



UNIVERSITY of  
RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY



AFRICAN CENTER OF  
EXCELLENCE ENERGY FOR  
SUSTAINABLE DEVELOPMENT

**University of Rwanda**

**College of Science and Technology**

Title of the Project: ***RELIABILITY ASSESSMENT OF DISTRIBUTION  
NETWORK FOR MEDIUM VOLTAGE SYSTEM***

***CASE STUDY: KIGOMA SUBSTATION***

A reaserch submitted to the African Center of Excellence in Energy Studies  
for Sustainable Development (ACE-ESD)

In partial fulfillment of the requirement for the degree of MASTERS OF  
SCIENCE IN ELECTRICAL POWER SYTEMS

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**October 2022**

**Kigali-Rwanda**

**DECLARATION**

I, the undersigned, declare that this Project proposal is my original work, and has not been presented for a degree in University of Rwanda or any other universities. All sources of materials that will be used for the thesis work will have been fully acknowledged.


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This thesis proposal has been submitted for examination with my approval as a university advisor.

Dr. Venant KAYIBANDA

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Thesis Advisor

Signature

## ACKNOWLEDGMENT

The writing and conducting this Dissertation would not have not been possible without contributions, encouragement and supports from many people in all corners of our life.

First and foremost, my special thanks goes to almighty GOD for his protection during dissertation writing and the whole period of my life.

I'd want to thank my wonderful family for their unwavering support, moral support and prayers during whole period of my studies.

My special thanks also goes to University of Rwanda/ Center of excellence in Energy for sustainable development provided required knowledge and skills for writing this dissertation.

I am absolutely thanking my supervisor **Dr. Venant KAYIBANDA** for his advices, encouragements and guidance during my Dissertation writing.

Finally, Special thanks goes to all my lectures who gave me helpful package of theoretical and practical knowledge, your help is warmly acknowledged.

## **Abstract**

The Electrical Power System (EPS) with its generation, as well as its transmission and distribution networks are subjected to many events such as accidents, random component failures, increasing power outage due to adverse weather and increased network risk due to aging assets. These kinds of events are unpredictable, but they can be taken into account when deciding the level of distribution at which the system should survive, on other hand EPS is a complicated system from the operation and infrastructure points of view. Despite this; it has to provide the end customers with continuous and reliable power supply. In this study, the reliability assessment of Medium-Voltage (MV) distribution network is investigated. The study examines one practical part of the MV network in KIGOMA substation of south Province with three feeders: Butare, Ntongwe and Gatumba. The network used in this study is the radial distribution system, which represents typical urban distribution systems consisting of residential and industrial customers. The degree of reliability of supply is measured by the frequency, duration and magnitude of disturbances to the electricity supply. Both system indices and system worth indices are calculated and evaluated. In addition, the degree of reliability of five case studies is conducted, which can investigate the effects of automation, ageing and load growth.

**Keywords**— Reliability assessment; Distribution systems; Customer indices; Worth indices, Medium Voltage.

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## **Abbreviations**

CB: Circuit Breaker

FAT: Factory acceptance test

DC: Direct Current

AC: Alternating Current

SAIDI: System Average interruption duration index

SAIFI: System Average Interruption Frequency index

CAIDI: Customer Average interruption duration index

ASAI: Average System Availability index

CIII: Customer Interrupted per Interruption Index

SAT: Site Acceptances test

ACCI: System Average Customer Curtailment Index

AENS: Average Energy Not Supplied

ALII: System Average Connected kVA Interrupted per kVA of Connected Load Served

ASAI: Average service Availability Index

ASUI: Average Service Unavailability Index

CTAIDI: System Customer Total Average Interruption Duration Index

ECOST: Expected Interruption Cost

EENS: Expected Energy Not Supplied

IEAR: Interruption Energy Assessment Rate

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# **1. INTRODUCTION**

## **1.1. General introduction**

Electrical energy has a significant impact on the economic development of every country on the planet because it is essential in performing many activities in our communities. Electricity, like water, is in high demand as the world's population grows. As the population grows, so does the demand for energy. Electrical energy has a significant impact on the economic development of every country on the planet because it is essential in performing many activities in our communities. Electricity, like water, is in high demand as the world's population grows. As the population grows, so does the demand for energy. However, the problem is not limited to the satisfaction of the demand but also the quality of the service delivery; it is in this regard we have to think the reliability of medium voltage distribution system.

Electrical power system mainly consists of three systems, which are generation, transmission and distribution, most of the people concentrate on generation and transmission systems thinking that are mainly responsible of the power system reliability. However, it is not correct because more than 80% of the system failure are due to failure of medium voltage distribution system. Different areas and countries are still straggling for development by focusing on increasing the energy generated and its transmission but they forget doing analysis of the reliability of distribution; or distribution system is the critical part because it is the one, which directly interact with investors or customers. [1].

There are different reasons that are making the reliability of medium voltage distribution network an important parameter:

- Reduction of energy not served,
- Network equipment life span extended,

- Customer appliances life span extended,
- Investors' attraction,
- Customer production target can be met,
- Image of the utility company is defended.
- Less intervention cost

At the same time, medium voltage distribution network counts numerous factors affecting reliability such as transient faults, influence of management mechanism on reliability of medium voltage supply influence of characteristics of medium voltage distribution network reliability, quality of network equipment, network configuration, natural disasters, operation management and maintenance of network among others. [2]

## **1.2. Background**

In electrical power system, generation, transmission and distribution reliability is an essential parameter for the economic development and modernization of any nation or any region boosting the productivity of key growth sectors such as mining, agro-processing, construction and the service sector. The most important purpose of power system is providing reliable, quality and affordable power supply to consumers. In (PS) power system reliability can be defined as the possibility of supplying load demand in adequate manner, it can be divided into two main parts, which are System capability and system security.[3] It is very necessary to assess the reliability of the substation, especially when there is a plan for the development of the supplied areas electrical supply require much money investment to get a reliable power supply. In electrical distribution network there are different components including Distribution substations, poles or towers, conductors, insulators, transformers, switching devises, and protective devices. [4]

Medium voltage distribution network can failure due to two main source of problems, internal faults and external faults. Internal faults can be caused by connection error between cables, corona effect, cable faults, transformer fault circuit breaker faults, and measurement transformers faults. External fault can occur due to thunderstorms, external projects like construction of roads, consumers load installation errors, and animal disturbances. [5].

Rwanda energy strategic plan and rural Electrification is to connect all public infrastructure, schools, health facilities, small businesses and administrative offices, and all house holder by 2024, where 52% will be connected to the grid and 48% connected off-grid. The off duration will be decreased by 50%. Poor performance of the grid, as seen in many countries today, adds to the appeal of decentralized solutions connect up to two-thirds of those gaining access to electricity.

Due to falling costs of decentralized systems, these off-grid solutions continue to be appealing even as grid reliability is increased. However, increasing grid reliability could enable infrastructure optimization by connecting more users and raising average electricity consumption, as well as by removing a significant barrier to the growth of businesses and community services. A decrease in the price per unit of demand served would offset the additional investments made to increase reliability by installing enough generation capacity to cover peaks.

### **1.3. Problem statement**

In today's life electricity supply plays a vital part in people's lives, but having access to electricity only is not enough, the quality and reliability of electricity supply also matter. Reliability of the system must be best as possible, normally 99.98 % availability, means two hours off service per year, is considered as the reasonable level of power availability. [6].

Reliability of medium voltage distribution system is very important in electrical power system. Most of the people think generation and transmission system are only the cause of system failure or inefficiency, it has indicated that worldwide 90% of electricity supply interruption is due to failure of distribution system. [7]. The main causes of low electrical distribution system are mainly operation management, system maintenance, and equipment failure and system protection conditions.

An assessment of the electrical equipment is the key to successfully reducing risk while improving performance and maintaining power system reliability. This project come to deal with the assessment of the power reliability by analyzing the strengths and weaknesses of the system, the condition of the equipment, the risks to safety and electrical distribution performance, the major risks to the process, and how the information can be used to manage risks and performance optimization. As the results the assessment of reliability will help utility company, or facility manager to identify vulnerabilities within the system and provide some guidance for modernization, replacement, or even an expansion of the system, this will improve customer satisfaction and will attract more people and investors to come living and doing business in that area.

#### **1.4. Objectives**

##### **1.4.1. General objective**

The main objective of this work is to make an assessment of reliability of the medium voltage distribution network at Kigoma Substation to know it level, propose some recommendations to the utility in order regarding the system reliability of this substation.

#### **1.4.2. Specific objective**

To achieve the main objective of the project the following specific objectives are proposed:

- i. To calculate the different indices related to reliability of electrical power system.
- ii. To identify the cause affecting the reliability at Kigoma substation.
- iii. To identify probable solution to the cause of unreliability power supply at Kigoma Substation.
- iv. Results analysis from the calculation and recommendations.

#### **1.5. Scope of the study**

This research will be done by analyzing data and incidents occurred at Kigoma Substation to assess the reliability level of medium voltage distribution network, the result will be used to make recommendation to the utility to achieve acceptable medium voltage reliability level.

#### **1.6. Expected Outcome and Significance of the study**

##### **1.6.1. Expected Outcome**

This study is aimed to assess the reliability of Kigoma Substation medium voltage side. Because power supply reliability is regarded as the most important factor in electrical network planning, design, and operation, proper reliability evaluation and maintainability must be coordinated throughout the electrical network life cycle. These indices are useful because they can identify weak areas that need to be strengthened, establish chronological trends in reliability performance, establish existing indices that serve as a guide for acceptable values in future reliability assessments, allow previous predictions to be compared with actual experience, and monitor the response to system design changes.

### **1.6.2. Significance of the study**

The reliability of medium voltage distribution network is very important in electrical power system because, distribution network is directly connected with the end users of network or consumers. when the system is not reliable there will be different negative impact in different areas. The supplied region will not be developed as people will fear to invest in that region, some network equipment will be damaged this will result to losses of the company, Appliances of customers will be malfunctioning and power system in general will be mal-operating which may cause total blackout, in such situation the reputation of the utility company is losing value and the economy of the country being negatively affected.

## **CHAPTER 2: LITERATURE REVIEW**

### **2.1 Introduction**

In electrical power system reliability of medium voltage distribution system is an important parameter to take into consideration by many researchers as it has been shown with big impact on general performance of the other parts of power system means generation, and transmission.

Looking at the causes affecting medium voltage distribution system reliability, the effects and how it can be minimized will boost the power system efficiency and reduction of losses due to bad operation of the connected equipment and appliances, as well as well avoiding unexpected degradation of system's devices. The basics concept needed to understand this study is going to be discussed in this part and more information has been read from different literatures.

### **2.2 Description of Medium voltage electrical distribution system**

#### **2.2.1 Electrical Distribution system overview**

Distribution systems is one the main parts of electrical power system, it is directly connected to the customer properties or loads. Usually employ such equipment as transformers, circuit breakers, and protective devices. In general, the distribution system refers to the part of the power system that distributes electric power for local use.[8] [9]

The distribution network can be constructed using the form of overhead lines or underground cables, depending on the geographical location. Underground cables are commonly used in cities, while overhead lines are usually used in rural areas. In order to meet the required supply reliability, various network configurations are possible such as radial and ring network, [10] [7][11]

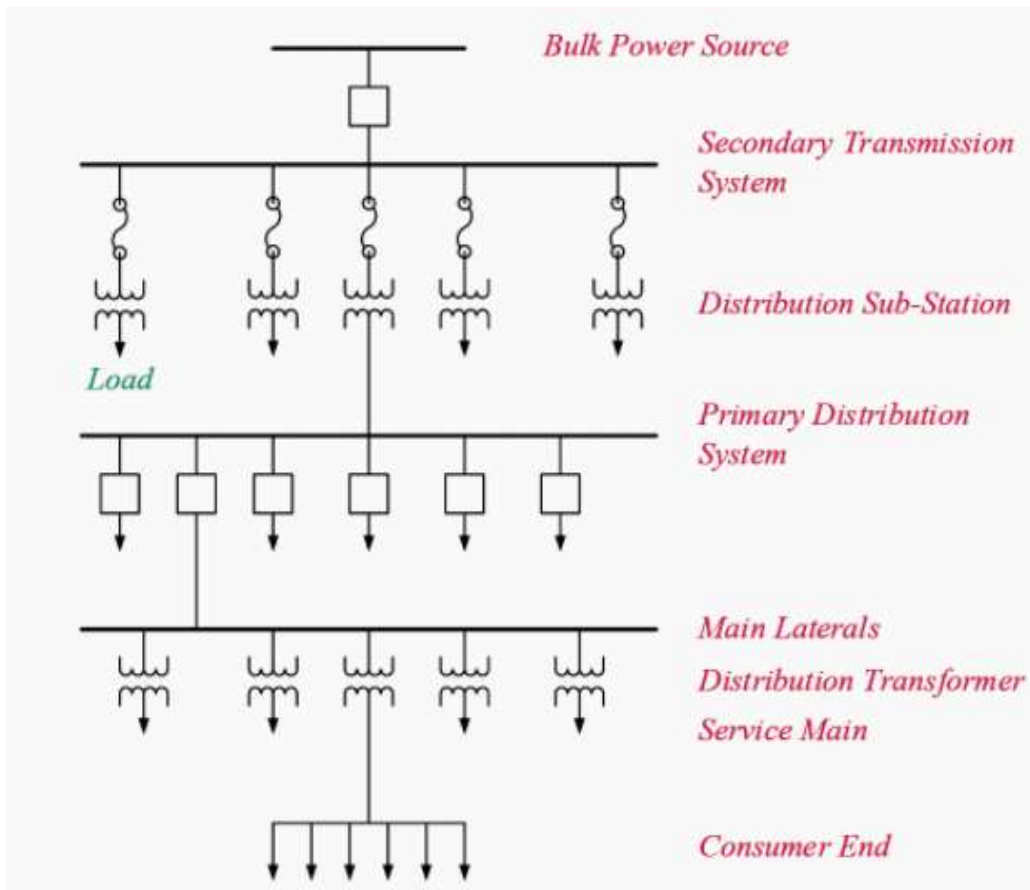


Figure 1. A typical power distribution System

Source: Electrical Engineering Portal

### 2.2.2 Components of distribution system

Electrical distribution system is mainly composed of:

#### A. Feeders

A feeder is a conductor that connects a substation or locally generated power station to the area where power is destined to be used. In most cases, no tappings or derivations are taken

from the feeder, ensuring that the current in it remains constant throughout no current division. [8]

The main consideration in the design of a feeder is its current carrying capacity of the feeder

## **B. Distributor**

A distributor is a conductor from which tapings are taken in order to supply customer loads. Because tapings are taken at various points along the length of a distributor, the current does not remain constant.

### **2.2.3 Service main**

A service main is typically a small cable that connects the distributor to the terminals of the consumers.

### **2.2.4 Classification of distribution system**

A distribution system can be classified based on the following criteria:

#### **According to nature of current:**

- Direct current (DC) distribution system
- Alternative current (AC) distribution system.

Nowadays, the alternating current (AC) system is universally used for electric power distribution because it is simpler and more cost-effective than the direct current method as distribution is done at limited distance and AC voltage magnitude can be conveniently changed using transformers. [12]

**The AC Distribution System is classified into two categories:**

### **1. Primary Distribution System**

The part of AC distribution system operating at somewhat high voltage than general utilization and handles large blocks of electrical energy than the average low voltage consumer uses is called primary distribution. The voltage to be used in primary distribution depend on the amount of power and distance of the substation required to be fed, commonly used primary distribution voltages are 11KV,15KV, and 33KV normally primary distribution is carried out by 3-phase, 3-wire system. [13]

### **2. Secondary Distribution System**

The part of AC distribution system includes range of voltages that match the required magnitude to the appliances terminals. Usually secondary distribution utilize 400/230V, 3-phase,4-wire system. The substation is located near the consumer and contain step down transformers.

## **DC Distribution System**

**Mainly DC supply may be obtained in two form:**

### **1. Two- wire**

As it name implies, a 2-wire system consists of positive outgoing wire and negative or return wire, the load is connected between in parallel between the wires.

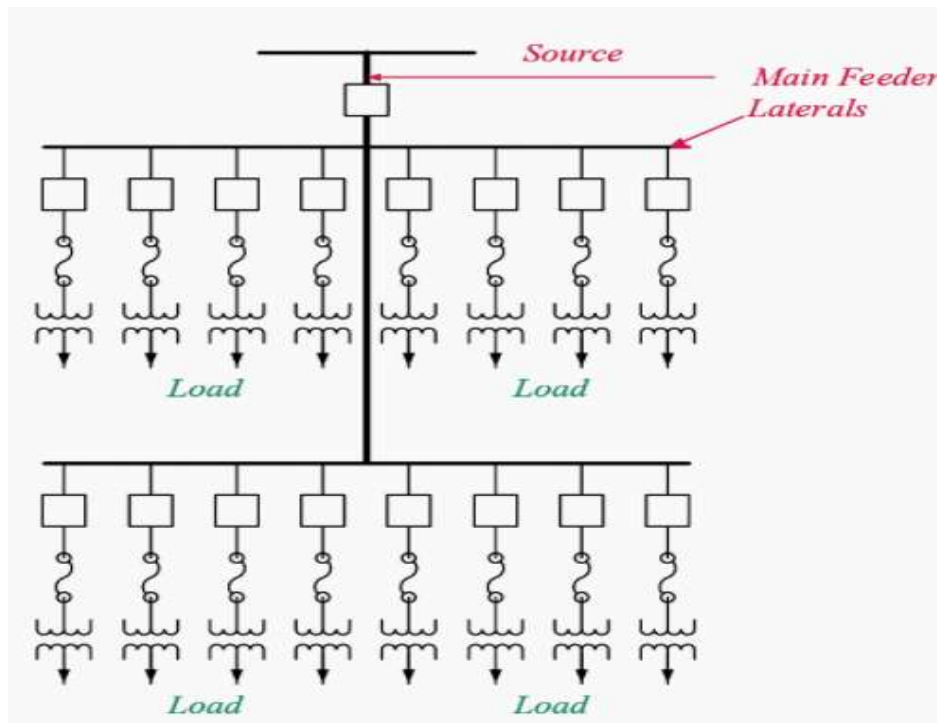
## **2. Three- wire**

This type of DC distribution system is consists of three wires, two are outgoing and the middle wire is neutral wire which is earthed at the substation. This system present advantages of having two voltages at consumer terminals means between outers and neutral, between the two outers.

### **According to scheme of connection:**

#### **1. Radial system**

In this scheme, separate feeders radiate from a single substation then feed the distributors at one end only. The structure of a radial network begins at the root node, where the generation is connected. In a radial network, a lateral line follows the root node or main node. This line starts with the main feeder and connects to the loads. The lateral line is the starting point for the sub-lateral line. Finally, the minor lines branch out from the sub-lateral line.[8]



*Figure 2. Radial distribution System*

The radial system has some benefits, including the use of a relatively straightforward circuit protection scheme for the coordination and design of radial network systems. An easy way to determine the system component rating requirements is to use a radial network. Reactive power techniques for voltage compensation are another benefit of using a radial network.

**This type of system has some drawbacks including:**

Customers depend on a single feeder and distributor, so when a fault occurs with either, the supply is cut off, and all customers who are on the side of the fault that is away from the substation are no longer receiving service. The consumer at the far end will experience severe voltage fluctuations when the load on the distributor changes. The radial system is only used for short distances because of these restrictions.

## 2. Ring main system

In a ring network, the distribution transformers' primary windings form a loop that begins at the substation and travels through the service area before returning to the substation. These networks have the following benefits: Voltage fluctuations at the consumer's terminals are reduced, and because each distributor is fed by two feeders, supply continuity is maintained even when a feeder section fails. This leads to an increase in system reliability.[14]

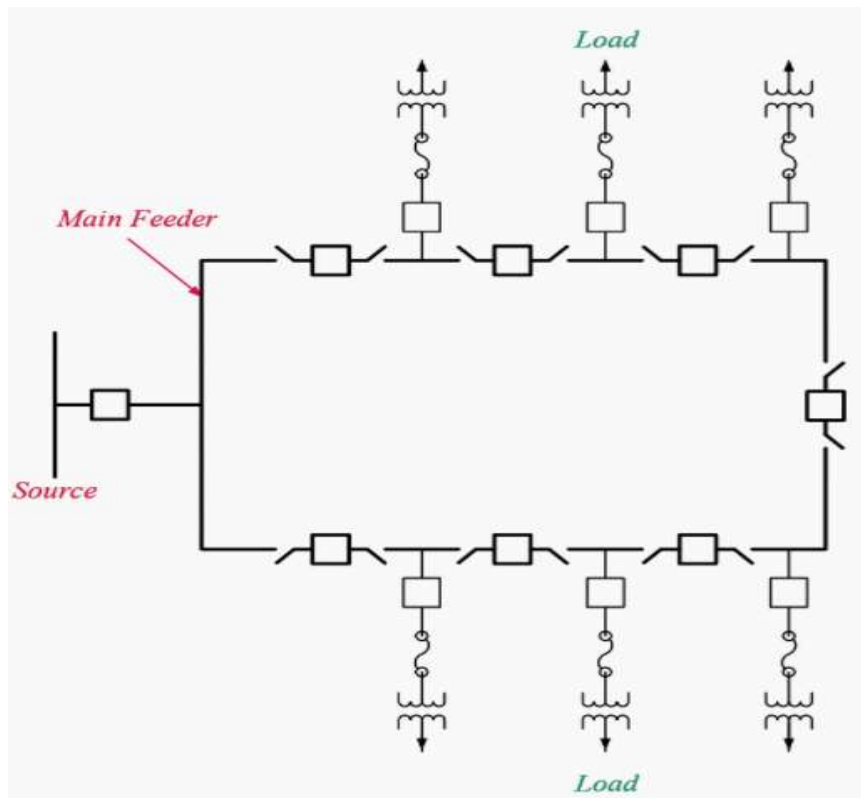


Figure 3. Ring distribution system

### 3. Inter-connected system.

The system is called interconnected when the feeder ring is energized by two or more sources, The interconnected system has different advantages such as increasing reliability of the service delivery, load sharing between generating stations which result in reduction of reserve power capacity and system efficiency increases.[15]

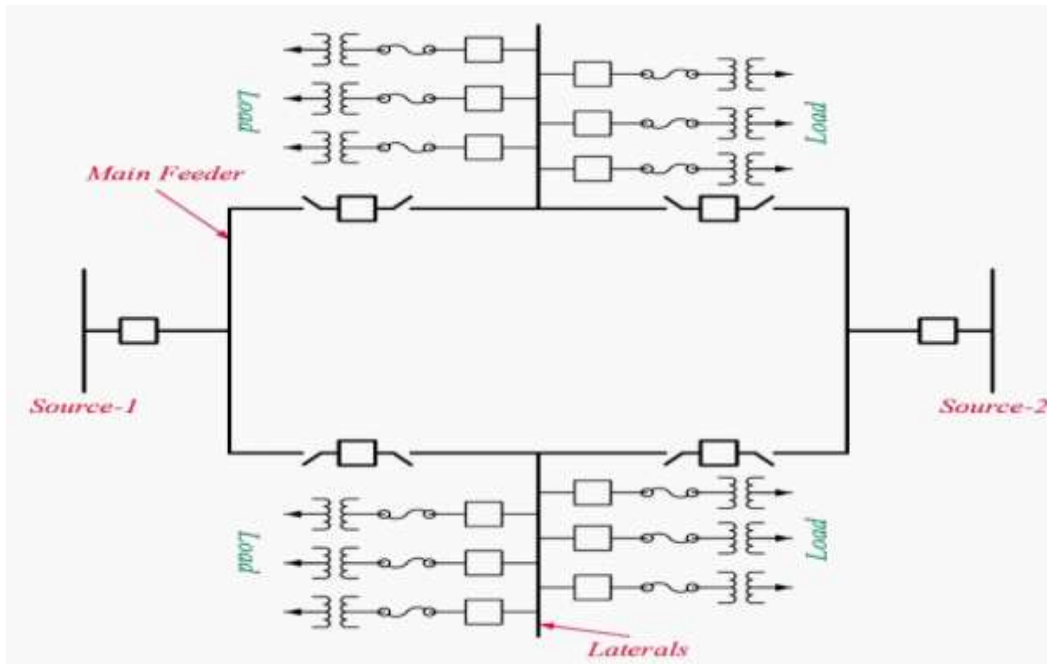


Figure 4. Inter-connected distribution system

### 2.3 Requirement for a good distribution system

It takes a lot of work to keep up a supply of electricity that can accommodate different consumer types. The following requirements must be met by a good distribution system:

- ✓ Proper voltage magnitude
- ✓ Availability of power on demand
- ✓ Reliability

### **a. Proper voltage**

Changes in voltage are typically caused by variations in the system's load. Low voltage results in revenue loss, inefficient lighting, and the possibility of a motor burnout. High voltage causes lamps to burn out permanently and can cause other appliances to fail. A good DS should ensure that the consumer's terminals voltage variations are within allowed limit, the standards voltage variation is +/- 5% of the rated voltage at consumer's terminals. Changes in voltage are typically caused by variations in the system's load. Low voltage results in revenue loss, inefficient lighting, and the possibility of a motor burnout.

### **b. Availability of power on demand**

Utility providers must make every effort to satisfy load demand at all times. The distribution system must be able to meet consumer load demands because electrical energy cannot be stored. To do this, the system operator must continuously study load patterns in order to forecast significant load variations that adhere to known schedules.

### **c. Reliability**

All electric loads their performance have relation with the reliability of power supply unfortunately electric power supply like all other man made can never be absolutely and 100% reliable, but there some solution are possible for reliability Improvement: using interconnected system, implementing reliability automatic control system, providing additional reserve facilities. [16]

*Table 1. Comparison of network types*

<b>Network</b>	<b>Sources</b>	<b>Stability</b>	<b>Reliability</b>	<b>Capital</b>	<b>Maintenance</b>	<b>Voltage Level</b>	<b>Protection Required</b>	<b>Renewable Penetration</b>
Radial	Single	Low	Low	Low	High	Low	Medium	Problematic
Ring	Multiple	High	Medium	High	Low	Low	High	Accepted
Mesh	Multiple	High	High	Low	High	Medium or High	Higher	Moderate

#### **2.4 Cause of interruptions in electrical distribution network**

If the reliability of the power distribution network is compromised, it will have a significant impact on the power supply situation of power enterprises. Below it is discussed the most common causes of interruption in medium voltage distribution network.

### **2.4.1 Component failures**

In electrical distribution network there are numerous equipment such as power transformers, instrument transformers, circuit breakers, re-closers, surge arresters. There exist different cause of equipment failure including:

Design flaws, as well as inadequate equipment and material specifications,

Manufacturing flaws and errors in equipment and materials,

Inadequate packaging, handling, and transportation,

Inadequate storage,

Errors and deficiencies in the installation of equipment and materials, as well as failure to perform Factory Acceptance Tests (FAT) and Site Acceptance Tests (SAT) in a way that complied with applicable standards and was seen by an owner representative. Inadequate use of equipment.

Inadequate or non-existent maintenance.

Each component of electrical power distribution network, same as any other piece of machinery, has the potential to fail at some point. Even if properly installed, a variety of factors such as high current, voltage fluctuation, animal interference, inclement weather, and so on can cause failures. Transformers causes problems with power distribution system in two main ways. They can either fail or overheat, resulting in a major power outage. When one transformer fails, the remaining transformers must pick up the slack. The most common problem with the CB is that they open when they should not, this condition known as false tripping, the other one is internal faults. [2]

### **2.4.2 Natural causes**

Natural disasters such as lightning, earthquakes, ice storms, land sliding and large wind

are not friendly with electrical distribution network reliability. There what called permanent fault and what called temporary fault, when it is a permeant means equipment is damaged and need repair or replacement but for a temporary fault, equipment is not damaged[17]. The goal of service restoration is to re-energize a section of the local distribution grid that was cut off automatically due to a fault on one or a very small number of components. This is typically done by switching the network's healthy parts back on and isolating the malfunctioning components. Damage from natural disasters is typically severe and takes more time to repair.. [18] [19] [20].

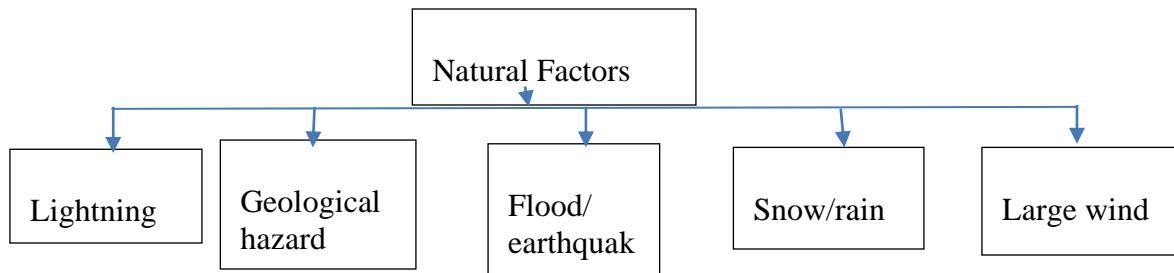


Figure 5. Natural disaster causes

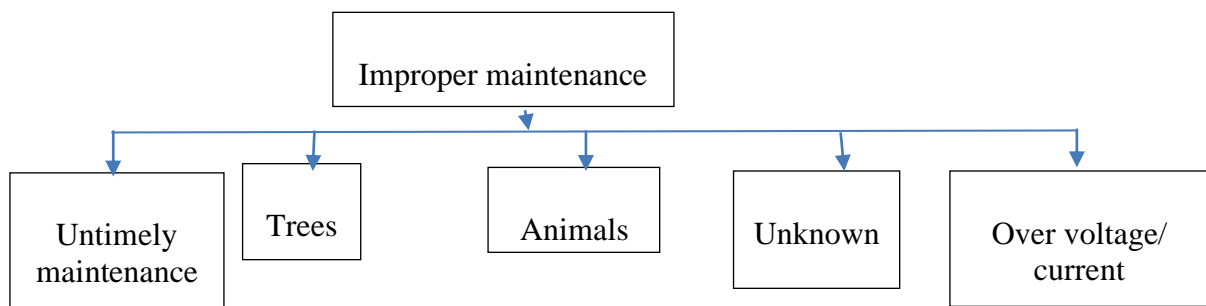
### 2.4.3 Animals, birds, trees and human error

Trees, Birds, snakes, and other animals, among others, have been known to cause power system outages. Animal-caused faults can also occur on overhead power lines, underground power lines, substations, and transmission lines. More tree-related faults would occur as a result of the high wind. According to the statistics, 35 of 84 utilities (42 percent) believe overhead distribution lines are responsible for 79 percent of historic animal-caused outages. Trees can cause faults in several ways, including growth into conductors, failing trees or branches that bridge gaps or push conductors together, and failing trees or branches that cause mechanical damage.[19]

#### 2.4.4 Ageing infrastructure and lack of maintenance

Many electricity companies own and operate a large number of equipment that can be identified as old equipment. That is almost worn out due to the stress of its operating time.

As the result of this condition, breakdown and failures, as well as the resulting customer reliability and operation cost are higher than average and will continue to rise as the equipment ages. In terms of both reliability and operating costs, aging infrastructure will become a growing concern for utilities.[21]



*Figure 6. Improper maintenance factors*

#### 2.4.5 Network overloading

Extreme load fluctuation there is a problem throughout the electrical network, which has a negative impact on the electrical installations. Furthermore, causing under-voltage, under-frequency, overcurrent, and instability.

Load shedding and CB Trip protection methodologies are used in some countries to deal with the unforeseen circumstances of a severe overload on electrical network installations. However, this method of dealing with the problem was inefficient because it only avoided the problem rather than solving it.

Distribution network overloading create negative effect some of them are:

Reduces the equipment's lifespan and, as a result, causes it to fail over time; as a result, it is critical to save network electrical equipment.

Overloading causes damage to the transformer. This is due to rising ambient temperatures, which cause an increase in oil temperature, resulting in hotspots and bubbles, which raise heat island temperatures and shorten the life of the oil.

The cables that were damaged as a result of the overloading, causing cable elongation and, after the load is removed, cable returns, resulting in the bubbles phenomenon, which leads to weak points.

Increasing the cost of replacing damaged installations with new ones.

Overload, under-frequency, and voltage protection cause frequent trips caused by protective relays.[22]

## **2.5 Reliability indexes calculation**

Utilities need accurate data on system performance to make sure maintenance fees are used wisely and that customer expectations are met. To evaluate system performance, the electric utility industry has created a number of reliability performance measures. These reliability indices include measurements of outage duration, frequency, system availability, and response time.

The most considered electrical distribution system reliability indices are:

- System Average interruption duration index
- Customer Average interruption duration index
- System Average interruption frequency index
- Customer interrupted per interruption index
- Average service availability index

### 2.5.1 System Average interruption duration index

The most popular performance metric for an extended interruption is the System Average Interruption Duration Index (SAIDI). This index determines the overall length of an interruption for the typical customer over a given time frame. SAIDI is typically calculated monthly or annually, but depending on the situation, it may also be calculated daily or for any other time period[23].

SAIDI is calculated by multiplying each interruption during the period by the duration of the interruption to find the customer-minutes of interruption. The total customer-minutes are calculated by adding the customer-minutes from all interruptions.

To calculate the SAIDI value, divide the customer-minutes by the total number of customers.

$$SAIDI = \frac{\sum(r_i * N_i)}{N_T}$$

Where,

$r_i$ : Restoration time in minutes

$N_i$ : Total number of customer interrupted

$N_T$ : Total number of customer served

### 2.5.2 Customer Average interruption duration index

When an outage occurs, the Customer Average Interruption Duration Index is used to calculate the average time to restore service (CAIDI).[9]

Calculation of CAIDI is done the same way as SAIDI only the difference is that the denominator is total number of customers of the substation.

$$CAIDI = \frac{\sum(r_i * N_i)}{\sum N_i}$$

$r_i$ : Restoration time in minutes

$N_i$ : Total number of customer interrupted

### 2.5.3 System Average interruption frequency index

The average number of outages a system customer experienced over the course of the study period is defined by the system average interruption frequency index. The dimensionless SAIFI is calculated by dividing the total customers served by the total customers affected.

$$SAIFI = \frac{\sum(N_i)}{N_T} = \frac{SAIDI}{CAIDI}$$

### 2.5.4 Customer average interruption frequency index (CAIFI)

This index shows the annual number of interruptions per customer. Simply divide the total number of interruptions by the total number of customers who were impacted by the interruptions to determine CAIFI.

$$CAIFI = \frac{\sum(N_o)}{\sum N_i}$$

$N_o$ : Number of interruptions

$N_i$ : Total number of customer interrupted

### 2.5.5 Customer Interrupted per Interruption Index (CIII)

This index gives the average number of customers interrupted during an outage.

$$CIII = \frac{\sum(N)}{\sum N_{oi}}$$

### 2.5.6 Average service availability index (ASAI)

This indicate the system availability rate, means it is the ratio of the total number customer hours on service during the period under study to the total hours demand. It sometime called service reliability index.

$$ASAI = \frac{\text{Customer Hours Service Available}}{\text{Customer Hours service demand}} pu$$

## 2.6 Related Works

**Bonifatius, SH had worked on” *Reliability Assessment of City of Windhoek Electrical Distribution Network*”** [7], He found that other companies, usually cutting the distributing underground cables while constructing other infrastructures such as road, mostly affect reliability of electrical distribution in Windhoek. Even though the reliability of electrical distribution in Windhoek is very good as he calculated the reliability indexes then find the average customer outages are less than 0.0999 Customer-minute, the system average interruption duration index were 0.00771 minutes. System average interruption frequency index were 0.0274. The factor that is behind that good performance of the medium voltage distribution network in Windhoek is due to technologies used by Namibia Power Company for clearing faults and restoring the system.

**Rosyadi, G; Syahputra, R, and Mujaahid, F, “*Electrical Power Distribution Network Reliability: A Case Study in Wates Substation, Yogyakarta, Indonesia*”** [24] They have calculated reliability indexes such as System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) of feeders for different years and compare the result with the standards of IEEE (Institute of Electrical and Electronic Engineers) and WCS (World Class Service), the purpose was to know whether the

substation's reliability is good enough so that it does not need improvement or if it need improvement. The IEEE standard is 1.45 times/customer/year, and they have found that there is feeder 2.21 that means the reliability is bad need some improvement.

**Trentini.C, Wanessa.O.G and Bruno.H.D** “*Maintenance Planning of Electric Distribution Systems—A Review*” [25] They have found that maintenance is very important to enhance distribution network reliability, they have mentioned different reliability indexes to be focused during maintenance planning. These indexes are: customer average interruption duration index (CAIDI),

Energy not supplied, Mean time between failure (MTBF), mean time to repair (MTTR), mean time to failure (MTTF), Service availability index (ASAI), and Service unavailability index (ASUI). After they have found that distribution maintenance is very necessary for network reliability enhancement.

**Khanyisile C Z** “*Reliability assessment for medium voltage electrical network: A case study within Eskom distribution*”.[6] [26]Has found that medium voltage distribution network count significant majority of power system outages duration. The research has found that medium voltage distribution network constitute a high risk of the power supply interruption, 80% of electrical power system interruption are found in distribution network. During electrical network planning, design, and operation reliability of power supply to customers must considered as the critical factor.

**Anteneh.D and Khan. B** “*Reliability Enhancement of Distribution Substation by Using Network Reconfiguration a Case Study at Debre Berhan Distribution Substation*”.[13] In their research they have found that the purpose of electrical power system is to supply electricity to end user, the power supply must be of good quality and economic, reliability is part of power quality indicators.

Reliability of power system plays a vital role in development of the countries, they found that radial system is less reliable than ring system. Different solutions have been used to enhance reliability some of them are: feeder re-configuration, installation of automatic reclosers to reduce the affected area.

***Duan. D, Jong. W and Deng.F “Analysis and Research on Factors Affecting the Reliability of Medium Voltage Power Supply”[12][2]*** In their research they have illustrated different factor that affecting the reliability of medium voltage electrical distribution system. They have mentioned the main factors including: Influence of management mechanism on reliability of medium voltage supply, Influence of characteristics of medium voltage distribution network reliability, after reviewing the major factor affecting distribution reliability they have provided possible solutions. After all they mentioned reliability of medium voltage distribution as an important key to the power system performance and countries development dependability.

## 2.7 Literature gaps

The followings table summarizes the previous research done and their findings and identify the gaps found which the area to focus in this research report.

<b>Research title and Authors</b>	<b>Research findings</b>	<b>Research gaps</b>
<p>Analysis and Research on Factors Affecting the Reliability of Medium Voltage Power Supply</p> <p><i>Duan. D, Jong. W and Deng.F</i></p>	<p>The different factors that affect the reliability of medium voltage electrical distribution system are identified and the main factors that were found were the Influence of management mechanism, Influence of characteristics of medium voltage distribution network reliability.</p>	<p>The researchers have focused on the analysis of factors affecting the reliability of medium distribution in ring network, difference and they had only calculated two parameters (SAIFI, CAIFI) to determine those factors which was not enough to come up to the conclusion.</p>
<p>Reliability assessment for medium voltage electrical network: A case study within Eskom distribution</p>	<p>This research study has found that medium voltage distribution network count significant majority of power system outages duration. The research has</p>	<p>The research was conducted at Eskom distribution network as the case study and the researcher has only used electric system average interruption</p>

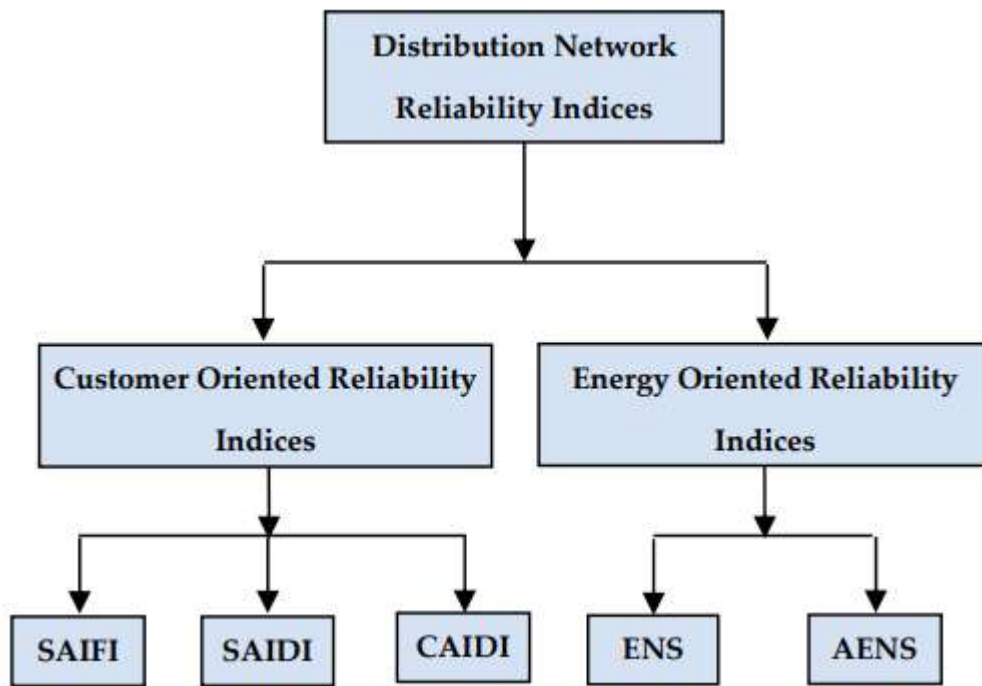
<p><b>Khanyisile C Z (2016)</b></p>	<p>found that medium voltage distribution network constitute a high risk of the power supply interruption, 80% of electrical power system interruption are found in distribution network. During electrical network planning, design, and operation reliability of power supply to customers must considered as the critical factor</p>	<p>duration index in his assessment, furthermore his study was focused on this area used in case study, thus does not compromises the generally other lines of electrical network distribution.</p>
<p>Electrical Power Distribution Network Reliability: A Case Study in Wates Substation, Yogyakarta, Indonesia</p> <p><b>Rosyadi, G; Syahputra, R, and Mujaahid, F, {2018}</b></p>	<p>The research was focused on calculating the reliability indexes such as System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) of feeders for different years and compare the result with the standards of IEEE (Institute of Electrical and Electronic Engineers) and WCS</p>	<p>The research was conducted where system average interruption frequency index and system average interruption duration index from multiple feeders was calculated and compared to the results with the standard of IEEE, therefore the results from this assessment was not compared to other calculations to decide what most factors affecting the</p>

	(World Class Service).	power reliability of the network distribution that will help in decision making for power reliability optimization
Evaluating the Reliability worth Indices of Electrical Medium Voltage Network: Case  <b>Maher M.A. Al-Maghalseh</b>	In this study, the reliability assessment of Medium-Voltage (MV) distribution network was investigated. The study examines one practical part of MV network in the North East of England and it is was conducted in radial distribution system. The degree of reliability of supply was measured by frequency, duration and magnitude of disturbances to the electricity supply.	The degree of reliability of supply was measured by frequency, duration and magnitude of disturbances to the electricity supply only which did not exactly provide accurate information of power reliability of that distribution network.
<b>Area of Improvement in current research being conducted</b>	It is obvious that many research have been conducted in reliability assessment of distribution network, thus many researchers used to calculate few reliability indices to determine factors affecting power reliability and also many of them used study case of particular distribution network	

	<p>in their home country, consequently the use of few indices may not be good in the determination of power reliability , therefore this study will be focusing on assessment of power reliability by taking into consideration six reliability indices (to be calculated) classified into two categories, mainly customers oriented reliability that include SAIDI, SAIFI, CAIFU and Energies oriented reliability that includes ENS and AENS.</p>
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### CHAPTER 3: METHODOLOGY

The study will be carried out at the Kigoma Substation, where the medium voltage distribution system's reliability will be evaluated in terms of reliability indices. The distribution network's reliability parameters, including statistical information on the failure rate, repair rate, average outage duration, voltage, and load profile, will be gathered. According to the figure below, the reliability indices of the distribution network can be broadly divided into customer- and energy-oriented reliability indices.



*Figure 7. Distribution network reliability indices.*

### 3.1 Modeling in ETAP

The Electrical Transient Analyzer Program (ETAP) tool is used for data analysis and simulation. ETAP is a powerful electric power simulation tool with the help of which many analyses related to power systems can be performed. The reliability analysis with the help of ETAP used an analytical approach to evaluate the distribution system reliability. The result should be the level of reliability of the distribution and their impacts on customers, such as residential, industrial, commercial, and governmental customers, that are connected to different feeders in a distribution system since they are affected by interruptions that are caused due to component failures or deficits in the energy supplied to the load centers.

### 3.2 Failure rate model

There is a failure rate associated with each piece of equipment in a system, and if it is used for an extended period of time, it will eventually fail. The failure rate can range from being very high for some items to being very low for others.

### 3.3 Mean time to failures (MTTF)

The exponential reliability function has an expected value that can be viewed as the average time value for the entire function because it is a continuous probability density function with respect to time. The mean time to failures, or MTTF, is the average time it takes for a failure to occur because the reliability function is actually a failure density function. A probability density function's anticipated value is given by

$$E(x) = \int xf(x) dx$$

It turns out that the failure rate is the reciprocal of this mean time between failures. Only the exponential reliability functions exhibit this result. From  $t=0$  to MTTF, there is a chance of failure of

$$Q(\text{MTTF}) = 1 - e^{-\lambda/\lambda} = 1 - e^{-1} = 0.632$$

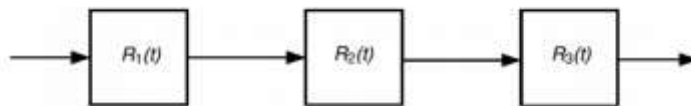
The probability of failure in the first MTTF interval is therefore 63.2% rather than 50%, despite the fact that the MTTF is the average time for a failure to occur.

### 3.4 Reliability of complex systems

#### 3.4.1 Series Systems

The majority of systems are composed of smaller systems or parts that are connected either in series, parallel, or both. A series connection indicates that each element in the series is necessary for the system to operate. The failure rate and reliability of a system depend on the failure rate and reliability of each individual component, each of which has its own characteristics. The probability that all the components will function is simply the product of the probabilities that each component will function individually, according to the product law of probability, if the failures of the components are independent.

If the failures of the components are not dependent, then the probability of all the components functioning is simply the product of the probabilities of individual components functioning, which is the product law of probability.



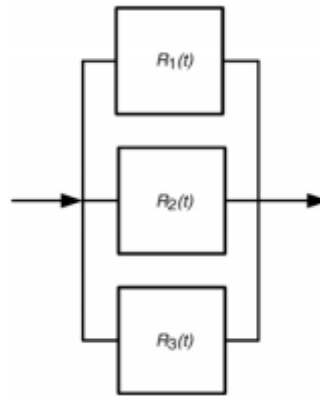
*Figure 8. A series connection*

If the components have exponential failure probabilities with corresponding failure rates, and so on, then the system reliability is given by the composite failure rate of the series

system, .

### 3.4.2 Parallel systems

In terms of reliability, a parallel system is one in which only one of the elements in the parallel connections must operate for the system to function. According to the diagram, there are a number of different routes that can be taken to connect the input and output



sides of the system.

*Figure 9. A Parallel connection*

The other components of the parallel connection are redundant because only one of them is necessary for the system to function. Because every component in the parallel connection must fail for the system to fail, redundancy makes the overall system reliability high. In the event that each failure is unrelated to the others, the likelihood that they will all occur is equal to the product of the failure probabilities of each individual component.  $Q(t)$ , or the likelihood that something will go wrong within a certain time frame, indicates unreliability.

### 3.6 Data Collection

The data are collected from KIGOMA substation within its three feeders namely BUTARE, GATUMBA and NTONGWE. These data include real time active and reactive power, transformers' capacities and their locations, yearly fault interruptions and repair period. the

table 3.1 shows the data collected from three different feeders.

Table 2 Kigoma substation data

DATE	INPUT TRANSFO				OUTPUT TRANSFO				BUTARE FEEDER				GATUMBA FEEDER				NTONGWE FEEDER				AUXILIARIES			
	Hours	P(Mw)	Hours	Q(Mvar)	Hours	P(Mw)	Hours	Q(Mvar)	Hours	P(Mw)	Hours	Q(Mvar)	Hours	P(Mw)	Hours	Q(Mvar)	Hours	P(Mw)	Hours	Q(Mvar)	Hours	P(Mw)	Hours	Q(Mvar)
01/01/2021	20:00	7.900	20:00	5.800	20:00	8.100	20:00	6.900	19:00	3.300	19:00	2.600	19:00	3.500	19:00	2.500	19:00	1.400	19:00	2.000	18:00	0.004	17:00	0.002
02/01/2021	19:00	7.900	20:00	5.800	20:00	8.100	19:00	6.800	19:00	3.300	19:00	2.600	19:00	3.600	19:00	2.600	19:00	0.800	20:00	2.000	19:00	0.004	18:00	0.002
03/01/2021	19:00	7.500	19:00	6.600	19:00	7.900	19:00	7.100	19:00	3.300	20:00	2.900	20:00	3.600	20:00	2.700	19:00	1.000	20:00	1.900	19:00	0.004	17:00	0.002
04/01/2021	19:00	8.100	21:00	5.800	19:00	8.300	20:00	7.900	19:00	3.300	20:00	3.100	19:00	3.500	20:00	3.100	19:00	1.400	20:00	2.100	20:00	0.004	17:00	0.002
05/01/2021	19:00	8.300	19:00	6.200	20:00	8.300	20:00	6.900	20:00	3.500	20:00	2.700	19:00	3.600	20:00	2.700	19:00	1.000	20:00	1.600	19:00	0.004	18:00	0.002
06/01/2021	20:00	9.400	20:00	6.100	20:00	9.600	20:00	7.400	20:00	5.300	19:00	3.800	20:00	3.100	20:00	2.200	20:00	0.900	19:00	1.800	19:00	0.004	18:00	0.002
07/01/2021	19:00	7.600	20:00	5.600	19:00	7.800	20:00	6.500	20:00	3.400	20:00	2.800	20:00	3.000	20:00	2.000	20:00	1.300	20:00	2.000	19:00	0.004	18:00	0.002
08/01/2021	19:00	7.200	19:00	5.700	19:00	7.400	19:00	5.900	19:00	3.200	19:00	2.500	19:00	2.900	19:00	1.700	19:00	1.200	19:00	1.800	18:00	0.004	18:00	0.001
09/01/2021	19:00	7.300	20:00	5.900	19:00	7.500	20:00	6.900	19:00	3.200	20:00	2.900	8:00	4.600	9:00	2.900	7:00	1.900	19:00	1.800	20:00	0.004	17:00	0.002
10/01/2021	19:00	7.100	19:00	5.700	20:00	7.300	19:00	6.600	19:00	3.100	19:00	2.700	20:00	2.900	19:00	2.100	1:00	0.900	19:00	1.700	19:00	0.004	17:00	0.002
11/01/2021	19:00	8.200	19:00	6.300	19:00	8.300	19:00	8.200	19:00	3.100	19:00	3.000	20:00	3.300	19:00	3.000	19:00	0.800	19:00	1.700	19:00	0.004	18:00	0.002
12/01/2021	20:00	8.600	20:00	5.700	20:00	8.700	20:00	6.500	20:00	3.500	20:00	2.600	20:00	4.200	20:00	2.800	19:00	1.000	19:00	1.700	18:00	0.004	17:00	0.002
13/01/2021	20:00	8.400	20:00	6.400	20:00	8.700	20:00	7.700	20:00	3.500	20:00	3.200	20:00	4.100	20:00	3.100	17:00	0.900	20:00	1.600	19:00	0.004	18:00	0.002
14/01/2021	20:00	8.700	20:00	5.600	20:00	8.800	20:00	6.600	20:00	3.600	20:00	2.500	20:00	4.100	20:00	2.500	20:00	1.400	20:00	1.900	18:00	0.004	17:00	0.002
15/01/2021	20:00	8.200	20:00	6.400	20:00	8.400	20:00	7.500	20:00	3.300	21:00	3.100	19:00	3.800	20:00	3.000	19:00	0.800	20:00	1.600	20:00	0.004	18:00	0.002
16/01/2021	20:00	8.600	20:00	5.600	20:00	8.800	20:00	6.700	20:00	3.500	20:00	2.500	20:00	4.100	20:00	2.400	16:00	1.600	20:00	1.500	18:00	0.004	17:00	0.002
17/01/2021	19:00	7.700	20:00	6.100	19:00	8.000	19:00	6.400	19:00	3.100	20:00	2.600	19:00	3.500	19:00	2.600	19:00	1.200	19:00	1.700	18:00	0.004	18:00	0.002
18/01/2021	20:00	8.900	20:00	6.200	20:00	9.000	20:00	6.900	20:00	3.700	20:00	2.500	20:00	3.900	20:00	2.900	19:00	1.100	20:00	1.600	18:00	0.004	17:00	0.002
19/01/2021	19:00	8.400	20:00	6.300	19:00	8.600	20:00	6.500	20:00	3.700	20:00	2.400	19:00	4.000	20:00	2.500	19:00	0.800	20:00	1.600	19:00	0.004	18:00	0.002
20/01/2021	20:00	7.300	6:00	4.800	20:00	7.400	7:00	4.500	20:00	3.400	20:00	2.200	20:00	2.700	6:00	2.100	18:00	1.200	20:00	1.500	18:00	0.004	17:00	0.002
21/01/2021	21:00	7.200	20:00	5.600	21:00	7.400	20:00	6.500	21:00	3.200	19:00	2.900	19:00	2.500	19:00	1.800	21:00	1.300	20:00	1.600	20:00	0.004	18:00	0.002
22/01/2021	20:00	7.600	21:00	4.600	20:00	7.700	1:00	5.100	20:00	3.600	1:00	2.400	20:00	2.800	21:00	1.300	17:00	1.600	20:00	1.500	18:00	0.004	6:00	0.002
23/01/2021	19:00	6.900	20:00	5.100	19:00	7.100	20:00	5.800	20:00	2.800	20:00	2.400	20:00	2.700	20:00	1.600	20:00	0.900	20:00	1.600	19:00	0.004	18:00	0.002
24/01/2021	20:00	7.400	20:00	5.100	20:00	7.400	20:00	5.600	20:00	3.400	19:00	2.500	19:00	2.700	20:00	1.400	18:00	1.300	20:00	1.600	18:00	0.004	17:00	0.002
25/01/2021	20:00	7.100	19:00	5.700	20:00	7.300	20:00	6.100	20:00	3.300	20:00	2.800	20:00	2.700	20:00	1.500	20:00	1.000	20:00	1.900	20:00	0.004	18:00	0.002
26/01/2021	20:00	7.500	20:00	4.800	20:00	7.500	19:00	5.400	20:00	3.500	19:00	2.400	19:00	2.700	19:00	1.400	18:00	1.200	20:00	1.700	18:00	0.004	17:00	0.002
27/01/2021	19:00	7.300	20:00	5.400	19:00	7.400	20:00	6.400	19:00	3.500	20:00	2.800	20:00	2.600	19:00	1.900	17:00	1.400	20:00	2.100	19:00	0.004	17:00	0.002
28/01/2021	19:00	7.100	20:00	5.700	19:00	7.200	20:00	6.600	19:00	3.200	19:00	3.100	20:00	2.600	19:00	1.900	18:00	1.500	19:00	1.600	19:00	0.004	17:00	0.002
29/01/2021	20:00	6.700	20:00	5.300	20:00	6.800	20:00	6.200	20:00	3.200	20:00	2.500	19:00	1.600	17:00	1.400	20:00	1.800	19:00	0.004	19:00	0.004	18:00	0.002
30/01/2021	19:00	7.000	20:00	5.500	20:00	7.000	20:00	6.000	19:00	3.200	19:00	2.200	20:00	2.700	20:00	1.500	19:00	1.200	20:00	1.600	18:00	0.004	17:00	0.002
31/01/2021	19:00	7.000	20:00	5.600	20:00	7.400	20:00	6.500	20:00	3.200	20:00	2.900	20:00	2.900	20:00	1.800	18:00	1.100	20:00	1.700	19:00	0.004	18:00	0.002

01/02/2021	19:00	7.400	19:00	4.900	19:00	7.400	19:00	5.300	19:00	3.300	20:00	2.300	19:00	2.900	19:00	1.600	11:00	1.400	20:00	1.600	18:00	0.004	17:00	0.002
02/02/2021	21:00	7.200	21:00	6.100	20:00	7.500	20:00	7.300	20:00	3.300	20:00	3.200	21:00	3.200	21:00	2.600	18:00	1.200	21:00	1.600	19:00	0.004	17:00	0.002
03/02/2021	20:00	8.100	19:00	5.600	20:00	8.300	20:00	7.400	20:00	3.500	20:00	2.900	20:00	3.600	20:00	2.900	18:00	1.400	19:00	1.900	19:00	0.004	17:00	0.002
04/02/2021	20:00	8.200	20:00	6.000	20:00	8.300	20:00	7.200	20:00	3.500	20:00	2.900	20:00	3.500	20:00	2.600	18:00	1.300	20:00	1.600	19:00	0.004	18:00	0.002
05/02/2021	20:00	7.600	20:00	6.500	20:00	7.800	20:00	7.200	20:00	3.400	20:00	2.900	20:00	3.300	20:00	2.800	17:00	1.400	20:00	1.700	18:00	0.004	17:00	0.002
06/02/2021	19:00	7.500	19:00	5.900	19:00	8.000	19:00	7.300	19:00	3.200	20:00	2.900	19:00	3.400	20:00	2.900	18:00	1.400	19:00	1.800	20:00	0.004	18:00	0.002
07/02/2021	20:00	7.200	20:00	5.600	20:00	7.300	20:00	6.300	20:00	3.300	20:00	2.800	20:00	2.900	20:00	1.600	17:00	1.300	20:00	1.700	18:00	0.004	17:00	0.002
08/02/2021	19:00	7.200	20:00	5.600	19:00	7.400	20:00	6.400	19:00	3.300	20:00	2.900	20:00	2.700	21:00	1.800	17:00	1.800	20:00	1.600	20:00	0.004	18:00	0.002
09/02/2021	19:00	7.300	20:00	5.600	19:00	7.600	20:00	6.500	20:00	3.300	20:00	2.800	20:00	2.700	20:00	1.800	20:00	1.400	20:00	2.100	20:00	0.004	17:00	0.002
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11/02/2021	20:00	7.600	20:00	5.400	20:00	7.600	20:00	5.800	20:00	3.700	20:00	2.600	20:00	2.800	20:00	1.600	18:00	1.300	20:00	1.600	18:00	0.004	17:00	0.002
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14/02/2021	19:00	7.400	21:00	5.600	19:00	6.900	19:00	6.500	19:00	2.900	19:00	2.800	20:00	2.800	19:00	2.800	18:00	1.300	20:00	1.800	19:00	0.004	17:00	0.002
15/02/2021	19:00	7.900	20:00	6.400	20:00	7.600	20:00	7.400	19:00	3.600	20:00	3.100	20:00	2.900	20:00	2.600	18:00	1.400	20:00	1.700	20:00	0.004	17:00	0.002
16/02/2021	20:00	7.800	20:00	6.000	20:00	7.900	20:00	7.300	20:00	3.400	20:00	3.000	20:00	3.000	20:00	2.600	18:00	1.100	20:00	1.600	20:00	0.004	17:00	0.002
17/02/2021	19:00	8.100	20:00	4.800	19:00	8.200	20:00	5.600	19:00	3.600	19:00	2.200	20:00	3.300	19:00	2.100	17:00	1.800	21:00	1.500	18:00	0.004	17:00	0.002
18/02/2021	20:00	7.800	20:00	6.000	20:00	8.000	20:00	7.000	19:00	3.700	20:00	2.800	20:00	3.200	20:00	2.400	17:00	1.500	21:00	1.700	19:00	0.004	18:00	0.002
19/02/2021	20:00	8.000	21:00	6.100	20:00	8.000	21:00	6.700	19:00	3.500	21:00	2.600	20:00	3.200	20:00	2.300	17:00	1.400	21:00	1.600	18:00	0.004	17:00	0.002
20/02/2021	19:00	7.500	20:00	6.400	19:00	7.700	20:00	7.600	19:00	3.200	20:00	3.100	20:00	3.100	20:00	2.600	19:00	1.100	20:00	1.600	19:00	0.004	17:00	0.002
21/02/2021	19:00	7.900	20:00	6.100	19:00	8.100	20:00	7.100	19:00	3.500	20:00	2.900	20:00	3.300	20:00	2.600	18:00	1.600	20:00	2.100	20:00	0.004	17:00	0.002
22/02/2021	20:00	7.800	20:00	6.400	19:00	7.900	20:00	7.400	20:00	3.600	20:00	2.800	19:00	3.100	19:00	2.700	18:00	1.500	21:00	1.700	19:00	0.004	18:00	0.002
23/02/2021	20:00	7.500	21:00	5.800	20:00	7.500	20:00	6.600	20:00	3.200	20:00	2.700	19:00	3.300	20:00	2.300	17:00	1.500	20:00	1.600	18:00	0.004	17:00	0.002
24/02/2021	19:00	7.500	20:00	6.100	19:00	7.900	20:00	7.300	20:00	3.400	20:00	2.800	20:00	3.100	20:00	2.700	18:00	1.500	20:00	1.600	19:00	0.004	18:00	0.002
25/02/2021	19:00	8.200	20:00	5.300	19:00	8.200	20:00	6.000	19:00	3.500	21:00	2.400	20:00	3.200	20:00	2.300	18:00	1.600	20:00	1.500	18:00	0.004	17:00	0.002
26/02/2021	20:00	7.400	20:00	5.700	20:00	7.500	20:00	6.600	19:00	3.600	20:00	2.700	19:00	3.000	20:00	2.300	17:00	1.300	20:00	1.600	20:00	0.004	18:00	0.002
27/02/2021	15:00	4.900	1:00	4.200	15:00	4.900	6:00	4.700	20:00	3.500	20:00	2.800	0:00	5.400	0:00	2.100	18:00	1.600	20:00	1.800	19:00	0.004	17:00	0.002
28/02/2021	19:00	8.100	20:00	5.900	19:00	8.200	20:00	7.000	19:00	3.500	20:00	2.800	6:00	5.300	11:00	3.800	18:00	1.800	20:00	1.900	18:00	0.004	18:00	0.002

01/03/2021	19:00	8.300	20:00	5.200	19:00	8.300	20:00	5.700	18:00	3.700	20:00	2.300	13:00	5.400	14:00	3.300	17:00	1.700	21:00	1.500	18:00	0.004	17:00	0.002
02/03/2021	19:00	8.500	20:00	6.800	19:00	8.600	20:00	7.900	18:00	3.600	20:00	3.200	19:00	3.200	20:00	2.700	17:00	2.000	20:00	2.100	18:00	0.004	18:00	0.002
03/03/2021	20:00	8.000	20:00	5.400	20:00	8.000	20:00	6.100	20:00	3.500	20:00	2.400	20:00	3.200	20:00	2.300	17:00	1.600	20:00	1.500	18:00	0.004	17:00	0.002
04/03/2021	19:00	8.400	20:00	6.500	19:00	8.600	20:00	7.500	19:00	3.700	20:00	3.000	20:00	3.100	19:00	2.800	21:00	1.400	20:00	1.600	18:00	0.004	18:00	0.002
05/03/2021	19:00	7.800	20:00	6.600	19:00	8.200	20:00	7.300	19:00	3.400	20:00	2.900	19:00	3.200	20:00	2.700	18:00	1.200	21:00	1.900	19:00	0.004	17:00	0.002
06/03/2021	19:00	5.400	19:00	4.200	19:00	5.700	19:00	4.800	23:00	2.200	23:00	2.300	20:00	3.000	20:00	2.700	19:00	1.800	21:00	1.900	18:00	0.004	18:00	0.002
07/03/2021	19:00	8.100	19:00	5.300	19:00	8.100	19:00	5.900	19:00	3.600	19:00	2.600	19:00	3.200	19:00	2.300	17:00	1.500	20:00	1.500	18:00	0.004	17:00	0.002
08/03/2021	19:00	8.600	20:00	6.300	19:00	8.700	20:00	7.500	19:00	3.700	20:00	3.000	20:00	3.100	20:00	2.700	17:00	1.400	20:00	1.600	19:00	0.004	18:00	0.002
09/03/2021	20:00	7.900	20:00	5.900	20:00	7.900	20:00	6.500	19:00	3.600	20:00	2.700	20:00	3.200	20:00	2.300	18:00	1.500	20:00	1.500	18:00	0.004	17:00	0.002
10/03/2021	19:00	8.500	20:00	6.500	19:00	8.700	20:00	6.900	19:00	3.500	20:00	2.800	19:00	3.300	20:00	2.600	19:00	1.900	21:00	1.800	19:00	0.004	17:00	0.002
11/03/2021	19:00	9.100	20:00	5.800	19:00	9.200	20:00	7.000	19:00	4.000	20:00	2.800	19:00	3.100	20:00	2.700	19:00	1.600	20:00	1.500	18:00	0.004	17:00	0.002
12/03/2021	19:00	7.700	20:00	5.200	19:00	7.900	20:00	6.700	19:00	3.400	20:00	2.700	19:00	2.900	19:00	2.500	18:00	1.500	20:00	1.700	18:00	0.004	17:00	0.002
13/03/2021	19:00	8.400	20:00	5.200	19:00	8.400	20:00	5.800	19:00	3.800	20:00	2.500	20:00	3.100	20:00	2.200	18:00	1.500	20:00	1.400	18:00	0.010	17:00	0.003
14/03/2021	19:00	7.500	20:00	5.800	19:00	7.600	19:00	5.900	20:00	3.500	20:00	2.700	20:00	2.900	20:00	2.600	19:00	1.700	21:00	1.900	19:00	0.010	18:00	0.003
15/03/2021	19:00	8.300	20:00	5.200	19:00	8.300	20:00	5.900	18:00	3.800	20:00	2.500	20:00	3.200	20:00	2.100	13:00	1.600	19:00	1.600	19:00	0.010	7:00	0.003
16/03/2021	19:00	8.000	20:00	6.700	19:00	8.000	20:00	7.500	19:00	3.600	20:00	3.000	19:00	3.200	20:00	2.500	17:00	1.500	20:00	2.200	19:00	0.010	18:00	0.003
17/03/2021	19:00	7.600	20:00	6.500	20:00	7.800	20:00	7.600	19:00	3.500	20:00	3.000	20:00	3.100	20:00	2.600	17:00	1.500	20:00	1.600	19:00	0.010	18:00	0.003
18/03/2021	19:00	7.400	20:00	5.500	19:00	7.700	20:00	6.500	19:00	3.500	20:00	3.000	20:00	2.700	20:00	1.800	20:00	1.300	20:00	2.000	18:00	0.010	17:00	0.003
19/03/2021	17:00	7.600	20:00	4.000	17:00	7.600	20:00	4.600	20:00	3.500	20:00	2.100	19:00	2.800	19:00	1.300	12:00	2.000	20:00	1.400	18:00	0.010	17:00	0.003
20/03/2021	19:00	8.700	20:00	5.700	19:00	8.900	20:00	6.900	19:00	3.600	20:00	2.700	19:00	3.700	20:00	2.100	17:00	1.200	20:00	1.400	18:00	0.010	18:00	0.003
21/03/2021	19:00	8.000	20:00	5.400	19:00	8.200	20:00	6.100	19:00	3.600	19:00	2.500	19:00	3.300	19:00	2.000	19:00	1.300	20:00	1.500	18:00	0.010	6:00	0.003
22/03/2021	19:00	8.600	20:00	5.800	19:00	8.700	20:00	6.900	19:00	3.800	20:00	2.800	19:00	3.300	20:00	2.300	19:00	1.200	20:00	1.600	19:00	0.010	18:00	0.003
23/03/2021	19:00	7.700	20:00	6.700	19:00	8.000	20:00	7.100	19:00	3.600	22:00	3.000	19:00	2.900	19:00	2.700	16:00	1.400	20:00	1.800	19:00	0.010	18:00	0.003
24/03/2021	19:00	8.000	20:00	5.600	19:00	8.200	19:00	6.300	19:00	3.500	20:00	2.700	19:00	3.100	20:00	2.500	19:00	1.700	20:00	1.800	18:00	0.010	17:00	0.003
25/03/2021	19:00	8.400	19:00	4.400	19:00	8.400	19:00	5.100	19:00	3.500	19:00	2.300	19:00	3.300	19:00	1.900	17:00	1.600	20:00	1.500	18:00	0.010	6:00	0.003
26/03/2021	16:00	7.400	20:00	5.700	16:00	7.700	20:00	6.800	20:00	3.300	19:00	2.900	20:00	3.000	19:00	2.500	18:00	1.600	20:00	1.500	19:00	0.010	18:00	0.003
27/03/2021	19:00	7.500	20:00	4.600	19:00	7.500	20:00	5.100	19:00	3.500	20:00	2.400	19:00	2.900	20:00	1.300	16:00	1.300	20:00	1.500	18:00	0.010	17:00	0.003
28/03/2021	19:00	7.600	20:00	5.400	19:00	7.900	20:00	6.200	18:00	3.300	19:00	3.100	19:00	2.700	19:00	1.800	17:00	1.300	20:00	1.500	19:00	0.010	17:00	0.003
29/03/2021	20:00	7.100	20:00	5.800	16:00	7.400	20:00	6.000	20:00	3.300	19:00	2.900	20:00	3.000	20:00	1.800	16:00	1.700	19:00	1.700	19:00	0.010	18:00	0.003
30/03/2021	18:00	7.100	20:00	5.400	20:00	7.200	20:00	6.200	20:00	3.300	20:00	3.100	20:00	3.000	20:00	2.100	18:00	1.400	20:00	1.800	19:00	0.010	18:00	0.003
31/03/2021	19:00	7.600	19:00	4.800	19:00	7.600	19:00	5.300	19:00	3.500	19:00	2.600	19:00	2.800	20:00	1.500	17:00	1.500	19:00	1.700	18:00	0.010	6:00	0.003

## **CHAPTER 4: RESULT AND DISCUSSION**

The model is designed and simulated in Electrical Transient and Analysis Program (ETAP) to determine different reliability indices of Kigoma substation that can be used to for distribution planning, monitoring and evaluation. The figure 10 shows the model to be simulated and the results are taken at the load points. The reliability indices of the test system models were calculated and compared with reliability indices of IEEE standard.



Table 3 Load point output report

Bus ID	Average interrupting rate f/yr	Average duration autage(hr)	Annual outage duration hr/yr
TB3	7.697989	23.84255	183.5397
TB15	6.955489	23.775	165.3667
TB16	6.955489	23.775	165.3667
TB17	6.955489	23.775	165.3667
TB21	7.449988	23.89852	178.0437
TB22	7.449988	23.89852	178.0437
TB23	7.449988	23.89852	178.0437
TB36	7.437989	23.8021	177.0397
TB37	7.437989	23.8021	177.0397
TB38	7.537989	23.81799	179.5397
TB39	7.537989	23.81799	179.5397
TB40	7.537989	23.81799	179.5397
TB41	7.437989	23.8021	177.0397
TB117	7.63799	23.83346	182.0397
TB118	7.63799	23.83346	182.0397
TB119	7.63799	23.83346	182.0397
TB120	7.697989	23.84255	183.5397
TB121	7.697989	23.84255	183.5397
TB122	7.697989	23.84255	183.5397
TB123	6.83799	23.69699	162.0397
TB124	6.83799	23.69699	162.0397
TB125	6.83799	23.69699	162.0397
TB126	6.95799	23.71946	165.0397
TB127	6.95799	23.71946	165.0397

TB128	6.95799	23.71946	165.0397
TB129	7.43399	23.80145	176.9397
TB130	7.43399	23.80145	176.9397
TB131	7.43399	23.80145	176.9397
TB159	6.877989	23.70457	163.0397
TB160	6.877989	23.70457	163.0397
TB161	6.877989	23.70457	163.0397
TB162	6.93399	23.71503	164.4397
TB163	6.93399	23.71503	164.4397
TB164	6.93399	23.71503	164.4397

The average number of interruptions and length of outages for each bus are shown in Table 3 as a measure of the studied system's dependability. For each feeder, it can be seen that the average duration of the interruption increases for the bus that is furthest from the source of power, while it decreases significantly for the bus that is closest to it, known as the slack bus (KIGOMA S/S). For each bus, the length of the outages has gotten longer the further away it is from the power source. The reliability values from table 3 can be represented graphically, and figures 11 and 12 show the average amount of interruption and outage duration.

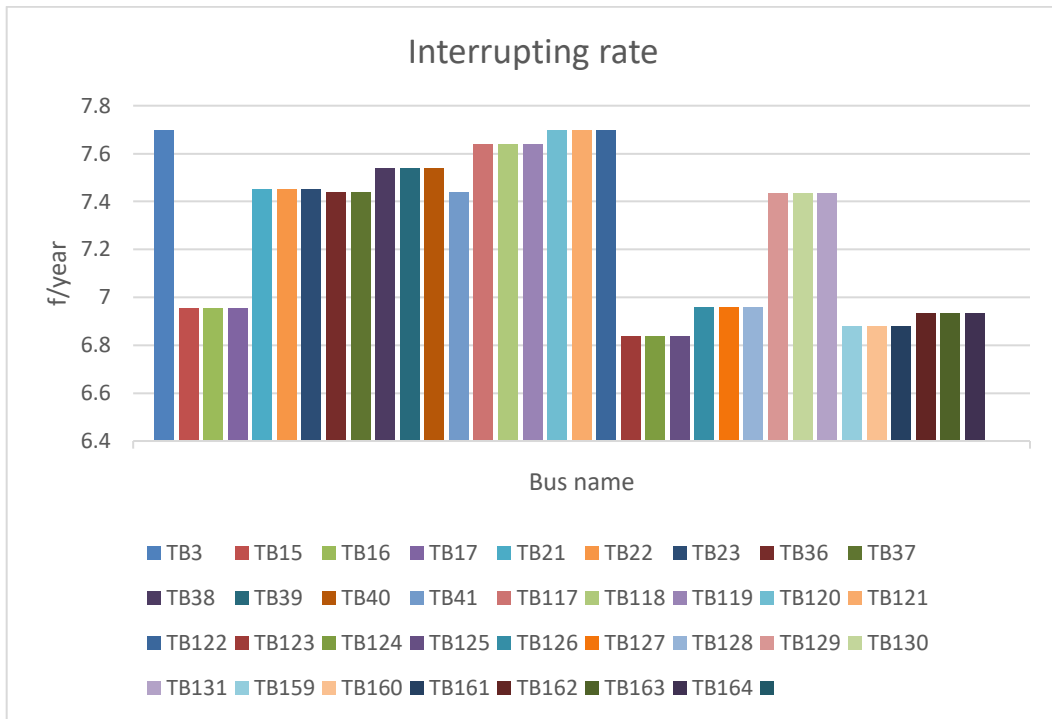


Figure 11 Average interrupting rate

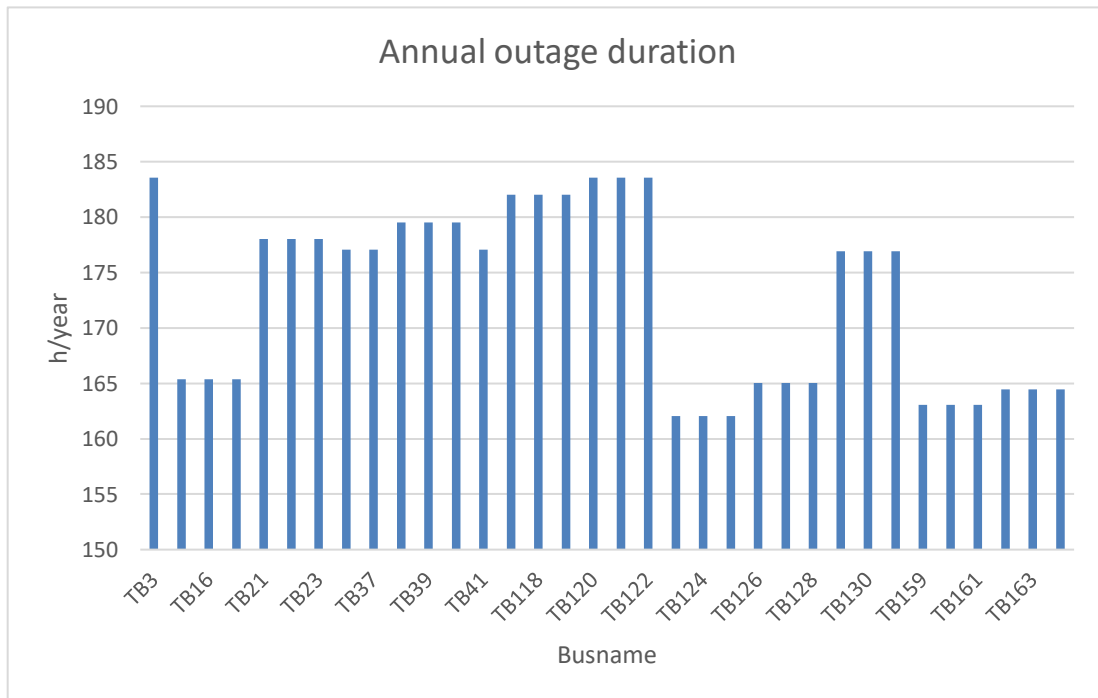


Figure 12 Annual outage duration

The results of reliability indices calculations for the modelled system with ETAP software can be shown in table 4. They show that the SAIFI index value of 7.2459 f / customer is higher than the IEEE standard std1366-2000 which is 1.45 f / customer. The SAIDI and CAIDI index values from table 4 are 172.3119 hour / customer. year and 23.781 hour / customer interruption respectively, these values exceed the IEEE standard std1366- 2000, respectively 2.3 hour / customer. year and 1.58 hour / customer interruption.

*Table 4 System reliability indices*

Type	Index value
ACCI	302.56
AENS	5.66645
ALII	7.19
ASAI	0.9803
ASUI	0.01967
CAIDI	23.781
CTAIDI	172.312
ECOST	0
EENS	260.569
IEAR	0
SAIDI	172.3119
SAIFI	7.2459

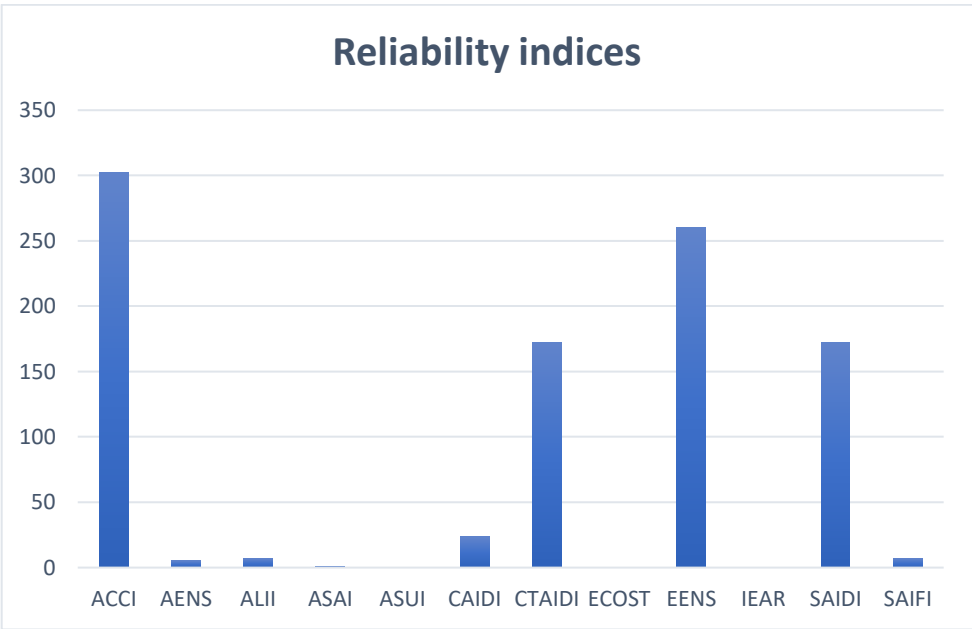


Figure 13 System reliability indices

## **CHAPTER 5: Conclusion and recommendations**

### **5.1 CONCLUSION**

The reliability of distribution network for medium voltage system is assessed through reliability indices such as SAIDI, SAIFI, CAIDI among others. The simulation of the results was conducted on KIGOMA substation alongside its three feeders namely NTONGWE, BUTARE and GATUMBA, and auxiliary via ETAP software.

The results show that the system is less reliable compared to the IEE standards and the most important cause of small reliability is concerned with distribution system connection as it is radially connected and the lack of distributed generation (DG) integration along feeders' travel even though the ageing of distribution infrastructures as well as their length and loadability can to the poor reliability of the system.

The reliability indicators such as average interrupting rate, average outage duration and annual outage duration at all loading busses have been studied and the results showed that their values are least at the slack bus and go by increasing towards the busses far away from the substation.

### **5.2. RECOMMENDATIONS**

The results shown indicates poor reliability in studied distribution system, hence mitigation procedures have to be taken by energy utility and regulators in order to improve the system reliability which in turn fast track the economic development of the country through attractiveness of investors and sustainability of beneficiaries' activities.

The reliability improvement should be achieved by integrating DGs near the load centers at specific locations and/ or shifting from radial system of connection to ring main and interconnected distribution system structures. Further researchers may contribute in the determination of proper size and appropriate locations of DGs required in distribution system reliability improvement.

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