence?

A [ ] Barracks

B [ ] Government Bungalow

C [ ] Personal Residence

D [ ] Compound House

Section B Acquisition of meter

10. Do you have meter in your house?

A [ ] Yes

B [ ] No

If no go to section C

11. If yes, what type of meter do you have?

A [ ] Post-paid meter

B [ ] pre-paid meter

12. How did you acquire the meter?

A [ ] Self

B [ ] Through Mediator

C [ ] others, please

Specify……………………………………………………………………..

13. For how long were you able to secure the meter?

A [ ] Less Than one week

B [ ] Between one to two weeks

C [ ] Between two to three weeks

D [ ] Between three to one month

E [ ] Between one month to two month

F [ ] Others, please

Specify……………………………………………………………………………

Section C – Payment of bill

14. Do you have any knowledge of wattage(s) of your electrical gadgets?

A [ ] Yes

B [ ] No

If yes mention the wattage of any two of them.

……………………………………………………………………………………

……………………………………………………………………………………

15. How many electrical gadgets have wattages more than 100?

A [ ] Non

B [ ] One

C [ ] Two

D [ ] Three

E [ ] Four

F [ ] More than four

16. Do you use air-condition(s) in your house?

A [ ] Yes

B [ ] No

17. How much electricity bill do you pay every month?

A [ ] Less than GH¢10.0

B [ ] GH¢11.0 -GH¢20.0

C [ ] GH¢21.0- GH¢30.0

D [ ] GH¢31.0 GH¢40.0

E [ ] GH¢41.0 GH¢50.0

F [ ] More than GH¢50.0

18. Do your bill payment matches with your consumption?

A [ ] Yes

B [ ] No

If no Why?..

……………………………………………………………………………………

19. Do your think people use electricity without paying?

A [ ] Yes

B [ ] No

Please indicate your level of agreement or disagreement to the following statements.

S/N	Statement	Strongly agree	Agree	Strongly disagree	Disagree	Don"t know
18	NEDCo offers good services					
19	NEDCo tariff is not fair					
20	NEDCo workers connive with consumers to cheat					
21	Distribution losses are passed on to consumers to pay					
22	Government should subsidized electricity for every one					
23	NEDCo putting measures to reduce distribution losses					
24	Rewards of informant of electricity theft can help reduce loss					
25	Losses control unit (LCU) is helping to reduce losses					
26	High system loss is as a result of inadequate investment and preventive maintenance					
27	Metering of all customers and installation of pre – paid meters will help to reduce losses					
28	Reducing losses of electricity can bring massive infrastructure development to the country					
29	High tariff can cause theft of electricity					
30	Faulty wiring of houses can cause system losses					
31	The position of the meter can contributes to system losses					

APPENDIX B

QUESTIONNAIRE

UNIVERSITY OF EDUTION, WINNEBA- KUMASI

SCHOOLOF RESEARCH AND GRADUATE STUDIES

DEPARTMENT OF AUTO AND ELECTRICAL AND ELECTRONICS TECHNOLOGY

This questionnaire is design to elicit information on the losses of electrical power distribution in NEDCo and how the losses affect tariff on the consumers. This research work is being carried out by an M.TECH student of the above department and institution.

NEDCo in Brong Ahafo region has been selected for the study and you are kindly requested to provide responses to the questions to enable the researcher to contribute his knowledge in field of study.

Please all information given will be treated with outmost confidentiality.

Please tick in the appropriate box below.

Section A: Bio – Data

1. Gender

   A [ ] Female

   B [ ] Male

2. Age

   A [ ] Below 25 years

   B [ ] 26- 30 years

   C [ ] 30-35 years

   D [ ] 36-40 years

   E [ ] 41 years and above

3. Marital status

A [ ] Married

B [ ] Single

C [ ] Divorced

D [ ] Widow/widower

4. Highest Education

A [ ] Secondary/Technical/Commercial

B [ ] Tertiary

C [ ] Others

Specify……………………………………..……………………………

5. Profession/Occupation

A [ ] Engineer

B [ ] Technician

C [ ] Artisan

D [ ] Foremen

E [ ] Others

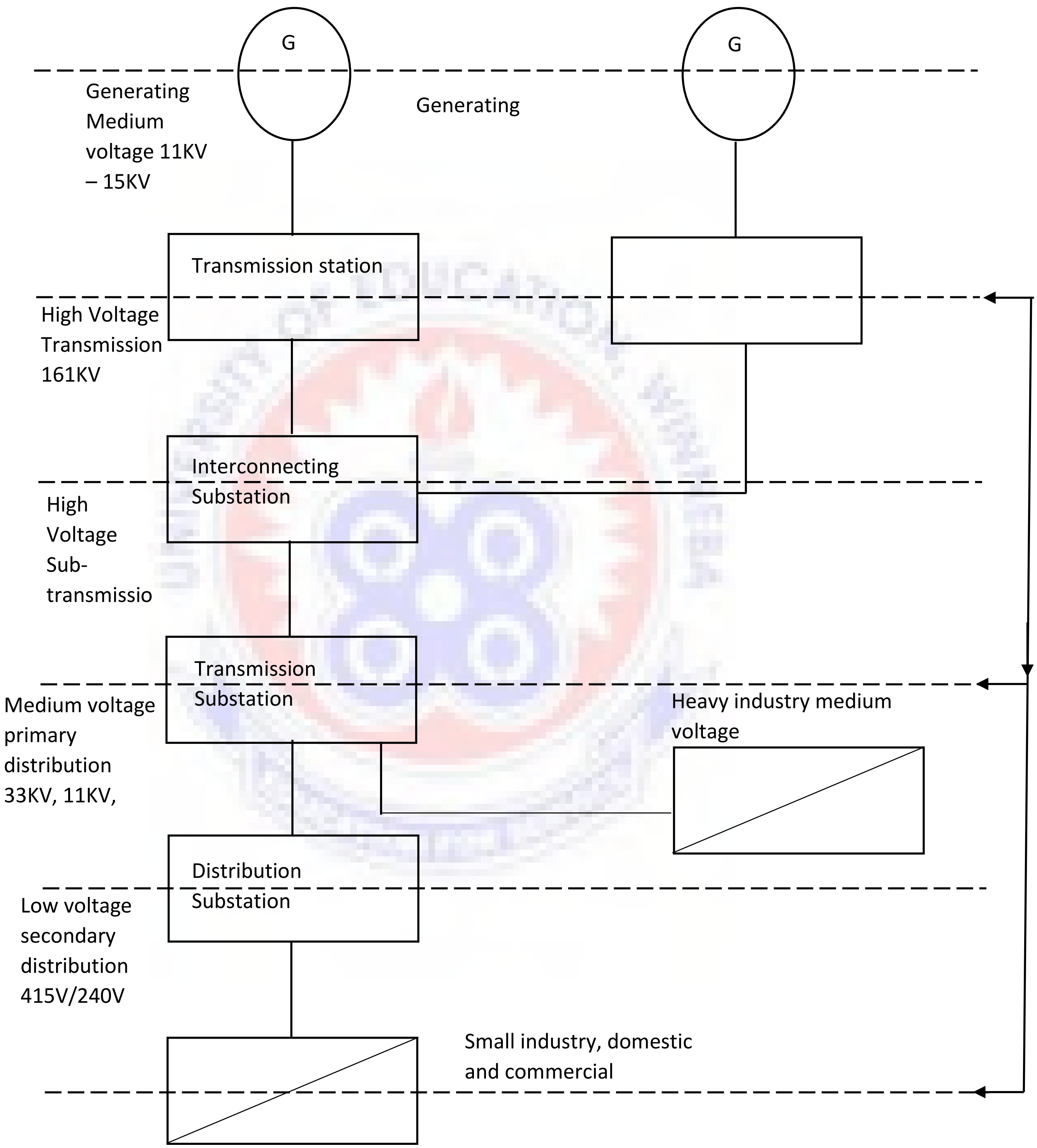
Specify…………………………………………………………………..

Please indicate your level of agreement or disagreement to the following statements

S/N	**Statement**	**Strongly agree**	**Agree**	**Strongly disagree**	**Disagree**	**Don't know**
6	NEDCo putting measures to reduce distribution losses					
7	Non- technical losses result illegal connections, inefficiencies in metering etc.					
8	Technical losses result from inefficiencies in the distribution networks during distribution process					
9	Faulty meter can cause losses in NEDCo					
10	Losses can be causes by underestimation of consumption					
11	Faulty transformer can cause losses					
12	System losses causes frequent network outages					
13	Bills to Factories are too huge so they connive to cheat					
14	Increase in losses calls for tariff increase					
15	System losses causes low revenue collection					

APPENDIX C

A single line diagram of a generation, transmission and distribution system in Ghana



APPENDIX D

Sunyani strategy of reducing distribution losses to 24% by 2020.

Specified task	Implied Task	Delivery Deadline	Accountability
Intensify losses reduction activities	(1) Identify all unmetered premises and have them metered	January – December	Stephen amaesewu (CSE) and Samuel Dekyem (LCU)
	(2) Replace all faulty and over-aged meters	January – December	Stephen amaesewu (CSE) and Samuel Dekyem (LCU)
	(3) Ensure prompt capturing of new service connection and street lights	January – December	Stephen amaesewu (CSE) and Samuel Dekyem (LCU)
	(4) Task force at each district for replacement of defective and over-aged meters	January – December	Stephen amaesewu (CSE) and Samuel Dekyem (LCU)
	(5) Sealing of all meters	January – December	Stephen amaesewu (CSE) and Samuel Dekyem (LCU)
	(6) Reduce illegal connection to barest minimum	January – December	Stephen amaesewu (CSE) and Samuel Dekyem (LCU)

APPENDIX E

General strategies for monitoring distribution losses in power systems

Distribution Losses	Organization	General Action
L =TL+NTL		
L<10%	Excellent organization	Effort to maintain the level and vigilance
L=10%	Good	Major investment required if losses are to be reduced further. Effort to maintain the level
10%≤L≤15%	Correct significant commercial losses	Improvement possible in the existing structure maintaining
15%≤L≤20%	Improvable. organization Major commercial losses	Partial reorganization sometimes is necessary. Establishing the loss reduction as a strategic project and mobilizing the company
20%≤L≤30%	Defective substantial losses	In depth reorganization. A strategic project is necessary. Support of authorities is necessary
30%≤L	Exceptional situation linked to a crisis in the power sector. Highly deficient organization	Reconstructing the company from the ground up, with the authorities

APPENDIX F

COMPUTATION OF TARIFF BY AUTOMATIC ADJUSTMENT (INDEXATION) FORMULA PROVIDED IN THE FIFTH SCHEDULE

Electricity Tariff Adjustment (Indexation) Formula

The adjustment energy price is computed as follows:

P = PO $\{\alpha\frac{FP}{FPO} + \beta\frac{CPI}{CPIO}\}$ .... (1)

Where

P = Adjustment Variable Energy Price

PO = Base Thermal Variable Energy Price:

Oil Fired Sample Cycle Plant = 4.61 cents/KWh.

Oil Fired Combined Cycle Plan t = 3.03 cents/KWh.

Levelized energy price for natural gas fired thermal plant = 2.9 cents/KWh.

FP = Fuel Price (For liquid fuels, the reference fuel is Bonny Crude Oil)

FPO=Base Fuel Price (20 us$/bbl + a premium 2.0 US $/bbl) = 22 US $/bbl

CPI = % change in the Consumer Price Index of USA

CPIO = % change in the Base Consumer Price Index of USA = 2.0%

α = Annual Fuel coefficient.

β = Annual CPIO coefficient

The Annual Fuel and CPI coefficient are defined in the table below.

Coefficient	Crude Oil	Natural Gas
Fuel Coefficient (α)	0.89	0.89
CPI Coefficient (β)	0.11	0.11

Upon attainment of economic efficient tariff, the fuel adjustment formula would triggered in accordance with the following mathematical relationship:

Fuel Price Change= (30 ± 1.5) US $/bbl

Calculation of Adjusted Weighted Average Cost of Generation BGCADJUST:

The Adjusted Weighted Average Cost of Bulk Generation Charge,

BGC ADJUST. Is computed as follows:

BGCADJUST (Cents/KWh) = [(XIHC + X2P2 + X3P3) + nK]

Where;

X1 = Percentage of Hydro Contribution in the Generation Mix

X2 = Percentage of Simple Cycle Thermal Energy in the Total Generation Mix

X3 = Percentage of Combined Cycle Thermal Energy in the Total Generation Mix

HC = Hydro Cost (cents/KWh) determined by PURC

P2 = Adjusted Variable Energy Price (cents/KWh) of a Simple Cycle Plant (calculated from equation 1 above).

P3 = Adjusted Variable Energy Price (cents/KWh) of a Combined Cycle Plant (calculated from equation 1 above).

K = System Capacity Price (12.20 US $/KWh-month = 1.67 cents/KWh).

n = Effective percentage thermal capacity contribution to system demand.

Conversion BGC ADJUST, in cents/KWh to cedis/KWh:

Since the Bulk generation charge (adjusted) is computed in cents/KWh, PURC will use Bank of Ghana"s average exchange rate projection for the next period to effect the conversion from cents/KWh to cedis/KWh using the following relationship:

BGC (ADJUST) (cedis/KWh) = (ADJUST) (cedis/KWh)× EXCHt /100

Where:

(ADJUST) (Cedi/KWh) = Adjusted Bulk generation charge = Average Cedi-to-US $ exchange rate in the next period (as projected by the Bank of Ghana)

Calculate: BST = BGC (ADJUST) + TSC

Where: BST Bulk Supply Tariff (Cedi/KWh)

TSC = Transmission Service Charge (Cedi/KWh)

For TSC, the PURC Benchmark = 0.9 Cent/KWh

Convert TSC in Cent/KWh to Cedi/KWh using the following relationship:

TSC (Cedi/KWh) = TSC (Cent/KWh) x EXCHt /100

Conversion of Distribution Service Charge (DSC) for depreciation/appreciation of cedi against the US Dollar.

DSC t = DSC t – 1X EXCH t / EXCH t – 1

Where: DSCt Distribution Service Charge in (Cedi/KWh) for next period of time

DSCt Distribution Service Charge in (Cedi/KWh) for previous period

EXCH t = Average Exchange Rate in (Cedi to US dollar), for next period as projected by the Bank of Ghana

EXCH t – 1 = Average Exchange Rate in (Cedi to US dollar), used by PURC for previous period

End User Tariff Determination:

Calculate EUT using the following mathematical formula:

EUT (Cedi/KWh) = BST (Cedi/KWh) + DSC (Cedi/KWh)