Addis Ababa University

Addis Ababa Institute of Technology

African Railway Center of Excellence

Study on Improvement of the Existing Power Reliability of Addis Ababa Light Railway Transit

Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfilment of the Requirements for the Degree of Masters of Science in Railway Engineering (Traction and Train Control Engineering)

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Approval

The undernamed have assessed the thesis entitled '**Study on Improvement of the Existing Power Reliability Problem of Addis Ababa Light Railway Transit**' presented by **Eleni Sisay**, a candidate for the degree of **Master of Science in Railway Engineering (Traction and Train Control)** and hereby certify that it is worthy of acceptance.

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Chairperson	Signature	Date

Undertaking

I confirm that the study and Improve Existing Power Reliability Problem of Addis Ababa Light Railway is entirely my original work. The work hasn't been submitted for evaluation elsewhere else. When content has been taken from outside sources, due credit has been given.

Name: Eleni Sisay

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Place: Addis Ababa

Date of submission: ______________________

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

Dr.-Ing Getachew Biru

Advisor's Name ______________________ Signature

Abstract

The DC Railway Traction Power Supply System is a widely used technology around the world, particularly in urban and inter-urban regions. The system operates on standard DC traction voltages of 750 V, 1500 V, and 3000 V, which require less electrical clearance than the AC Railway Traction Power Supply System catenary. However, power interruptions can have a significant impact on the system. In the case of AALRT, frequent power interruptions led to thousands of passengers being evacuated from subway cars and stranded at stations.

This tesis analyses the reliability of the Addis Ababa Light Rail Transit (AALRT) Traction Power Supply System (TPSS) using interruption data collected from AALRT, Ethiopian Electric Power (EEP), and Ethiopian Electric Utility (EEU). The data includes the number of customers interrupted, number of trips cancelled due to power interruption, daily number of customers served, daily customer interruption duration, number of times the power interruption occurred, number of passenger flow in both lines, and number of passengers interrupted. The causes of power interruption from EEP and EEU sides and duration of power interruption from incoming line 132/15kV are also included. Then, reliability indices are calculated and analysis results indicate that the highest mean time between failures (MTBF) was 2688.98 hours on the East-West (EW) line in 2019 G.C. and 4705 hours on the North-South (NS) line in 2020 G.C from the collected data. The highest duration of power interruption recorded was 804.47 hours on NS in 2019 G.C, and the highest frequency of power interruption recorded was 154 interruption/year on NS in 2020 G.C.

In this thesis, two power reliability improvement technologies, substation reconfiguration and distributed generation, were analysed. The thesis was modelled in Matlab Simulink and the results were compared and best reliability mitigation techniques were identified. Substation reconfiguration by using redundant line has been found the best alternative for improving the power reliability for AALRT. As per the model developed, system average interruption frequency index and system average interruption duration index of 10.0490 interruptions/year and 24.0280 hr/customer/year, respectively have been achieved. This method is optimal in terms its applicability and cost.

Key words: Power reliability, power reliability indices, Power reliability mitigation, DG system, Automatic recloser, DC railway traction supply system.

Acknowledgement

I want to start by giving thanks to Almighty God for His support throughout my life and for allowing me to finish my post-graduate studies, which has allowed me to advance in my academic career. Additionally, I would like to sincerely thank Dr. Eng. Getachew Biru, my adviser, for his invaluable guidance, supervision, and professional advice during the time I was working on my thesis. I am appreciative that the Africa Railway Center of Excellence, Addis Ababa University, and Addis Ababa Institute of Technology (AAiT) gave me the chance to advance my academic standing.

Last but not least, I want to thank my parents for helping me become the best version of myself through their amazing support. Their guidance and support have aided in my growth as a self-assured individual who can confidently face challenging circumstances. Additionally, this work is dedicated to them. Additionally, I would like to express my gratitude to my post-graduate peers for their invaluable assistance and contributions—both direct and indirect—that have played a significant role in my achievement.

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Acronyms and Abbreviations

AALRT……………………..Addis Ababa Light Rail Transit

AIS……………………….Air Insulated substation

ASAI……………………. Average Service Availability Index

ASUI……………………. Average Service Unavailability Index

CAIDI ………………….... Customer Average Interruption Duration Index

DA……………………….Distribution Automation

DG………………………..Distribution Generation

EEP………………………Ethiopian Electric Power

EEU……………………...Ethiopian Electric Utility

ETAP…………………… Electrical Transient Analyser Program Software

FDIR……………………. Fault Detection, Identification and Recovery

GIS………………………Gas Insulated substation

IEEE……………………..Institute of Electrical and Electronics Engineers

IGBT…………………......Insulated Gate Bipolar Transistors

LRT ……………………...Light Rail Transit

MAIFI ……………….…..Momentary Average Interruption Frequency Index.

MTBF…………………….Mean Time Between Failures

MTTF…………………….Mean Time To Failures

MTTR……………………Mean Time to Repair

OCC……………………...Operation Control Center

SAIDI…………………….System Average Interruption Duration Index

SAIFI……………………..System Average Interruption Frequency Index

SCADA…………………..Supervisory control and data acquisition

TBF………………………Time Between Failures

THD ………………………Total Harmonic Distortion

TPLS………………………Traction power line system

TPSS …………………….. Traction Power Supply System

Symbols

CB : Circuit Breaker

CT : Current Transformer

DS : Disconnecter

EW : East west line

NS : North south

S_T : Transformer capacity

U_k : Short circuit transformer capacity

U_{2N} : Low voltage side

Λ : Failure rate

Chapter one

1.Introduction

1.1.Background

Light rail transit is a contemporary, pleasant, eco-friendly, accessible, punctual, expeditious, and secure transportation mode. It is a system of electrically powered light rail trains that run on a track in a dedicated right-of-way, designed to provide fast, dependable, and safe transportation services.

Power reliability is the extent to which the components of a large-scale system deliver electricity to trains in the required amount and within acceptable standards. The reliability level can be assessed by examining the frequency, duration, and magnitude of negative effects on the electric supply. There are several indices used to measure reliability, including SAFI, SAIDI, MTBF, MTTF, MTTR, ASAI, and ASUI [1].

The Addis Ababa Light Rail Transit (AALRT) comprises two lines: the first one runs from Ayat to Torhailoch (EW line), while the second one runs from Kality to Menelik II Square (NS line). The total length of the system is 31.05 kilometers, with a common section from Stadium to St.Lideta stations that stretches 2.662 km and covers five passenger stations. The service has 39 passenger stations, of which nine are elevated, two are semi-underground, and one is underground. Escalators and lifts have been installed at some of the stations for those in need. There are two depots for maintenance purposes, one at Kality (10 hectares) and the other at Ayat (7.2 hectares). Currently, there are 41 trains available for operation, marked with different colors to help passengers identify them easily. Trains with green and white paint provide service from east to west, while trains with blue and white paint run from north to south. The trains are powered by electricity generated from hydropower, making the service environmentally friendly. There are 39 ticket offices available near the passenger stations. This kind of service is the first of its kind in sub-Saharan countries.

The power system of the Addis Ababa Light Rail Transit (AALRT) is supplied by Ethiopia Electric Power from four gas-insulated substations, each with two step-down transformers (132/15 kV, 500 MVA) [1].The East-West line is powered by EW22 and AYAT electric power substations, which support each other similarly, while the north and south are powered by NS27 and Kality electric power substations. These four electric power substations supply nineteen traction power step-down hybrid substations and one step-down substation (EW 18) to supply communication and signalling equipment. There is a traction step-down substation at an interval of 3 to 4 passenger stations on the light rail.

Traction step-down hybrid substations feature a mixed step-down function, i.e., voltage level step-down for traction, signalling and communication, and auxiliary use. Each traction step-down hybrid substation is fitted with a rectifier transformer (three-winding dry-type, 15 kV, 590 volts) and another transformer (15 kV, 400 volts) fed by the same section of the bus. The 590 VAC at the secondary of the rectifier transformer is converted to 750V DC by means of a 12-pulse diode rectifier, and this is what energizes the catenary. The other step-down transformer energizes the communication and signalling equipment as well as the lighting system in and around the substation. It also supports depot offices at Kality and Ayat.

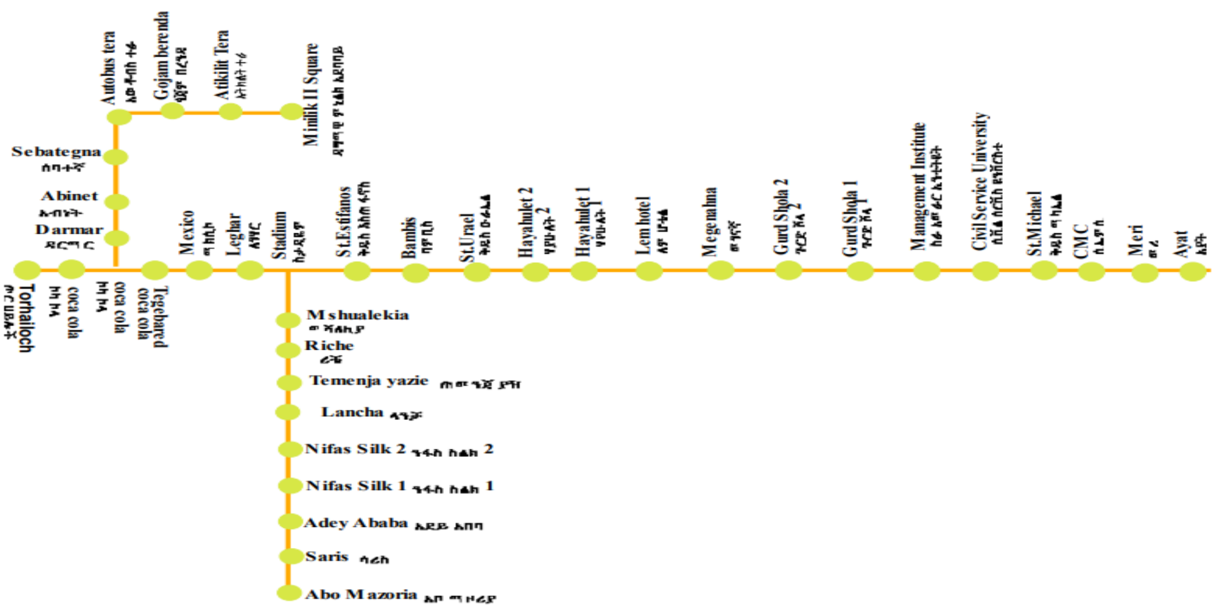


Figure 1. 1. The diagram of the track layout for the East-West Line and North-South Line

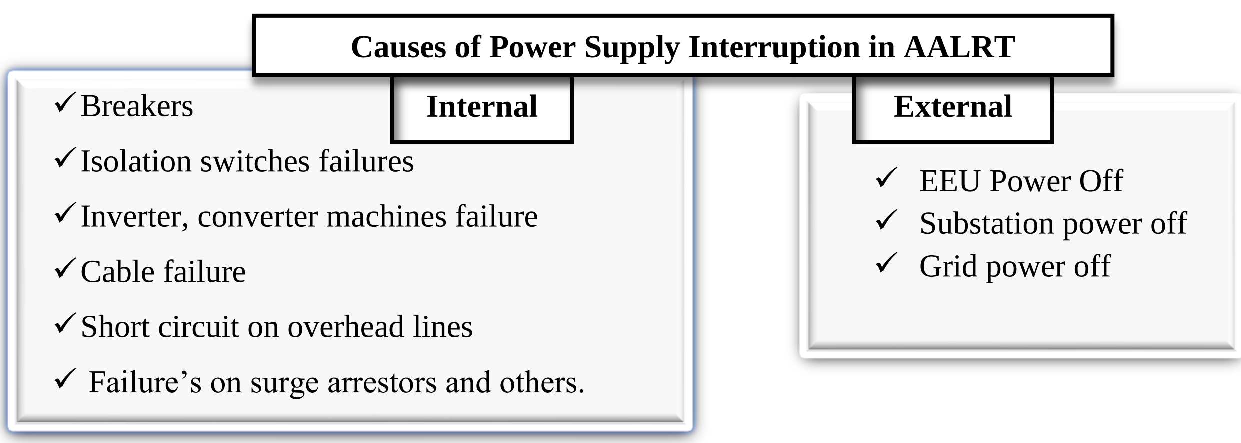


Figure 1. 2.Classification of power supply interruption in AALRT from OCC recorded data.

1.2.Problem Statement

Railway transportation is becoming the most important mode of transportation for the world's working societies. Rail transport may be limited or halted due to electrification of rail transit routes[2]. In AALRT, due to frequent power interruptions, thousands of passengers had to be evacuated from subway cars, and passenger trains were stranded at stations of AALRT there is congestion and long waiting times, which reduce customer satisfaction. The longer the power outage, the more severe impact it has on passengers [3]. Thus, this thesis focuses on evaluating this critical problem and studying possible methods for improving the power reliability of AALRT.

1.3. Objective

1.3.1.General Objective

The general objective of thesis is to analyse the power reliability problems of Addis Ababa Light Rail Transit and propose a possible mitigation mechanism.

1.3.2.Specific Objectives

The specific objectives of this thesis are:

- Study the level of power reliability problems of AALRT and perform a comparison of the power reliability indices with international standard.
- Investigation of technologies that are applicable to overcome the power reliability issue in the railway power supply system.
- Select the best technology for power reliability improvement.
- Model the appropriate technique with the supply system to evaluate the power reliability improvements.

1.4.Research Questions

Introduction: The thesis is planning to address or answer the following research questions.

- What is the current power reliability level of the Addis Ababa Light Rail Transit?
- What are the major causes and effects for power reliability problem in AALRT?
- What are the different technologies used to mitigate power reliability in railway power supply system?
- Which one is the best technique and technology for power reliability improvement for AALRT?

1.5.Significance of the Research

The major significances of this thesis work include:

Informing the Corporation and the public about the current power reliability problems of the railway line and on ways of reducing equipment failure or malfunctioning and helping to inform the AALRT on the causes of power system disturbances and how to mitigate them.Providing knowledge-based information on how a safe, efficient, reliable, and sustainable railway system is secured. This thesis directly or indirectly benefits the following members of society:

- The researcher (student) who can gain knowledge in this area.
- Passengers who can possibly get better service due to the later impact of the research.
- Ethiopian Railway Corporation (ERC).
- The Government of Ethiopia.

1.6.Scope

The study gathered and assessed pertinent data on power reliability from the Ethiopian Electric Power (EEP), Ethiopian Electric Utility (EEU), and Addis Ababa Light Rail Transit (AALRT) Kality substations. It calculated reliability levels by analyzing the primary causes and consequences of power reliability problems. The study took into account the failure data for power outages as reported in the maintenance intervention database from 2018 to 2021. Based on this analysis, it recommended appropriate technologies and methods to address the current power reliability issue of Addis Ababa Light Rail Transit. Finally, the study displayed its findings in Matlab Simulink.

1.7. Methodology

Literature Review and Theoretical Background :This section of the study investigated the reliability problems of the Addis Ababa Light Rail Transit. Recent and unpublished historical outage data related to power reliability was collected from the Kality substation of the Addis Ababa Light Rail Transit (AALRT) and Ethiopian Electric Utility (EEU). Interviews were conducted with a variety of professional workers at the AALRT and Kality substations.

With an emphasis on power system reliability, this thesis work offers a scientific foundation in the topic of reliability. Power supply system dependability indices and criteria for power outages and interruptions are presented in this work.

Data Collection and Analysis: Throughout a period of four years (2018, 2019, 2020, and 2021) the daily reports from the AALRT Operations Control Center provided the data used in this thesis. Processing, analysis, and sorting of this data were done to find critical reliability elements such failure mode, failure reason, and outage/downtime.

Reliability Assessment, Modeling and Simulation: The process of assessing reliability involves calculating fundamental reliability indices and evaluating the reasons for traction power outages. In order to reduce the causes of power supply disruptions, reliability improvement options are simulated by incorporating them into the current traction power supply system.

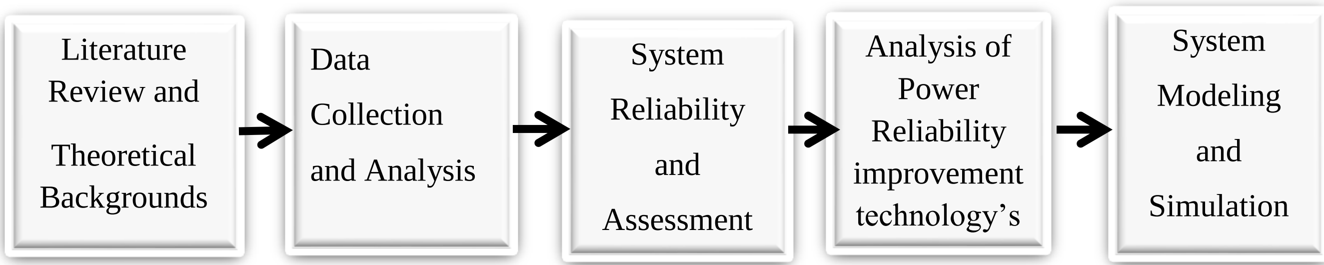


Figure 1. 3.Research methodology diagram

1.8.Thesis Layout

There are five chapters in the thesis, which are outlined below.

Chapter One: gives an overview of the study's background, objectives, research question, problem statements, significance, methods, and scope. It also includes an outline of the thesis.

Chapter Two: examines the theoretical frameworks of reliability, reliability analysis, protection systems, and literature review.

Chapter Three: interruption data from AALRT Kality substations, EEP and EEU are collected and analysis then reliability indices are calculated and analysis of different mitigation alternatives have been presented in.

Chapter Four: Simulation studies, system modeling of different mitigation.

Chapter Five: discusses conclusions and future work of the thesis.

Chapter Two

2. Theoretical Background and Literature Review

2.1. Theoretical Background

One of the biggest users of electricity is electric traction, which means that power must come from two separate sources. The traction units are driven by a sizable portion of the energy that is sent from the power system to a traction substation once it has been converted to DC. The equipment that is powered by the track-side power supply is impacted by the disruptions that propagate through it. Given that train traffic management equipment is powered by the track-side power source, this is very crucial. Reliability of the power supply is a critical issue for all modes of transportation, but particularly for rail[4].Trains are rendered absolutely immobile when there is no electricity supply.The effects on passengers are more severe the longer the power outage lasts[3].

2.1.1 Reliability Definition

The possibility that an item can carry out the necessary function for a particular amount of time under specific conditions is known as reliability[5]. Two fundamental components of power system reliability are system security and system adequacy[6]. Security is the system's dynamic reaction to disruptions (such faults), whereas adequacy is the system's capacity in relation to energy demand[1]. The number of customers, the connected load, the quantity of power (kVA) interrupted, and the duration of the interruption measured in seconds, minutes, hours, or days are among the factors that reliability indices generally take into account[6]. When a component operates within its useful life and has a constant failure rate, its reliability can be stated as follows:

$$R(t)=e^{-\lambda t} \quad (1)$$

$$\lambda = \frac{Number\ of\ times\ that\ the\ failure\ occured}{Number\ of\ unit\text{-}hours\ of\ operation} \quad (2)$$

When t is the time, R(t) is the possibility that the system will still function properly at time t, and λ is its constant failure rate.

A real number between 0 and 1 is reliability; that is, at any given time, $0 \le R(t) < 1$[7].

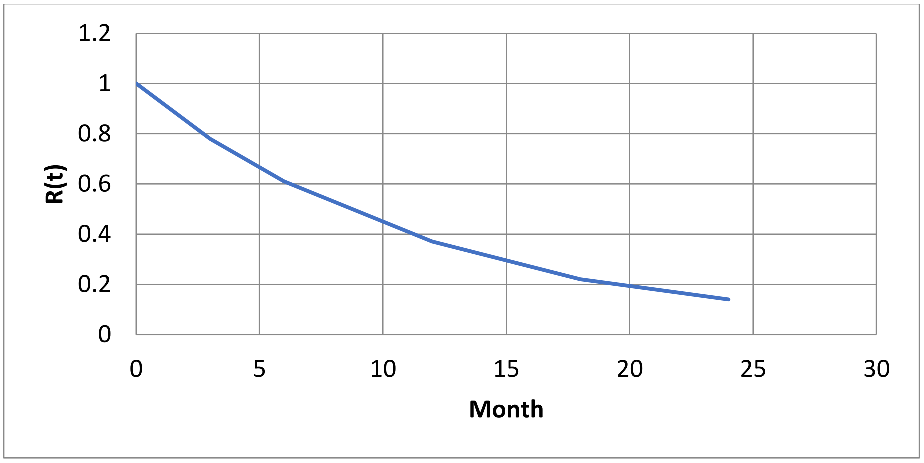


Figure 2. 1.Typical Reliability function

2.1.2 Indices Used for Power Reliability Analysis

There are many indices for evaluating power reliability of AALRT. The most common indices used in railway power system reliability analysis are MTBF, ASAI, ASUI,MTTF MTTR[8].

ASAI: Average System Availability Index,This index represents the fraction of time (often in percentage) that a train has power provided during one year or defined reporting period.

$$\mathrm{ASAI} = \frac{\text{Customer hours of available service}}{\text{Customer hours of Demand}} \quad (3)$$

ASUI: Average System Unavailability Index, This index is the complementary value to the average service availability index.

$$\mathrm{ASUI} = \frac{\text{Customer hours of unavailable service}}{\text{Customer hours of Demand}} \quad (4)$$

SAIFI : system average intruption frequency indices, is a measure of how many sustained interruptions an average customer experienced .

$$\mathrm{SAIFI} = \frac{\text{Total number of customer's interruption}}{\text{Total number of customer served}} \quad (5)$$

SAIDI: system average intruption duration indices to provide information as to the average time the customers are interrupted.

$$\mathrm{SAIDI} = \frac{\text{Total customer's interruption durations}}{\text{Total number of customer served}} \quad (6)$$

Availability (A): This represents the possibility that a given object will be usable or applied when required.Given that the component was good at time zero, it is the likelihood that it will be normal at any given time.

Unavailability (U): is the probability that a component will become unavailable at any given moment t and be unable to function.The following equation illustrates how availability and unavailability are related, based on the definition of each term:

$$u = 1 - A \qquad (7)$$

Failure Frequency (f): The amount of failures that could occur during a certain period of time. Failures per year is the dimension of failure frequency in this study.

Mean Time to Failure (MTTF): The average amount of time, calculated from t=0, that passes before a system or component fails.This is the total number of failures divided by the operating time of the specified components.

Mean Time to Repair (MTTR): A measurement in hours that represents the average amount of time needed to locate and fix a fault[9].

Mean Time between Failures (MTBF): is the arithmetic mean of the intervals between failures and is used as a reliability metric for repairable systems.

$$MTBF = \frac{1}{\lambda} \qquad (8)$$

2.2 Causes and Effects of Power Interruptions

There are diferrent causes for power interruption which are short circuit fault, earth fault,ground fault and black out then the causes of this power interruption are discussed below.

- **Short Circuits**

An electrical circuit that has no or very little electrical impedance and permits current to flow in an unforeseen direction is known as a short circuit. As a result, the circuit has an excessive current flowing through it, which increases the risk of explosion, fire, and circuit damage. Breakdowns in the insulation of the used wiring can result in short circuits. It may also happen as a result of an unintentional introduction of an external conducting material (like water) into the circuit. Table 2.1 illustrates traction substation short circuit analysis[10].

Table 2. 1 The power network analysis of short circuit in the traction supply system

Power Network Characteristics	
Network Topology	Single-side fed contact line Length of the line : 1.500m Length of the segment : 60m
Substation	Power rating :800kVA Rated DC voltage :750V Vcc % Transformer:5%
Contact line	Positive feeder section : $300mm^2$ Negative feeder section : $300mm^2$ Positive conductor section : $334mm^2$ Negative conductor section : $2692\ mm^2$
Fault characteristics	Fault impedance : 0Ω Maximum temperature : $0℃ - 65℃$

- **Ground Fault**

An accidental conduit for stray electrical current to travel directly to the earth (to the ground) is known as a ground fault. A malfunction or contact between the live conductors and the ground/neutral point may cause this to happen. One phase to ground (L-G), one or more phases to ground (LLG), or LLLG may have a defect.

- **Reason for Ground Fault:**

The failure of insulation (loss of dielectric property), physical damage to subterranean cables, water seeping into cable trenches, overloading of cables due to conductors that may break and fall into the ground point, and natural disturbances like falling trees in the conductor, water flowing on the insulator, and living things touching the live wire and ground point are some of the causes of ground faults.

The ground fault may occur in three ways:

- Single-Line-to-Ground Fault (L-G fault): A single live phase reaches the ground in an L-G fault. The fault current travels to the ground from the live phase. The fault current is supplied by the other two healthy phases.

- Double-line-to-Ground Fault (L-L-G fault): Fault current flows from two phases to the ground when two live phases come into contact with the earth. The fault current is supplied by the third healthy phase.
- Triple Line-to-Ground Fault (L-L-L-G Fault): This type of fault arises when three live conductors come into contact with the earth.

- **Blackouts**

The most extreme type of power outage is referred to as a blackout, which is the total absence of power in a certain area. Restoring power can frequently be a difficult process for utilities and power plants, with repair times varying widely depending on the layout of the damaged electrical network and the underlying reason of the blackout.

- **Power Surges**

Voltage spikes on the power system caused by lighting or switching are known as power surges. Rapid overheating, insulation failure, and the loss of pricey and essential equipment can all result from a power surge. Thankfully, surge protectors and circuit breakers offer protection against these kinds of surges.

- **Over current**

An electrical circuit is said to be over current when the normal load current is exceeded or when the electric current's intensity exceeds a predetermined level. Several factors can contribute to over current, such as an arc fault (ground fault), short circuits, excessive load, and poor design.The main purpose of fuses, circuit breakers, and current limiters in a circuit is to safeguard people and property against potentially harmful excessive currents.

Power interruption types according to duration

Depending on how long the interruption lasts, there are many kinds of interruptions to electricity, which are covered in the sections below.

Permanent Interruption are those that require the repair team's attention. Damaged cables, insulators failing, transformer failure, etc. might all lead to a permanent outage.In order to restore service, it fixes broken or burned-down conductors, blown fuses, or any other damaged equipment, clears tree limbs from the line, and manually closes circuit breakers or reclosers[11]. This supply outage to the traction supply, which often lasts for many hours but occasionally for days. If a temporary issue is not fixed right away, it may result in a permanent disruption.

Temporary Interruption: This is typically classified as a few-hour-long disruption. It is usually less in duration than a sustained interruption and higher than a momentary interruption. Usually, an operator must manually restart the system after this disruption. Because of this, the length of time is typically dictated by the operator's unavailability to complete the switching action right away. It is anticipated that this disruption will pass in less than two hours. Short-term and long-term disruptions may arise from lightning strikes, two conductors coming into touch in a wind, etc. and eliminated by a long enough service disruption to put out the power arc. In order to prevent the transient fault from becoming permanent, the breaker speed, relay settings, and re closer characteristics are chosen in a way that interrupts the fault current before a series fuse (i.e., the nearest source-side fuse) blows[11].

Momentary Interruption : Usually, an operator must manually restart the system after this disruption. In this instance, the customer's utility supply of electricity is interrupted for a few of minutes or less. Per IEEE 1366-2003 standard, a client is considered to have suffered a brief interruption if the power supply is interrupted and restored within five minutes. This interruption is caused by the activation of a circuit breaker or re-closer, which briefly opens the circuit to remove faults and then closes it again. Interruptions of brief duration can occasionally cause voltage dips and impact the quality of power.

Planned Interruption : This is what happens when a component is purposefully pulled out of service to perform construction or maintenance. Usually, a planned outage is accompanied by this disruption. Usually, it is scheduled, and the clients are informed of the operation's loss[12].

2.3.Reliability Improvement technologies

2.3.1.Distribution Generation(DG)

In order to prevent power interruptions at traction substations, distributed generation, sometimes referred to as embedded generation or dispersed generation, is essential to the future of energy. Small-scale generating linked to the grid at traction supply voltage is referred to as distributed generation (DG). The two types of DG energy resources are renewable (non-conventional) and non-renewable (conventional). Renewable energy-based technologies include wind turbines, geothermal systems, and photovoltaic modules. Heat engines, fuel cells, and cogeneration facilities employ non-conventional resource-based technology[13]. A DG connected to the distribution feeder can improve the power system's ability to sustain voltage and reactive power, reduce losses, and increase reliability. DG might, however, also negatively affect the power system, resulting in voltage instability, frequency variations, and spikes and dips[14].

- **Equipment used for solar system**

Photovoltaic cells, another name for solar cells, are devices that use light energy to generate electricity. The photovoltaic effect, which is comparable to the photoelectric effect, provides the basis for how solar cells operate. The distinction is that in photovoltaic cells, the electrons are retained in the material around the surface rather than being released, which results in a voltage differential. For the most part, crystalline silicon is the material utilized to make solar cells.

A solar panel or PV array is made up of many photovoltaic cells arranged in a way that uses photons to excite the electrons in the substance that makes up the solar cells. The sun's position affects how much sunlight solar panels receive on average. For this reason, solar power is used to generate electricity through solar panels. They are arranged in various orientations to maximize solar energy harvesting. However, sunlight must shine directly on solar panels at an orthogonal angle to the panel in order for them to absorb or collect solar power. Very little solar electricity is caught during other times of the day when the sun's rays are at various angles[15].

2.3.2. Substation Configuration

An infrastructure that receives electricity from one or more EEP (EEU) power plants and converts it to DC, lowers the voltage, or switches before powering the traction is known as a substation configuration[16]

The transmission networks fall into two categories:

Switching station: A switching station only operates at one voltage level and without a transformer. It is employed in the transmission network to switch electrical energy, tying the traction and power plants together.

Substation : An electrical generation, transmission, and distribution system includes a substation.Through the use of a transformer, the energy from the transmission network is reduced in voltage.and it carries out numerous crucial switching tasks.

The output voltage of the traction substation is 750 DCV. The traction motors convert the 750V DC to 380/400V AC because they are AC motors.

- **Bus bar protection**

The system's three phase short circuit level determines the rated short circuit breaking current. Currently, a short circuit level for each voltage ranges from 400 MVA to 4000 MVA, depending on how close the generating station is. The following are the rated circuit breaking current ratings based on the short circuit levels.

2.3.3 Bus Bar Arrengiments

Several variables influence substation configuration, most of which are related to the circuit's priority, or availability and dependability. Below is a discussion of typical single line diagrams for substation setups[17].

- **Single bus bar Configuration**

As seen in Fig. 2, every element (transformers and transmission lines) is directly connected to a single bus. 2. When load and availability needs are minimal, a single bus arrangement is appropriate. Although this kind of arrangement has comparatively low construction costs, it has little operating flexibility and low reliability (e.g., an outage on the associated element is necessary for switchgear maintenance)[18].

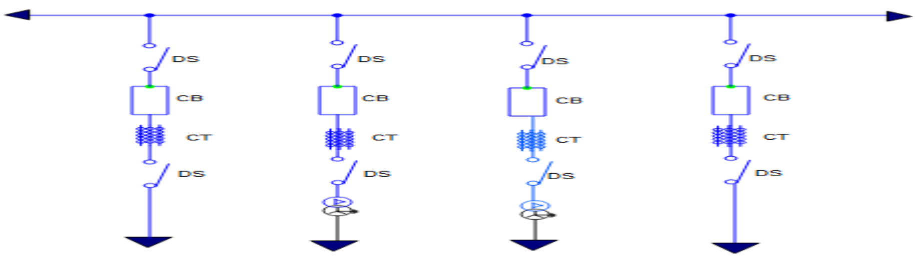


Figure 2. 2.Single Bus Configuration

- **Single bus bar arrangements with bus sectionalized**

A circuit breaker and isolator switches are used to split a single bus bar into two portions in a single bus-bar setup with bus sectionalization. The weight is split equally between the two portions, as Fig. 2.3 illustrates. There are benefits to this bus bar design when a circuit breaker is used to split a bus bar into two portions, preventing a defect on one from cutting off power to the other. Only a small number of loads will experience a power outage, and by including a current-limiting reactor, the fault level can be decreased. Nevertheless, additional isolators and circuit breakers are needed for this setup. Consequently, the arrangement's overall cost is extremely expensive[18].

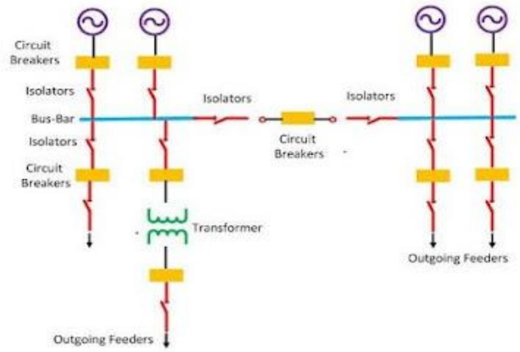


Figure 2. 3.Single bus bar arrangements with bus sectionalized

- **Double bus arrangements:**

A double bus arrangement consists of two bus bars, and isolators are used to link the incoming and outgoing feeders in parallel to both buses. The feeders can be connected to either bus-bar 1 or bus-bar 2 by closing the isolator switch. Isolator switches can be used to distribute the load between the two busses. The load can be connected to bus-bar 1 by shutting the isolator switch that is linked to the feeder and bus-bar 1. In a similar vein, the load is linked to bus-bar 2 by shutting the isolator switch that is connected to bus-bar 2 and feeder. In Fig. 2.4, this is illustrated. For bus transfer operations, a bus coupler breaker is utilized. In order to move a load from one bus to another, you must first close the bus coupler and then the isolators of the bus that the load is going to be attached to. Next, turn on the isolator switch that is connected to the fault bus, and lastly, turn on the bus coupler breaker. This configuration offers a number of benefits, including increased flexibility and continuous power supply to the load even in the event of a malfunction. It is challenging to move a load from one bus to another, nevertheless, without the power supply stopping for a brief period of time[18].

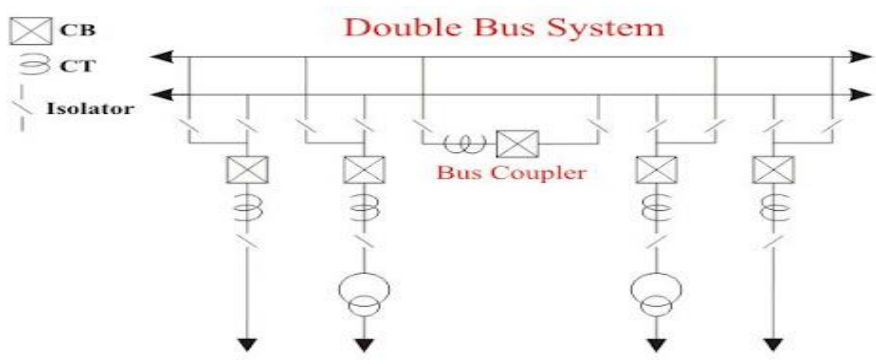


Figure 2. 4.Double bus arrangement

- **Double Bus Double Breaker Configuration**

Two buses and two circuit breakers are utilized in this design, one for each circuit. Both buses are powered on when everything are normal. It is possible to remove any circuit breaker for maintenance purposes without disrupting the associated circuit. Additionally, no circuit is interrupted by the breakdown of one of the two buses because the defective bus can be isolated and all circuits can be fed from the surviving bus. It is possible to balance the loading on the buses by switching circuits between them. This configuration is displayed in Fig. 2.5.

The double bus, double breaker arrangement works well in situations where circuit availability and dependability are crucial considerations.This configuration offers greater operational flexibility (e.g., no downtime is needed for circuit breakers repair) and dependability (bus faults do not affect any element). But the price of building is really considerable[18].

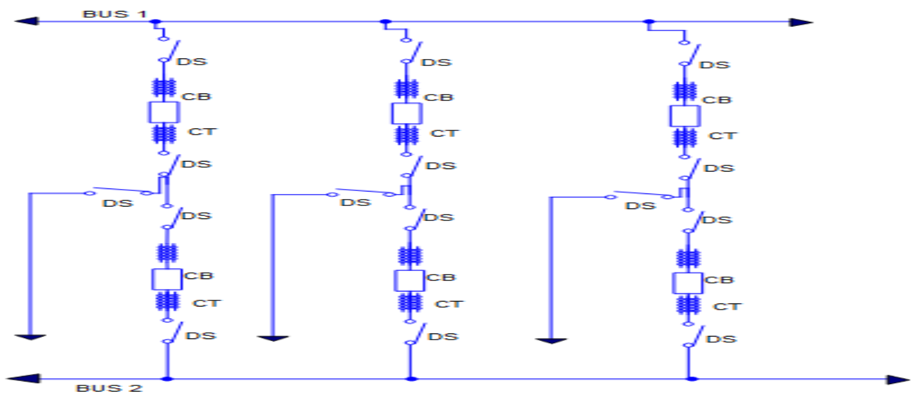


Figure 2. 5.Double Bus Double Breaker Configuration.

- **One And A Half Breaker Arrangement**

As seen in Fig. 2.6, the two feeders in this instance are connected by a third circuit breaker known as a tiebreaker. The two feeders are fed through the matching bus-bars. The half bus and breaker layout works well in situations when the circuit's availability and dependability are crucial. All three circuit breakers are closed and both circuits run in parallel when everything is normal. Feeders receive power from the two bus bars. The benefits of a one-and-a-half breaker system include no power interruption during the case of a fault because all feeders can be switched to a healthy bus immediately; increased reliability (bus fault does not affect any element); increased operational flexibility (e.g., no outage is needed for circuit breaker maintenance); ease of adding additional circuits to the system; and lower cost when compared to double bus double breaker arrangements.But this setup is difficult since there are two circuit breakers that need to be opened in the event of a problem, and maintenance is expensive[18].

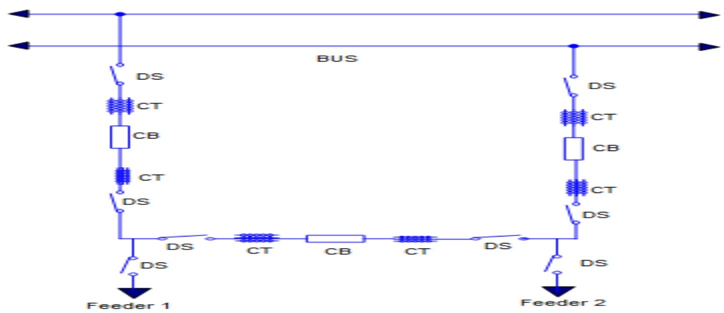


Figure 2. 6.One and a Half Bus Configuration.

- **Main and Transfer Bus Configuration**

An additional bus added in this configuration. Circuits between the main and transfer bus are connected, and the elements (transformers and transmission lines) are organized.One additional circuit breaker, referred to as a tie circuit breaker (bus coupler), may be utilized in this configuration, as illustrated in Fig. 2.7. This tie breaker is not connected to any circuit. When load and availability needs are minimal, the main and transfer buses are appropriate. Because of the transfer bus and tie breaker (which eliminates the need for an outage on the related element for switchgear maintenance), this system has lower operational flexibility and construction costs than a single bus scheme, but it also has lower reliability[18].

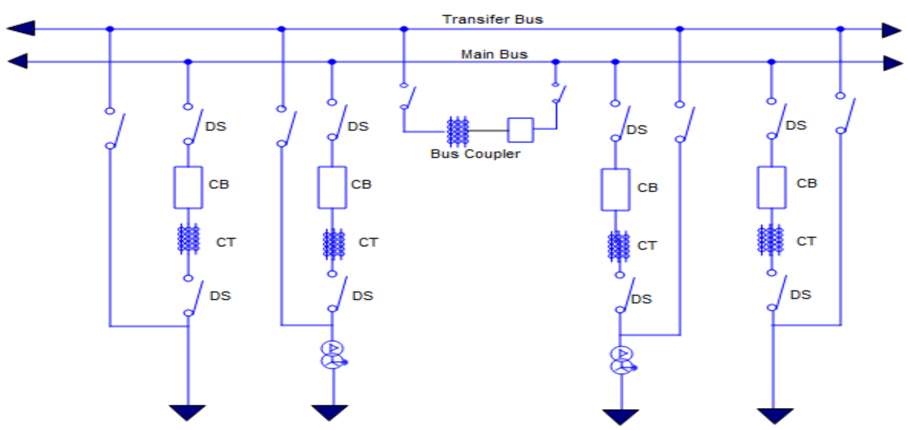


Figure 2. 7.Main and Transfer Bus Configuration

- **Double Bus Single Breaker Configuration**

There are two busses in this configuration. Every circuit has a single breaker, and isolators connect it to both buses. Between two busses, there is a single tiebreaker. Normally, the tiebreaker is closed. By closing the corresponding switch, the circuit can be connected to either bus when the tie breaker is in the closed position. As seen in Fig. 2.8, it is evident that a fault on one bus needs isolating that bus and feeding the circuits from the other bus. In situations when load transfer and increased operating reliability are crucial, the double bus single breaker is appropriate. This bus bar configuration is more reliable than the Main & Transfer bus scheme and has comparatively lower construction costs (bus fault restricted to the affected bus due to availability of tie breaker) however, there is little operational flexibility (e.g., an associated element outage is necessary for switch gear maintenance)[18].

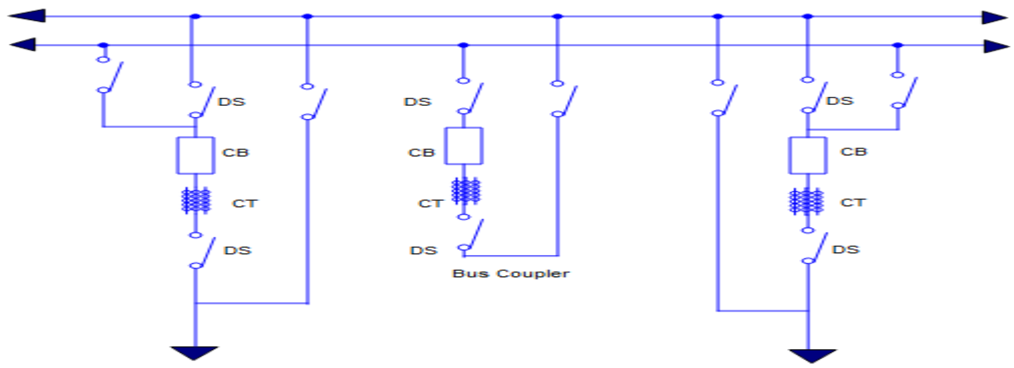


Figure 2. 8..Double Bus Single Breaker Configuration.

- **Ring Bus Configuration**

The breakers are connected to form a ring. Circuits terminate in between breakers, and each breaker has an isolator on both sides. There are the same number of breakers and circuits. Each circuit in a ring bus system receives input from both sides. Any of the breakers can be opened and isolated for repair without disrupting any circuits. Two breakers on different ends of the circuit can be tripped to isolate any circuit from a fault. When both breakers trip, just the malfunctioning circuit is isolated; the other circuits continue to operate in an open ring configuration. This scheme offers high reliability (bus fault limited to affected section & faults to individual elements do not affect others) and good operational flexibility (e.g., no outage is required on the associated element for the maintenance of switch gear)[18]. Fig 2.9 illustrates this bus bar arrangement, which comes with a comparatively high construction cost.

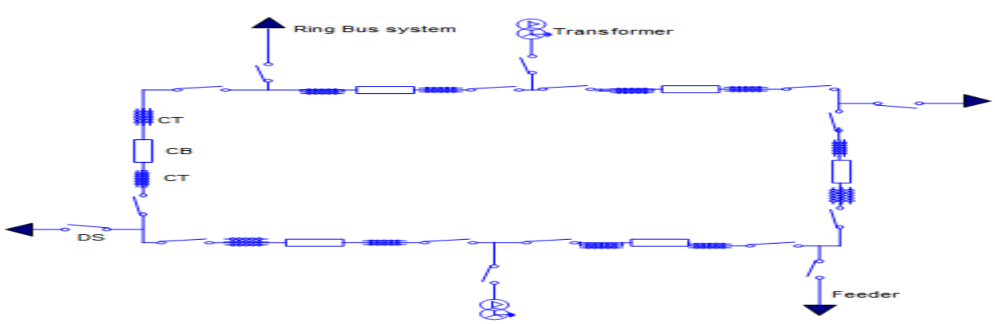


Figure 2. 9.Ring Bus Configuration.

- **Mesh arrangements:**

Circuit breakers are placed in the mesh arrangement between the bus bar mesh as shown in Fig. 2.10 the circuit is tapped at the mesh node point. When a failure arises, we must open two circuit breakers in order to receive protection; however, switching is not an option for substations with many circuits; therefore, this configuration is appropriate and offers protection against the fault. But it lacks switching capabilities and isn't appropriate for all kinds of substations[18].

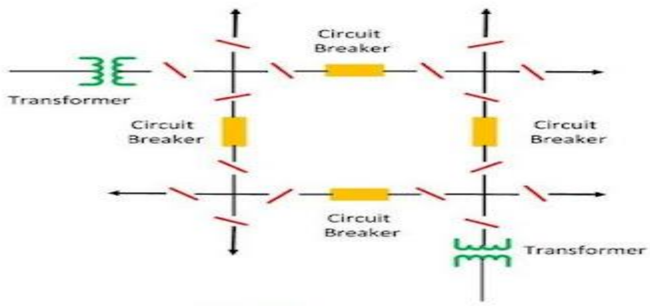


Figure 2. 10.Mesh arrangement.

- **Criteria For Choosing Types Of Bus – Bar Arrangement:**

We have a variety of bus-bar configurations available for analysis, and the choice is based on a number of variables, including the voltage of the system, the substation's location within the system, the supply's dependability, flexibility, cost, the availability of backup plans in case any equipment fails, and maintenance simplicity. In addition to being simple to use and to maintain, the bus-bar configuration should be installed as cheaply possible while yet considering needs and supply continuity into consideration.

Cost Comparison of bus bar arraignments

The above substation bus-bar arrangements can be compared in terms of their cost (investment and operational). Table 2.2 shows a comparison of the nine substation arrangements. It can be seen that the single bus-bar arrangement has a low investment cost, but it has the disadvantage of being unreliable.

Table 2. 2 :Cost Comparison of bus bar arrangements[19]

Substation Configurations	Relative cost comparison	Remark
Single bus	100%	Hence , it has low cost but low reliability, and low operational flexibility
Sectionalized bus	122%	It requires further expense since a circuit breaker and isolator switches are used to split a single bus bar into two portions.
Main and Transfer bus	143%	Thus, there is some operational flexibility and relatively low constructing costs; however, this structure works best in situations with minimal load and availability needs.
Ring bus	114%	Even if it has higher construction cost compared to the above, this arrangement has higher operational flexibility and reliability.
Breaker and a Half	158%	Higher reliability and flexibility However, because two circuit breakers must be opened in the event of a failure and maintenance costs are high this configuration is complicated.
Double Breaker and Double bus	214%	It has higher construction cost because it uses double breaker and double bus but it works well in situations when the circuit's availability and dependability are crucial.

2.3.4. Automatic Recosers

Reclosers: - A re closer is a device that can identify over current conditions in both phase and phase-to-ground conditions. If the over current continues for a predefined amount of time, the circuit will be interrupted, and the line will automatically re-close to re-energize it. The recloser will remain open after a predetermined number of operations if the defect that caused the operation is still present, isolating the malfunctioned area from the rest of the system. The majority of errors in the AALRT system are short-term in nature, lasting only a few cycles or seconds at most. Because of its ability to open and close, the recloser keeps distribution circuits from being shut down due to temporary faults. Re closers are used in a distribution network at places as follows:

- In substations: to serve as a circuit's primary protection
- In main feeder circuits; to enable the segmentation of long lines and so avoid the loss of an entire circuit as a result of a fault near the circuit's terminus.
- In branches or spurs, to avoid faults on the branches from tripping the main circuit.

System voltage, short circuit level, maximum load current, minimum short circuit current inside the zone to be protected by the re closer, and sensitivity of operation for ground fault are all important considerations when installing reclosers.

2.4. Related Work

Brian, et.al, examined the AALRT reliability issue by gathering and examining data on power outages during the research period (2016, 2017, and 2018). This study demonstrates that the frequency of disruptions is rising annually. In certain cases, there were multiple power outages in a single day, which had a significant impact on railroad operations. About thirty percent of all traction power supply outages are caused by cable failure, which is one of the main reasons of these disruptions. Investigations into power supply cables should focus on matters such voltage "spikes" analysis, appropriate cable sizing, protective mechanisms, working temperatures, safe levels, and heating brought on by prolonged overload situations.If over-voltage or overload is the reason for cable failure, it is necessary to determine the extent of the over-voltage, the cause of the overload, and the impact of both on the protective system.Ethiopia Electric utility an analysis of supply side outages shows that issues with the AALRT side account for 58.3% of power outages. It is imperative that scientific study be used to determine what goes wrong with Ethiopia Electric utility companies and what potential mitigation strategies exist[17].This thesis makes no recommendations for mitigating the power reliability issues associated with AALRT.**M.R. Elkadeem, M. A. Li Ji 1** explained the effective use of PV system for the railways and Distribution Generation is a powerful technology for reducing emissions, but installation of DG requires a lot of space and very expensive [21] so it is impossible to use in AALRT due to it use a lot of space and cost. **Daniel Nack** explained different substation bus bar arrangements for possible improvement of the power reliability and analysis helping to select best arrangement in terms of reliability improvement and less initial cost and gives a relative cost comparison of the different substation configurations discussed and the findings are Double Breaker-Double Bus has very high reliability and flexible operation as it compared with other bus bar arrangements but it has very high cost because this configuration uses 2 breakers per circuit and Single Bus Arrangement has the lowest reliability and lowest cost compared with the other bus bar arrangements[19]. **Hassan Haes Alhelou , ME Hamedsni ,[2019]** described the reasons of power system outages.The study also identifies the underlying causes of many global blackouts. In addition, methodologies for blackout and cascade analysis as well as the effects of blackouts are reviewed. Additionally, the difficulties with the protection plans in place as well as the knowledge gaps surrounding power system blackouts and cascading crises are noted. Future power system blackout study topics and research directions are also suggested[22]. **Zikola chovancikow, ZDvorak,** discussed how the power outage affected the Zelina railway junction and how the disruption of electrical supplies caused rail transportation to be limited or halted because rail transit routes are electrified and cannot function without electricity[23]. **A. Ashour,** One of the most crucial pieces of smart grid hardware, the auto recloser, has a control circuit that is improved upon in this work. The circuit breaker and the modelled control circuit are linked together so that, in the event of a fault, the breaker automatically closes without human intervention. The auto recloser prevents outages for extended periods of time whenever a transient failure arises in the system at the distribution level. But, in the event that the issue persists, the auto recloser separates the system's impacted portion while preventing a disruption to other system components[24].**D.legesse,** The Lideta rectifier substation is used for the tesis. Matlab/Simulink is used to model the traction system. Simulation is performed using data from Ethiopian Railway Corporation (ERC) and compared with IEEE standard limits[25]. **B. Glennon et al,** In order to reconfigure the network in the event of system faults and changes in loads, this article discusses the automation of distribution systems[26]. In this thesis "Study on Improvement of the Existing Power Reliability of Addis Ababa Light Railway Transit"we analyzed the root causes of power interruption using data collected from EEU, EEP, and AALRT (OCC). Then, we compared reliability indices with international standards and EEA benchmarks. Afterward, we analyze and model various mitigation alternatives or techniques in MATLAB. Finally, we select the best technology, which involves reconfiguring the substation, and demonstrate improvement using ETAP.

2.5. AALRT TPSS Components

Traction substation and traction network are components of a traction power supply system. The primary substation and SCADA communication functioning condition, in addition to these subsystems, are necessary for the AALRT TPSS to function. Therefore, for the purpose of studying reliability of AALRT TPSS, the primary elements influencing the system's normal functioning may be divided into four subsystems: the traction substation, traction network, main substation, and SCADA communication. As a result, the following provides a quick overview of those subsystems' roles and how they contribute to the operation of AALRT TPSS during power outages.

Traction substation: It transforms the 15 kV power coming from the near AIS into energy needed for traction. The four types of electric equipment found in the AALRT traction substation are: transformation, control, protection, and compensation equipment. Equipment used to convert voltage or current is known as transformation equipment. Examples include rectifier transformers, rectifiers, VT, CT, and soon more. Switch devices with varying voltages are examples of control equipment that is used to turn on and off control circuits. Protection devices, such as surge arrestors, lighting fuses, and high/low voltage fuses, are used to shield circuits from overvoltage and overcurrent. Static compensators and high/low voltage capacitors are examples of compensation equipment that is used to boost power factor by compensating the circuit's reactive power.

Traction network: is a grid of power used to supply electrified light rail systems (AALRTs). Power supply components such the feeding section, 15kV power cable, OCS feeder cable, Overhead contact system (OCS), track, stray current collection cables, and over voltage protection devices (OVPD) are arranged in a series composition. Because they are interconnected, the failure of one of the aforementioned components has been linked to the breakdown of the traction network and the AALRT TPSS as a whole.

Main substation: Its main role is to receive high voltage electricity for AALRTS from the 132/15kV EEU power grid. After step-down, it becomes an AIS switching substation. Additionally known as TPLS, AIS provides middle voltage (15kV) power to the traction substations. A variety of known circumstances have contributed to the development of problems at the main substation, including technical errors or blackouts at the GIS or AIS, as well as incompatibility caused by relay setting variations between AIS and TPLS. SCADA systems are used for supervisory control, real-time processing, display, and massive data collecting all at once. When a traction substation's SCADA fails, the OCC is unable to obtain information on the state of the power supply, which causes an interruption in operations for the particular area that the TPLS supplies. Dead stop is the SCADA error that has been reported thus far. Resetting it and reporting the issue to the manufacturer has temporarily resolved this failure. Dead halt, according to SCADA, happens when it locks up and is unable to process commands.

System protection

Protection device coordination is done to stop equipment from operating uninvitedly in the event that a system malfunction occurs. Protection and coordination of the distribution system's primary goals are:-

- To minimize the duration of a fault.
- To eliminate safety hazards as fast as possible.
- To limit service outages to the smallest possible segment of the system
- To protect equipment’s (apparatus)
- To protect the system from unnecessary service interruptions and disturbances.
- To disconnect faulted lines, transformers, or other apparatus

Chapter Three

3. Failure Study of AALRT Traction Power Supply Substations

The approaches for gathering and analyzing data from the current system are briefly covered in this chapter. The following information is required for reliability analysis: the length, frequency, and total number of construction transport customers provided and interrupted; failure data; and fundamental electrical data of power system equipment. These data are examined in order to determine the substation's present dependability status and to pinpoint the primary causes of power outages in AALRT.

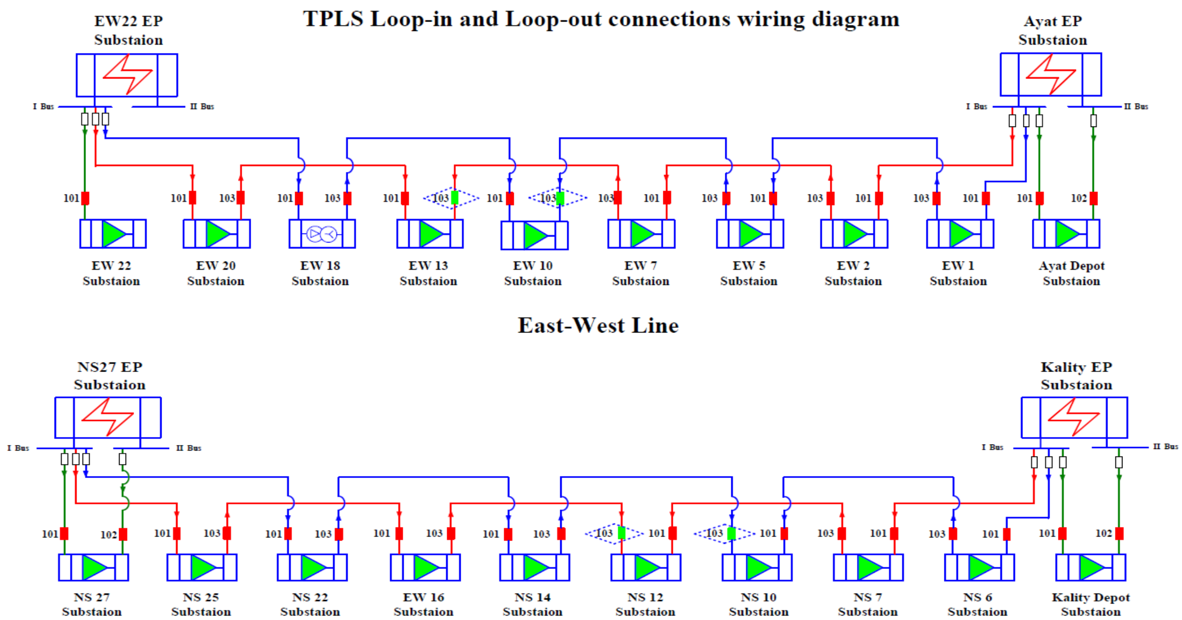
3.1. AALRT's Traction Substation Power Feeding Configuration

AALRT deploys rectifier substations (SS) to convert three-phase 15KV, 50Hz AC to 750-900 V DC voltage. One of these types of substations feeds about 1.5 to 2 kilometers of railway line.

Four 132/15kV GIS substations dedicated from EEU are part of the main substation, which is fed by a double-side power supply arrangement for AALRT. The specific AIS that powers each of the three TPLSs is the source of each 15kV feeder.The twenty substations that make up the AALR TPSS are as follows: two independent 15kV feeder cables feed four of the TPLSs (Kality depot, Ayat depot, Minilik II square, and Torhailoch station); one 15kV feeder cable feeds the remaining nine TPLSs (NS6, NS7, NS22, NS25, EW1, EW2, EW18, and EW20); the remaining eight TPLSs are supplied from those TPLSs using the loop in loop out arrangements as illustrated in figure 3.1. Therefore, each TPLS feeds its designated feeding zone, on average, over a distance of roughly 2 km, under typical operating conditions. When a TPLS goes down, neighboring TPLSs use loop in loop out configurations to feed the failed TPLS's feeding zones.

3.1.1.Site description

There are two routes on the AALRT: East–West and North–South. Four distinct EEP substations, situated around the four perimeters of rail routes, supply power to each route. These substations receive their supply from five grid substations that are connected in a ring configuration: Gefersa, Sebeba-I, Kality-I, Legetafo, and Sululta. The four EEP side railway substations, Menelik II, Ayat, Torhailoch, and Kality, are equipped with double circuit transformers that have a 25 MVA, 132 kV/15 kV capacity. Every rectifier substation changes the 15 kV AC input voltage to 750 V DC.



North-South line

Figure 3. 1.AALRTS Power Feeding Arragment.

3.1.2. AALRT Traction Power Substation Configuration

There are two receiving circuit breakers in a usual DC traction system for a railroad. The rectifier, which converts AC to DC, traction transformer (TT), disconnector (DS), and AC circuit breaker (CB) are important parts of DC substations. and DC circuit breakers, which are also seen in Figure 3.2, improve power reliability[19].

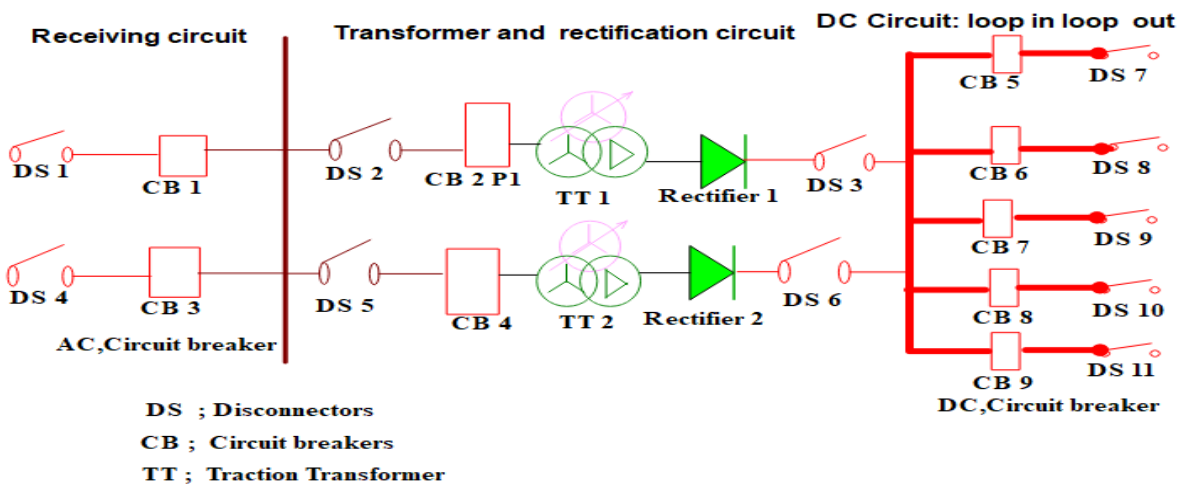


Figure 3. 2.Typical configuration of DC Traction substation

However, the Addis Ababa Light Rail Transit (AALRT) system has two receiving circuit breakers, two disconnectors, and two traction transformers (SRTr), but only one rectifier, as shown in Figure 3.3. This configuration may decrease the reliability of the traction power supply system. If one of the traction transformers fails, it may lead to an interruption of railway operation

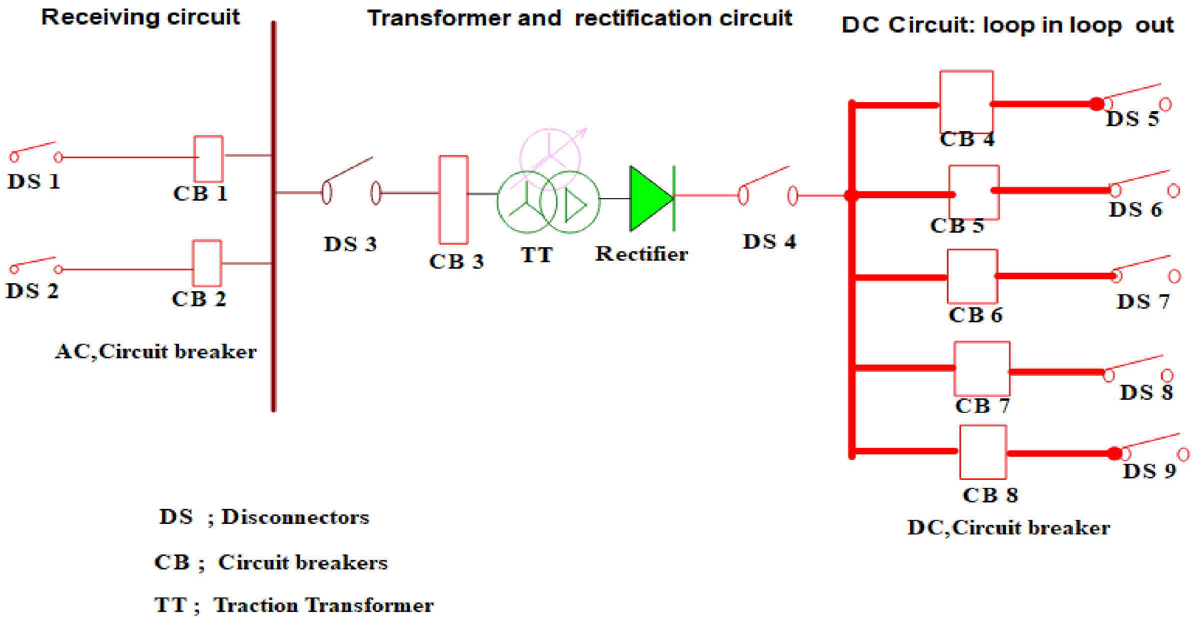


Figure 3. 3. Typical configuration of AALRT Traction substation

- **Traction Transformer**

Rectifiers and traction transformers work together to guarantee the qualities of a full set of units with the following ratings:

- The rated AC voltage of the traction transformer's output is 590V.
- DC 825V is the rated DC no-load voltage.
- Impedance of the primary and the secondary: 5%
- Maximum DC output voltage: DC 900V

The transformer output voltages of 0.59kV in the Y and 0.59kV in the Δ connections are rectified into DC 750V using a 12 pulse rectifier for the purpose of rectification, as seen in figure 3.4.

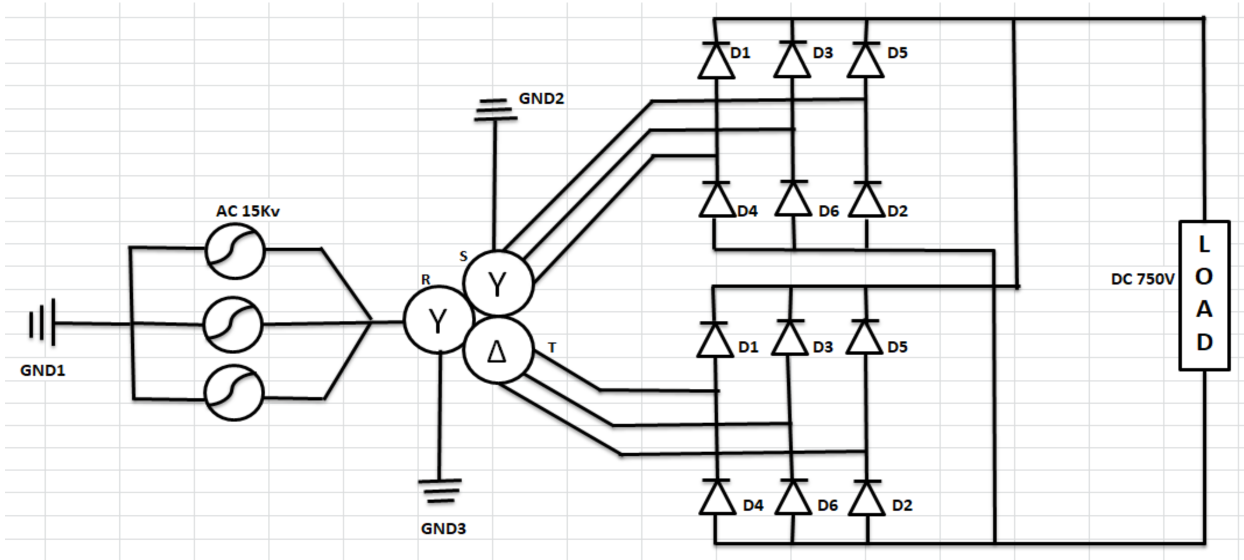


Figure 3. 4.Traction power supply system

3.1.3. Description of Kality traction substation

A dual-sided power supply configuration is used for feeding AALRT Traction Power Supply Systems (TPLSs) from the main 132/15kV Kality GIS substation to dedicated EEU 15kV/750-900V Kality AIS substation. Each 15kV feeder is supplied straight from the Kality AIS that provides power for the Kality Traction Substation. The purpose of these substations is to convert three-phase 15KV, 50 Hz AC to 750V-900V DC catenary voltage. The single-line diagram of the Kality Traction Substation is shown in Figure 3.5.

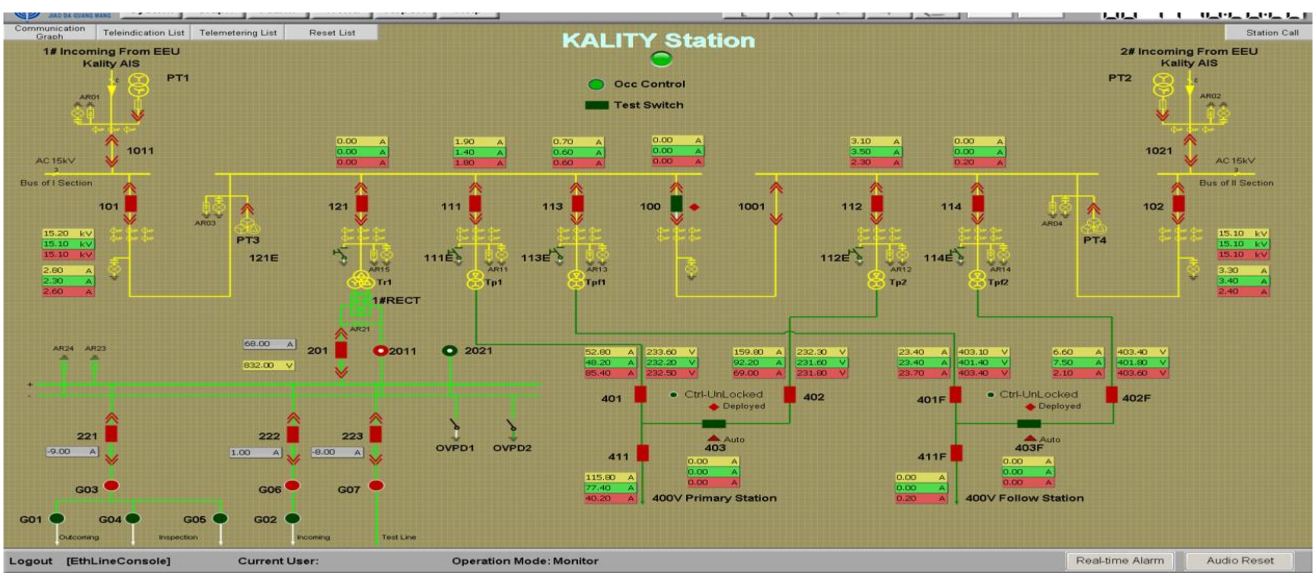


Figure 3. 5. AALRT Kality substation single line diagram.

3.2.Flow chart of thesis methodology

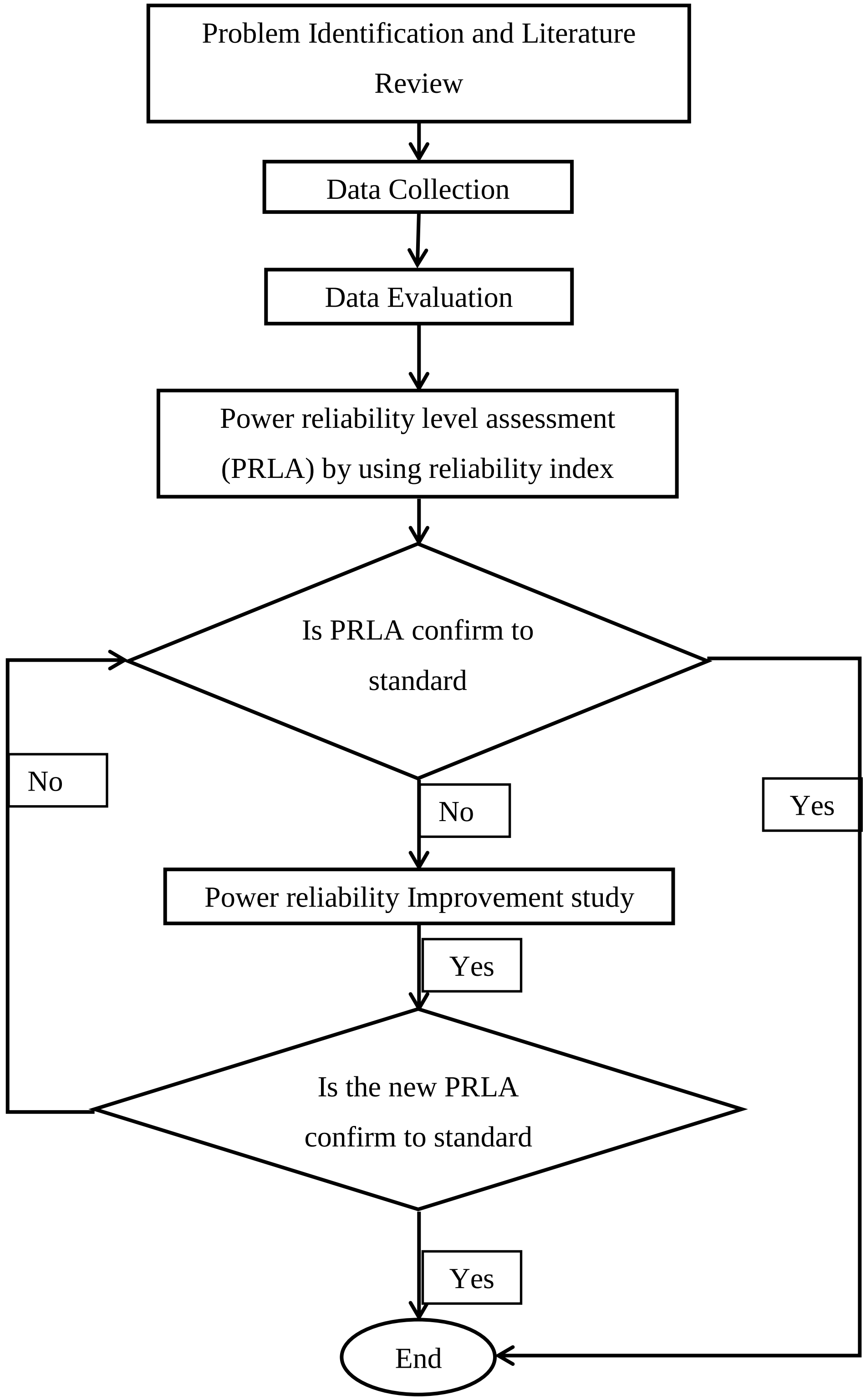


Figure 3. 6 . Block schematics of the study methodology

3.3.Data collection

Data was gathered from daily reports issued by the AALRT operating control center and also prepare direct questionaries' for AALRT stuffs, EEP ,EEU operators and additionally analysing different research papers.

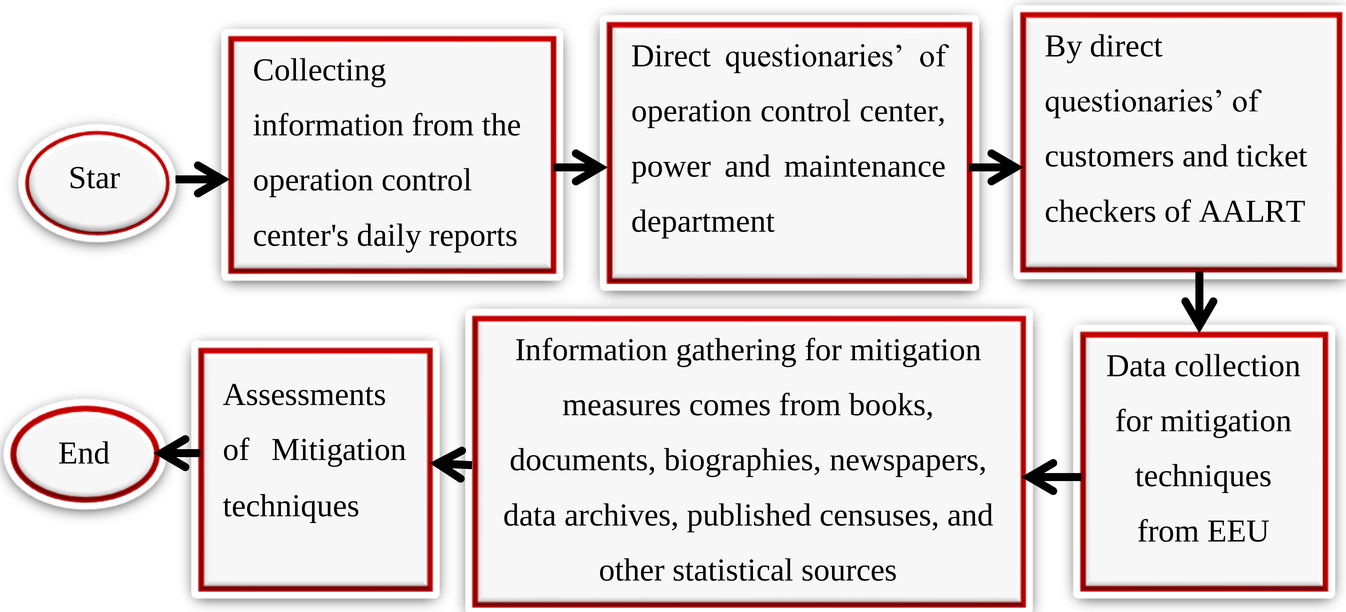


Figure 3. 7..Data collection method.

3.4. Analysis of Reliability Data

3.4.1. Collected Power Reliability Data

Between 2018 and 2021, information was gathered from the AALRT Operations Control Center. The information includes how many customers were interrupted, how many trips were canceled because of power outages, how many customers were served each day by train transport, how long the daily train transport customer interruption lasted (later changed to a monthly average), how frequently power outages occurred, how many passengers were interrupted, and how many customers were interrupted. Furthermore, the daily data sheet log documents the reasons for power outages on the AALRT side.

The data gathered from EEP and EEU side interruption records, which includes the reasons for and length of the power outage from the incoming line 132/15kV side, is displayed in Table 3.1. This information aids in pinpointing the primary source of disruption and identifying the underlying reasons of external disruptions.

Table 3. 1.Collected power interruption data from EEPand EEU

SUBSTATION	EFFECT	VOLTAGE RATING	OUTAGE	REVIVAL	DURATION	CAUSE
KALITI I-KALI T GIS	TR.LINE	132	01/04/2022 14:03	01/04/2022 14:18	0.15	DUE EARTH FAULT IA=4.974A
KALITI NORTH TRANSFOEMER I	TRANSFORMER	132/15	13/01/22 16:01	13/01/22 16:07	0.1	DUE TO EARTH FAULT ON 15 KV SIDE
KALITI I TRANSFORMER	TRANSFORMER	132/45	28/01/22 13:19	28/01/22 13:21	0.03	DUE TO AKAKI I- DUKEM FAULT
KALITI I TRANSFORMER III	132KV TRANSFORMER	230/132	31/01/22 05:30	31/01/22 05:46	0.27	NO SIGNAL
KALITI II GIS TRANSORMER II	TRANSFORMER	132/15	10/05/2020 14:12	10/05/2020 14:26	0.2333	DUE TO EARTH FAULT(15 KV FAULT)
KALITI-II GIS TRANSFORMER II	TRANSFORMER	132/15	25/10/20 16:14	25/10/20 16:21	0.1167	DUE TO 15 KV FEEDER FAULT
KALITI NORTH TRANSFORMER I	TRANSFORMER	132/15	27/10/20 15:23	27/10/20 15:50	0.45	DUE TO 15KV FAULT.
KALITY II GIS TRANSFORMER I	TRANSFORMER	132/15	30/03/2021 18:19	30/03/2021 18:32	0.2167	DUE TO EARTH FAULT
KALITI-I TRANSFORMER II	TRANSFORMER	132/45	20/12/20 08:16	20/12/20 08:25	0.15	DUE TO SHORT CIRCUIT IA=1.60KA
KALITI I-KALITI II	TR.LINE	132	15/05/21 07:44	15/05/21 08:04	0.3333	NO SPECIFIED REASON IA=1.020A
KALITI I-KALITI II	TR.LINE	132	17/05/21 15:43	17/05/21 15:47	0.0667	DUE TO SHORT CIRCUIT
KALITI I-KALITI II	TR. LINE	132	18/05/21 10:13	18/05/21 10:16	0.05	NO SIGNAL
KALITI II - KALITI I	TR.LINE	132	22/05/21 10:32	22/05/21 10:35	0.05	NO SIGNAL

3.4.2 Data Analysis

The reliability indices, including MTBF, ASAI, MTTR, frequency of faults, and duration of faults from 2018 to 2021, have been calculated in Excel format and are shown in Tables 3.3 to 3.6. These tables help calculate the reliability, availability rate, and unavailability rate of faults.

How to calculate in EW line is Number of times that the failure occurred from collected data was in 2021 =47 and avarege value is 3.916666667 frequency.

Total working time= 8784

$$MTBF = \frac{1}{\lambda} \quad (9)$$

$$\lambda = \frac{Number\ of\ times\ that\ the\ failure\ occurred}{Total\ operating\ time} \quad (10)$$

$$\lambda = \frac{3.916666667}{8784} = 0.000445886$$

$$MTBF = \frac{1}{0.000445886} = 2242.723404\ \text{hr}$$

Total customer interruption duration =294

Customer hourse of demand =4392

Customer hours of available service=4098

$$\text{ASAI} = \frac{\text{Customer hours of available service}}{\text{Customer hours of Demand}} \quad (11)$$

$$ASAI = \frac{4098}{4392} = 0.933060109\ p.u \quad (12)$$

$$\text{ASUI} = \frac{\text{Customer hours of unavailable service}}{\text{Customer hours of Demand}} = 1 - ASAI \quad (14)$$

$$\text{MTTR} = \frac{\text{Total number of maintenance time}}{\text{Total nimber of repair}} = \frac{294}{47} = 6.255\ hr$$

The reliability equation for this system is given by

Reliability = e^(-λt) = 1.

The total reliability for both routes is calculated as 0.464527057 in the EW route and 0.453290033 in the NS route. Therefore, it is possible to conclude that the system had unreliable power in 2018 as shown in Table 3.2.

Table 3. 2: 2018's reliability indices

Months	MTBF(hr)		ASAI A(p.u)		ASUI U(p.u)		λ(events/hr)		RELIABILITY		λt		MTTR(hr)		FRIQUENCY (int)		OUTAGE DURATION(hr)		SAIFI(int/customer)		SAIDI(hr/cust)	
	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS
Jan.	4612.8	3844	0.852151	0.96707	0.147849	0.03293	0.000217	0.00026	0.9225287	0.90777	0.081	0.0968	11	2.04167	5	6	55	12.25	0.25	0.3	2.75	0.6125
Feb.	5046	1682	0.933908	0.929339	0.066092	0.07066	0.000198	0.00059	0.9333655	0.81312	0.069	0.2069	5.75	2.04917	4	12	23	24.59	0.2	0.6	1.15	1.2295
Mar.	4612.8	2883	0.841398	0.931371	0.158602	0.06863	0.000217	0.00035	0.9225287	0.87896	0.081	0.129	11.8	3.19125	5	8	59	25.53	0.25	0.4	2.95	1.2765
Apr.	5400	0	0.966278	**1**	0.033722	0	0.000185	0	0.9355135	**1**	0.067	0	3.035	0	4		12.14	0	0.2	0	0.607	0
May	1774.2	1537.6	0.901102	0.968656	0.098898	0.03134	0.000564	0.00065	0.8108634	0.78513	0.21	0.2419	2.83	0.77733	13	15	36.79	11.66	0.65	0.75	1.8395	0.583
Jun.	5400	0	0.89425	**1**	0.10575	0	0.000185	0	0.9355135	**1**	0.067	0	9.5175	0	4		38.07	0	0.2	0	1.9035	0
Jul.	0	0	**1**	**1**	0	0	0	0	**1**	**1**	0	0	0	0			0	0	0	0	0	0
Aug.	0	0	**1**	**1**	0	0	0	0	**1**	**1**	0	0	0	0			0	0	0	0	0	0
Sep.	0	0	**1**	**1**	0	0	0	0	**1**	**1**	0	0	0	0			0	0	0	0	0	0
Oct.	0	0	**1**	0.819861	0	0.18014	0	0	**1**	**1**	0	0	0	0			0	76.85	0	0	0	3.8425
Nov	0	3085.7	0.967742	0.862285	0.032258	0.13772	0	0.00032	**1**	0.88989	0	0.1167	0	5.60429		7	0	39.23	0	0.35	0	1.9615
Dec.	1922	0	0.811828	0.940403	0.188172	0.0596	0.00052	0	0.8240465	**1**	0.194	0	5.8333	0	12		70	22.17	0.6	0	3.5	1.1085
TOTAL	2242.7	2196	0.93306	0.951667	0.06694	0.04833	0.000446	0.00046	**0.46453**	**0.453**	0.767	0.7913	49.766	13.6637	47	48	294	212.28	2.35	2.4	14.7	10.614

Reliability = $e^{-\lambda t}$=0.199489334 and = $e^{-\lambda t}$ = 0.088406087 this result shows that the system is **unreliable power** in 2019.

Table 3. 3: Reliability indices for 2019

Months	MTBF(hr)		ASAI A(p.u)		ASUI U(p.u)		λ(events/hr)		RELIABILITY		λt		MTTR(hr)		FRIQUENCY(int)		OUTAGE DURATION(hr)		SAIFI(int/customer)		SAIDI(hr/cust)	
	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS
Jan.	5766	1647.4	0.909059	0.86245	0.090941	0.137554	0.0001734	0.000607	0.9375273	0.797891	0.064516	0.22581	8.4575	3.655	4	14	33.83	51.17	0.2	0.7	1.6915	2.5585
Feb.	2242.7	2883.4	0.828161	0.93566	0.171839	0.064339	0.0004459	0.000347	0.8562813	0.88632	0.155172	0.12069	6.64444	3.1986	9	7	59.8	22.39	0.45	0.35	2.99	1.1195
Mar.	1774.2	1774.2	0.85078	0.84613	0.14922	0.153871	0.0005636	0.000564	0.8108634	0.810863	0.209677	0.20968	4.27	4.4031	13	13	55.51	57.24	0.65	0.65	2.7755	2.862
Apr.	2160	0	0.905889	0.72878	0.094111	0.271222	0.000463	0.00088	0.8464964	0.728597	0.166667	0.31667	3.388	5.1389	10	19	33.88	97.64	0.5	0.95	1.694	4.882
May	4612.8	823.71	0.971075	0.34266	0.028925	0.657339	0.0002168	0.001214	0.9225287	0.63663	0.080645	0.45161	2.152	8.7332	5	28	10.76	244.53	0.25	1.4	0.538	12.2265
Jun.	2160	0	0.886333	0.48986	0.113667	0.510139	0.000463	0.001343	0.8464964	0.616755	0.166667	0.48333	4.092	6.3328	10	29	40.92	183.65	0.5	1.45	2.046	9.1825
Jul.	0	0	0.912796	0.93527	0.087204	0.064731	0.0002168	0.00039	0.9225287	0.864896	0.080645	0.14516	6.488	2.6756	5	9	32.44	24.08	0.25	0.45	1.622	1.204
Aug.	0	0	0.937285	0.8822	0.062715	0.117796	0.0003902	0.000347	0.8648958	0.878957	0.145161	0.12903	2.59222	5.4775	9	8	23.33	43.82	0.45	0.4	1.1665	2.191
Sep.	0	0	0.891972	0.94847	0.108028	0.051528	0.000463	0.000324	0.8464964	0.889893	0.166667	0.11667	3.889	2.65	10	7	38.89	18.55	0.5	0.35	1.9445	0.9275
Oct.	0	0	0.922715	0.89546	0.077285	0.104543	0.0001734	0.000304	0.9375273	0.893248	0.064516	0.1129	7.1875	5.5557	4	7	28.75	38.89	0.2	0.35	1.4375	1.9445
Nov	0	7200	0.828139	0.97672	0.171861	0.023278	0.000463	0.000139	0.8464964	0.951234	0.166667	0.05	6.187	2.7933	10	3	61.87	8.38	0.5	0.15	3.0935	0.419
Dec.	2562.7	0	0.821129	0.96202	0.178871	0.037984	0.0003902	0.000173	0.8648958	0.937527	0.145161	0.06452	7.39333	3.5325	9	4	66.54	14.13	0.45	0.2	3.327	0.7065
TOTAL	2689	1780.5	0.889226	0.81683	0.110774	0.183167	0.0003719	0.000562	**0.1994893**	**0.088406**	1.612162	2.42607	62.741	54.146	98	148	486.52	804.47	4.9	7.4	24.326	40.2235

Reliability = $e^{-\lambda t}$ = 0.091080947 and= $e^{-\lambda t}$ =0.397426802 this result shows that the system is **unreliable power** in 2020.

Table 3. 4: Reliability indices for 2020.

Months	MTBF(hr)		ASAI A(p.u)		ASUI U(p.u)		λ(events/hr)		RELIABILITY		λt		MTTR(hr)		FRIQUENCY (int)		OUTAGE DURATION(hr)		SAIFI(int/customer)		SAIDI(hr/cust)	
	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS
Jan.	3844	3294.9	0.9311828	0.932957	0.0688172	0.067043	0.00026	0.0003	0.90777	0.89325	0.097	0.113	4.266667	3.56286	6	7	25.6	24.94	0.3	0.35	1.28	1.247
Feb.	1345.6	2883.4	0.8214943	0.887672	0.1785057	0.112328	0.000743	0.00035	0.772137	0.88632	0.259	0.121	4.141333	5.58429	15	7	62.12	39.09	0.75	0.35	186.36	117.27
Mar.	1774.2	4612.8	0.9091935	0.989247	0.0908065	0.010753	0.000564	0.00022	0.810863	0.92253	0.21	0.081	2.598462	0.8	13	5	33.78	4	0.65	0.25	101.34	12
Apr.	1800	5400	0.9131944	0.980111	0.0868056	0.019889	0.000556	0.00019	0.818748	0.93551	0.2	0.067	2.604167	1.79	12	4	31.25	7.16	0.6	0.2	93.75	21.48
May	1922	7688	0.8989516	0.947124	0.1010484	0.052876	0.00052	0.00013	0.824046	0.95277	0.194	0.048	3.1325	6.55667	12	3	37.59	19.67	0.6	0.15	112.77	59.01
Jun.	1542.9	2160	0.8498611	0.90025	0.1501389	0.09975	0.000648	0.00046	0.791909	0.8465	0.233	0.167	3.860714	3.591	14	10	54.05	35.91	0.7	0.5	162.15	107.73
Jul.	1537.6	5766	0.8757527	0.959086	0.1242473	0.040914	0.00065	0.00017	0.785127	0.93753	0.242	0.065	3.081333	3.805	15	4	46.22	15.22	0.75	0.2	138.66	45.66
Aug.	1356.7	4612.8	0.7733333	0.915323	0.2266667	0.084677	0.000737	0.00022	0.760207	0.92253	0.274	0.081	4.96	6.3	17	5	84.32	31.5	0.85	0.25	252.96	94.5
Sep.	1542.9	7200	0.8103889	0.957194	0.1896111	0.042806	0.000648	0.00014	0.791909	0.95123	0.233	0.05	4.875714	5.13667	14	3	68.26	15.41	0.7	0.15	204.78	46.23
Oct.	1774.2	7688	0.7265323	0.910699	0.2734677	0.089301	0.000564	0.00013	0.810863	0.95277	0.21	0.048	7.825385	11.0733	13	3	101.73	33.22	0.65	0.15	305.19	99.66
Nov	3600	4320	0.9151111	0.959528	0.0848889	0.040472	0.000278	0.00023	0.904847	0.92005	0.1	0.083	5.093333	2.914	6	5	30.56	14.57	0.3	0.25	91.68	43.71
Dec.	2562.7	0	0.9556989	0.947957	0.0443011	0.052043	0.00039	0	0.864896	**1**	0.145	0	1.831111	0	9		16.48	19.36	0.45	0	49.44	58.08
TOTAL	1804.9	4705.7	0.8652186	0.94079	0.1347814	0.05921	0.000554	0.00021	**0.091081**	**0.39743**	2.396	0.923	48.27072	51.1138	146	56	591.96	260.05	7.3	2.8	1700.36	706.577

Reliability from the months= $e^{-\lambda t}$ = 0.122483 and = $e^{-\lambda t}$ = 0.076812 this result shows that the system is **unreliable power** in 2021.

Table 3. 5: Reliability indices for 2021.

Months	MTBF(hr)		ASAI A(p.u)		ASUI U(p.u)		λ(events/hr)		RELIABILITY		λt		MTTR(hr)		FRIQUENCY (int)		OUTAGE DURATION(hr)		SAIFI (int/customer)		SAIDI (hr/cust)	
	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS	EW	NS
Jan.	2306.4	2306.4	0.841022	0.8635753	0.1589785	0.136425	0.000434	0.000434	0.85106	0.8511	0.16129	0.16129	5.914	5.075	10	10	59.14	50.75	0.5	0.5	177.42	152.25
Feb.	1682	1682	0.657989	0.8581034	0.3420115	0.141897	0.000595	0.000595	0.81312	0.8131	0.2069	0.2069	9.91833	4.115	12	12	119.02	49.38	0.6	0.6	357.06	148.14
Mar.	1774.15	1922	0.793656	0.8178226	0.2063441	0.182177	0.000564	0.00052	0.81086	0.824	0.20968	0.19355	5.90462	5.6475	13	12	76.76	67.77	0.65	0.6	230.28	203.31
Apr.	1661.54	1080	0.855611	0.6504167	0.1443889	0.349583	0.000602	0.000926	0.80522	0.7166	0.21667	0.33333	3.99846	6.2925	13	20	51.98	125.85	0.65	1	155.94	377.55
May	2883	1774.2	0.878441	0.8533333	0.1215591	0.146667	0.000347	0.000564	0.87896	0.8109	0.12903	0.20968	5.6525	4.19692	8	13	45.22	54.56	0.4	0.65	135.66	163.68
Jun.	1963.64	1440	0.866194	0.8045278	0.1338056	0.195472	0.000509	0.000694	0.83251	0.7788	0.18333	0.25	4.37909	4.69133	11	15	48.17	70.37	0.55	0.75	144.51	211.11
Jul.	1774.15	1356.7	0.858253	0.7881452	0.1417473	0.211855	0.000564	0.000737	0.81086	0.7602	0.20968	0.27419	4.05615	4.63588	13	17	52.73	78.81	0.65	0.85	158.19	236.43
Aug.	2096.73	1537.6	0.868737	0.8486022	0.1312634	0.151398	0.000477	0.00065	0.83744	0.7851	0.17742	0.24194	4.43909	3.75467	11	15	48.83	56.32	0.55	0.75	146.49	168.96
Sep.	1800	1800	0.859944	0.8618333	0.1400556	0.138167	0.000556	0.000556	0.81875	0.8187	0.2	0.2	4.20167	4.145	12	12	50.42	49.74	0.6	0.6	151.26	149.22
Oct.	2562.67	1922	0.920161	0.8084677	0.0798387	0.191532	0.00039	0.00052	0.8649	0.824	0.14516	0.19355	3.3	5.9375	9	12	29.7	71.25	0.45	0.6	89.1	213.75
Nov	2160	1963.6	0.865139	0.8413889	0.1348611	0.158611	0.000463	0.000509	0.8465	0.8325	0.16667	0.18333	4.855	5.19091	10	11	48.55	57.1	0.5	0.55	145.65	171.3
Dec.	5766	4612.8	0.967312	0.9435753	0.0326882	0.056425	0.000173	0.000217	0.93753	0.9225	0.06452	0.08065	3.04	4.198	4	5	12.16	20.99	0.2	0.25	36.48	62.97
TOTAL	2091.43	1711.2	0.85367	0.828577	0.1463297	0.171423	0.000478	0.000584	**0.12248**	**0.0768**	2.1	2.56667	59.6589	57.8802	126	154	642.68	752.89	6.3	7.7	1928.04	2258.67

Based on the analysis results from the past four years, it was found that the MTBF was higher in 2019 G.C. and lower in 2020 G.C. The highest system availability results were recorded in 2018, followed by 2019 G.C. Additionally, the lowest outage frequency and duration were recorded in 2018, followed by 2019 G.C. The analysis shows that MTBF, availability, and reliability have a direct relationship, while outage frequency and duration are inversely proportional to reliability.

Table 3. 6 Four years (2018-2021) reliability indices analysis result

years	MTBF	Friquency(int)	Interuption duration(hr)
2018	4439	95	506.28
2019	4470	246	1291
2020	6511	202	852.01
2021	3803	280	1395.6

3.4.3 Root Causes Of Power Interruption

In 2018 and 2019 G.C., the root cause of power interruption in AALRT was EEU power interruption, which was due to several reasons that were explained earlier. However, in 2020 G.C., the root cause is earth fault.

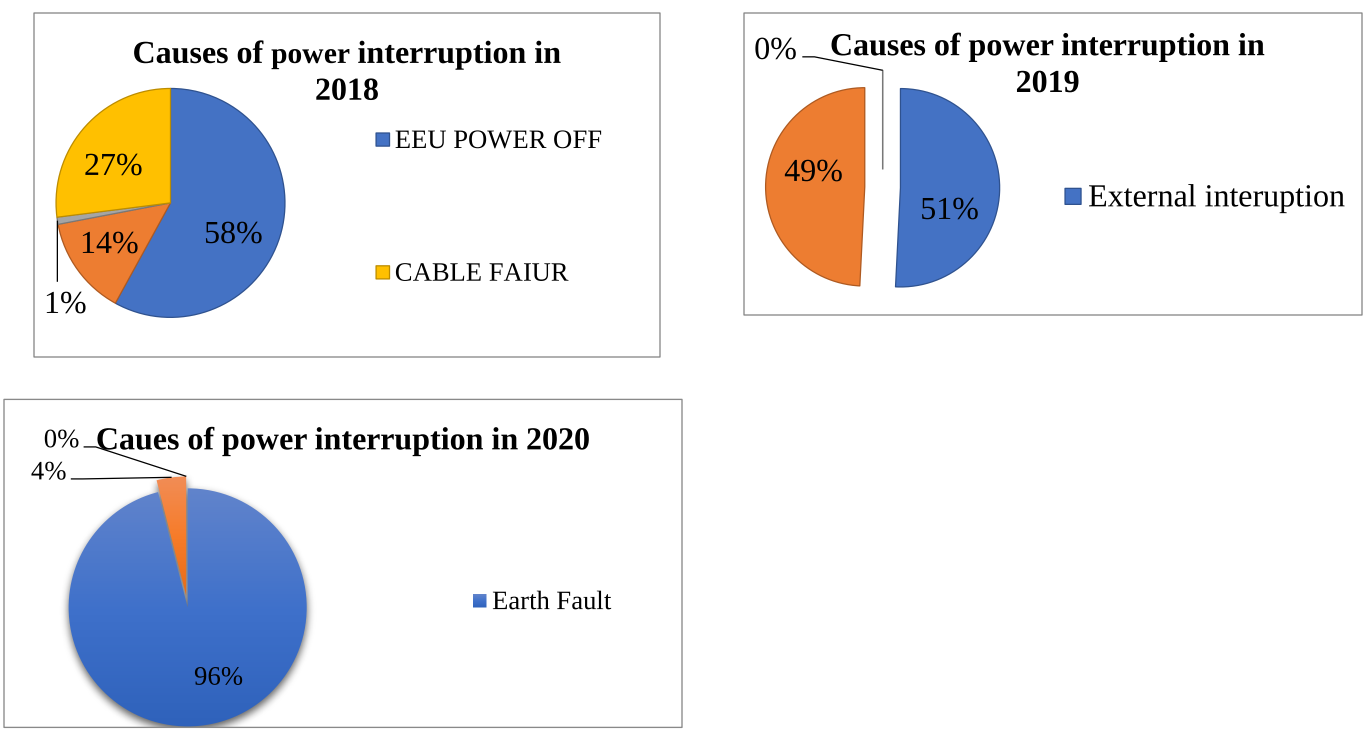


Figure 3. 8.Power Interruption Analysis in from 2018-2021

- **MTBF Graphical Analysis**

MTBF is the average time between system breakdowns as analyzed over four years (2018-2021). MTBF is a basic measure of power reliability; the higher the MTBF, the higher the power reliability. Traction equipment uptime increases with an increase in MTBF. Monitoring the Mean Time Between Failures (MTBF) of every piece of equipment—particularly those that need to run continuously—enables the maintenance staff to plan maintenance tasks effectively. According to the AALRT analysis (from 2018 to 2021), a system with a lower MTBF is **unreliable system**.

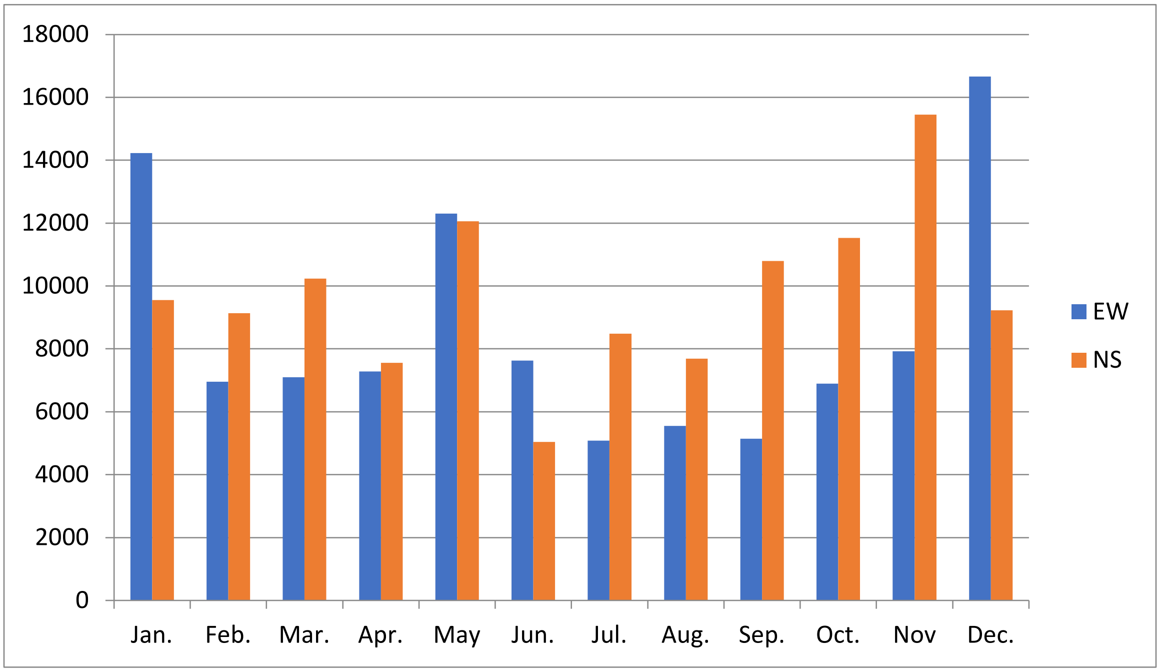


Figure 3. 9.MTBF bar graph in from 2018 to 2021.

- **ASAI Graphical Analysis**

Availability is a measure of the percentage of time that a system is operational and available for use. In the analysis, the availability must range between 1 and 0. In 2018, the EW line had an availability of 1 in July, August, and September, making it **reliable**. Similarly, the NS line had an availability index of 1 in June, July, August, and September, indicating that it was reliable during those months. However, as a general trend in 2018, AALRT was unreliable. In 2019, 2020, and 2021, there was an improvement in reliability because the availability was almost close to 1 in both the EW and NS lines. However, the system is still unreliable and needs improvement. You can find more information about this in the bar graph below.

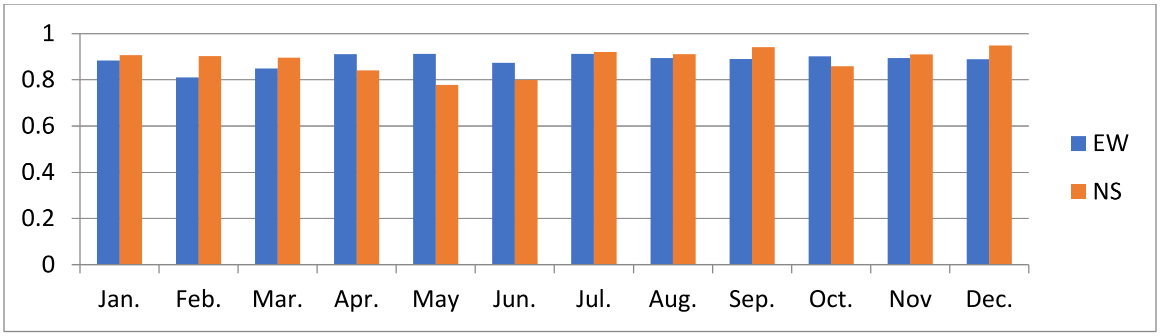


Figure 3. 10.ASAI bar graph from 2018 to 2021

- **ASUI Graphical Analysis**

Unavailability (U): is the probability that the component is down at any time and unable to operate.In AALRT in four years analysis result shows that it is highly **unavailable** and is closed to 0. The system is **unreliable.**

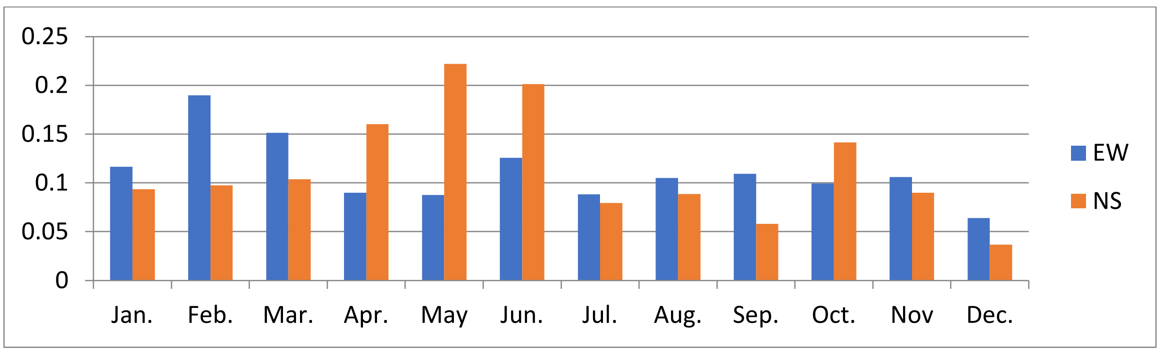


Figure 3. 11.ASUI Bar graph from 2018 -2021

Generally As seen in the above 4 years (2018-2021) availability and unavailability analysis data availability is very low so this result shows that the system is **unreliabile.**

- **MTTR Graphical Analysis**

The average amount of time needed to fix a system—usually a mechanical or technological one is called the mean time to repair, or MTTR. It accounts for both the time needed for repairs and any testing. If it goes down, then it may indicate that your service level to your customers is improving. However, in the AALRT system, MTTR has not decreased year over year. In 2018, the MTTR was 49.76583333 and 13.66370238 in the EW and NS lines, respectively. In 2019, the MTTR was 62.741 in the EW line and 54.1461718 in the NS line. In 2020, the MTTR was 48.27071917 in the EW line and 51.11380952 in the NS line. Finally, in 2021, the MTTR was 59.65891259 in the EW line and 57.88021452 in the NS line. The increase in MTTR year over year shows that the system is unreliable.

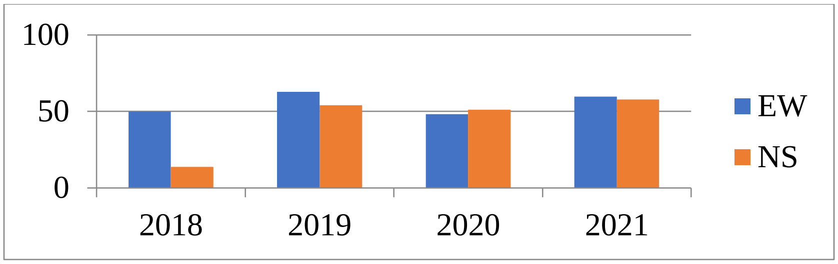


Figure 3. 12.MTTR Graphical Analysis Bar graph from 2018 -2021.

3.5.Comparison Of Reliability Indices With International Standards

Table3.7 shows that comparison of reliability indices parameters (SAIFI and SAIDI) with Ethiopian standards as well as international standards selecting eight country. From the table we can concluded that AALRT didn't satisfy international reliability indices set by Ethiopian Electric Agency(EEA) and international standards.

Table 3. 7 Comparison of Reliability analysis indices with Ethiopian and International standards.

Country		SAIFI (f/yr)	SAIDI(hr/yr)
Australiya		0.9	72
Denmark		0.5	24
France		1	62
Germany		0.5	23
Italy		2.2	58
Netherlands		0.3	33
Spain		2.2	104
Uk		0.8	90
Ethiopia		20	25
AALRT	**2018**	95	506.3
	2019	246	1290.99
	2020	202	852.01
	2021	280	1395.57

Source :council of europian energy regulator[27] and EEA.

3.6. Analysis & Result of Faults Duration and Percentage level

Using the collected data from OCC of AALRT and from EEP and EEU Reliability indices calculated and the result is compared with standards. The major causes of external 15kV power outages and fault duration (permanent or temporary) from EEP and EEU are analyzed in the tables below (Table 3.8-Table 3.11).

Table 3. 8: Fault causes analysis of year 2020 from EEP and EEU side.

Faults Type	Faults Reputations(times)	Percentage of faults
Earth fault	4	80%
Short circuit fault	1	20%
Other	0	0
Total	5	100%

Table 3. 9:Fault cause Analysis of year 2021 from EEP and EEU side.

Faults Type	Faults Reputations(times)	Percentage of faults
Earth fault	37	41.11111%
Short circuit fault	9	1.111111%
Safety for maintenance	15	10%
No signal	19	21.11111%
Over current	6	6.666667%
No reason	1	2.2222225%
Spark	2	16.66667%
Phase unbalance	1	1.111111%
Total	90	100%

Table 3. 10:Fault analysis from EEP and EEU side from in year 2022.

Faults Type	Faults Reputations(times)	Percentage of faults
Earth fault	13	61.90%
Short circuit fault	2	9.52%
No signal	1	4.76%
Over current	1	4.76%
Safety for maintenance	4	19.04%
Spark	0	0%
Phase unbalance	0	0%
Total	21	100%

Table 3. 11: Fault Analysis of EEP and EEU from 2020-september 2022.

Faults Type	Faults Reputations(times)	Percentage of faults
Earth fault	54	46.55172414%
Short circuit fault	12	10.34482759%
Safety for maintenance	19	16.37931034%
No signal	20	17.24137931%
Over current	7	6.034482759%
Spark	2	1.724137931%
Phase unbalance	1	0.862068966%
Total	116	100%

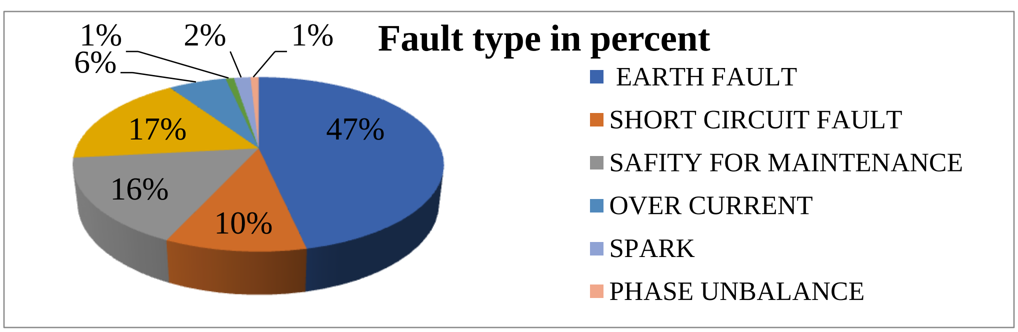


Figure 3. 13. External power interruption Analysis

From this percentage of faults in EEU side analysis as follow

Table 3. 12:Duration of Fault in per cent.

Temporary fault	70.68965517
Permanent Fault	29.31034483

From OCC of AALRT data fault classified as internal and external : EEU Power Off, Substation power off, Grid power off are included in external fault and breakers , isolation switches failures, Inverter, converter machines failure are included in internal fault.

Table 3. 13 Fault Analysis.

Fault Type	Total	Percentage of Total
External Power Interruptions	221	63.32378
Civic power Interruptions	128	36.67622

3.7. A Review of Traction Power Reliability Problem Mitigations Methods

This section thoroughly studies power reliability problem mitigation mechanisms. Additionally, we compared different mitigation techniques in terms of cost, time, and their advantages, which improve the power reliability of AALRT. We also analyzed the specifications for substation reconfiguration.

3.7.1. Substation Configuration

An infrastructure that receives energy from one or more EEP (EEU) 15kV power stations and converts it to DC, lowers the voltage, or switches before feeding power to the traction is known as a substation configuration.

3.7.1.1.Substation design

- **Rectifier**

For the following series bridge uncontrolled rectifier circuit:

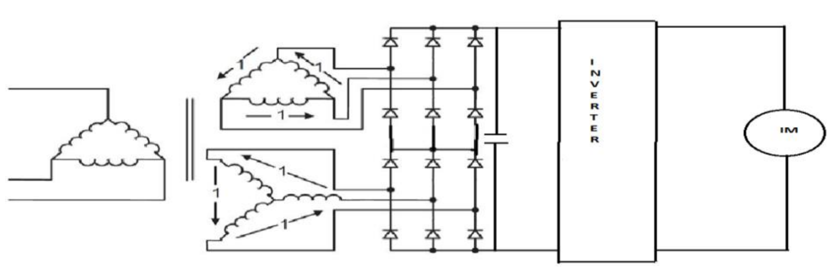


Figure 3. 14. Series bridge uncontrolled rectifier circuit.

The grid transformer converts 132KV/15KV, which is distributed to each traction substation. The rectifier transformer converts the substation voltage (15KV) into a maximum short-time operating voltage of 750V and feeds this voltage to two pairs of 12-pulse rectifier units. Two rectifier units are used for safety purposes in case one fails, the other remains operational. The purpose of the transformer connection is to introduce a phase shift between the source and bridge. Phase shift between source and bridge is introduced by the transformer connection. This produces inputs to two separate bridges. In addition to being comparable, the two bridge outputs are 300 degrees apart.In any electrification system, the distance between substations is determined by the availability of real estate, system design, and train power demand. For 750 V DC networks, the typical substation spacing is between 1.5 and 2 km. Although the DC system is very straightforward, the large currents needed necessitate thick cables and close spacing between feeder stations. Not insignificant resistive losses are also present.

- **Current Transformer**

15 kV current transformers shall be of the epoxy resin type and shall be suitable for indoor installations and have the current rating as specified. Current transformers shall be capable of carrying 120 % of the rated current continuously and eight times the normal current for one second.

Table 3. 14: Rating of current transformer used for traction substation.

Description	Unit	Requirement
Rated voltage	KV	15
Rated current, primary	A	300 – 600
Rated current, secondary	A	5
Frequency	Hz	50

- **Voltage Transformer**

Voltage transformers must be appropriate for use with instruments, synchronization devices, protective gear, and voltage regulating devices and/or metering and shall be of the electromagnetic and capacitive type as specified. In cases where directional earth fault or directional overcurrent protection requires a polarizing source voltage, a broken delta connected residual voltage winding must be installed.

Voltage transformers' ratio and phase angle errors must not go beyond the allowable bounds specified in the applicable standard and must be able to satisfy the ensuing extra requirements from 5% rated primary voltage to 90% rated primary voltage:

Voltage error - not exceed +3%

Phase angle error - not exceeding + 120 minutes

Table 3. 15: Rating of voltage transformer used in traction substation.

Description	Unit	Requirement
Rated voltage	Kv	15
Highest system voltage	Kv	17.5
Lightning impulse withstand voltage	kV	125
Power frequency withstand voltage	Kv	50
Rated voltage, primary	kV	15/√3
Rated voltage, secondary	V	100

- **Circuit Breaker**

In the event of a malfunction, it must have the ability to break and isolate the region that is broken. This is referred to as a transformer's breaking capability.It must have the ability to create a circuit when there is the highest asymmetric peak current; this is the equivalent of having circuit breakers with this capacity.

A circuit breaker needs to be able to temporarily handle short circuit currents.

- **Problems to be overcome by DC circuit breakers**

Creation of artificial current zero –using parallel LC circuit which avoids quenching

Prevention of re strikes:- A sharp spike in striking voltage is produced by the brief cutting of the current.

Dissipation of stored energy

Breaking capacity of circuit breaker= $\sqrt{3} * \text{voltage rating KV} * \text{current Ratting KA}$

Circuit breakers shall use SF6 gas as the prime-insulating medium. The SF6 gas shall conform to IEC standard and shall also be used for arc quenching.

Table 3. 16: Rating of circuit breaker used in traction substation.

15 kV Circuit Breakers	
Description	**Required**
- Installation	Indoor
- Rated voltage (kV)	15
-Maximum System voltage	17.5
- Rated current for transformer incoming bay, (A)	≥ 2500
- Rated current for outgoing line bay, (A)	630
- Rated current for outgoing line bay, (A)	1250
- Rated frequency (Hz)	50
- Rated short time withstand current:-	
(a) 1 second, kA rms	≥ 25
(b) 3 second, kA rms	≥ 25
- Rated short circuit breaking current	
(a) Symmetrical, kA rms	≥ 25
- Standards applied	IEC 60056

- **Lightning Arrestor**

The purpose of the surge arrestor is to shield station equipment from lightning and switching surges. The discharge current rated for 15 kV lightning arresters must be 10 kA.

15 kV Circuit Breakers Switch Boards

Table 3. 17: Rating of circuit Breakers Switch Boards used in traction substation.

Description	Required
	15 Kv
- Rated voltage, (kV)	15
- Highest system voltage, (kV)	17.5
- Short - circuit rating, (kA / 1 sec.)	31.5
- Bus bars	
a. Current rating, (A)	2500
c. Permissible temperature rise over ambient temperature of 40°C	50
d. Type of insulators installed	Porcelain
- Thickness of sheet steel used for the cubicle, (mm)	2.5 – 3

- **Disconnector**

Motor operated drives shall be suitable for local, remote and supervisory control (supervisory control of earth switches is not required) and should be fitted with a removal emergency manual operation facility. 15 kV transformer side disconnector shall be manually gang-operated as well as motor operated and with the 15kV bus bar side three pole switch having a mechanical and electrical interlock with the main disconnector.The 15 kV bus bar disconnectors shall comply with the following characteristics.

Table 3. 18: Rating of Disconnector used in traction substation.

Description	**15 Kv**
Bus bar Disconnector	Two fixed and one rotating column
Rated Voltage, Kv	15
Highest System Voltage, Kv	17.5
Lightning Impulse Withstand voltage, kV to earth and between poles, at sea level	125
across isolating distance at at sea level	145
1-minute power frequency withstand voltage, Kv	50
Switching Impulse withstand, kV	NA
Line bay rated Current, A	630
Transformer bay rated Current, A	2000 A
Short Time thermal Current, kA	>25
Operating Mechanism	Motor and manual operation

- **DC Switch Gear**

Table 3. 19: DC Circuit breaker specification.

Description	Requirement
Rated voltage	750v
Rated current	1595.29amp
Short circuit current	>=4.79 Kamp for 4.5 km

- **15kV Transformer**

Table 3. 20: Rating of 15 kV Transformer used in traction substation.

Description	Unit	Requirement
Rated Primary Voltage	KV	15
Rated Secondary Voltage	V	277.68
Frequency	Hz	50
Rated Power	KVA	1500
% Impedance		5%

3.7.2. Using Automatic Recloser

Reclosers, also known as Automatic Circuit Reclosers, are highly dependable electrical devices that are precisely automatic switchgear. Its advanced detectors and electronics are built with safety in mind for both the electrical grid and the consumer. They immediately isolate errors and resume operation after they have been fixed.

- **Recloser**

Important real-time line status data, like power (A, W, VAR), voltage (V), and frequency (f) readings, are provided. The mid-voltage grid operates more efficiently thanks to this data, which also makes fault investigation and system diagnostics possible. Using a load breaker or fuse switch, the Recloser may identify a fault region and restore power to a problem-free area. It can be applied to distribution transformer stations and overhead distribution lines, combining fault detection, control, protection, measurement, and online monitoring of closing or opening circuits.

- **Recloser components**

The control unit is installed in an outdoor pole mounted cabinet under tropical conditions, using an electronic chip, includes functions for measuring, protecting and saving events, and capable of allowing monitoring, control locally and remotely, and connect to the system. Basically, the Recloser consists of a conventional circuit breaker with a controller that allows programming of the number of repetitive closings according to predetermined requirements.

- **How does recloser work?**

Reclosers open (cut-off) in the event of a short circuit, and then automatically close (return to initial state) after a certain amount of time. If the issue still exists at this point, the recloser will keep opening the circuit until it eventually closes it on its own. The recloser then functions in accordance with the initial program configuration, and on the third occasion, it will totally cut the circuit off from the electrical system. Additionally, the user has the ability to modify the number of cuts and the switching time through programming. The recloser can cut four times before locking, and it can repeat at least three times. You can alter the dwell time (also known as the closing time) as shown in figure 3.15 below.

How Automatic recloser work for a transient fault:[28]

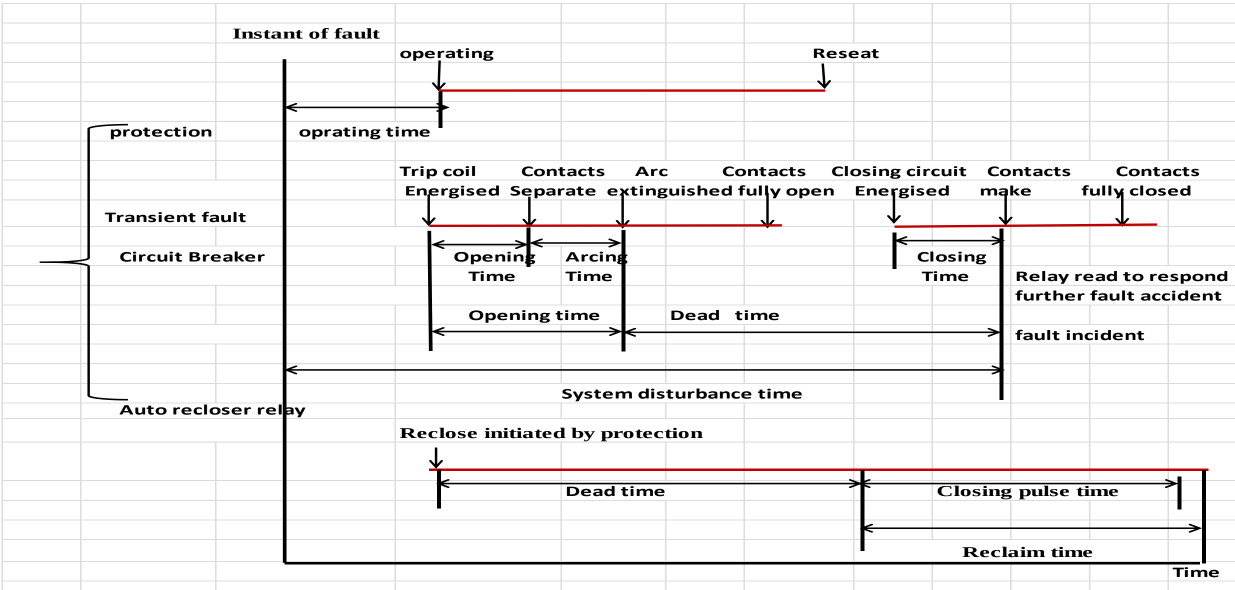


Figure 3. 15. Operation of single-shot auto-re closer technique for a temporary problem

Transient fault means the temporary unavailability of a service, or time-outs. These faults are often self-correcting, and if the action is repeated after a suitable delay it is likely to succeed. This picture shows that how automatic re closer works for temporary fault which is after some operating time Trip coil energized then after some steps detect the fault and restore the line.

Automatic re closer work for Permanent fault:[28]

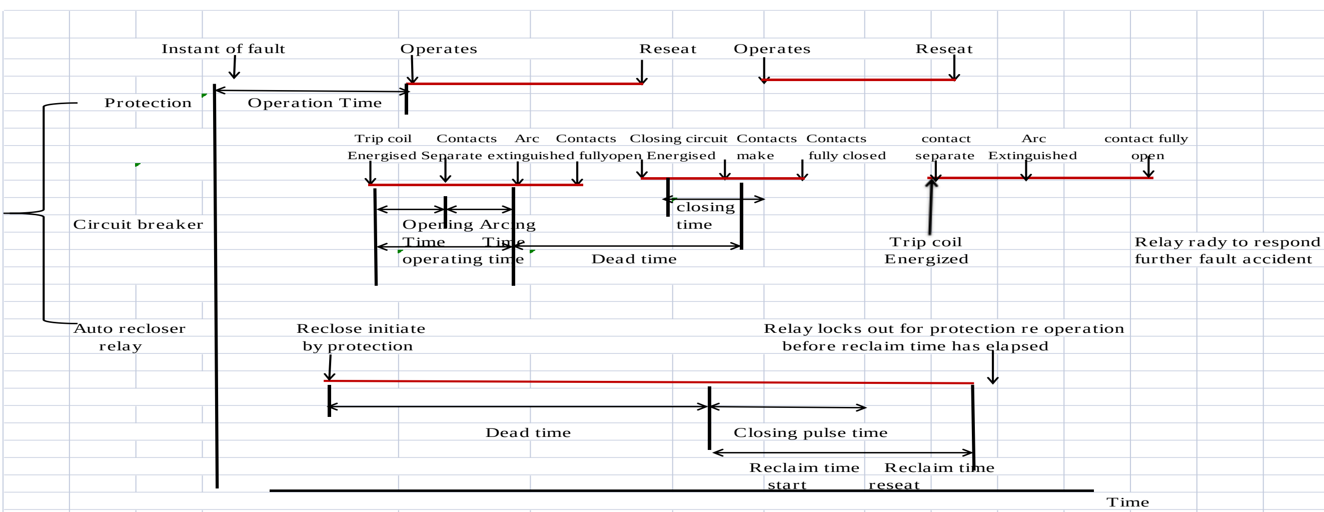


Figure 3. 16. Operation of a single-shot auto-reclose technique for an ongoing fault

A permanent fault is one that continues to exist until the faulty component is repaired. The above picture shows that how automatic re closer works for permanent fault. Automatic Recloser has advantages of continuity of power supply to the traction resulting reduce the number of customer complaints in train accessibility,reduce the time of power supply disconnection in cases of temporary faults,reduce the cost of work force operating in managing disconnected lines,easily integrated into Smart Grid applications with advanced capabilities such as loop automation and automatic changeover and improved power supply reliability and power quality of supply.

3.7.3. Comparison of the mitigating techniques

Table 3. 21 Comparative analysis of the mitigation methods

Mitigation Method	**Comparison and drawbacks**
1,Distributed Generation	• It needs a lots of space in AALRT doesn't have enough space • Highest initial investment cost • Production process of solar cells and other components requires lar ge amount of energy and water so it s resource intensive • It depends on sunlight, solar panels don't work at night so it may be scarcity of supply will results • The construction of solar energy power plants contains hazardous materials can pose hazards to air quality. • Solar energy storage (battery) is expensive. • Construction of solar panel hazard to air quality • Solar panel doesn’t work for every roof type.
2,Substation reconfiguration	
Automatic recloser	• Although initial investment cost is chipper ,it doesn’t need additional space and there is no environmental impact . • It s applicable for Transient power interruption only.
Changing Bus bar arrange ment's	• It is expensive and complicated as there is no much effect for the reliabiliy when it compared to changing incoming power supply line.
Changing incoming power supply line	• Even if its initial investment cost is expensive once it constructed there is no cost and it increased reliability.

Chapter four

4. Modeling and Simulation

The rectifier substation at Kality depot, named NS6 substation, is chosen as a case study to be modeled on MATLAB/SIMULINK.The purpose of these substations is to convert three-phase 15KV, 50 Hz AC to 750V-900 V DC catenary voltage. For developing the model, basic power system components like voltage source and transformer are taken from the Sim Scape library of MATLAB. Commonly used blocks like scope, voltage measurement, current measurement are also used for measurement and display of power system parameters. Voltage transformation, AC to DC rectification as well as power system protection and optimization operations are included in the model. Finally, all the elements of the substation are logically connected on the SIMULINK model.

4.1 Design of traction transformer capacity.

The AALRT system consists of a grid source, feeder bus bar, rectifier transformer, and 12-pulse rectifier. The rated output voltage of the reactor is 750 V DC. The secondary side of the traction transformer has two windings that are connected in star and delta form. The load will be distributed to the two traction transformers. The two six-pulse rectifiers are connected in parallel, and one of the rectifiers delivers half of the 750 DC volt. The power capacity of the two traction transformers is half of the load. The rated load for AALRT is 8 MW. A six-pulse rectifier uses two diodes as power electronics devices, and the average DC output voltage of a six-pulse rectifier is calculated using the following equation[29].

where V_{ap} is the the peak value of the phase voltage and V_{dc} is the output of the six pulse rectifier dc value.

$$V_{dc} = \frac{(3)\sqrt{3}}{\pi} V_{ap} \tag{16}$$

A 15 Kv Phase to Phase (LL) peak value is supplied from the EEU power grid. The load value determines the capacity of the traction transformer, which means the power delivered from the traction transformer through the rectifier has to be greater than the power demand of the system. For ideal condition (rectifier power loss is negligible), the output power of the rectifier must be equal to the input from the traction transformer, where the P_Y is the star-connected transformer power output and P_Δ is the delta-connected transformer output power.

$$P_{dc} = P_{\Delta} + P_{Y} \tag{17}$$

$Pdc = Vdctotal * Idc$ where $V_{dctotal}$: dc of 12 puls rectifier

$P_{\Delta} = P_{Y}$ (equal power sharing)

$$P_{Y} = \sqrt{3}(V_{LL}) * I_{L} \cos\phi \tag{18}$$

Where ϕ is the angle between the current and voltage.

$v_{LL} = \sqrt{3}(V_{P})$ for satr connected network

$I_{Ls} = I_{p}$ where $V_{P} * I_{P}$ are the peak value

From the rectifier (six pulse rectifier)

$$V_{dc} = \frac{1}{2} V_{dc_{total}} = \left(\frac{3\sqrt{3}}{\Pi} V_{P} . \right) \tag{19}$$

The secondary star connected phase voltage value calculated as follow

$$V_{S} P_{S} = \frac{750 * \Pi}{3\sqrt{3}} * \frac{1}{2} \tag{20}$$

$$= \frac{375 * \Pi}{3\sqrt{3}} V$$

The secondary Delta connected out put voltage $V_{\Delta} = \frac{375 * \Pi}{3\sqrt{3}} * \sqrt{3} V$ (21)

$$\frac{375 * \Pi}{3} V$$

The primary side input variables are

$$V_{LL} = 15Kv * \sqrt{2} = 15\sqrt{2} Kv \tag{22}$$

$$V_{pp} = 15 \frac{\sqrt{2}}{\sqrt{3}} Kv \tag{23}$$

Three phase short circuit level at base voltage (VA)= $Isc = \frac{Vp}{\sqrt{3(ZT)}}$ (24)

where

- ZT = total impedance per phase of the installation upstream of the fault location (in Ω)

Transformer rating :In secondary voltage considering some voltage drop

$$E_S = V_{drop} + V_O \quad (25)$$

$$V_O = \frac{V_{dc}}{2} * \frac{\Pi}{3\sqrt{3}} \quad (26)$$

$$\begin{aligned} V_{drop} &= I_{rated} * Z \\ &= I_{rated}[R + JWL] \end{aligned} \text{ but } JEL = 2\Pi f \text{ and } f = 50\text{H}$$

Three phase transformer three winding transformer is used in AALRT the connections are star in primary winding and star and delta at secondary windings (YYΔ).The AALRT DC traction power supply system was designed in the Matlab simulation program, and the results of the simulation were used to demonstrate reliability analysis. Knowing the precise system's appearance, which is DC constant voltage as shown by the simulation result.

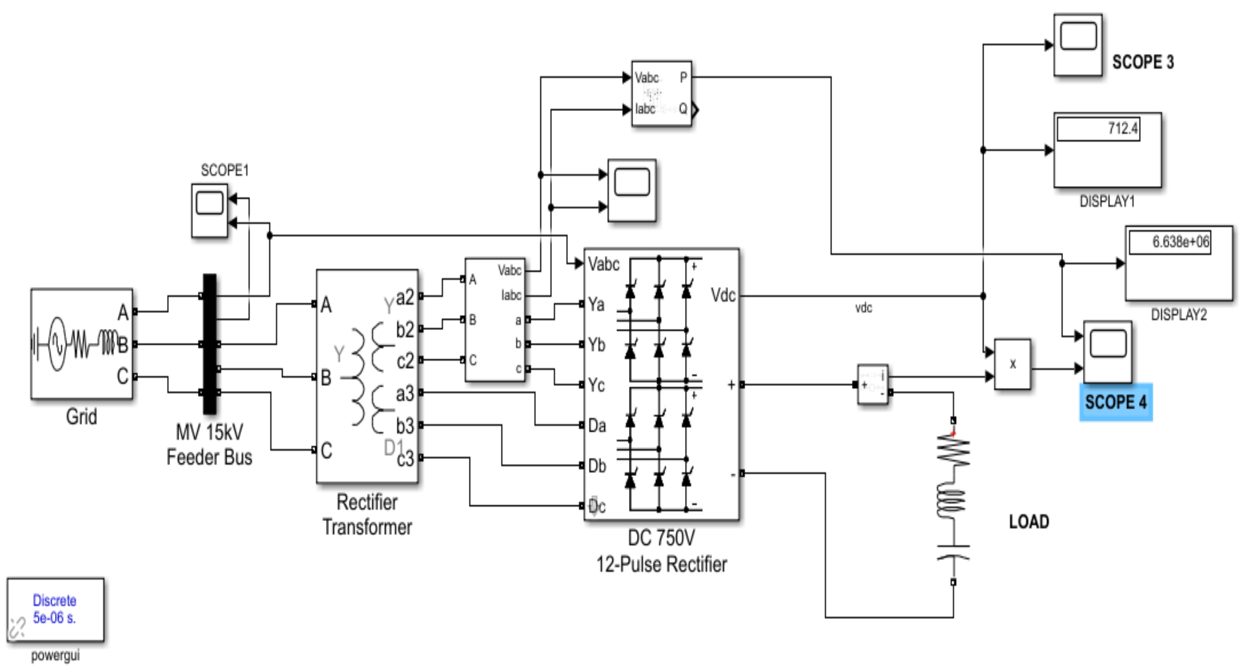


Figure 4. 1.Design of AALRT DC traction substation.

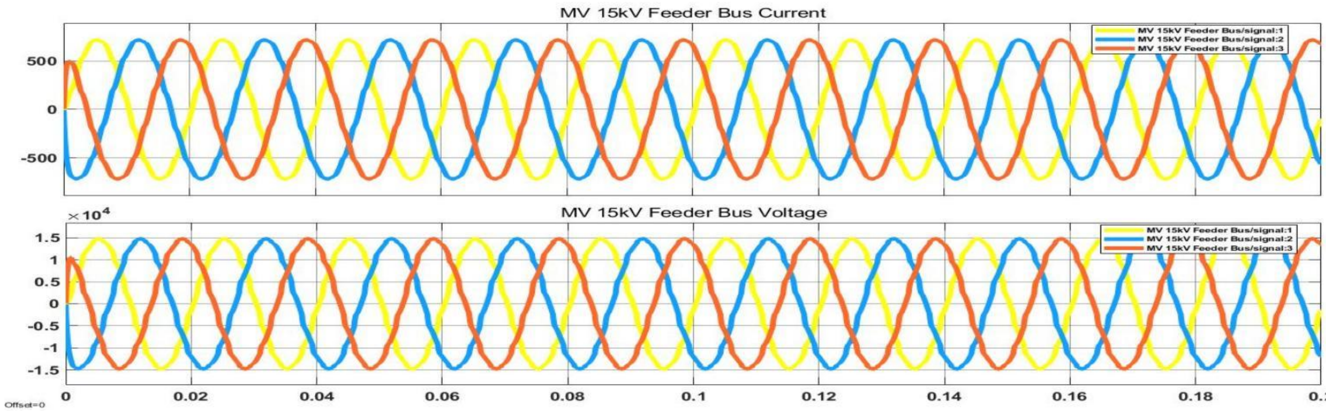


Figure 4. 2 simulation results of voltage and current DC tracton model.

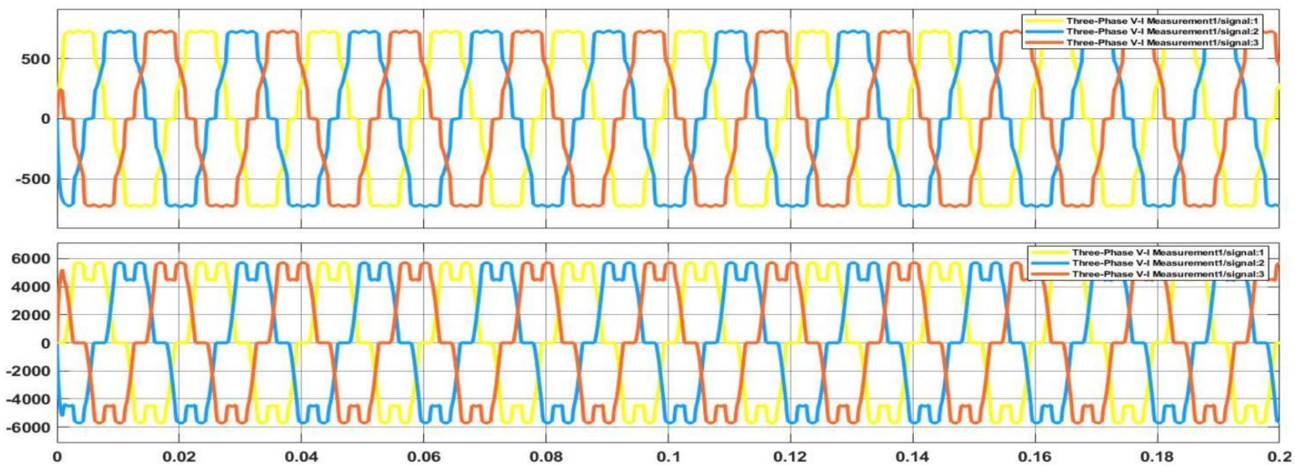


Figure 4. 3 Simulation Result of AALRT DC traction substation.

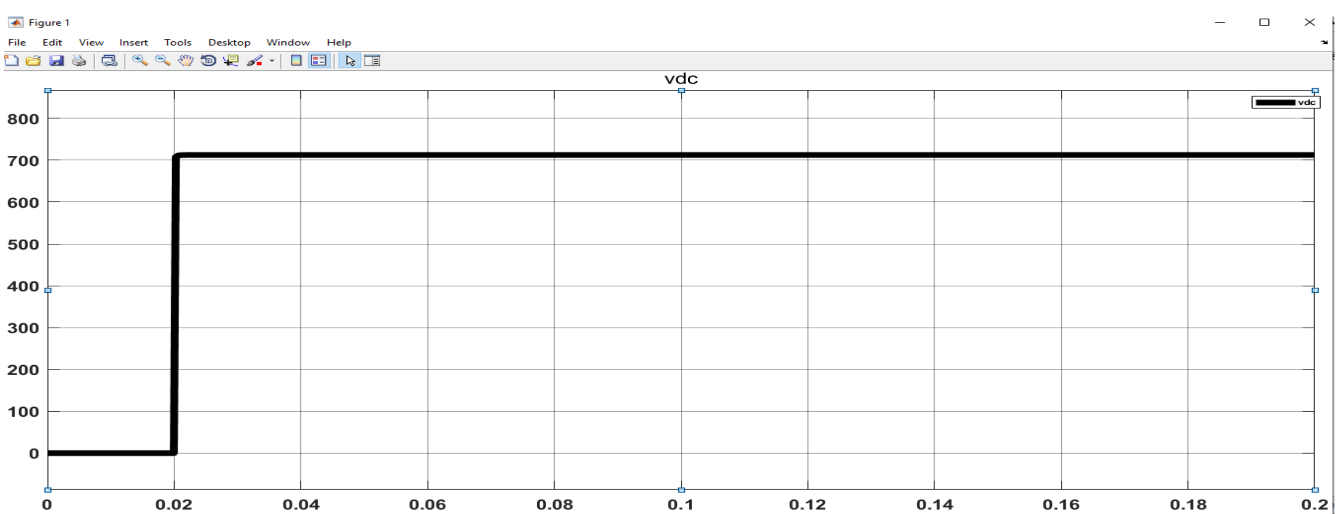


Figure 4. 4 simulation result of load voltage

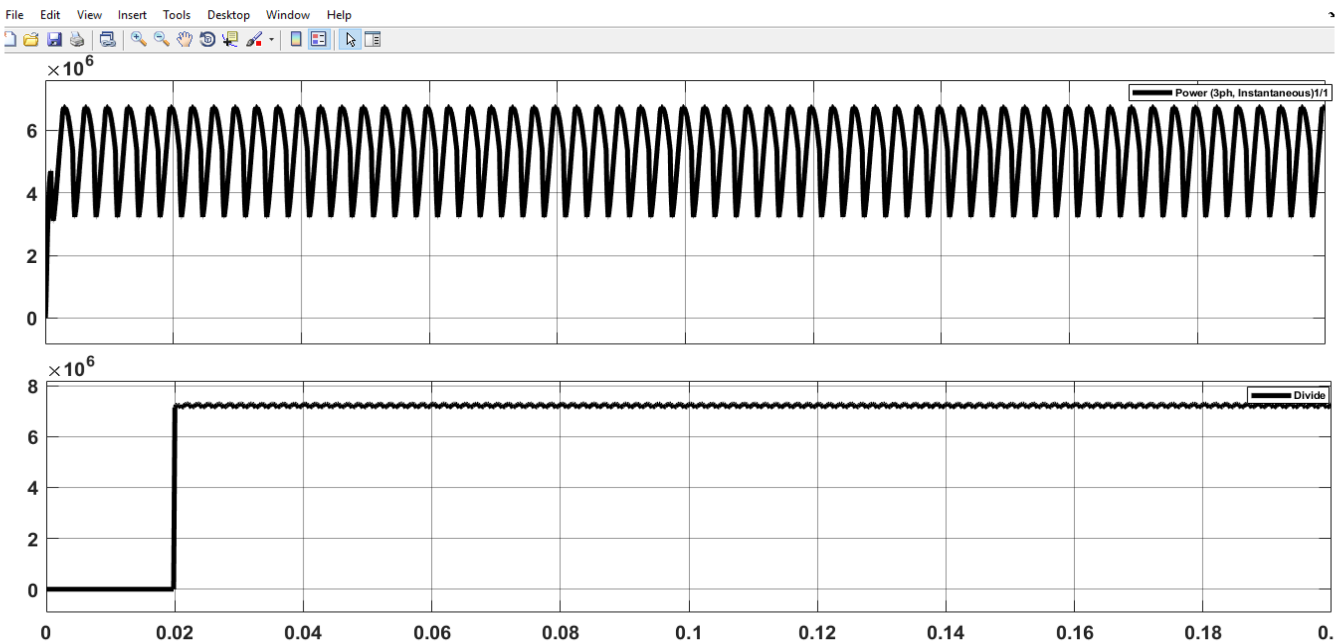


Figure 4. 5 Simulation results of power in DC traction of AALRT

If a fault exists in the DC traction supply, the simulation result also changes, reading zero, and the traction power supply is interrupted.

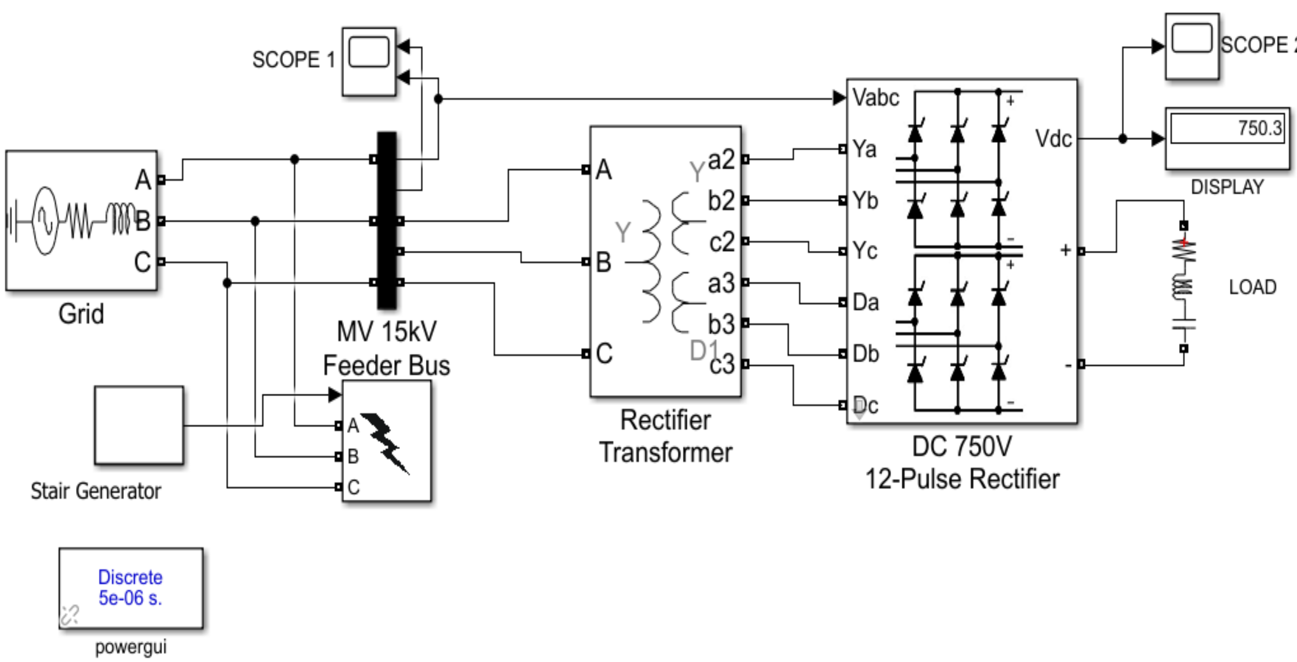


Figure 4. 6 Model of AALRT DC traction with fault condition.

Simulation

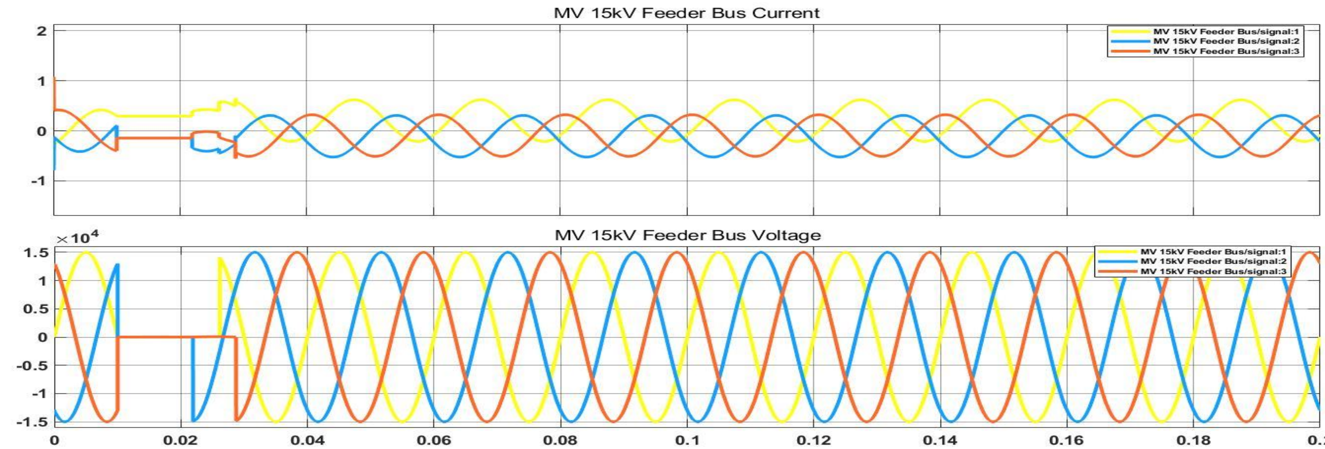


Figure 4. 7 Simulation results of voltage and current in fault condition.

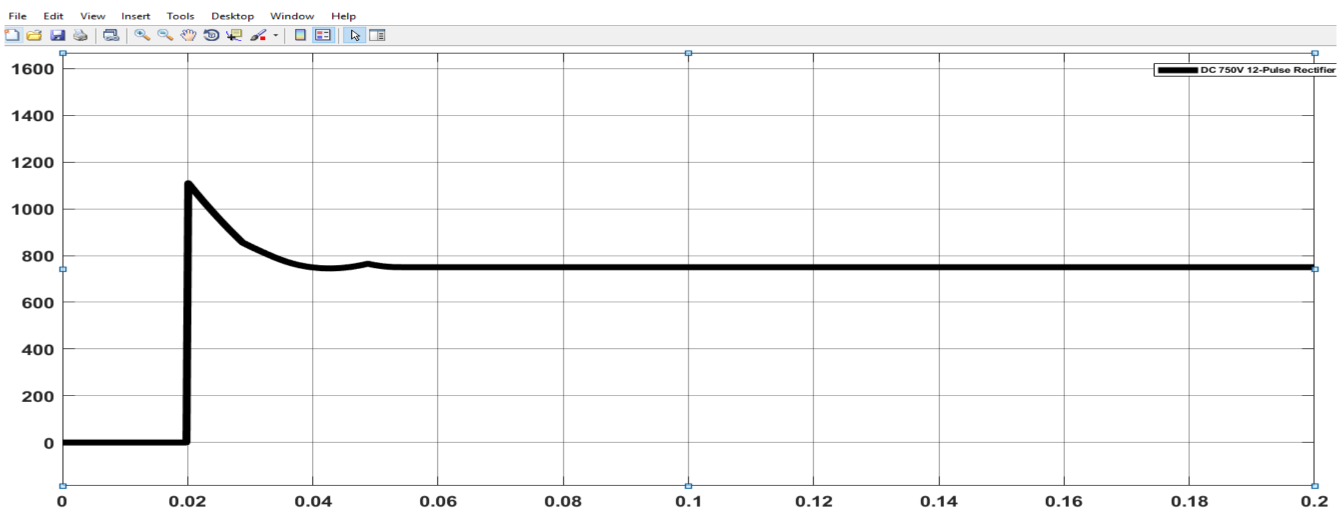


Figure 4. 8 Simulation results of interrupted load voltage.

4.2. Model of DG system

Distributed generation is a powerful technology for reducing emissions. However, if it were employed to improve the AALRT model's power interruption issues, it would require a lot of space and be expensive, making its use in AALRT challenging. The comparator circuit displays a power supply interruption by comparing two voltages (current) and producing an output of either 1 (the voltage at the plus side) or 0 (the voltage at the negative side). Comparators compare the two inputs applied to them and produce the comparison. They are used to detect whether an arbitrary changing input signal hits the reference level or a predetermined threshold level. They are made up of specialized high-gain differential amplifiers.

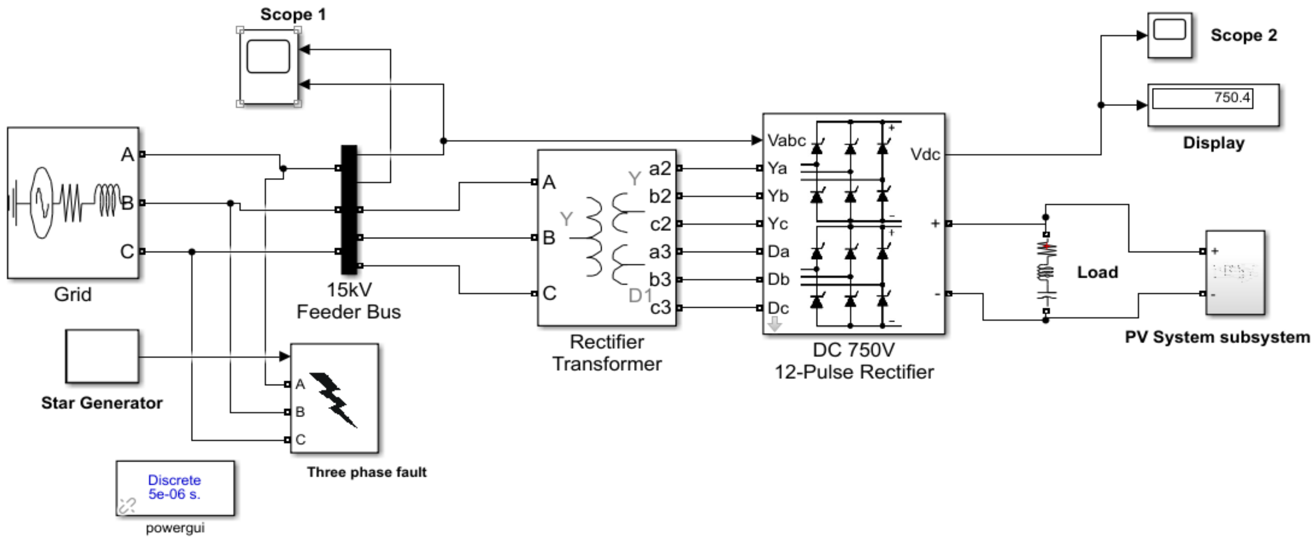


Figure 4. 9.DG model of Matlab

The simulation run as

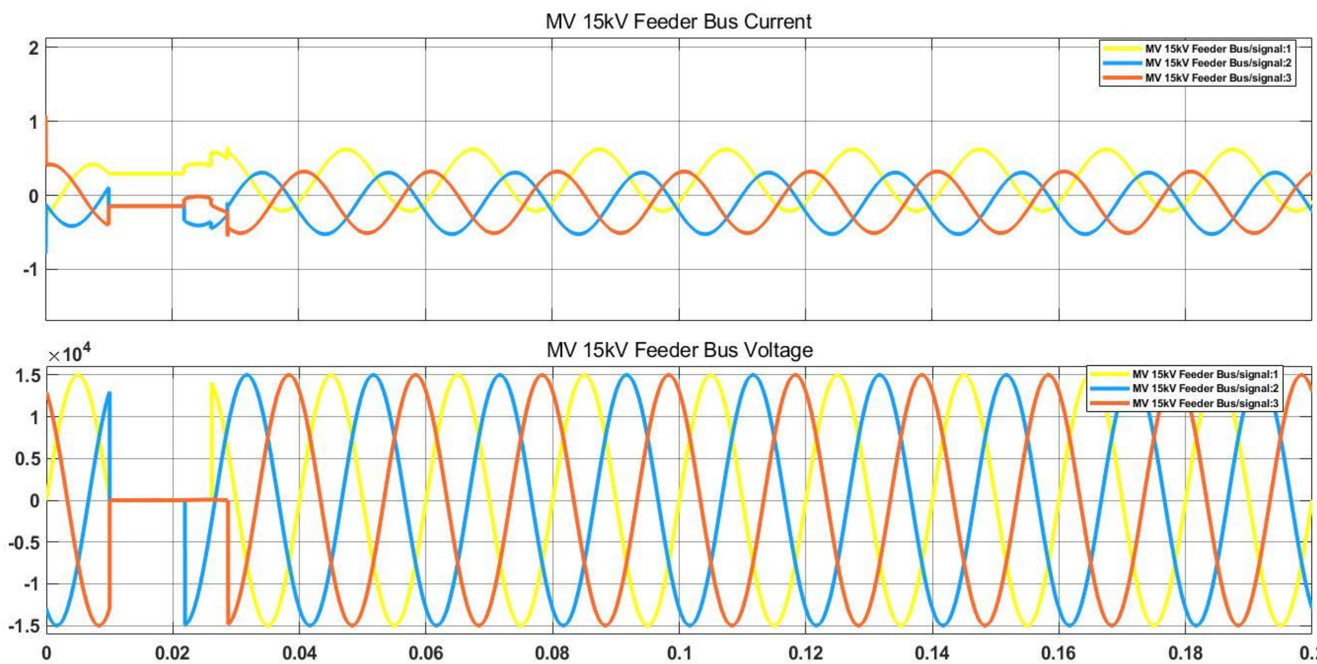


Figure 4. 10 simulation results of voltage and current .

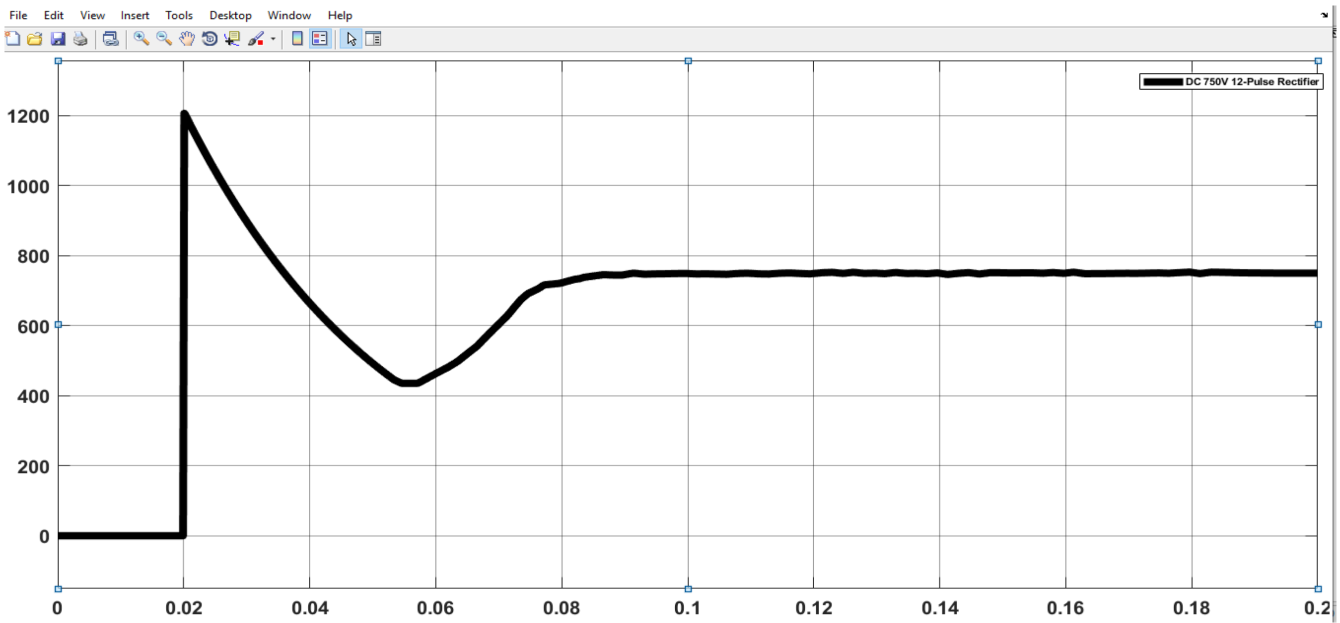


Figure 4. 11 Simulation results of load voltage in DG model .

4.3. Model of Automatic re closer

According to the estimated calculated data, 70% of defects on the EEU side are transient (temporary). Therefore, we can use an automatic recloser to fix them. Automatic reclosers are only applicable for transitory faults; they are not applicable for the other 30% of faults, which are permanent faults, as shown in the figure below. The result is that the traction power supply system continues to function without any power interruptions in case of a temporary fault.

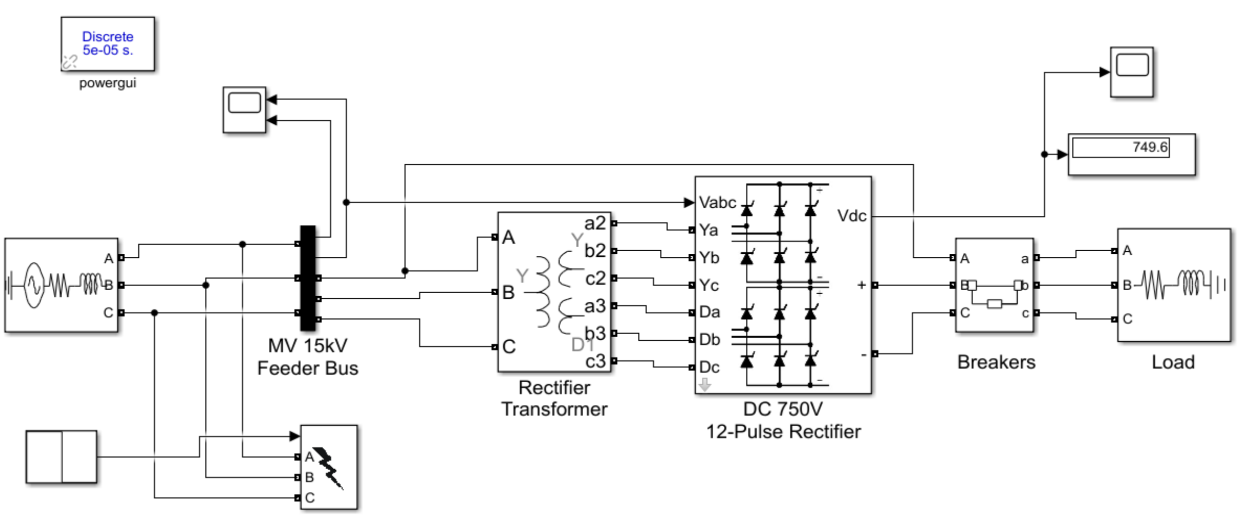


Figure 4. 12.Model of Automatic re-closer in matlab.

Simulation

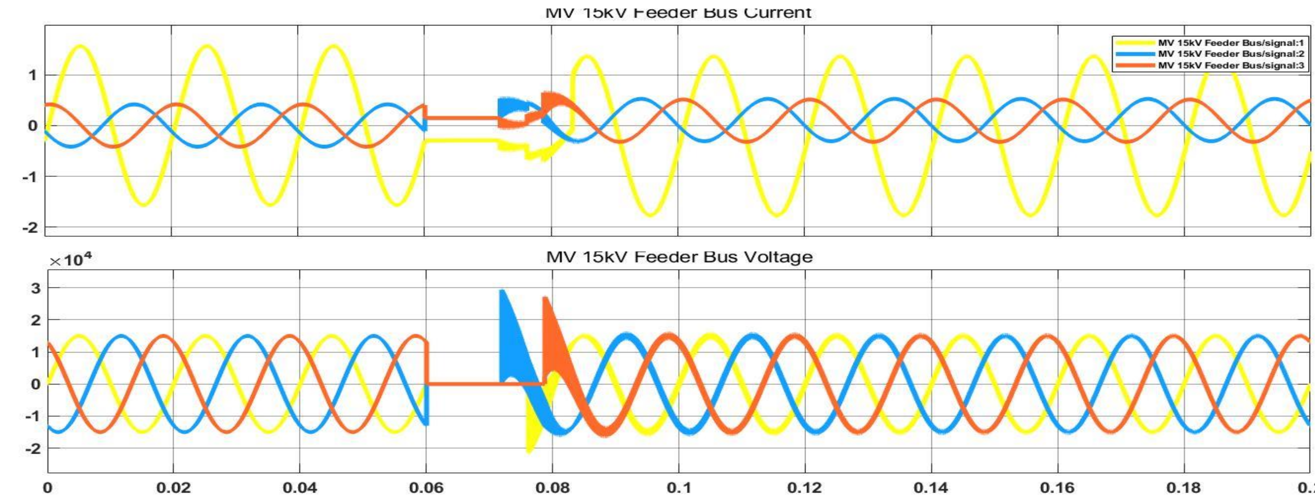


Figure 4. 13 Simulation of voltage and current in incoming side.

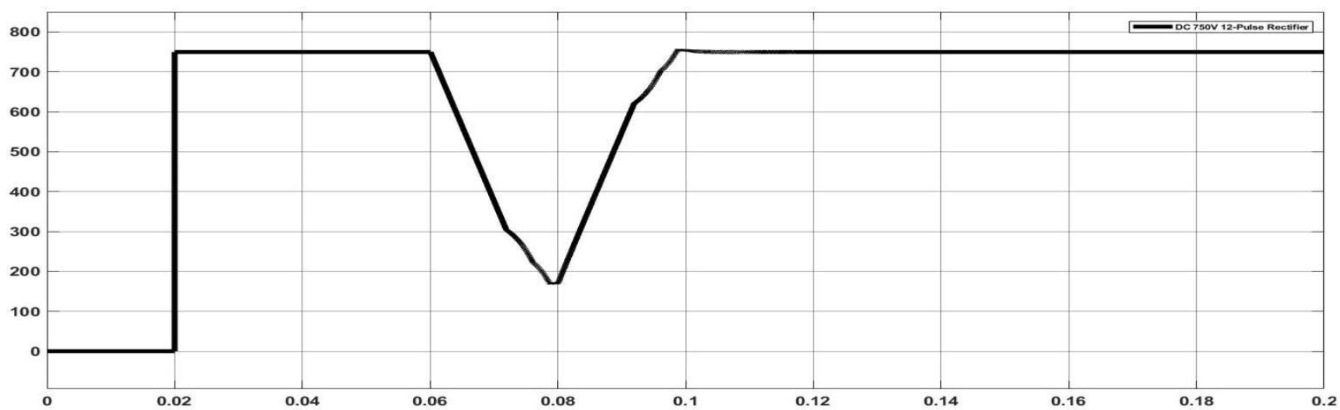


Figure 4. 14 Simulation of load voltage using Automatic re closer

The above figure 4.14 shows that using automatic recloser in dc traction supply system works its normal operation without any interruption but it handle only temporary fault.

4.4. Model of Substation Reconfiguration

- **How and Why selected Substation reconfiguration**

Different power reliability improvement technologies were analyzed in this thesis, such as Automatic Recloser and Distributed Generation. If DG is used, it takes the highest initial investment cost and requires larger spaces. However, in AALRT, there is not enough space to design a DG system. If Automatic Recloser is used, it only improves temporary faults. Substation Reconfiguration is the best way to improve the power reliability problem in AALRT because the above analysis results show that 63% of faults are due to external faults, which means interruptions caused by EEU power supply due to earth fault, short circuit, and other temporary and permanent faults. Substation reconfiguration can improve both internal and external types of faults in AALRT and does not require additional space.

- **How to design**

The existing arrangement takes AC power from the Kality GIS 132kV and transfers it to the Kality AIS 15kV substation. By using a 15kV bus bar, power directly goes to the rectifier transformer to convert AC power to DC power for traction supply. To improve power reliability, two incoming 15kV power supplies are paralleled using two bus bars, and the bus bars are connected by a bus coupler. If there is a fault (interruption) in one incoming line, the system will work with the other incoming line, creating a redundant system.

- Two power incoming line from two EEP/EEU substations
- Two bus bar
- Breakers
- Rectifier transformer: utilized to convert the necessary DC voltage from the ac voltage supplied by a power grid.
- DC 750V 12 pulse rectifiers: uses two 6-pulse rectifiers in parallel (12 diodes) to feed a common DC bus. A transformer with one primary and two secondary windings creates a 30 degree phase shift between the two current waveforms, which eliminates the 5^{th} and 7^{th} harmonics and reduces current THD between 10 and 15 per cent.
- IGBT with Diode : The IGBT block implements a semiconductor device controllable by the gate signal. The IGBT is simulated as a series combination of a resistor Ron, inductor Lon, and a DC voltage source Vf in series with a switch controlled by a logical signal[30][31].The IGBT turns on when the collector-emitter voltage is positive (the incoming power without fault condition) and greater than Vf and a positive signal is applied at the gate input ($g > 0$). It turns off when the collector-emitter voltage is positive and a 0 signal is applied at the gate input ($g = 0$).The IGBT device is in the off state when the collector-emitter voltage is negative. Note that many commercial IGBTs do not have the reverse blocking capability[32]. Therefore, we used with an antiparallel diode.

- Not Get: If the input is a vector, the logical complements of the input vector components are contained in the output, which is also a vector of the same size.In Not get If the input is true(1) then the output is fauls.
- Stair Generator Block : The Stair Generator block generates a signal changing at specified transition times. We used the stair generator block to generate a logical signal to control the opening and closing of the Breaker block and the ideal switch block and also used the stair generator block to generate a signal whose amplitude changes by steps at specified transition times.
- **Substation reconfiguration analysis model**

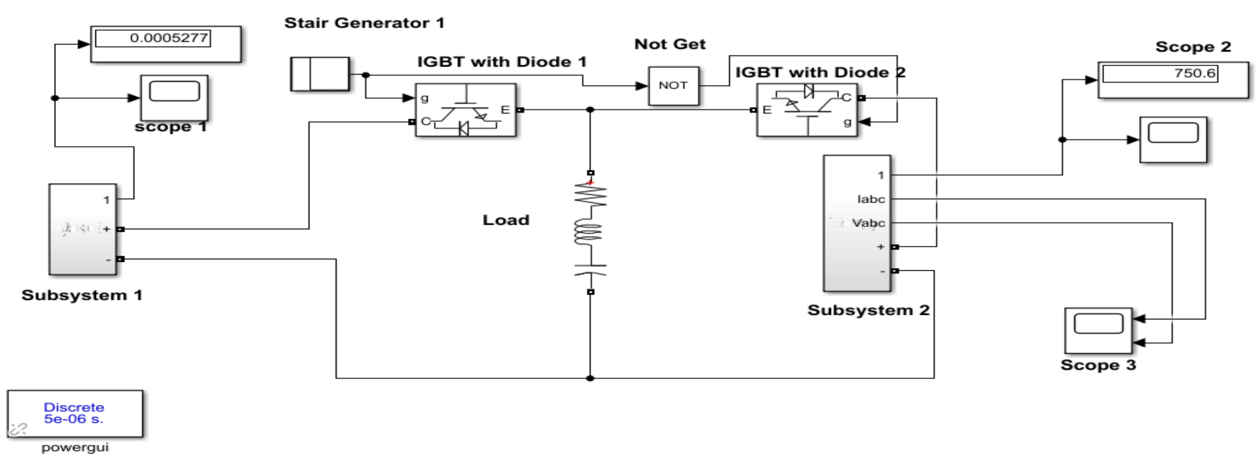


Figure 4. 15.Model of Substation Reconfiguration in Matlab

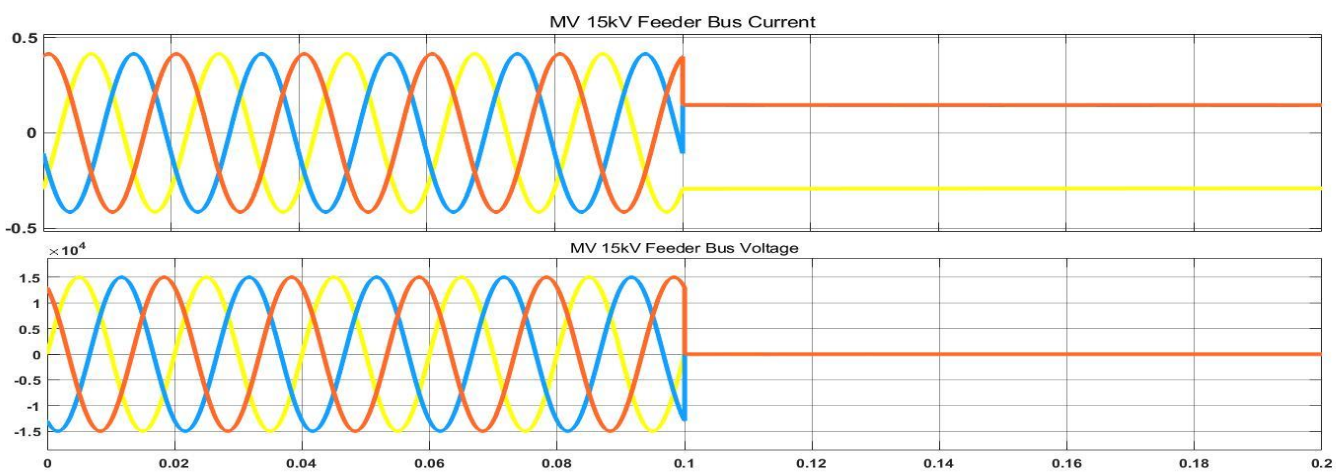


Figure 4. 16 Simulation of voltage and current with fault in the incoming line.

The simulation results of load voltage with a fault in the primary side are shown in Figure 4.17. The voltage is zero due to the interruption. However, the AALRT traction supply system power is not interrupted because it receives power from the other incoming line.

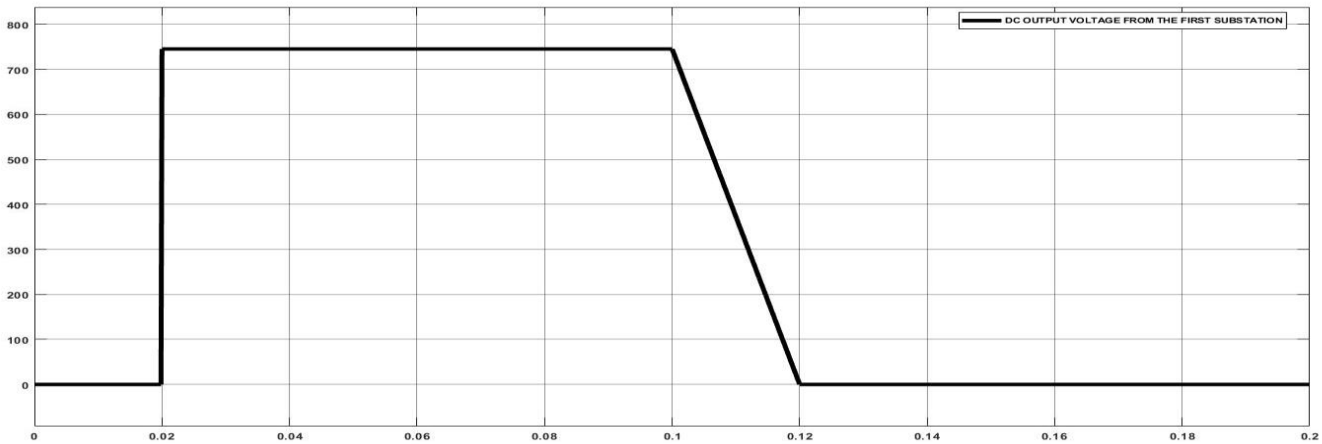


Figure 4. 17 Simulation results of load voltage after reconfiguring the substation.

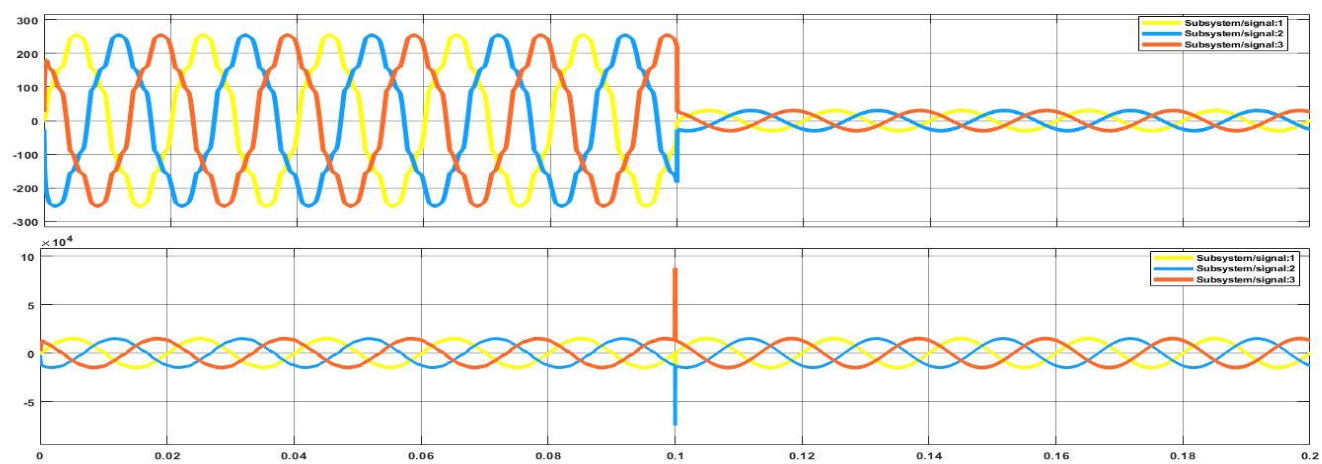


Figure 4. 18 Simulation results of voltage and current with the second incoming line.

Figure 4.19 shows the simulation results of load voltage after reconfiguring the substation with two incoming lines. If a fault occurs in the primary incoming line, there is no interruption in the secondary side, and it does not affect the traction system. Even if there is a power interruption in the primary incoming line, the system is not interrupted. As we can see from the simulation result display below, the load supply reads 750V DC.

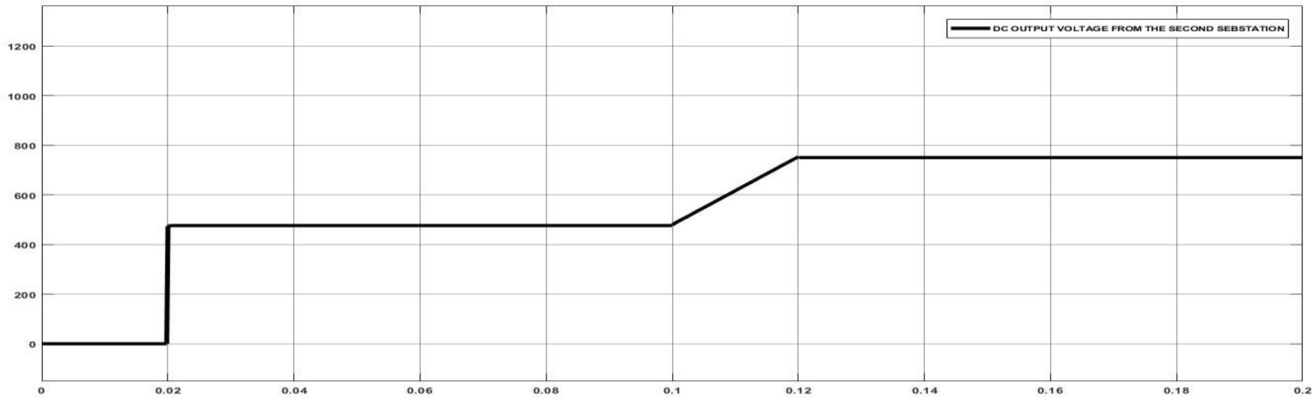


Figure 4. 19. simulation result of substation reconfiguration in matlab

Substation reconfiguration, which makes use of two incoming lines from the EEP power grid, is the chosen way to increase the reliability of the power supply. This kind of solution offers the highest level of supply flexibility and dependability because it uses a redundant supply system. This means that failures and maintenance won't affect the supply's continuity.

4.5.Reliability Improvement Analyticaly

To show the improvments of AALRT power supply system analytically we use etab software and compared the reliability of AALRT after reconfiguring the substation with the existing system .

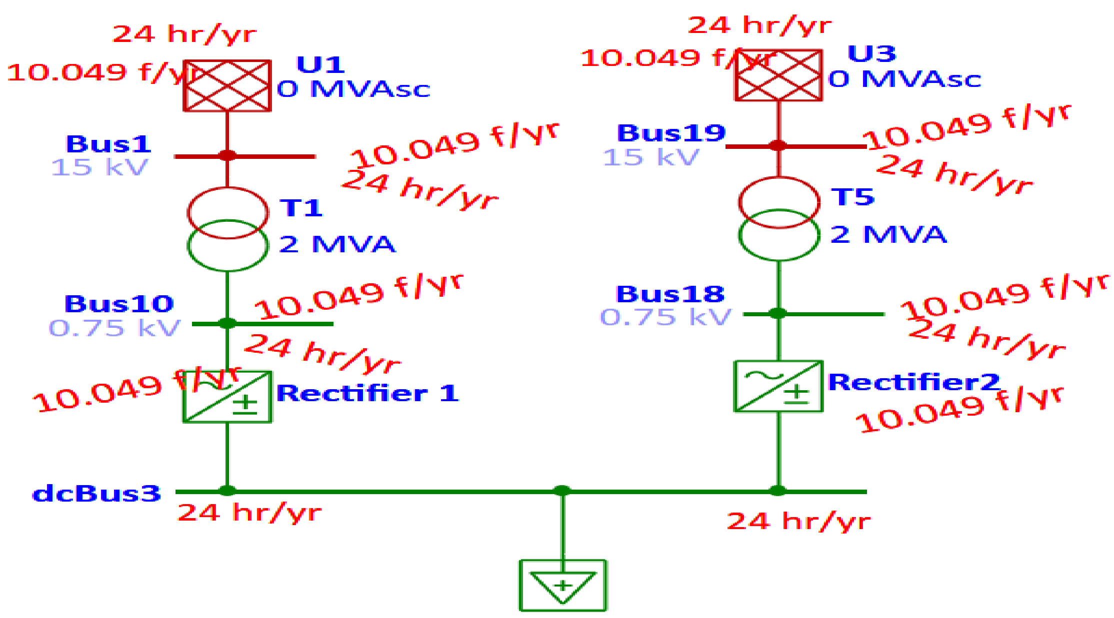


Figure 4. 20.substation reconfigurig in AALRT single line diagram using etab software.

Project:	POWER RELIABILITY ANALYSIS	ETAP		Page:	1
Location:	Addis Ababa	19.0.1C		Date:	03-09-2023
Contract:	elenisisay215@gmail.com			SN:	
Engineer:	Eleni Sisay	Study Case:	RA	Revision:	Base
Filename:	single line diagram of AALRT			Config.:	Normal

Reliability analysis results of AALRT by reconfiguring the substation .

SUMMARY

System Indexes

ASAI 0.9973 pu

ASUI 0.00274 pu

SAIDI 24.0280 hr / customer. yr

ASAI Average service Availability Index
ASUI Average Service Unavailability Index
SAIDI System Average Interruption Duration Index
SAIFI System Average Interruption Frequency Index

Figure 4. 21.Reliability indices Simulation results of AALRT after Reconfiguaring the substation.

Chapters Five

5.1. Conclusions

Based on the analysis, the primary cause of AALRT interruptions is external fault utility side power interruption, which accounts for about 63% of all interruptions. Of these, 70% are temporary and 29% are permanent faults. The external fault in this network is caused by a number of factors, including the failure of protection equipment, short circuits, poor cable quality, lack of effective maintenance for underground cables, cable theft by thieves, and dirty-affected cables. Windy conditions, which occur particularly during the rainy season, are the cause of temporary short circuits. Short circuit conditions on the AALRT account for half of the issue. This happens as a result of sudden phase contact brought on by windy conditions and occasionally by the sudden contact of three phases, which causes a temporary earth fault. According to AALRT's analysis, longer circuits cause more disruptions. There are only four switching substations that span several kilometers. The reliability of the power supply in AALRT generally falls short of the standards set by the regulating body, EEA. Additionally, the reliability of AALRT power supply is not good enough in comparison to the international reliability indices of best-experienced countries. Furthermore, there is a high level of service unavailability.

In this tesis, various mitigation strategies were analyzed and modeled in Matlab Simulink. The results were compared, and it was found that reconfiguring the substation is the most effective method. A model quality substation (NS 6) was reconfigured.After the improvement, SAIFI (frequency) was recorded at 10.0490 fri/customer.yr, and SAIDI (duration) was recorded at 24.0280 hr/customer.yr This method is optimal in terms of space utilization and cost minimization and after improvement it can satisfy standards set by regulatory body, EEA.

5.2. Recommendations for Future Work

For internal faults require different testing, such as a withstand test to ensure that an electrical product has enough insulation (dielectric) strength for any voltage it may be exposed to. It is also preferable to measure the total insulation resistance between any two points. Check for protective coordinating arrangements needs an analysis. Distribution Technology is the best technology if the substation is expanded there is enough open space in the future to improve power reliability and cost reduction for the future. It is also possible to use DG and electric power system interchangeably using comparator circuit by comparing if there is power works in normal operation otherwise work as DG system.

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Appendix A: Reliability Index calculation

RELIABILITY INDEX CALCULATION

No	Date	Passenger flow of both line			late train of both line			Trips on Both lines						Cancel trip of both line			Train KM of both line			Total Passenger Interupted (passenger not flow)			Total customer interuption duration			LEVEL OF POWER INTERUPTION IN PERCENT		
		BW	NS	Total	BW	NS	Total	plan-BW	Actual-HEW	Plan-NS	Actual-NS	plan total	Actual-total	BW	NS	Total	BW	NS	Total	BW	NS	Total	BW	NS	Total	BW	NS	Total
2018	2018-01	182692	139014	321706	302	369	671	3844	3798	3813	3758	7657	7552	12	33	105	116130	74962	191092	10560	12540	23100	6E+05	153615	734415	1.2488993	1.494898	1.371294
	2018-02	164820	123597	288417	381	325	706	3472	3465	3444	3410	6916	6875	1	8	25	96300	74680	170980	1100	4400	5500	25300	101196	133496	0.2016129	0.987224	0.592828
	2018-03	183396	135548	318944	319	344	663	3844	3788	3813	3776	7657	7564	21	51	93	115787	80222	196009	12320	8140	20460	7E+05	207914	934694	1.4568158	0.970365	1.214575
	2018-04	179257	147911	327168	252	244	496	3720	3710	3690	3684	7410	7394	46	52	14	100576	78298	178874	2200	880	3080	26708	0	26708	0.2688172	0.162602	0.215924
	2018-05	187291	133592	320883	371	409	780	3844	3781	3813	3752	7657	7533	61	60	122	117581	80470	198051	13640	13200	26840	5E+05	153912	655728	1.6389178	1.59979	1.619433
	2018-06	168127	120763	288890	211	421	632	3472	3234	3444	3309	6916	6543	217	103	209	100763	86858	167621	27500	18480	45980	1E+06	0	1E+06	6.8548387	3.919861	5.392291
	2018-07	171706	120236	291942	226	398	624	3844	3381	3813	3538	7657	6919	159	124	826	104368	74693	179061	94160	87560	181720	0	0	0	12.044745	7.212169	9.63824
	2018-08	190498	1364859	1555357	253	270	523	3844	3817	3813	3758	7657	7575	13	50	72	110291	74553	184844	4840	11000	15840	0	0	0	0.7029333	1.442434	1.070916
	2018-9	153979	1059438	1213417	166	136	302	3720	3387	3690	3288	7410	6675	96	161	735	89391	62958	152349	73260	88440	161700	0	0	0	8.9516129	10.89431	9.919028
	2018-10	212209	1445753	1657962	213	306	519	3844	3736	3813	3782	7657	7518	30	35	139	113606	79086	192692	23760	6820	30580	0	524117	524117	2.8095734	0.813008	1.815332
	2018-11	188990	1410566	1599556	98	257	355	3720	3085	3690	3652	7410	6737	56	60	673	110864	77932	188596	139700	8360	148060	0	327963	327963	17.068592	1.02981	9.082321
	2018-12	201548	1462932	1664480	251	220	471	4340	4021	3925	3714	8265	7735	285	78	407	124682	89943	214625	70180	19360	89540	5E+06	429211	5E+06	7.3502304	5.375796	6.412583
Total		2E+06	7662209	9844722	3043	3699	6742	45508	43201	44761	43419	90269	86620	977	815	3420	1300139	914835	2214774	473220	279180	752400	8E+06	1904828	1E+07	60.598149	35.90225	48.34577
2019	2019-01	214208	144921	359129	465	164	629	4805	4767	4030	3841	8835	8608	37	191	228	141835	99520	241355	8140	42020	50160	3E+05	2150163	2E+06	0.7908429	4.889828	2.589327
	2019-02	184357	132886	317243	272	140	412	4340	3955	3640	3592	7980	7547	385	48	433	115193	89541	204734	84700	10560	95260	5E+06	236038	5E+06	8.8709677	1.318681	5.426065
	2019-03	213833	151885	365718	335	91	426	4849	4744	4624	4468	9473	9212	104	156	260	137791	98127	235918	22880	34320	57200	1E+06	1964477	3E+06	2.1659949	3.373702	2.755199
	2019-04	189582	141533	331115	322	102	424	4710	4513	4710	4457	9420	8970	291	332	623	120231	86724	206955	64020	73040	137060	2E+06	7131626	9E+06	4.1825902	5.37155	4.77707
	2019-05	205984	154068	380830	420	80	500	4887	4831	4887	4148	9734	8979	38	719	755	108881	82182	190843	7920	158180	166100	85219	3.9E+07	4E+07	0.7398754	14.77298	7.756318
	2019-06	176554	134716	311270	461	84	545	4710	4439	4710	3995	9420	8434	271	680	951	92846	82513	175359	59620	149600	209220	2E+06	2.7E+07	3E+07	5.7537155	15.18047	10.46709
	2019-07	219329	168099	387428	319	133	452	4887	4710	4887	4738	9734	9448	157	129	286	137716	97806	235522	34540	28380	62920	1E+06	680390	2E+06	3.2258065	2.850503	2.938155
	2019-08	204672	159592	364264	419	114	533	5259	5148	5259	5223	10518	10371	111	36	147	117204	103741	220945	24420	7920	32340	6E+05	347054	916773	2.1106674	0.684541	1.397604
	2019-09	165579	129233	294812	295	51	346	5550	5215	5550	5361	11100	10576	268	118	386	111062	99723	210785	58960	25960	84920	2E+06	481558	3E+06	6.036036	3.405405	4.720721
	2019-10	175355	140366	315721	275	26	301	5735	5415	5735	5452	11470	10867	282	286	568	110579	108216	218795	62040	62920	124960	2E+06	2610959	4E+06	5.5797733	4.934812	5.257193
	2019-11	167813	140937	308750	240	28	268	5550	5200	5550	5383	11100	10583	350	167	517	109610	110164	219774	77000	36740	113740	5E+06	307881	5E+06	6.3063063	3.009009	4.657658
	2019-12	173233	146248	319481	282	40	322	5735	5735	5551	5617	11286	11352	184	118	302	119448	113070	232518	40480	25960	66440	3E+06	366815	3E+06	0	-1.188975	-0.5848
Total		2E+06	1745382	4035761	4105	1053	5158	60977	58872	59093	58275	120070	114947	2476	2980	5456	1422174	1171127	2593301	544720	655800	1E+06	2E+07	8.2E+07	1E+08	45.761776	58.20228	52.1376
2020	2020-01	171660	143512	315172	214	79	293	5735	5467	5735	5407	11470	10874	268	304	572	120174	107289	227463	58960	66880	125840	2E+06	1667987	3E+06	4.6730602	5.719288	5.196164
	2020-02	158868	124571	283239	241	60	301	5365	4961	5365	5107	10730	10068	404	258	662	104391	98635	203026	88880	56760	145640	6E+06	2218749	8E+06	7.5302889	4.808947	6.169618
	2020-03	118461	106533	224994	110	6	116	5247	5014	5177	5119	10424	10133	233	58	291	104438	101238	205676	51260	12760	64020	2E+06	51040	2E+06	4.4406327	1.12034	2.791635
	2020-04	50979	392273	443252	1	0	1	4974	4855	4968	4628	9942	9283	319	340	659	118486	104159	222645	70180	74800	144980	2E+06	535568	3E+06	6.4133494	6.8438	6.628445
	2020-05	60960	453234	514194	7	6	13	5270	4987	5270	5170	10540	10137	302	101	403	129912	117255	247167	66440	22220	88660	2E+06	437067	3E+06	5.7405258	1.897533	3.823529
	2020-06	59163	394854	454017	0	0	0	5100	4649	5100	4705	10200	9354	451	395	846	117871	108187	226058	99220	86900	186120	5E+06	3120579	8E+06	8.8431373	7.745098	8.294118
	2020-07	64041	427760	491801	0	0	0	5270	4880	5270	4958	10540	9838	390	314	704	102450	91111	193561	85800	69080	154880	4E+06	1051398	5E+06	7.4003795	5.958254	6.679317
	2020-08	750057	517423	1267480	0	0	0	5270	4440	5270	4856	10540	9296	830	414	1244	111870	108045	219915	182800	91080	273880	2E+07	2869020	2E+07	15.749526	7.855787	11.80266
	2020-09	765785	605197	1370982	0	0	0	5270	4584	5270	4587	10540	9171	686	683	1369	102918	106073	208991	150820	150280	301180	1E+07	2315507	1E+07	13.017078	12.96015	12.98861
	2020-10	665289	434821	1100110	0	0	0	5270	3911	5270	4512	10540	8423	1359	758	2117	59903	98095	155998	298880	186780	485740	3E+07	5539767	4E+07	25.787478	14.3833	20.08539
	2020-11	851002	758041	1609043	0	0	0	5100	4224	5100	4350	10200	8574	717	589	1306	70351	84228	154579	157740	129680	287320	5E+06	1887981	7E+06	17.176471	14.70588	15.94118
	2020-12	103779	993084	1096863	0	0	0	5270	4571	5270	4829	10540	9400	707	456	1163	79823	90311	189934	155540	100320	255860	3E+06	1942195	5E+06	13.283757	8.388121	10.81594
Total		4E+06	5351303	9171147	573	151	724	63141	58323	63065	58226	126206	114549	6866	4870	11336	1222387	1212626	2435013	1468520	1E+06	2E+06	9E+07	2.4E+07	1E+08	130.04468	92.36849	111.2166
2021	2021-01	99593	987870	1087463	2	3	5	5270	4288	5270	4354	10540	8642	980	906	1886	76377	82076	158453	215600	199320	414920	1E+07	1E+07	2E+07	18.633776	17.3814	18.00759
	2021-02	98249	110291	208540	0	0	0	4760	3658	4760	4326	9520	7984	1102	434	1536	67070	81462	148532	242440	95480	337920	3E+07	471.4902	3E+07	23.151261	9.117647	16.13445
	2021-03	89812	974621	1064433	0	0	0	5270	3394	5270	4005	10540	7399	1876	1265	3141	54389	78566	132955	412720	278300	691020	3E+07	1.9E+07	5E+07	35.597723	24.0038	29.80076
	2021-04	60829	82057	142886	0	0	0	5100	3512	5100	3987	10200	7499	1588	1113	2701	57097	63838	120935	349360	244860	594220	2E+07	1.1E+07	5E+07	31.137255	21.82353	26.48039
	2021-05	88281	102875	190956	0	0	0	5270	3687	5270	4255	10540	7942	1413	839	2252	66911	77587	144498	310860	184580	495440	1E+07	1E+07	2E+07	30.037951	19.25998	24.84896
	2021-06	73410	998212	1071622	0	0	0	5100	2856	5100	4210	10200	7066	2244	890	3134	41234	74309	115543	493680	195800	689480	2E+07	1.4E+07	4E+07	44	17.45098	30.72549
	2021-07	78254	104064	182318	0	0	0	5270	2723	5270	4361	10540	7084	2547	909	3456	42042	77644	119686	560340	199980	760320	3E+07	1.0E+07	5E+07	48.330171	17.24858	32.78937
	2021-08	83200	107207	190407	0	0	0	5270	2344	5270	4631	10540	6975	2926	639	3565	57056	81067	138123	643720	140580	784300	3E+07	791.7466	4E+07	55.521822	12.12524	33.82353
	2021-09	85221	950530	1035751	0	0	0	4230	3612	4230	3767	8460	7379	618	463	1081	60131	65708	125839	135960	101860	237820	7E+06	5066516	1E+07	14.609929	10.94563	12.77778
	2021-10	98887	104630	203497	0	0	0	4371	3575	4371	3690	8742	7265	796	681	1477	60207	65338	125545	175120	149820	324940	5E+06	1.1E+07	2E+07	18.210936	15.57996	16.89545
	2021-11	79839	86046	166485	0	0	0	4230	2798	4230	3345	8460	6143	1432	885	2317	48164	60122	108286	315040	194700	509740	2E+07	1.1E+07	3E+07	33.853428	20.92199	27.38771
	2021-12	74469	121715	196184	0	0	0	4371	2540	4371	3744	8742	6284	1831	627	2458	51326	66124	117450	402820	137940	540760	5E+06	2895361	8E+06	41.889728	14.34454	28.11714
Total		1E+08	4730818	5740542	2	3	5	58512	38987	58512	48675	117024	87662	19353	9851	29204	682004	873341	1555345	4257660	2E+06	6E+06	2E+08	1.4E+08	4E+08	394.97396	200.2032	297.5886

Appendix B: Interruption data of EW and NS line

Date G.C	Date E.C	EW line	NS line	Total
1/1/2022	4/23/2014	39	0	39
1/2/2022	4/24/2014	0	0	0
1/3/2022	4/25/2014	0	0	0
1/4/2022	4/26/2014	0	0	0
1/5/2022	4/27/2014	0	0	0
1/6/2022	4/28/2014	0	0	0
1/7/2022	4/29/2014	0	0	0
1/8/2022	4/30/2014	0	0	0
1/9/2022	5/1/2014	0	0	0
1/10/2022	5/2/2014	0	0	0
1/11/2022	5/3/2014	0	0	0
1/12/2022	5/4/2014	73	76	149
1/13/2022	5/5/2014	0	0	0
1/14/2022	5/6/2014	0	0	0
1/15/2022	5/7/2014	0	0	0
1/16/2022	5/8/2014	14	0	14
1/17/2022	5/9/2014	0	0	0
1/18/2022	5/10/2014	0	0	0
1/19/2022	5/11/2014	0	0	0
1/20/2022	5/12/2014	0	0	0
1/21/2022	5/13/2014	0	0	0
1/22/2022	5/14/2014	0	0	0
1/23/2022	5/15/2014	0	0	0
1/24/2022	5/16/2014	0	0	0
1/25/2022	5/17/2014	14	14	28
1/26/2022	5/18/2014	26	0	26
1/27/2022	5/19/2014	0	0	0
1/28/2022	5/20/2014	0	0	0
1/29/2022	5/21/2014	0	0	0
1/30/2022	5/22/2014	0	0	0
1/31/2022	5/23/2014	0	0	0
	Total	166	90	256

Date G.C	Date E.C	EW line	NS line	Total
2/1/2022	5/24/2014	0	0	0
2/2/2022	5/25/2014	0	0	0
2/3/2022	5/26/2014	0	3	3
2/4/2022	5/27/2014	0	0	0
2/5/2022	5/28/2014	0	0	0
2/6/2022	5/29/2014	0	0	0
2/7/2022	5/30/2014	102	0	102
2/8/2022	6/1/2014	0	0	0
2/9/2022	6/2/2014	0	0	0
2/10/2022	6/3/2014	0	0	0
2/11/2022	6/4/2014	0	0	0
2/12/2022	6/5/2014	0	0	0
2/13/2022	6/6/2014	0	0	0
2/14/2022	6/7/2014	0	0	0
2/15/2022	6/8/2014	4	0	4
2/16/2022	6/9/2014	0	0	0
2/17/2022	6/10/2014	0	0	0
2/18/2022	6/11/2014	25	0	25
2/19/2022	6/12/2014	0	0	0
2/20/2022	6/13/2014	0	0	0
2/21/2022	6/14/2014	0	9	9
2/22/2022	6/15/2014	77	0	77
2/23/2022	6/16/2014	85	0	85
2/24/2022	6/17/2014	5	6	11
2/25/2022	6/18/2014	0	0	0
2/26/2022	6/19/2014	0	0	0
2/27/2022	6/20/2014	0	6	6
2/28/2022	6/21/2014	0	0	0
	Total	298	24	322

Date G.C	Date E.C	EW line	NS line	Total
3/1/2022	6/22/2014	0	0	0
3/2/2022	6/23/2014	0	0	0
3/3/2022	6/24/2014	0	0	0
3/4/2022	6/25/2014	0	0	0
3/5/2022	6/26/2014	0	0	0
3/6/2022	6/27/2014	37	10	47
3/7/2022	6/28/2014	11	0	11
3/8/2022	6/29/2014	14	0	14
3/9/2022	6/30/2014	0	0	0
3/10/2022	7/1/2014	0	0	0
3/11/2022	7/2/2014	0	4	4
3/12/2022	7/3/2014	0	0	0
3/13/2022	7/4/2014	0	0	0
3/14/2022	7/5/2014	122	98	220
3/15/2022	7/6/2014	0	0	0
3/16/2022	7/7/2014	6	0	6
3/17/2022	7/8/2014	0	0	0
3/18/2022	7/9/2014	0	0	0
3/19/2022	7/10/2014	141	30	171
3/20/2022	7/11/2014	19	9	28
3/21/2022	7/12/2014	0	0	0
3/22/2022	7/13/2014	0	0	0
3/23/2022	7/14/2014	134	0	134
3/24/2022	7/15/2014	40	0	40
3/25/2022	7/16/2014	0	0	0
3/26/2022	7/17/2014	38	0	38
3/27/2022	7/18/2014	0	0	0
3/28/2022	7/19/2014	55	0	55
3/29/2022	7/20/2014	0	0	0
3/30/2022	7/21/2014	0	0	0
3/31/2022	7/22/2014	0	1	1
	Total	617	152	769

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
4/1/2022	7/23/2014	0	0	0
4/2/2022	7/24/2014	0	0	0
4/3/2022	7/25/2014	0	0	0
4/4/2022	7/26/2014	0	0	0
4/5/2022	7/27/2014	0	0	0
4/6/2022	7/28/2014	0	0	0
4/7/2022	7/29/2014	1	2	3
4/8/2022	7/30/2014	0	0	0
4/9/2022	8/1/2014	0	0	0
4/10/2022	8/2/2014	0	0	0
4/11/2022	8/3/2014	7	3	10
4/12/2022	8/4/2014	26	0	26
4/13/2022	8/5/2014	0	0	0
4/14/2022	8/6/2014	0	0	0
4/15/2022	8/7/2014	0	0	0
4/16/2022	8/8/2014	0	0	0
4/17/2022	8/9/2014	0	0	0
4/18/2022	8/10/2014	0	0	0
4/19/2022	8/11/2014	0	0	0
4/20/2022	8/12/2014	4	0	4
4/21/2022	8/13/2014	8	2	10
4/22/2022	8/14/2014	32	0	32
4/23/2022	8/15/2014	4	0	4
4/24/2022	8/16/2014	0	0	0
4/25/2022	8/17/2014	0	0	0
4/26/2022	8/18/2014	10	0	10
4/27/2022	8/19/2014	0	0	0
4/28/2022	8/20/2014	102	40	142
4/29/2022	8/21/2014	0	0	0
4/30/2022	8/22/2014	0	0	0
	Total	194	47	241

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
5/1/2022	8/23/2014	0	0	0
5/2/2022	8/24/2014	0	0	0
5/3/2022	8/25/2014	0	0	0
5/4/2022	8/26/2014	0	0	0
5/5/2022	8/27/2014	0	0	0
5/6/2022	8/28/2014	13	0	13
5/7/2022	8/29/2014	0	0	0
5/8/2022	8/30/2014	0	0	0
5/9/2022	9/1/2014			0
5/10/2022	9/2/2014			0
5/11/2022	9/3/2014			0
5/12/2022	9/4/2014			0
5/13/2022	9/5/2014			0
5/14/2022	9/6/2014			0
5/15/2022	9/7/2014			0
5/16/2022	9/8/2014			0
5/17/2022	9/9/2014			0
5/18/2022	9/10/2014			0
5/19/2022	9/11/2014			0
5/20/2022	9/12/2014			0
5/21/2022	9/13/2014			0
5/22/2022	9/14/2014			0
5/23/2022	9/15/2014			0
5/24/2022	9/16/2014			0
5/25/2022	9/17/2014			0
5/26/2022	9/18/2014			0
5/27/2022	9/19/2014			0
5/28/2022	9/20/2014			0
5/29/2022	9/21/2014			0
5/30/2022	9/22/2014			0
5/31/2022	9/23/2014			0
	Total	13	0	13

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
1/1/2020	4/22/2012	0	0	0
1/2/2020	4/23/2012	0	0	0
1/3/2020	4/24/2012	0	0	0
1/4/2020	4/25/2012	0	0	0
1/5/2020	4/26/2012	0	0	0
1/6/2020	4/27/2012	0	0	0
1/7/2020	4/28/2012	31	21	52
1/8/2020	4/29/2012	0	0	0
1/9/2020	4/30/2012	0	0	0
1/10/2020	5/1/2012	0	0	0
1/11/2020	5/2/2012	0	0	0
1/12/2020	5/3/2012	28	24	52
1/13/2020	5/4/2012	0	0	0
1/14/2020	5/5/2012	0	27	27
1/15/2020	5/6/2012	0	0	0
1/16/2020	5/7/2012	0	0	0
1/17/2020	5/8/2012	0	0	0
1/18/2020	5/9/2012	43	45	88
1/19/2020	5/10/2012	76	90	166
1/20/2020	5/11/2012	0	0	0
1/21/2020	5/12/2012	0	0	0
1/22/2020	5/13/2012	20	14	34
1/23/2020	5/14/2012	0	0	0
1/24/2020	5/15/2012	0	0	0
1/25/2020	5/16/2012	0	0	0
1/26/2020	5/17/2012	0	0	0
1/27/2020	5/18/2012	0	0	0
1/28/2020	5/19/2012	0	0	0
1/29/2020	5/20/2012	0	0	0
1/30/2020	5/21/2012	0	0	0
1/31/2020	5/22/2012	0	0	0
	Total	198	221	419

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
2/1/2020	5/23/2012	0	0	0
2/2/2020	5/24/2012	0	0	0
2/3/2020	5/25/2012	0	0	0
2/4/2020	5/26/2012	0	0	0
2/5/2020	5/27/2012	0	0	0
2/6/2020	5/28/2012	0	0	0
2/7/2020	5/29/2012	0	0	0
2/8/2020	5/30/2012	77	69	146
2/9/2020	6/1/2012	75	0	75
2/10/2020	6/2/2012	0	0	0
2/11/2020	6/3/2012	0	0	0
2/12/2020	6/4/2012	5	0	5
2/13/2020	6/5/2012	0	0	0
2/14/2020	6/6/2012	0	0	0
2/15/2020	6/7/2012	0	0	0
2/16/2020	6/8/2012	0	0	0
2/17/2020	6/9/2012	0	0	0
2/18/2020	6/10/2012	0	0	0
2/19/2020	6/11/2012	0	0	0
2/20/2020	6/12/2012	32	0	32
2/21/2020	6/13/2012	2	0	2
2/22/2020	6/14/2012	0	0	0
2/23/2020	6/15/2012	0	0	0
2/24/2020	6/16/2012	0	0	0
2/25/2020	6/17/2012	45	0	45
2/26/2020	6/18/2012	0	0	0
2/27/2020	6/19/2012	0	0	0
2/28/2020	6/20/2012	33	33	66
2/29/2020	6/21/2012	0	29	29
	Total	269	131	400

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
3/1/2020	6/22/2012	2	0	2
3/2/2020	6/23/2012	0	0	0
3/3/2020	6/24/2012	0	0	0
3/4/2020	6/25/2012	0	0	0
3/5/2020	6/26/2012	0	0	0
3/6/2020	6/27/2012	0	0	0
3/7/2020	6/28/2012	0	0	0
3/8/2020	6/29/2012	0	0	0
3/9/2020	6/30/2012	0	0	0
3/10/2020	7/1/2012	1	0	1
3/11/2020	7/2/2012	26	0	26
3/12/2020	7/3/2012	0	0	0
3/13/2020	7/4/2012	0	0	0
3/14/2020	7/5/2012	76	0	76
3/15/2020	7/6/2012	10	0	10
3/16/2020	7/7/2012	0	0	0
3/17/2020	7/8/2012	2	2	4
3/18/2020	7/9/2012	0	0	0
3/19/2020	7/10/2012	0	0	0
3/20/2020	7/11/2012	6	0	6
3/21/2020	7/12/2012	9	0	9
3/22/2020	7/13/2012	39	0	39
3/23/2020	7/14/2012	0	0	0
3/24/2020	7/15/2012	21	21	42
3/25/2020	7/16/2012	0	0	0
3/26/2020	7/17/2012	0	0	0
3/27/2020	7/18/2012	0	0	0
3/28/2020	7/19/2012	0	0	0
3/29/2020	7/20/2012	0	0	0
3/30/2020	7/21/2012	0	0	0
3/31/2020	7/22/2012	0	0	0
	Total	192	23	215

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
4/1/2020	7/23/2012	37	93	130
4/2/2020	7/24/2012	16	16	32
4/3/2020	7/25/2012	0	3	3
4/4/2020	7/26/2012	0	0	0
4/5/2020	7/27/2012	0	0	0
4/6/2020	7/28/2012	0	0	0
4/7/2020	7/29/2012	0	0	0
4/8/2020	7/30/2012	0	0	0
4/9/2020	8/1/2012	0	0	0
4/10/2020	8/2/2012	0	0	0
4/11/2020	8/3/2012	8	7	15
4/12/2020	8/4/2012	0	0	0
4/13/2020	8/5/2012	0	0	0
4/14/2020	8/6/2012	0	0	0
4/15/2020	8/7/2012	2	0	2
4/16/2020	8/8/2012	0	0	0
4/17/2020	8/9/2012	0	0	0
4/18/2020	8/10/2012	0	0	0
4/19/2020	8/11/2012	5	0	5
4/20/2020	8/12/2012	0	0	0
4/21/2020	8/13/2012	0	0	0
4/22/2020	8/14/2012	0	0	0
4/23/2020	8/15/2012	16	0	16
4/24/2020	8/16/2012	0	0	0
4/25/2020	8/17/2012	0	0	0
4/26/2020	8/18/2012	0	0	0
4/27/2020	8/19/2012	0	0	0
4/28/2020	8/20/2012	21	0	21
4/29/2020	8/21/2012	0	0	0
4/30/2020	8/22/2012	0	0	0
	Total	105	119	224

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
5/1/2020	8/23/2012	0	0	0
5/2/2020	8/24/2012	15	0	15
5/3/2020	8/25/2012	0	0	0
5/4/2020	8/26/2012	9	71	80
5/5/2020	8/27/2012	0	0	0
5/6/2020	8/28/2012	27	23	50
5/7/2020	8/29/2012	0	0	0
5/8/2020	8/30/2012	0	0	0
5/9/2020	9/1/2012	0	0	0
5/10/2020	9/2/2012	0	0	0
5/11/2020	9/3/2012	22	0	22
5/12/2020	9/4/2012	44	0	44
5/13/2020	9/5/2012	0	0	0
5/14/2020	9/6/2012	0	0	0
5/15/2020	9/7/2012	0	0	0
5/16/2020	9/8/2012	0	0	0
5/17/2020	9/9/2012	0	0	0
5/18/2020	9/10/2012	0	0	0
5/19/2020	9/11/2012	0	0	0
5/20/2020	9/12/2012	0	0	0
5/21/2020	9/13/2012	0	0	0
5/22/2020	9/14/2012	0	0	0
5/23/2020	9/15/2012	0	0	0
5/24/2020	9/16/2012	0	0	0
5/25/2020	9/17/2012	1	0	1
5/26/2020	9/18/2012	0	0	0
5/27/2020	9/19/2012	68	50	118
5/28/2020	9/20/2012	0	0	0
5/29/2020	9/21/2012	0	0	0
5/30/2020	9/22/2012	0	0	0
5/31/2020	9/23/2012	0	0	0
	Total	186	144	330

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
6/1/2020	9/24/2012	0	0	0
6/2/2020	9/25/2012	8	17	25
6/3/2020	9/26/2012	0	0	0
6/4/2020	9/27/2012	0	0	0
6/5/2020	9/28/2012	0	0	0
6/6/2020	9/29/2012	0	0	0
6/7/2020	9/30/2012	0	0	0
6/8/2020	10/1/2012	0	0	0
6/9/2020	10/2/2012	0	0	0
6/10/2020	10/3/2012	0	0	0
6/11/2020	10/4/2012	0	0	0
6/12/2020	10/5/2012	0	0	0
6/13/2020	10/6/2012	0	0	0
6/14/2020	10/7/2012	0	0	0
6/15/2020	10/8/2012	7	0	7
6/16/2020	10/9/2012	0	0	0
6/17/2020	10/10/2012	5	0	5
6/18/2020	10/11/2012	0	0	0
6/19/2020	10/12/2012	0	0	0
6/20/2020	10/13/2012	19	18	37
6/21/2020	10/14/2012	9	0	9
6/22/2020	10/15/2012	29	29	58
6/23/2020	10/16/2012	12	0	12
6/24/2020	10/17/2012	0	0	0
6/25/2020	10/18/2012	9	4	13
6/26/2020	10/19/2012	0	0	0
6/27/2020	10/20/2012	78	80	158
6/28/2020	10/21/2012	0	0	0
6/29/2020	10/22/2012	2	0	2
6/30/2020	10/23/2012	0	0	0
	Total	178	148	326

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
7/1/2020	10/24/2012	0	0	0
7/2/2020	10/25/2012	0	0	0
7/3/2020	10/26/2012	0	0	0
7/4/2020	10/27/2012	0	0	0
7/5/2020	10/28/2012	0	0	0
7/6/2020	10/29/2012	4	0	4
7/7/2020	10/30/2012	0	0	0
7/8/2020	11/1/2012	0	0	0
7/9/2020	11/2/2012	17	0	17
7/10/2020	11/3/2012	8	0	8
7/11/2020	11/4/2012	6	0	6
7/12/2020	11/5/2012	0	0	0
7/13/2020	11/6/2012	0	0	0
7/14/2020	11/7/2012	0	0	0
7/15/2020	11/8/2012	14	0	14
7/16/2020	11/9/2012	53	0	53
7/17/2020	11/10/2012	0	0	0
7/18/2020	11/11/2012	18	0	18
7/19/2020	11/12/2012	5	0	5
7/20/2020	11/13/2012	0	0	0
7/21/2020	11/14/2012	5	0	5
7/22/2020	11/15/2012	0	0	0
7/23/2020	11/16/2012	4	0	4
7/24/2020	11/17/2012	0	0	0
7/25/2020	11/18/2012	72	76	148
7/26/2020	11/19/2012	58	61	119
7/27/2020	11/20/2012	26	58	84
7/28/2020	11/21/2012	0	0	0
7/29/2020	11/22/2012	16	0	16
7/30/2020	11/23/2012	0	0	0
7/31/2020	11/24/2012	0	0	0
	Total	306	195	501

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
8/1/2020	11/25/2012	0	0	0
8/2/2020	11/26/2012	0	0	0
8/3/2020	11/27/2012	4	0	4
8/4/2020	11/28/2012	0	0	0
8/5/2020	11/29/2012	8	0	8
8/6/2020	11/30/2012	0	0	0
8/7/2020	12/1/2012	0	0	0
8/8/2020	12/2/2012	3	0	3
8/9/2020	12/3/2012	2	0	2
8/10/2020	12/4/2012	0	0	0
8/11/2020	12/5/2012	15	14	29
8/12/2020	12/6/2012	0	0	0
8/13/2020	12/7/2012	0	0	0
8/14/2020	12/8/2012	102	0	102
8/15/2020	12/9/2012	80	0	80
8/16/2020	12/10/2012	13	0	13
8/17/2020	12/11/2012	45	50	95
8/18/2020	12/12/2012	0	0	0
8/19/2020	12/13/2012	0	0	0
8/20/2020	12/14/2012	0	0	0
8/21/2020	12/15/2012	0	0	0
8/22/2020	12/16/2012	0	0	0
8/23/2020	12/17/2012	0	0	0
8/24/2020	12/18/2012	0	0	0
8/25/2020	12/19/2012	0	0	0
8/26/2020	12/20/2012	2	2	4
8/27/2020	12/21/2012	0	0	0
8/28/2020	12/22/2012	0	0	0
8/29/2020	12/23/2012	0	0	0
8/30/2020	12/24/2012	0	0	0
8/31/2020	12/25/2012	0	0	0
	Total	274	66	340

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
9/1/2020	12/25/2012	2	0	2
9/2/2020	12/26/2012	0	0	0
9/3/2020	12/27/2012	0	0	0
9/4/2020	12/28/2012	0	0	0
9/5/2020	12/29/2012	0	0	0
9/6/2020	12/30/2012	0	0	0
9/7/2020	13/1/2012	0	0	0
9/8/2020	13/2/2012	0	0	0
9/9/2020	13/3/2012	34	32	66
9/10/2020	13/4/2012	0	0	0
9/11/2020	13/5/2012	5	0	5
9/12/2020	1/1/2013	0	0	0
9/13/2020	1/2/2013	0	0	0
9/14/2020	1/3/2013	0	0	0
9/15/2020	1/4/2013	22	0	22
9/16/2020	1/5/2013	0	0	0
9/17/2020	1/6/2013	5	0	5
9/18/2020	1/7/2013	0	0	0
9/19/2020	1/8/2013	0	0	0
9/20/2020	1/9/2013	0	0	0
9/21/2020	1/10/2013	0	0	0
9/22/2020	1/11/2013	0	0	0
9/23/2020	1/12/2013	0	0	0
9/24/2020	1/13/2013	0	0	0
9/25/2020	1/14/2013	0	0	0
9/26/2020	1/15/2013	0	0	0
9/27/2020	1/16/2013	0	0	0
9/28/2020	1/17/2013	0	0	0
9/29/2020	1/18/2013	0	0	0
9/30/2020	1/19/2013	0	0	0
	Total	68	32	100

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
10/1/2020	1/20/2013	25	0	25
10/2/2020	1/21/2013	0	0	0
10/3/2020	1/22/2013	0	0	0
10/4/2020	1/23/2013	0	0	0
10/5/2020	1/24/2013	0	0	0
10/6/2020	1/25/2013	0	0	0
10/7/2020	1/26/2013	0	0	0
10/8/2020	1/27/2013	0	0	0
10/9/2020	1/28/2013	0	0	0
10/10/2020	1/29/2013	92	0	92
10/11/2020	1/30/2013	122	92	214
10/12/2020	2/1/2013	0	0	0
10/13/2020	2/2/2013	0	0	0
10/14/2020	2/3/2013	0	0	0
10/15/2020	2/4/2013	0	0	0
10/16/2020	2/5/2013	0	0	0
10/17/2020	2/6/2013	0	0	0
10/18/2020	2/7/2013	0	0	0
10/19/2020	2/8/2013	0	0	0
10/20/2020	2/9/2013	0	0	0
10/21/2020	2/10/2013	0	0	0
10/22/2020	2/11/2013	12	0	12
10/23/2020	2/12/2013	170	111	281
10/24/2020	2/13/2013	0	0	0
10/25/2020	2/14/2013	170	170	340
10/26/2020	2/15/2013	4	40	44
10/27/2020	2/16/2013	14	0	14
10/28/2020	2/17/2013	16	0	16
10/29/2020	2/18/2013	0	0	0
10/30/2020	2/19/2013	23	0	23
10/31/2020	2/20/2013	0	0	0
	Total	648	413	1061

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
11/1/2020	2/21/2013	0	0	0
11/2/2020	2/22/2013	0	0	0
11/3/2020	2/23/2013	0	0	0
11/4/2020	2/24/2013	28	0	28
11/5/2020	2/25/2013	0	0	0
11/6/2020	2/26/2013	25	0	25
11/7/2020	2/27/2013	14	0	14
11/8/2020	2/28/2013	0	0	0
11/9/2020	2/29/2013	0	0	0
11/10/2020	2/30/2013	0	0	0
11/11/2020	3/1/2013	0	0	0
11/12/2020	3/2/2013	0	0	0
11/13/2020	3/3/2013	0	0	0
11/14/2020	3/4/2013	0	0	0
11/15/2020	3/5/2013	0	0	0
11/16/2020	3/6/2013	0	0	0
11/17/2020	3/7/2013	6	10	16
11/18/2020	3/8/2013	0	0	0
11/19/2020	3/9/2013	0	0	0
11/20/2020	3/10/2013	0	0	0
11/21/2020	3/11/2013	0	0	0
11/22/2020	3/12/2013	0	0	0
11/23/2020	3/13/2013	0	0	0
11/24/2020	3/14/2013	117	93	210
11/25/2020	3/15/2013	0	0	0
11/26/2020	3/16/2013	0	0	0
11/27/2020	3/17/2013	0	0	0
11/28/2020	3/18/2013	0	0	0
11/29/2020	3/19/2013	0	0	0
11/30/2020	3/20/2013	21	41	62
	Total	211	144	355

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
12/1/2020	3/22/2013	0	0	0
12/2/2020	3/23/2013	0	0	0
12/3/2020	3/24/2013	0	0	0
12/4/2020	3/25/2013	66	43	109
12/5/2020	3/26/2013	24	25	49
12/6/2020	3/27/2013	0	0	0
12/7/2020	3/28/2013	0	0	0
12/8/2020	3/29/2013	0	0	0
12/9/2020	3/30/2013	0	0	0
12/10/2020	4/1/2013	0	0	0
12/11/2020	4/2/2013	0	0	0
12/12/2020	4/3/2013	0	0	0
12/13/2020	4/4/2013	14	5	19
12/14/2020	4/5/2013	0	0	0
12/15/2020	4/6/2013	0	0	0
12/16/2020	4/7/2013	0	0	0
12/17/2020	4/8/2013	0	0	0
12/18/2020	4/9/2013	0	0	0
12/19/2020	4/10/2013	0	0	0
12/20/2020	4/11/2013	0	0	0
12/21/2020	4/12/2013	31	6	37
12/22/2020	4/13/2013	9	0	9
12/23/2020	4/14/2013	0	0	0
12/24/2020	4/15/2013	0	0	0
12/25/2020	4/16/2013	0	0	0
12/26/2020	4/17/2013	0	0	0
12/27/2020	4/18/2013	0	0	0
12/28/2020	4/19/2013	0	0	0
12/29/2020	4/20/2013	0	0	0
12/30/2020	4/21/2013	0	0	0
12/31/2020	4/22/2013	0	0	0
	Total	144	79	223

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
1/1/2021	4/23/2013	0	0	0
1/2/2021	4/24/2013	159	161	320
1/3/2021	4/25/2013	0	0	0
1/4/2021	4/26/2013	0	0	0
1/5/2021	4/27/2013	0	0	0
1/6/2021	4/28/2013	0	0	0
1/7/2021	4/29/2013	0	0	0
1/8/2021	4/30/2013	0	0	0
1/9/2021	5/1/2013	0	0	0
1/10/2021	5/2/2013	0	0	0
1/11/2021	5/3/2013	0	0	0
1/12/2021	5/4/2013	6	9	15
1/13/2021	5/5/2013	34	34	68
1/14/2021	5/6/2013	10	12	22
1/15/2021	5/7/2013	10	0	10
1/16/2021	5/8/2013	0	0	0
1/17/2021	5/9/2013	0	0	0
1/18/2021	5/10/2013	0	0	0
1/19/2021	5/11/2013	0	0	0
1/20/2021	5/12/2013	0	0	0
1/21/2021	5/13/2013	0	0	0
1/22/2021	5/14/2013	0	0	0
1/23/2021	5/15/2013	0	0	0
1/24/2021	5/16/2013	0	0	0
1/25/2021	5/17/2013	0	0	0
1/26/2021	5/18/2013	0	0	0
1/27/2021	5/19/2013	61	59	120
1/28/2021	5/20/2013	14	14	28
1/29/2021	5/21/2013	0	0	0
1/30/2021	5/22/2013	0	0	0
1/31/2021	5/23/2013	0	0	0
	Total	294	289	583

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
2/1/2021	5/24/2013	0	1	1
2/2/2021	5/25/2013	0	0	0
2/3/2021	5/26/2013	0	0	0
2/4/2021	5/27/2013	0	0	0
2/5/2021	5/28/2013	0	2	2
2/6/2021	5/29/2013	0	2	2
2/7/2021	5/30/2013	0	0	0
2/8/2021	6/1/2013	78	0	78
2/9/2021	6/2/2013	54	62	116
2/10/2021	6/3/2013	116	0	116
2/11/2021	6/4/2013	170	0	170
2/12/2021	6/5/2013	0	0	0
2/13/2021	6/6/2013	0	0	0
2/14/2021	6/7/2013	0	0	0
2/15/2021	6/8/2013	0	0	0
2/16/2021	6/9/2013	149	0	149
2/17/2021	6/10/2013	0	0	0
2/18/2021	6/11/2013	0	0	0
2/19/2021	6/12/2013	0	0	0
2/20/2021	6/13/2013	0	0	0
2/21/2021	6/14/2013	44	43	87
2/22/2021	6/15/2013	0	0	0
2/23/2021	6/16/2013	0	0	0
2/24/2021	6/17/2013	0	5	5
2/25/2021	6/18/2013	0	0	0
2/26/2021	6/19/2013	35	30	65
2/27/2021	6/20/2013	5	8	13
2/28/2021	6/21/2013	10	0	10
	Total	661	153	814

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
3/1/2021	6/22/2013	0	10	10
3/2/2021	6/23/2013	0	0	0
3/3/2021	6/24/2013	0	115	115
3/4/2021	6/25/2013	0	0	0
3/5/2021	6/26/2013	0	6	6
3/6/2021	6/27/2013	32	64	96
3/7/2021	6/28/2013	0	0	0
3/8/2021	6/29/2013	117	0	117
3/9/2021	6/30/2013	146	170	316
3/10/2021	7/1/2013	0	0	0
3/11/2021	7/2/2013	0	0	0
3/12/2021	7/3/2013	0	0	0
3/13/2021	7/4/2013	0	0	0
3/14/2021	7/5/2013	0	0	0
3/15/2021	7/6/2013	0	4	4
3/16/2021	7/7/2013	3	54	57
3/17/2021	7/8/2013	0	0	0
3/18/2021	7/9/2013	0	0	0
3/19/2021	7/10/2013	0	0	0
3/20/2021	7/11/2013	21	9	30
3/21/2021	7/12/2013	0	0	0
3/22/2021	7/13/2013	114	114	228
3/23/2021	7/14/2013	4	0	4
3/24/2021	7/15/2013	2	2	4
3/25/2021	7/16/2013	0	0	0
3/26/2021	7/17/2013	55	0	55
3/27/2021	7/18/2013	0	0	0
3/28/2021	7/19/2013	74	88	162
3/29/2021	7/20/2013	0	0	0
3/30/2021	7/21/2013	22	22	44
3/31/2021	7/22/2013	0	0	0
	Total	590	658	1248

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
4/1/2021	7/23/2013	0	0	0
4/2/2021	7/24/2013	0	0	0
4/3/2021	7/25/2013	0	0	0
4/4/2021	7/26/2013	0	4	4
4/5/2021	7/27/2013	0	0	0
4/6/2021	7/28/2013	16	17	33
4/7/2021	7/29/2013	2	0	2
4/8/2021	7/30/2013	14	15	29
4/9/2021	8/1/2013	0	0	0
4/10/2021	8/2/2013	0	0	0
4/11/2021	8/3/2013	0	0	0
4/12/2021	8/4/2013	15	14	29
4/13/2021	8/5/2013	46	46	92
4/14/2021	8/6/2013	62	56	118
4/15/2021	8/7/2013	0	0	0
4/16/2021	8/8/2013	16	19	35
4/17/2021	8/9/2013	0	0	0
4/18/2021	8/10/2013	0	0	0
4/19/2021	8/11/2013	0	0	0
4/20/2021	8/12/2013	0	30	30
4/21/2021	8/13/2013	78	72	150
4/22/2021	8/14/2013	90	130	220
4/23/2021	8/15/2013	61	87	148
4/24/2021	8/16/2013	31	30	61
4/25/2021	8/17/2013	0	17	17
4/26/2021	8/18/2013	0	0	0
4/27/2021	8/19/2013	0	0	0
4/28/2021	8/20/2013	0	8	8
4/29/2021	8/21/2013	4	14	18
4/30/2021	8/22/2013	0	8	8
	Total	435	567	1002

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
5/1/2021	8/23/2013	46	0	46
5/2/2021	8/24/2013	0	0	0
5/3/2021	8/25/2013	0	21	21
5/4/2021	8/26/2013	0	0	0
5/5/2021	8/27/2013	0	0	0
5/6/2021	8/28/2013	0	0	0
5/7/2021	8/29/2013	0	0	0
5/8/2021	8/30/2013	0	0	0
5/9/2021	9/1/2013	0	0	0
5/10/2021	9/2/2013	34	10	44
5/11/2021	9/3/2013	0	4	4
5/12/2021	9/4/2013	0	0	0
5/13/2021	9/5/2013	0	0	0
5/14/2021	9/6/2013	74	76	150
5/15/2021	9/7/2013	0	54	54
5/16/2021	9/8/2013	0	0	0
5/17/2021	9/9/2013	0	0	0
5/18/2021	9/10/2013	77	0	77
5/19/2021	9/11/2013	49	0	49
5/20/2021	9/12/2013	144	20	164
5/21/2021	9/13/2013	25	0	25
5/22/2021	9/14/2013	32	0	32
5/23/2021	9/15/2013	0	0	0
5/24/2021	9/16/2013	0	0	0
5/25/2021	9/17/2013	0	0	0
5/26/2021	9/18/2013	0	0	0
5/27/2021	9/19/2013	27	10	37
5/28/2021	9/20/2013	0	0	0
5/29/2021	9/21/2013	0	5	5
5/30/2021	9/22/2013	0	0	0
5/31/2021	9/23/2013	0	0	0
	Total	508	200	708

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
6/1/2021	9/24/2013	18	20	38
6/2/2021	9/25/2013	0	0	0
6/3/2021	9/26/2013	0	0	0
6/4/2021	9/27/2013	48	19	67
6/5/2021	9/28/2013	0	1	1
6/6/2021	9/29/2013	0	0	0
6/7/2021	9/30/2013	0	31	31
6/8/2021	10/1/2013	24	71	95
6/9/2021	10/2/2013	0	42	42
6/10/2021	10/3/2013	0	0	0
6/11/2021	10/4/2013	87	20	107
6/12/2021	10/5/2013	156	103	259
6/13/2021	10/6/2013	0	0	0
6/14/2021	10/7/2013	22	20	42
6/15/2021	10/8/2013	5	6	11
6/16/2021	10/9/2013	0	0	0
6/17/2021	10/10/2013	0	0	0
6/18/2021	10/11/2013	3	3	6
6/19/2021	10/12/2013	0	0	0
6/20/2021	10/13/2013	0	0	0
6/21/2021	10/14/2013	0	0	0
6/22/2021	10/15/2013	120	118	238
6/23/2021	10/16/2013	0	0	0
6/24/2021	10/17/2013	26	6	32
6/25/2021	10/18/2013	0	0	0
6/26/2021	10/19/2013	0	0	0
6/27/2021	10/20/2013	0	8	8
6/28/2021	10/21/2013	0	0	0
6/29/2021	10/22/2013	0	0	0
6/30/2021	10/23/2013	0	0	0
	Total	509	468	977

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
7/1/2021	10/24/2013	6	6	12
7/2/2021	10/25/2013	6	5	11
7/3/2021	10/26/2013	0	0	0
7/4/2021	10/27/2013	0	0	0
7/5/2021	10/28/2013	0	0	0
7/6/2021	10/29/2013	0	0	0
7/7/2021	10/30/2013	30	53	83
7/8/2021	11/1/2013	42	45	87
7/9/2021	11/2/2013	0	0	0
7/10/2021	11/3/2013	9	8	17
7/11/2021	11/4/2013	8	6	14
7/12/2021	11/5/2013	0	0	0
7/13/2021	11/6/2013	0	4	4
7/14/2021	11/7/2013	0	0	0
7/15/2021	11/8/2013	0	0	0
7/16/2021	11/9/2013	16	6	22
7/17/2021	11/10/2013	30	12	42
7/18/2021	11/11/2013	0	0	0
7/19/2021	11/12/2013	0	0	0
7/20/2021	11/13/2013	0	0	0
7/21/2021	11/14/2013	0	0	0
7/22/2021	11/15/2013	0	0	0
7/23/2021	11/16/2013	0	58	58
7/24/2021	11/17/2013	0	0	0
7/25/2021	11/18/2013	0	54	54
7/26/2021	11/19/2013	0	0	0
7/27/2021	11/20/2013	20	56	76
7/28/2021	11/21/2013	101	28	129
7/29/2021	11/22/2013	0	0	0
7/30/2021	11/23/2013	0	0	0
7/31/2021	11/24/2013	0	0	0
	Total	268	341	609

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
8/1/2021	11/25/2013	0	0	0
8/2/2021	11/26/2013	24	14	38
8/3/2021	11/27/2013	8	3	11
8/4/2021	11/28/2013	26	1	27
8/5/2021	11/29/2013	0	0	0
8/6/2021	11/30/2013	31	4	35
8/7/2021	12/1/2013	3	9	12
8/8/2021	12/2/2013	0	0	0
8/9/2021	12/3/2013	0	0	0
8/10/2021	12/4/2013	0	0	0
8/11/2021	12/5/2013	66	19	85
8/12/2021	12/6/2013	0	5	5
8/13/2021	12/7/2013	0	0	0
8/14/2021	12/8/2013	0	0	0
8/15/2021	12/9/2013	0	0	0
8/16/2021	12/10/2013	0	0	0
8/17/2021	12/11/2013	0	0	0
8/18/2021	12/12/2013	0	4	4
8/19/2021	12/13/2013	0	0	0
8/20/2021	12/14/2013	0	0	0
8/21/2021	12/15/2013	0	0	0
8/22/2021	12/16/2013	0	0	0
8/23/2021	12/17/2013	0	0	0
8/24/2021	12/18/2013	13	9	22
8/25/2021	12/19/2013	0	0	0
8/26/2021	12/20/2013	0	0	0
8/27/2021	12/21/2013	0	0	0
8/28/2021	12/22/2013	0	0	0
8/29/2021	12/23/2013	104	120	224
8/30/2021	12/24/2013	33	5	38
8/31/2021	12/25/2013	14	2	16
	Total	322	195	517

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
9/1/2021	12/26/2013	0	0	0
9/2/2021	12/27/2013	0	0	0
9/3/2021	12/28/2013	37	0	37
9/4/2021	12/29/2013	29	27	56
9/5/2021	12/30/2013	0	0	0
9/6/2021	13/1/2013	0	0	0
9/7/2021	13/2/2013	0	0	0
9/8/2021	13/3/2013	0	0	0
9/9/2021	13/4/2013	30	10	40
9/10/2021	13/5/2013	0	0	0
9/11/2021	1/1/2014	0	0	0
9/12/2021	1/2/2014	0	0	0
9/13/2021	1/3/2014	0	0	0
9/14/2021	1/4/2014	0	0	0
9/15/2021	1/5/2014	0	0	0
9/16/2021	1/6/2014	0	0	0
9/17/2021	1/7/2014	0	0	0
9/18/2021	1/8/2014	23	0	23
9/19/2021	1/9/2014	0	0	0
9/20/2021	1/10/2014	2	2	4
9/21/2021	1/11/2014	15	14	29
9/22/2021	1/12/2014	0	0	0
9/23/2021	1/13/2014	14	2	16
9/24/2021	1/14/2014	15	14	29
9/25/2021	1/15/2014	0	0	0
9/26/2021	1/16/2014	0	0	0
9/27/2021	1/17/2014	0	0	0
9/28/2021	1/18/2014	5	0	5
9/29/2021	1/19/2014	0	0	0
9/30/2021	1/20/2014	35	32	67
	Total	205	101	306

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
10/1/2021	1/21/2014	18	23	41
10/2/2021	1/22/2014	0	0	0
10/3/2021	1/23/2014	0	0	0
10/4/2021	1/24/2014	0	0	0
10/5/2021	1/25/2014	0	0	0
10/6/2021	1/26/2014	0	0	0
10/7/2021	1/27/2014	0	0	0
10/8/2021	1/28/2014	0	0	0
10/9/2021	1/29/2014	0	0	0
10/10/2021	1/30/2014	0	0	0
10/11/2021	2/1/2014	0	0	0
10/12/2021	2/2/2014	0	0	0
10/13/2021	2/3/2014	0	0	0
10/14/2021	2/4/2014	0	0	0
10/15/2021	2/5/2014	0	0	0
10/16/2021	2/6/2014	0	0	0
10/17/2021	2/7/2014	0	0	0
10/18/2021	2/8/2014	0	0	0
10/19/2021	2/9/2014	0	0	0
10/20/2021	2/10/2014	60	26	86
10/21/2021	2/11/2014	27	33	60
10/22/2021	2/12/2014	15	21	36
10/23/2021	2/13/2014	17	24	41
10/24/2021	2/14/2014	0	0	0
10/25/2021	2/15/2014	24	30	54
10/26/2021	2/16/2014	3	3	6
10/27/2021	2/17/2014	0	0	0
10/28/2021	2/18/2014	0	0	0
10/29/2021	2/19/2014	0	0	0
10/30/2021	2/20/2014	0	0	0
10/31/2021	2/21/2014	0	0	0
	Total	164	160	324

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
11/1/2021	2/22/2014	0	0	0
11/2/2021	2/23/2014	0	0	0
11/3/2021	2/24/2014	6	11	17
11/4/2021	2/25/2014	8	92	100
11/5/2021	2/26/2014	0	42	42
11/6/2021	2/27/2014	0	40	40
11/7/2021	2/28/2014	0	0	0
11/8/2021	2/29/2014	0	40	40
11/9/2021	2/30/2014	0	38	38
11/10/2021	3/1/2014	0	20	20
11/11/2021	3/2/2014	0	0	0
11/12/2021	3/3/2014	18	25	43
11/13/2021	3/4/2014	0	0	0
11/14/2021	3/5/2014	0	0	0
11/15/2021	3/6/2014	45	47	92
11/16/2021	3/7/2014	51	0	51
11/17/2021	3/8/2014	13	0	13
11/18/2021	3/9/2014	0	0	0
11/19/2021	3/10/2014	0	70	70
11/20/2021	3/11/2014	0	0	0
11/21/2021	3/12/2014	0	0	0
11/22/2021	3/13/2014	49	50	99
11/23/2021	3/14/2014	36	3	39
11/24/2021	3/15/2014	0	0	0
11/25/2021	3/16/2014	0	0	0
11/26/2021	3/17/2014	79	0	79
11/27/2021	3/18/2014	0	0	0
11/28/2021	3/19/2014	0	0	0
11/29/2021	3/20/2014	0	0	0
11/30/2021	3/21/2014	0	0	0
	Total	305	478	783

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
12/1/2021	3/22/2014	0	0	0
12/2/2021	3/23/2014	0	0	0
12/3/2021	3/24/2014	0	0	0
12/4/2021	3/25/2014	0	0	0
12/5/2021	3/26/2014	0	0	0
12/6/2021	3/27/2014	0	0	0
12/7/2021	3/28/2014	0	0	0
12/8/2021	3/29/2014	0	0	0
12/9/2021	3/30/2014	60	62	122
12/10/2021	4/1/2014	19	0	19
12/11/2021	4/2/2014	0	0	0
12/12/2021	4/3/2014	0	0	0
12/13/2021	4/4/2014	0	0	0
12/14/2021	4/5/2014	0	0	0
12/15/2021	4/6/2014	0	0	0
12/16/2021	4/7/2014	0	42	42
12/17/2021	4/8/2014	12	2	14
12/18/2021	4/9/2014	0	0	0
12/19/2021	4/10/2014	0	0	0
12/20/2021	4/11/2014	0	0	0
12/21/2021	4/12/2014	96	4	100
12/22/2021	4/13/2014	0	0	0
12/23/2021	4/14/2014	0	7	7
12/24/2021	4/15/2014	0	0	0
12/25/2021	4/16/2014	0	0	0
12/26/2021	4/17/2014	0	0	0
12/27/2021	4/18/2014	0	0	0
12/28/2021	4/19/2014	4	2	6
12/29/2021	4/20/2014	6	0	6
12/30/2021	4/21/2014	0	0	0
12/31/2021	4/22/2014	0	0	0
	Total	191	119	310

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
1/1/2019	4/23/2011			0
1/2/2019	4/24/2011		61	61
1/3/2019	4/25/2011			0
1/4/2019	4/26/2011		12	12
1/5/2019	4/27/2011	4	4	8
1/6/2019	4/28/2011			0
1/7/2019	4/29/2011			0
1/8/2019	4/30/2011			0
1/9/2019	5/1/2011			0
1/10/2019	5/2/2011			0
1/11/2019	5/3/2011			0
1/12/2019	5/4/2011			0
1/13/2019	5/5/2011			0
1/14/2019	5/6/2011			0
1/15/2019	5/7/2011			0
1/16/2019	5/8/2011			0
1/17/2019	5/9/2011		6	6
1/18/2019	5/10/2011			0
1/19/2019	5/11/2011			0
1/20/2019	5/12/2011			0
1/21/2019	5/13/2011	9		9
1/22/2019	5/14/2011			0
1/23/2019	5/15/2011			0
1/24/2019	5/16/2011		29	29
1/25/2019	5/17/2011		2	2
1/26/2019	5/18/2011			0
1/27/2019	5/19/2011	11	9	20
1/28/2019	5/20/2011			0
1/29/2019	5/21/2011	12	8	20
1/30/2019	5/22/2011		36	
1/31/2019	5/23/2011			0
	Total	36	167	203

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
2/1/2019	5/24/2011			0
2/2/2019	5/25/2011			0
2/3/2019	5/26/2011			0
2/4/2019	5/27/2011			0
2/5/2019	5/28/2011	43		43
2/6/2019	5/29/2011			0
2/7/2019	5/30/2011			0
2/8/2019	6/1/2011			0
2/9/2019	6/2/2011			0
2/10/2019	6/3/2011			0
2/11/2019	6/4/2011			0
2/12/2019	6/5/2011			0
2/13/2019	6/6/2011	85		85
2/14/2019	6/7/2011			0
2/15/2019	6/8/2011			0
2/16/2019	6/9/2011			0
2/17/2019	6/10/2011	11	14	25
2/18/2019	6/11/2011			0
2/19/2019	6/12/2011			0
2/20/2019	6/13/2011	1		1
2/21/2019	6/14/2011			0
2/22/2019	6/15/2011	45		45
2/23/2019	6/16/2011			0
2/24/2019	6/17/2011		3	3
2/25/2019	6/18/2011			0
2/26/2019	6/19/2011			0
2/27/2019	6/20/2011			0
2/28/2019	6/21/2011			0
	Total	185	17	202

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
3/1/2019	6/22/2011		9	9
3/2/2019	6/23/2011	11		11
3/3/2019	6/24/2011			0
3/4/2019	6/25/2011			0
3/5/2019	6/26/2011		8	8
3/6/2019	6/27/2011			0
3/7/2019	6/28/2011			0
3/8/2019	6/29/2011			0
3/9/2019	6/30/2011			0
3/10/2019	7/1/2011			0
3/11/2019	7/2/2011			0
3/12/2019	7/3/2011			0
3/13/2019	7/4/2011			0
3/14/2019	7/5/2011	32	32	64
3/15/2019	7/6/2011			0
3/16/2019	7/7/2011	8		8
3/17/2019	7/8/2011			0
3/18/2019	7/9/2011	2		2
3/19/2019	7/10/2011			0
3/20/2019	7/11/2011	20		20
3/21/2019	7/12/2011		1	1
3/22/2019	7/13/2011	3		3
3/23/2019	7/14/2011	2		2
3/24/2019	7/15/2011		2	2
3/25/2019	7/16/2011			0
3/26/2019	7/17/2011			0
3/27/2019	7/18/2011			0
3/28/2019	7/19/2011		18	18
3/29/2019	7/20/2011		4	4
3/30/2019	7/21/2011			0
3/31/2019	7/22/2011	4	11	15
	Total	82	85	167

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
4/1/2019	7/23/2011	0	9	9
4/2/2019	7/24/2011	0	0	0
4/3/2019	7/25/2011	0	0	0
4/4/2019	7/26/2011	0	17	17
4/5/2019	7/27/2011	0	0	0
4/6/2019	7/28/2011	0	21	21
4/7/2019	7/29/2011	0	0	0
4/8/2019	7/30/2011	0	0	0
4/9/2019	8/1/2011	0	0	0
4/10/2019	8/2/2011	0	24	24
4/11/2019	8/3/2011	0	13	13
4/12/2019	8/4/2011	0	0	0
4/13/2019	8/5/2011	0	9	9
4/14/2019	8/6/2011	0	14	14
4/15/2019	8/7/2011	94	0	94
4/16/2019	8/8/2011	0	2	2
4/17/2019	8/9/2011	90	64	154
4/18/2019	8/10/2011	0	6	6
4/19/2019	8/11/2011	0	0	0
4/20/2019	8/12/2011	7	5	12
4/21/2019	8/13/2011	0	6	6
4/22/2019	8/14/2011	0	6	6
4/23/2019	8/15/2011	0	6	6
4/24/2019	8/16/2011	0	0	0
4/25/2019	8/17/2011	0	0	0
4/26/2019	8/18/2011	0	0	0
4/27/2019	8/19/2011	46	46	92
4/28/2019	8/20/2011	0	0	0
4/29/2019	8/21/2011	0	0	0
4/30/2019	8/22/2011	0	0	0
	Total	237	248	485

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
5/1/2019	8/23/2011	0	0	0
5/2/2019	8/24/2011	0	7	7
5/3/2019	8/25/2011	0	0	0
5/4/2019	8/26/2011	0	0	0
5/5/2019	8/27/2011	0	2	2
5/6/2019	8/28/2011	0	0	0
5/7/2019	8/29/2011	0	0	0
5/8/2019	8/30/2011	0	13	13
5/9/2019	9/1/2011	0	11	11
5/10/2019	9/2/2011	0	20	20
5/11/2019	9/3/2011	0	41	41
5/12/2019	9/4/2011	0	0	0
5/13/2019	9/5/2011	0	32	32
5/14/2019	9/6/2011	0	11	11
5/15/2019	9/7/2011	0	23	23
5/16/2019	9/8/2011	0	11	11
5/17/2019	9/9/2011	0	44	44
5/18/2019	9/10/2011	0	5	5
5/19/2019	9/11/2011	0	19	19
5/20/2019	9/12/2011	0	52	52
5/21/2019	9/13/2011	19	20	39
5/22/2019	9/14/2011	0	27	27
5/23/2019	9/15/2011	0	53	53
5/24/2019	9/16/2011	0	42	42
5/25/2019	9/17/2011	0	54	54
5/26/2019	9/18/2011	0	32	32
5/27/2019	9/19/2011	0	9	9
5/28/2019	9/20/2011	8	60	68
5/29/2019	9/21/2011	0	26	26
5/30/2019	9/22/2011	0	37	37
5/31/2019	9/23/2011	0	48	48
	Total	27	699	726

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
6/1/2019	9/24/2011	9	6	15
6/2/2019	9/25/2011	0	31	31
6/3/2019	9/26/2011	9	28	37
6/4/2019	9/27/2011	5	0	5
6/5/2019	9/28/2011	0	31	31
6/6/2019	9/29/2011	36	56	92
6/7/2019	9/30/2011	19	41	60
6/8/2019	10/1/2011	26	62	88
6/9/2019	10/2/2011	25	51	76
6/10/2019	10/3/2011	0	28	28
6/11/2019	10/4/2011	0	45	45
6/12/2019	10/5/2011	0	35	35
6/13/2019	10/6/2011	0	30	30
6/14/2019	10/7/2011	0	23	23
6/15/2019	10/8/2011	0	32	32
6/16/2019	10/9/2011	0	25	25
6/17/2019	10/10/2011	0	33	33
6/18/2019	10/11/2011	0	25	25
6/19/2019	10/12/2011	0	32	32
6/20/2019	10/13/2011	0	8	8
6/21/2019	10/14/2011	0	4	4
6/22/2019	10/15/2011	0	0	0
6/23/2019	10/16/2011	0	2	2
6/24/2019	10/17/2011	0	10	10
6/25/2019	10/18/2011	0	0	0
6/26/2019	10/19/2011	0	0	0
6/27/2019	10/20/2011	18	19	37
6/28/2019	10/21/2011	0	0	0
6/29/2019	10/22/2011	0	2	2
6/30/2019	10/23/2011	0	2	2
	Total	147	661	808

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
8/1/2019	10/24/2011	0	0	0
7/2/2019	10/25/2011	0	0	0
7/3/2019	10/26/2011	0	0	0
7/4/2019	10/27/2011	0	0	0
7/5/2019	10/28/2011	0	0	0
7/6/2019	10/29/2011	0	1	1
7/7/2019	10/30/2011	0	0	0
7/8/2019	11/1/2011	0	0	0
7/9/2019	11/2/2011	0	0	0
7/10/2019	11/3/2011	0	0	0
7/11/2019	11/4/2011	0	0	0
7/12/2019	11/5/2011	0	0	0
7/13/2019	11/6/2011	0	0	0
7/14/2019	11/7/2011	0	0	0
7/15/2019	11/8/2011	17	0	17
7/16/2019	11/9/2011	0	0	0
7/17/2019	11/10/2011	7	0	7
7/18/2019	11/11/2011	0	0	0
7/19/2019	11/12/2011	24	0	24
7/20/2019	11/13/2011	0	0	0
7/21/2019	11/14/2011	0	0	0
7/22/2019	11/15/2011	15	0	15
7/23/2019	11/16/2011	0	0	0
7/24/2019	11/17/2011	0	0	0
7/25/2019	11/18/2011	0	0	0
7/26/2019	11/19/2011	0	2	2
7/27/2019	11/20/2011	0	14	14
7/28/2019	11/21/2011	0	0	0
7/29/2019	11/22/2011	0	0	0
7/30/2019	11/23/2011	0	0	0
		63	17	80

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
8/1/2019	11/25/2011	0	0	0
8/2/2019	11/26/2011	0	0	0
8/3/2019	11/27/2011	14	0	14
8/4/2019	11/28/2011	32	0	32
8/5/2019	11/29/2011	0	0	0
8/6/2019	11/30/2011	0	0	0
8/7/2019	12/1/2011	0	0	0
8/8/2019	12/2/2011	0	0	0
8/9/2019	12/3/2011	0	0	0
8/10/2019	12/4/2011	0	0	0
8/11/2019	12/5/2011	0	0	0
8/12/2019	12/6/2011	0	0	0
8/13/2019	12/7/2011	0	0	0
8/14/2019	12/8/2011	0	0	0
8/15/2019	12/9/2011	0	0	0
8/16/2019	12/10/2011	0	0	0
8/17/2019	12/11/2011	0	0	0
8/18/2019	12/12/2011	0	0	0
8/19/2019	12/13/2011	0	0	0
8/20/2019	12/14/2011	0	0	0
8/21/2019	12/15/2011	0	0	0
8/22/2019	12/16/2011	0	0	0
8/23/2019	12/17/2011	0	0	0
8/24/2019	12/18/2011	0	0	0
8/25/2019	12/19/2011	0	0	0
8/26/2019	12/20/2011	0	0	0
8/27/2019	12/21/2011	0	0	0
8/28/2019	12/22/2011	0	0	0
8/29/2019	12/23/2011	0	0	0
8/30/2019	12/24/2011	0	0	0
8/31/2019	12/25/2011	0	0	0
	Total	46	0	46

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
9/1/2019	12/26/2011	0	0	0
9/2/2019	12/27/2011	0	0	0
9/3/2019	12/28/2011	5	0	5
9/4/2019	12/29/2011	0	0	0
9/5/2019	12/30/2011	19	19	38
9/6/2019	13/1/2011	18	0	18
9/7/2019	13/1/2011	0	0	0
9/8/2019	13/1/2011	0	0	0
9/9/2019	13/1/2011	42	0	42
9/10/2019	13/1/2011	0	0	0
9/11/2019	1/1/2012	0	0	0
9/12/2019	1/2/2012	0	0	0
9/13/2019	1/3/2012	0	0	0
9/14/2019	1/4/2012	0	0	0
9/15/2019	1/5/2012	0	0	0
9/16/2019	1/6/2012	0	0	0
9/17/2019	1/7/2012	0	0	0
9/18/2019	1/8/2012	0	0	0
9/19/2019	1/9/2012	0	0	0
9/20/2019	1/10/2012	6	7	13
9/21/2019	1/11/2012	0	0	0
9/22/2019	1/12/2012	0	0	0
9/23/2019	1/13/2012	0	0	0
9/24/2019	1/14/2012	0	0	0
9/25/2019	1/15/2012	18	0	18
9/26/2019	1/16/2012	0	0	0
9/27/2019	1/17/2012	0	0	0
9/28/2019	1/18/2012	0	0	
9/29/2019	1/19/2012	0	0	
9/30/2019	1/20/2012	0	0	0
	Total	108	26	134

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	W line	NS line	Total
10/1/2019	1/21/2012	0	0	0
10/2/2019	1/22/2012	0	0	0
10/3/2019	1/23/2012	0	0	0
10/4/2019	1/24/2012	0	0	0
10/5/2019	1/25/2012	0	0	0
10/6/2019	1/26/2012	0	0	0
10/7/2019	1/27/2012	0	0	0
10/8/2019	1/28/2012	0	3	3
10/9/2019	1/29/2012	0	16	16
10/10/2019	1/30/2012	0	0	0
10/11/2019	2/1/2012	0	0	0
10/12/2019	2/2/2012	0	0	0
10/13/2019	2/3/2012	39	36	75
10/14/2019	2/4/2012	0	0	0
10/15/2019	2/5/2012	0	0	0
10/16/2019	2/6/2012	0	0	0
10/17/2019	2/7/2012	0	0	0
10/18/2019	2/8/2012	0	0	0
10/19/2019	2/9/2012	0	0	0
10/20/2019	2/10/2012	0	0	0
10/21/2019	2/11/2012	0	0	0
10/22/2019	2/12/2012	0	0	0
10/23/2019	2/13/2012	0	0	0
10/24/2019	2/14/2012	0	0	0
10/25/2019	2/15/2012	0	0	0
10/26/2019	2/16/2012	0	0	0
10/27/2019	2/17/2012	0	0	0
10/28/2019	2/18/2012	0	0	0
10/29/2019	2/19/2012	0	0	0
10/30/2019	2/20/2012	0	0	0
10/31/2019	2/21/2012	0	0	0
	Total	39	55	94

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
11/1/2019	2/22/2012	0	0	0
11/2/2019	2/23/2012	75	75	150
11/3/2019	2/24/2012	0	0	0
11/4/2019	2/25/2012	0	0	0
11/5/2019	2/26/2012	0	0	0
11/6/2019	2/27/2012	0	0	0
11/7/2019	2/28/2012	18	18	36
11/8/2019	2/29/2012	0	0	0
11/9/2019	2/30/2012	0	0	0
11/10/2019	3/1/2012	0	0	0
11/11/2019	3/2/2012	0	0	0
11/12/2019	3/3/2012	98	0	98
11/13/2019	3/4/2012	0	0	0
11/14/2019	3/5/2012	68	0	68
11/15/2019	3/6/2012	0	0	0
11/16/2019	3/7/2012	0	0	0
11/17/2019	3/8/2012	0	0	0
11/18/2019	3/9/2012	0	0	0
11/19/2019	3/10/2012	0	0	0
11/20/2019	3/11/2012	0	0	0
11/21/2019	3/12/2012	9	0	9
11/22/2019	3/13/2012	0	0	0
11/23/2019	3/14/2012	0	0	0
11/24/2019	3/15/2012	0	0	0
11/25/2019	3/16/2012	0	0	0
11/26/2019	3/17/2012	0	0	0
11/27/2019	3/18/2012	0	0	0
11/28/2019	3/19/2012	0	0	0
11/29/2019	3/20/2012	0	0	0
11/30/2019	3/21/2012	0	0	0
	Total	268	93	361

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	W line	NS line	Total
12/1/2019	3/22/2012	0	0	0
12/2/2019	3/23/2012	0	0	0
12/3/2019	3/24/2012	0	0	0
12/4/2019	3/25/2012	0	0	0
12/5/2019	3/26/2012	0	0	0
12/6/2019	3/27/2012	0	0	0
12/7/2019	3/28/2012	0	0	0
12/8/2019	3/29/2012	7	0	7
12/9/2019	3/30/2012	0	0	0
12/10/2019	4/1/2012	0	0	0
12/11/2019	4/2/2012	0	0	0
12/12/2019	4/3/2012	0	0	0
12/13/2019	4/4/2012	0	0	0
12/14/2019	4/5/2012	1	0	1
12/15/2019	4/6/2012	0	0	0
12/16/2019	4/7/2012	0	0	0
12/17/2019	4/8/2012	0	0	0
12/18/2019	4/9/2012	0	0	0
12/19/2019	4/10/2012	0	1	1
12/20/2019	4/11/2012	2	2	4
12/21/2019	4/12/2012	1	0	1
12/22/2019	4/13/2012	0	0	0
12/23/2019	4/14/2012	0	0	0
12/24/2019	4/15/2012	0	0	0
12/25/2019	4/16/2012	0	0	0
12/26/2019	4/17/2012	0	0	0
12/27/2019	4/18/2012	0	0	0
12/28/2019	4/19/2012	1	0	1
12/29/2019	4/20/2012	0	0	0
12/30/2019	4/21/2012	0	0	0
12/31/2019	4/22/2012	0	0	0
	Total	12	3	15

Date G.C	Date E.C	EW line	NS line	Total
1/1/2018	4/23/2010	0	0	0
1/2/2018	4/24/2010	0	0	0
1/3/2018	4/25/2010	0	0	0
1/4/2018	4/26/2010	0	0	0
1/5/2018	4/27/2010	0	0	0
1/6/2018	4/28/2010	0	0	0
1/7/2018	4/29/2010	0	0	0
1/8/2018	4/30/2010	0	0	0
1/9/2018	5/1/2010	0	0	0
1/10/2018	5/2/2010	0	0	0
1/11/2018	5/3/2010	0	0	0
1/12/2018	5/4/2010	0	1	1
1/13/2018	5/5/2010	0	0	0
1/14/2018	5/6/2010	0	0	0
1/15/2018	5/7/2010	0	0	0
1/16/2018	5/8/2010	0	7	7
1/17/2018	5/9/2010	5	11	16
1/18/2018	5/10/2010	0	0	0
1/19/2018	5/11/2010	0	0	0
1/20/2018	5/12/2010	0	0	0
1/21/2018	5/13/2010	0	0	0
1/22/2018	5/14/2010	0	0	0
1/23/2018	5/15/2010	0	5	5
1/24/2018	5/16/2010	0	0	0
1/25/2018	5/17/2010	0	0	0
1/26/2018	5/18/2010	0	0	0
1/27/2018	5/19/2010	0	0	0
1/28/2018	5/20/2010	0	0	0
1/29/2018	5/21/2010	0	0	0
1/30/2018	5/22/2010	7	9	16
1/31/2018	5/23/2010	0	0	0
	Total	12	33	45

Date G.C	Date E.C	EW line	NS line	Total
2/1/2018	5/24/2010	0	0	0
2/2/2018	5/25/2010	0	0	0
2/3/2018	5/26/2010	0	0	0
2/4/2018	5/27/2010	0	4	4
2/5/2018	5/28/2010	1	0	1
2/6/2018	5/29/2010	0	0	0
2/7/2018	5/30/2010	0	0	0
2/8/2018	6/1/2010	0	0	0
2/9/2018	6/2/2010	0	0	0
2/10/2018	6/3/2010	0	2	2
2/11/2018	6/4/2010	0	0	0
2/12/2018	6/5/2010	0	0	0
2/13/2018	6/6/2010	0	0	0
2/14/2018	6/7/2010	0	0	0
2/15/2018	6/8/2010	0	0	0
2/16/2018	6/9/2010	0	2	2
2/17/2018	6/10/2010	0	0	0
2/18/2018	6/11/2010	0	0	0
2/19/2018	6/12/2010	0	0	0
2/20/2018	6/13/2010	0	0	0
2/21/2018	6/14/2010	0	0	0
2/22/2018	6/15/2010	0	0	0
2/23/2018	6/16/2010	0	0	0
2/24/2018	6/17/2010	0	0	0
2/25/2018	6/18/2010	0	0	0
2/26/2018	6/19/2010	0	0	0
2/27/2018	6/20/2010	0	0	0
2/28/2018	6/21/2010	0	0	0
	Total	1	8	9

Date G.C	Date E.C	EW line	NS line	Total
3/1/2018	6/22/2010	0	0	0
3/2/2018	6/23/2010	0	5	5
3/3/2018	6/24/2010	0	0	0
3/4/2018	6/25/2010	0	1	1
3/5/2018	6/26/2010	0	0	0
3/6/2018	6/27/2010	0	0	0
3/7/2018	6/28/2010	0	0	0
3/8/2018	6/29/2010	1	0	1
3/9/2018	6/30/2010	0	0	0
3/10/2018	7/1/2010	16	7	23
3/11/2018	7/2/2010	2	0	2
3/12/2018	7/3/2010	0	0	0
3/13/2018	7/4/2010	0	0	0
3/14/2018	7/5/2010	0	0	0
3/15/2018	7/6/2010	0	0	0
3/16/2018	7/7/2010	0	0	0
3/17/2018	7/8/2010	0	0	0
3/18/2018	7/9/2010	0	0	0
3/19/2018	7/10/2010	0	0	0
3/20/2018	7/11/2010	0	0	0
3/21/2018	7/12/2010	0	0	0
3/22/2018	7/13/2010	0	0	0
3/23/2018	7/14/2010	0	0	0
3/24/2018	7/15/2010	0	9	9
3/25/2018	7/16/2010	0	0	0
3/26/2018	7/17/2010	0	0	0
3/27/2018	7/18/2010	0	29	29
3/28/2018	7/19/2010	2	0	2
3/29/2018	7/20/2010	0	0	0
3/30/2018	7/21/2010	0	0	0
3/31/2018	7/22/2010	0	0	0
	Total	21	51	72

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
4/1/2018	7/23/2010	0	0	0
4/2/2018	7/24/2010	0	0	0
4/3/2018	7/25/2010	0	13	13
4/4/2018	7/26/2010	0	0	0
4/5/2018	7/27/2010	0	5	5
4/6/2018	7/28/2010	0	0	0
4/7/2018	7/29/2010	0	0	0
4/8/2018	7/30/2010	0	0	0
4/9/2018	8/1/2010	7	0	7
4/10/2018	8/2/2010	0	0	0
4/11/2018	8/3/2010	0	0	0
4/12/2018	8/4/2010	0	0	0
4/13/2018	8/5/2010	0	0	0
4/14/2018	8/6/2010	4	0	4
4/15/2018	8/7/2010	0	0	0
4/16/2018	8/8/2010	0	0	0
4/17/2018	8/9/2010	0	0	0
4/18/2018	8/10/2010	25	7	32
4/19/2018	8/11/2010	0	0	0
4/20/2018	8/12/2010	0	5	5
4/21/2018	8/13/2010	0	0	0
4/22/2018	8/14/2010	0	0	0
4/23/2018	8/15/2010	0	0	0
4/24/2018	8/16/2010	0	0	0
4/25/2018	8/17/2010	0	0	0
4/26/2018	8/18/2010	0	8	8
4/27/2018	8/19/2010	0	0	0
4/28/2018	8/20/2010	10	14	24
4/29/2018	8/21/2010	0	2	2
4/30/2018	8/22/2010	29	36	65
	Total	46	52	98

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
5/1/2018	8/23/2010	46	49	95
5/2/2018	8/24/2010	0	0	0
5/3/2018	8/25/2010	0	0	0
5/4/2018	8/26/2010	9	0	9
5/5/2018	8/27/2010	0	0	0
5/6/2018	8/28/2010	0	0	0
5/7/2018	8/29/2010	0	0	0
5/8/2018	8/30/2010	6	3	9
5/9/2018	9/1/2010	0	0	0
5/10/2018	9/2/2010	0	0	0
5/11/2018	9/3/2010	0	2	2
5/12/2018	9/4/2010	0	3	3
5/13/2018	9/5/2010	0	0	0
5/14/2018	9/6/2010	0	0	0
5/15/2018	9/7/2010	0	0	0
5/16/2018	9/8/2010	0	0	0
5/17/2018	9/9/2010	0	0	0
5/18/2018	9/10/2010	0	0	0
5/19/2018	9/11/2010	0	0	0
5/20/2018	9/12/2010	0	0	0
5/21/2018	9/13/2010	0	3	3
5/22/2018	9/14/2010	0	0	0
5/23/2018	9/15/2010	0	0	0
5/24/2018	9/16/2010	0	0	0
5/25/2018	9/17/2010	0	0	0
5/26/2018	9/18/2010	0	0	0
5/27/2018	9/19/2010	0	0	0
5/28/2018	9/20/2010	0	0	0
5/29/2018	9/21/2010	0	0	0
5/30/2018	9/22/2010	0	0	0
5/31/2018	9/23/2010	0	0	0
	Total	61	60	121

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
6/1/2018	9/24/2010	0	16	16
6/2/2018	9/25/2010	0	0	0
6/3/2018	9/26/2010	0	4	4
6/4/2018	9/27/2010	55	31	86
6/5/2018	9/28/2010	0	0	0
6/6/2018	9/29/2010	0	0	0
6/7/2018	9/30/2010	0	0	0
6/8/2018	10/1/2010	0	2	2
6/9/2018	10/2/2010	0	0	0
6/10/2018	10/3/2010	7	8	15
6/11/2018	10/4/2010	0	0	0
6/12/2018	10/5/2010	0	0	0
6/13/2018	10/6/2010	0	1	1
6/14/2018	10/7/2010	0	0	0
6/15/2018	10/8/2010	0	0	0
6/16/2018	10/9/2010	2	5	7
6/17/2018	10/10/2010	0	0	0
6/18/2018	10/11/2010	11	13	24
6/19/2018	10/12/2010	0	0	0
6/20/2018	10/13/2010	0	12	12
6/21/2018	10/14/2010	0	0	0
6/22/2018	10/15/2010	0	0	0
6/23/2018	10/16/2010	0	0	0
6/24/2018	10/17/2010	0	4	4
6/25/2018	10/18/2010	31	0	31
6/26/2018	10/19/2010	56	7	63
6/27/2018	10/20/2010	55	0	55
6/28/2018	10/21/2010	0	0	0
6/29/2018	10/22/2010	0	0	0
6/30/2018	10/23/2010	0	0	0
	Total	217	103	320

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
7/1/2018	10/24/2010	0	0	0
7/2/2018	10/25/2010	8	9	17
7/3/2018	10/26/2010	8	8	16
7/4/2018	10/27/2010	2	7	9
7/5/2018	10/28/2010	0	0	0
7/6/2018	10/29/2010	0	0	0
7/7/2018	10/30/2010	0	0	0
7/8/2018	11/1/2010	0	0	0
7/9/2018	11/2/2010	0	0	0
7/10/2018	11/3/2010	0	0	0
7/11/2018	11/4/2010	0	2	2
7/12/2018	11/5/2010	0	0	0
7/13/2018	11/6/2010	0	0	0
7/14/2018	11/7/2010	60	0	60
7/15/2018	11/8/2010	0	0	0
7/16/2018	11/9/2010	0	0	0
7/17/2018	11/10/2010	0	0	0
7/18/2018	11/11/2010	0	0	0
7/19/2018	11/12/2010	0	0	0
7/20/2018	11/13/2010	0	0	0
7/21/2018	11/14/2010	0	0	0
7/22/2018	11/15/2010	80	78	158
7/23/2018	11/16/2010	0	0	0
7/24/2018	11/17/2010	0	0	0
7/25/2018	11/18/2010	0	0	0
7/26/2018	11/19/2010	0	17	17
7/27/2018	11/20/2010	0	0	0
7/28/2018	11/21/2010	0	0	0
7/29/2018	11/22/2010	0	0	0
7/30/2018	11/23/2010	0	0	0
7/31/2018	11/24/2010	1	3	4
	Total	159	124	283

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
8/1/2018	11/25/2010	0	0	0
8/2/2018	11/26/2010	0	0	0
8/3/2018	11/27/2010	0	0	0
8/4/2018	11/28/2010	0	0	0
8/5/2018	11/29/2010	0	0	0
8/6/2018	11/30/2010	0	0	0
8/7/2018	12/1/2010	0	0	0
8/8/2018	12/2/2010	0	0	0
8/9/2018	12/3/2010	1	4	5
8/10/2018	12/4/2010	0	1	1
8/11/2018	12/5/2010	0	0	0
8/12/2018	12/6/2010	0	0	0
8/13/2018	12/7/2010	0	0	0
8/14/2018	12/8/2010	0	0	0
8/15/2018	12/9/2010	12	23	35
8/16/2018	12/10/2010	0	0	0
8/17/2018	12/11/2010	0	0	0
8/18/2018	12/12/2010	0	0	0
8/19/2018	12/13/2010	0	0	0
8/20/2018	12/14/2010	0	0	0
8/21/2018	12/15/2010	0	0	0
8/22/2018	12/16/2010	0	22	22
8/23/2018	12/17/2010	0	0	0
8/24/2018	12/18/2010	0	0	0
8/25/2018	12/19/2010	0	0	0
8/26/2018	12/20/2010	0	0	0
8/27/2018	12/21/2010	0	0	0
8/28/2018	12/22/2010	0	0	0
8/29/2018	12/23/2010	0	0	0
8/30/2018	12/24/2010	0	0	0
8/31/2018	12/25/2010	0	0	0
	Total	13	50	63

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
9/1/2018	12/26/2010			0
9/2/2018	12/27/2010			0
9/3/2018	12/28/2010			0
9/4/2018	12/29/2010			0
9/5/2018	12/30/2010		16	16
9/6/2018	13/1/2011			0
9/7/2018	13/1/2012		32	32
9/8/2018	13/1/2013	8	11	19
9/9/2018	13/1/2014	37	37	74
9/10/2018	13/1/2015			0
9/11/2018	1/1/2011			0
9/12/2018	1/2/2011		4	4
9/13/2018	1/3/2011			0
9/14/2018	1/4/2011			0
9/15/2018	1/5/2011	19		19
9/16/2018	1/6/2011			0
9/17/2018	1/7/2011			0
9/18/2018	1/8/2011	15	14	29
9/19/2018	1/9/2011		12	12
9/20/2018	1/10/2011	3		3
9/21/2018	1/11/2011	14	3	17
9/22/2018	1/12/2011			0
9/23/2018	1/13/2011			0
9/24/2018	1/14/2011			0
9/25/2018	1/15/2011		8	8
9/26/2018	1/16/2011		24	24
9/27/2018	1/17/2011			0
9/28/2018	1/18/2011			
9/29/2018	1/19/2011			
9/30/2018	1/20/2011			0
	Total	96	161	257

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
10/1/2018	1/21/2011			0
10/2/2018	1/22/2011			0
10/3/2018	1/23/2011			0
10/4/2018	1/24/2011			0
10/5/2018	1/25/2011		2	2
10/6/2018	1/26/2011			0
10/7/2018	1/27/2011			0
10/8/2018	1/28/2011			0
10/9/2018	1/29/2011			0
10/10/2018	1/30/2011			0
10/11/2018	2/1/2011			0
10/12/2018	2/2/2011			0
10/13/2018	2/3/2011			0
10/14/2018	2/4/2011			0
10/15/2018	2/5/2011			0
10/16/2018	2/6/2011			0
10/17/2018	2/7/2011		14	14
10/18/2018	2/8/2011		12	12
10/19/2018	2/9/2011			0
10/20/2018	2/10/2011			0
10/21/2018	2/11/2011			0
10/22/2018	2/12/2011			0
10/23/2018	2/13/2011			0
10/24/2018	2/14/2011		1	1
10/25/2018	2/15/2011			0
10/26/2018	2/16/2011		6	6
10/27/2018	2/17/2011	1		1
10/28/2018	2/18/2011			0
10/29/2018	2/19/2011			0
10/30/2018	2/20/2011	16		
10/31/2018	2/21/2011	13	2	
	Total	30	35	36

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
11/1/2018	2/22/2011			0
11/2/2018	2/23/2011		11	11
11/3/2018	2/24/2011			0
11/4/2018	2/25/2011			0
11/5/2018	2/26/2011			0
11/6/2018	2/27/2011	28	28	56
11/7/2018	2/28/2011			0
11/8/2018	2/29/2011			0
11/9/2018	2/30/2011			0
11/10/2018	3/1/2011			0
11/11/2018	3/2/2011			0
11/12/2018	3/3/2011			0
11/13/2018	3/4/2011			0
11/14/2018	3/5/2011	17	7	24
11/15/2018	3/6/2011	11	10	21
11/16/2018	3/7/2011			0
11/17/2018	3/8/2011			0
11/18/2018	3/9/2011			0
11/19/2018	3/10/2011			0
11/20/2018	3/11/2011			0
11/21/2018	3/12/2011		4	4
11/22/2018	3/13/2011			0
11/23/2018	3/14/2011			0
11/24/2018	3/15/2011			0
11/25/2018	3/16/2011			0
11/26/2018	3/17/2011			0
11/27/2018	3/18/2011			0
11/28/2018	3/19/2011			0
11/29/2018	3/20/2011			
11/30/2018	3/21/2011			
	Total	56	60	116

Trips cancelled due to power fluctuation				
Date G.C	Date E.C	EW line	NS line	Total
12/1/2018	3/22/2011			0
12/2/2018	3/23/2011			0
12/3/2018	3/24/2011	42		42
12/4/2018	3/25/2011			0
12/5/2018	3/26/2011			0
12/6/2018	3/27/2011			0
12/7/2018	3/28/2011			0
12/8/2018	3/29/2011			0
12/9/2018	3/30/2011			0
12/10/2018	4/1/2011	8	1	9
12/11/2018	4/2/2011			0
12/12/2018	4/3/2011			0
12/13/2018	4/4/2011			0
12/14/2018	4/5/2011			0
12/15/2018	4/6/2011	1	1	2
12/16/2018	4/7/2011			0
12/17/2018	4/8/2011			0
12/18/2018	4/9/2011			0
12/19/2018	4/10/2011	87	64	151
12/20/2018	4/11/2011	85		85
12/21/2018	4/12/2011			0
12/22/2018	4/13/2011	8		8
12/23/2018	4/14/2011	7		7
12/24/2018	4/15/2011		12	12
12/25/2018	4/16/2011			0
12/26/2018	4/17/2011			0
12/27/2018	4/18/2011			0
12/28/2018	4/19/2011	7		7
12/29/2018	4/20/2011	20		20
12/30/2018	4/21/2011			0
12/31/2018	4/22/2011			0
	Total	265	78	343

Appendix C: Interruption data from EEP and EEU

Substation	Effect	Voltage Rating	Outage	Revival
Kaliti I-Kali T Gis	Tr.Line	132	4/1/2022 14:03	4/1/2022 14:18
Kaliti North Transfoemer I	Transformer	132/15	13/01/22 16:01	13/01/22 16:07
Kaliti I Transformer	Transformer	132/45	28/01/22 13:19	28/01/22 13:21
Kaliti I Transformer Iii	132kv Transformer	230/132	31/01/22 05:30	31/01/22 05:46
Kaliti Ii Gis Transormer Ii	Transformer	132/15	5/10/2020 14:12	5/10/2020 14:26
Kaliti-Ii Gis Transformer Ii	Transformer	132/15	25/10/20 16:14	25/10/20 16:21
Kaliti North Transformer-I	Transformer	132/15	27/10/20 15:23	27/10/20 15:50
Kality Ii Gis Transformer I	Transformer	132/15	3/30/2021 18:19	3/30/2021 18:32
Kaliti-I Transformer-Ii	Transformer	132/45	20/12/20 08:16	20/12/20 08:25
Kaliti I-Kaliti Ii	Tr.Line	132	15/05/21 07:44	15/05/21 08:04
Kaliti I-Kaliti Ii	Tr.Line	132	17/05/21 15:43	17/05/21 15:47
Kaliti I-Kaliti Ii	Tr. Line	132	18/05/21 10:13	18/05/21 10:16
Kaliti Ii - Kaliti I	Tr.Line	132	22/05/21 10:32	22/05/21 10:35
Kaliti Ii - Kaliti I	Tr Line	132	26/05/21 10:11	26/05/21 10:13
Kaliti I-Kaliti Ii	Tr.Line	132	29/05/21 11:03	29/05/21 13:40
Kalti I Transformer Iii	Transformer	230/132	5/5/2021 8:10	5/5/2021 11:46
Kaliti Gis Transformer Ii	Transformer	132/15	12/5/2021 10:36	12/5/2021 10:41
Kalit I Transformer Iii	Transformer	230/132	16/05/21 20:30	17/05/21 08:13
Kalt Ii Transformer Iii	Transformer	132/15	17/05/21 17:46	17/05/21 18:30
Kaliti Gis Transformer Ii	Transformer	132/15	20/05/21 09:57	20/05/21 10:06
Kaliti Ii Gis Transformer Ii	Transformer	13/15	21/05/21 11:58	21/05/21 12:04
Kalit Gis Transformer Ii	Transformer	132/15	28/05/21 10:06	28/05/21 10:15
Kaliti I- Kaliti Ii	Tr Line	132	14/03/21 19:33	14/03/21 20:11
Kaliti I - Kaliti Ii	Tr.Line	132	15/03/21 19:30	15/03/21 19:37
Kaliti Ii - Kaliti I	Tr.Line	132	23/03/21 15:49	23/03/21 15:58
Kaliti Ii - Kaliti Gis	Tr.Line	132	23/03/21 15:49	23/03/21 15:58
Kaliti I- Kaliti -Ii	Tr.Line	132	25/03/21 16:03	25/03/21 16:11

Kaliti I- Kaliti -Ii	Tr.Line	132	25/03/21 16:03	25/03/21 16:11
Kaliti I - Kaliti Ii	Tr.Line	132	5/1/2021 12:43	5/1/2021 12:54
Kaliti I - Kaliti Ii	Tr.Line	132	14/01/21 15:08	14/01/21 15:15
Kaliti I - Kaliti Gis	Tr.Line	132	14/01/21 15:08	14/01/21 15:32
Kaliti I - Kaliti Ii	Tr.Line	132	5/1/2021 12:43	5/1/2021 12:54
Kaliti I - Kaliti Ii	Tr.Line	132	14/01/21 15:08	14/01/21 15:15
Kaliti I - Kaliti Gis	Tr.Line	132	14/01/21 15:08	14/01/21 15:32
Kaliti I Transformer I 132/45	Transformer	132/45	20/01/21 13:45	22/01/21 14:20
Kaliti I Transformer Ii 132/45	Transformer	132/45	20/01/21 13:40	20/01/21 14:40
Kaliti I Transformer Iii 132/15	Transformer Iii	132/15	22/01/21 10:26	22/01/21 11:34
Kalit I Transformer I	Transformer	132/45	22/01/21 12:42	22/01/21 12:50
Kalit I Transformer Ii	Transformer	132/45	22/01/21 12:42	22/01/21 12:53
Mekele Transformer I 132/45/15 (For Mobile Substation)	Transformer	132/45/15	24/01/21 02:25	24/01/21 09:53
Gefersa Transformer Ii	Transformer	132/45/15	24/01/21 14:58	24/01/21 16:37
Gambela Transformer	Transformer	230/66/15	24/01/21 19:50	24/01/21 19:59
Mota Transformer I 230/33	Transformer	230/33	26/01/21 10:13	26/01/21 10:49
Kaliti I Transformer Ii 230/132	Transformer	230/132	19/01/21 08:00	27/01/21 15:52
Kalite Ii Transformer	Transformer	132/15	7/2/2021 23:21	7/2/2021 23:33
Kalit Ii Transformer Ii	Transformer	132/15	15/02/21 15:03	15/02/21 15:08
Kality I - Kality Ii	Tr.Line	132	17/02/21 19:11	17/02/21 19:21
Kalit Ii Transformer Iii	Transformer	132/15	19/02/21 18:47	19/02/21 18:56
Kaliti Ii Transformer Iii	Transformer	132/15	21/02/21 06:15	21/02/21 12:38
Kaliti Ii Transformer Iii	Transformer	132/15	21/02/21 06:15	21/02/21 12:38
Kaliti I - Kaliti Ii	Tr.Line	132	28/02/21 16:55	28/02/21 17:15
Kality I - Kality Ii	Tr.Line	132	17/02/21 19:11	17/02/21 19:21
Kaliti Ii Transformer Iii	Transformer	132/15	21/02/21 06:15	21/02/21 12:38
Kalti Ii Gis	Transformer I	132/15	21/02/21 09:31	21/02/21 10:35

Kalite Ii Transformer	Transformer	132/15	7/2/2021 23:21	7/2/2021 23:33
Kalit Ii Transformer Ii	Transformer	132/15	15/02/21 15:03	15/02/21 15:08
Kalit Ii Transformer Iii	Transformer	132/15	19/02/21 18:47	19/02/21 18:56
Kaliti-I - Kaliti-Ii	Tr.Line	132	18/04/21 06:30	18/04/21 11:18
Kaliti Ii - Kaliti I	Tr Line	132	1/4/2021 10:56	1/4/2021 10:59
Kaliti Ii - Kaliti Gis	Tr Line	132	1/4/2021 10:56	1/4/2021 10:59
Gefersa - Kaliti I	Tr Line	132	1/4/2021 10:56	1/4/2021 10:59
Kaliti Ii - Kaliti I	Tr Line	132	3/4/2021 14:45	3/4/2021 14:49
Kalit Ii - Kaliti Ii Gis	Tr Line	132	3/4/2021 14:45	3/4/2021 14:49
Kaliti I - Kaliti Ii	Tr.Line	132	3/4/2021 18:43	3/4/2021 19:20
Kaliti I- Kaliti Iioflo	Tr.Line	132	4/4/2021 15:48	4/4/2021 15:59
Kaliti I- Adiss Center	Tr Line	132	8/4/2021 12:55	8/4/2021 13:05
Kalit Ii - Kaliti Ii Gis	Tr.Line	132	10/4/2021 19:15	10/4/2021 19:20
Kaliti Ii - Kaliti I	Tr.Line	132	10/4/2021 19:15	10/4/2021 19:20
Kaliti Ii - Kaliti Gis	Tr Line	132	11/4/2021 13:51	11/4/2021 14:03
Kaliti I -Kaliti Ii	Tr.Line	132	11/4/2021 13:51	11/4/2021 14:09
Kaliti-I - Kaliti-Ii	Tr.Line	132	18/04/21 12:46	18/04/21 12:55
Kaliti Ii - Kaliti I	Tr.Line	132	19/04/21 03:30	19/04/21 03:52
Kaliti Ii - Kaliti I	Tr.Line	132	28/04/21 14:51	28/04/21 15:37
Kaliti Ii - Kaliti Gis	Tr.Line	132	28/04/21 14:51	28/04/21 15:38
Kaliti I- Yesu	Tr.Line	132	28/04/21 15:27	28/04/21 15:47
Kaliti Ii - Kaliti I	Tr.Line	132	30/04/21 06:58	30/04/21 07:00
Kaliti Ii - Kaliti I	Tr.Line	132	30/04/21 07:47	30/04/21 07:49
Kaliti I - Kaliti Ii	Tr Line	132	1/4/2021 10:56	1/4/2021 10:59
Kaliti Ii - Kaliti Gis	Tr Line	132	1/4/2021 10:56	1/4/2021 10:59
Gefersa - Kaliti I	Tr Line	132	1/4/2021 10:56	1/4/2021 10:59
Kaliti I - Kaliti Ii	Tr.Line	132	3/4/2021 18:43	3/4/2021 19:20
Kaliti Ii -Kaliti Ii Gis	Tr.Line	132	10/4/2021 19:15	10/4/2021 19:20
Kaliti I - Kaliti Ii	Tr.Line	132	10/4/2021 19:15	10/4/2021 19:20
Kaliti I - Sebeta I	Tr.Line	230	10/4/2021 19:13	10/4/2021 19:52
Kaliti I - Kaliti Ii	Tr.Line	132	11/4/2021 13:51	11/4/2021 14:09
Kaliti I - Kaliti Ii	Tr.Line	132	18/04/21 12:46	18/04/21 12:55

Kaliti North Transformer I	Transformer I	132/15	3/4/2021 14:45	3/4/2021 14:51
Kaliti2 Gis Transformer Ii	Transformer	132/15	6/4/2021 10:49	6/4/2021 10:58
Kaliti North Transformer I	Transformer	132/15	10/4/2021 19:20	10/4/2021 21:40
Kaliti I Transformer Iii	Transformer	132/15	10/4/2021 19:12	10/4/2021 19:25
Kaliti North Transformer I	Transformer	132/15	11/4/2021 13:50	11/4/2021 13:59
Kaliti2gis Transformer Ii	Transformer	132/15	19/04/21 15:34	19/04/21 15:40
Kaliti Gis Transformer Ii	Transformer	132/15	21/04/21 13:53	21/04/21 14:16
Kaliti North Transformer I	Transformer	132/15	28/04/21 15:36	28/04/21 15:38
Kaliti Ii Gis	Transformer Ii	132/15	30/04/21 12:17	30/04/21 12:24
Kaliti I Transformer	Transformer	132/45	6/12/2021 1:08	6/12/2021 1:36
Kaliti North Transformer Ii	Transformer	132/15	22/12/21 08:58	22/12/21 09:36
Kaliti Gis Transformer Ii	Transformer	132/15	28/12/21 13:49	28/12/21 14:01
Kaliti I Transformer	Transformer	132/45	6/12/2021 1:08	6/12/2021 1:36
Kaliti Gis Transfomer I&Ii	Transformer	132/15	5/4/2022 9:40	5/4/2022 10:05
Kaliti I Transfomer	Transformer	132/45	5/4/2022 11:48	5/4/2022 12:02
Kaliti North Transformer I	Transformer	132/15	5/8/2022 9:45	5/8/2022 9:50
Kaliti Ii Transformer Iii	Transformer	132/15	5/10/2022 17:08	5/10/2022 17:23
Kaliti I Transformer Ii	Transformer	132/45	5/29/2022 7:20	5/29/2022 7:45
Kaliti I Transformer Iii	Transformer	132/15	3/1/2022 0:00	3/31/2022 23:59
Kaliti Gis Transformer Ii	Transformer	132/15	3/11/2022 23:53	3/12/2022 0:07
Kaliti Ii Gis Transformer	Transformer	132/15	3/20/2022 8:24	3/20/2022 8:30
Kaliti North Transformer I	Transformer	132/15	3/24/2022 13:56	3/24/2022 14:00
Kaliti I Transformer I	Transformer	230/132	3/30/2022 8:19	3/30/2022 10:09
Kalilit Ii Gis Transformer Ii	Transformer	132/15	3/30/2022 20:22	3/30/2022 20:31
Kaliti I -Kalit Ii	Tr.Line	132	4/9/2022 7:59	4/9/2022 8:12
Kalit Ii Transformer	Transformer Ii	132/15	4/9/2022 7:32	4/30/2022 23:59
Kalit Ii Transformer	Transformer Ii	132/15	4/9/2022 7:32	4/9/2022 10:58
Kalit I Gis Transformer Ii	Transformer	132/15	4/6/2022 20:09	4/6/2022 20:19
Kaliti Ii Gis Transformer	Transformer	132/15	4/7/2022 11:49	4/7/2022 11:56
Kaliti I Transformer Ii	Transformer	132/15	4/27/2022 16:45	4/27/2022 17:10

Duration	Cause	Cause	Year	Duration Of Fault	Total Temporary Fault	Total Permanent Fault
0.15	Due Earth Fault Ia=4.974a Ib=444a Ic=804a D=1.10km	Er	2022	Temporary	T	T
0.1	Due To Earth Fault On 15 Kv Side	Er	2022	Temporary	T	T
0.03	Due To Akaki I- Dukem Fault	Er	2022	Temporary	T	T
0.27	No Signal	Ns	2022	Temporary	T	T
0.2333	Due To Earth Fault(15 Kv Fault)	Er	2020	Temporary	T	T
0.1167	Due To 15 Kv Feeder Fault	Er	2020	Temporary	T	T
0.45	Due To 15kv Fault.	Er	2020	Permanent	P	P
0.2167	Due To Earth Fault	Er	2020	Temporary	T	T
0.15	Due To Short Circuit Ia=1.69ka, Ib=1.58ka, Ic=1.665ka	Sc	2020	Temporary	T	T
0.3333	No Specified Reason ,Ia=1.939a Ib=1.066a Ic=1.919a	Nr	2021	Permanent	P	P
0.0667	Due To Short Circuit	Sc	2021	Temporary	T	T
0.05	No Signal	Ns	2021	Temporary	T	T
0.05	No Signal	Ns	2021	Temporary	T	T
0.0333	No Signal	Ns	2021	Temporary	T	T
2.6167	Due To Over Current Ia=682a,Ib=1.15ka,Ic=8.845ka,D=3.16km	Oc	2021	Permanent	P	P
3.6	No Signal	Ns	2021	Permanent	P	P
0.0833	Due To Earth Fault	Er	2021	Temporary	T	T
11.717	No Signal	Ns	2021	Permanent	P	P
0.7333	Due To Earth Fault	Er	2021	Permanent	P	P
0.15	Due To Earth Fault Occurs On 15kv Side	Er	2021	Temporary	T	T
0.1	Due To 15kv Side Earth Fault	Er	2021	Temporary	T	T
0.15	Due To Earth Fault Ia=23.14a Ib=23.1a Ic=23.28a	Er	2021	Temporary	T	T
0.6333	Due To Line Differential Relay	Sm	2021	Permanent	P	P
0.1167	Nosignal	Ns	2021	Temporary	T	T
0.15	No Signal	Ns	2021	Temporary	T	T

0.15	No Signal	Ns	2021	Temporary	T	T
0.1333	Due To Earth Fault Ia=1.98 Ib=1.35 Ic=1.24 (Due To 15kv Side Fault)	Er	2021	Temporary	T	T
0.1333	Due To Earth Fault Ia=1.98 Ib=1.35 Ic=1.24 (Due To 15kv Side Fault)	Er	2021	Temporary	T	T
0.1833	Due To Short Circuit	Sc	2021	Temporary	T	T
0.1167	Due To Earth Fault Ia= 138a ,Ib= 359.2a , Ic= 53.2a	Er	2021	Temporary	T	T
0.4	Due To Earth Fault Ia= 163 A ,Ib= 5.885a , Ic=1.18a	Er	2021	Permanent	P	P
0.1833	Due To Short Circuit	Er	2021	Temporary	T	T
0.1167	Due To Earth Fault Ia= 138a ,Ib= 359.2a , Ic= 53.2a	Er	2021	Temporary	T	T
0.4	Due To Earth Fault Ia= 163 A ,Ib= 5.885a , Ic=1.18a	Er	2021	Permanent	P	P
2.0243	Due Firing Of Lighting Arestor On ' S' & 'T' Phases	Sp	2021	Permanent	P	P
0.0417	Due To Buchholz Alarm	Sm	2021	Temporary	T	T
0.0472	For Safety To Maintain 132/45 Kv Transformer	Sm	2021	Temporary	T	T
0.0056	For Maintenance	Sm	2021	Temporary	T	T
0.0076	For Maintenance	Sm	2021	Temporary	T	T
0.3111	Due To Spark On 15kv Side Of The Transformer	Sp	2021	Permanent	P	P
0.0688	To Maintaine Transformer With Out The Command Of Ldc	Sm	2021	Temporary	T	T
0.0063	To Maintain Bushing	Sm	2021	Temporary	T	T
0.025	For Maintenance	Sm	2021	Temporary	T	T
8.3278	For Safety To Maintain Diferential Protection Relay	Sm	2021	Permanent	P	P
0:12	Due To Short Circuit	Sc	2021	Temporary	T	T
0:05	Due To Earth Fault	Er	2021	Temporary	T	T
0:10	Due To Over Current Ia = 1.528a Ib = 1.678a Ic	Oc	2021	Temporary	T	T

	=1.627a					
0:09	Due To Earth Fault ;Magnitude 128a	Er	2021	Temporary	T	T
6:23	To Asseble New 15kv Breaker	Sm	2021	Temporary	T	T
6:23	To Asseble New 15kv Breaker	Sm	2021	Temporary	T	T
0:20	No Signal (Open Only @ Kaliti I).	Oc	2021	Temporary	T	T
0.1667	Due To Over Current Ia = 1.528a Ib = 1.678a Ic =1.627a	Oc	2021	Temporary	T	T
6.3833	To Asseble New 15kv Breaker	Sm	2021	Permanent	P	P
1.0667	For Maintenance	Sm	2021	Permanent	P	P
0.2	Due To Short Circuit	Sc	2021	Temporary	T	T
0.0833	Due To Earth Fault	Er	2021	Temporary	T	T
0.15	Due To Earth Fault ;Magnitude 128a	Er	2021	Temporary	T	T
4.8	For Maintenance	Sm	2021	Permanent	P	P
0.05	Due To Earth Fault	Er	2021	Temporary	T	T
0.05	Due To Earth Fault	Er	2021	Temporary	T	T
0.05	Due To Earth Fault	Er	2021	Temporary	T	T
0.0667	No Signal	Ns	2021	Temporary	T	T
0.0667	No Signal	Ns	2021	Temporary	T	T
0.6167	Due To Tripped A B C,Ia=744a,Ib=1.1382ka,Ic=444.6a	Er	2021	Permanent	P	P
0.1833	No Signal	Ns	2021	Temporary	T	T
0.1667	Due To Short Circuit And Earth Fault	Sc	2021	Temporary	T	T
0.0833	Due To Earth Fault	Er	2021	Temporary	T	T
0.0833	Due To Earth Fault	Er	2021	Temporary	T	T
0.2	No Signal	Ns	2021	Temporary	T	T
0.3	Due To Over Current Ia=444.6a,Ib=696.6a,Ic=10.1298ka,D=7.8km	Oc	2021	Temporary	T	T
0.15	Due To Short Circuit Ia=750a,Ib=892.8a,Ic=919.8a	Sc	2021	Temporary	T	T
0.3667	No Signal	Ns	2021	Permanent	P	P
0.7667	No Signal	Ns	2021	Permanent	P	P

0.7833	No Signal	Ns	2021	Permanent	P	P
0.3333	Due To Earth Fault	Er	2021	Permanent	P	P
0.0333	No Signal	Ns	2021	Temporary	T	T
0.0333	Due To Phase Unbalnce	Pu	2021	Temporary	T	T
0.05	Due To Earth Fault	Er	2021	Temporary	T	T
0.05	Due To Earth Fault	Er	2021	Temporary	T	T
0.05	Due To Earth Fault	Er	2021	Temporary	T	T
0.62	Due To Tripped A B C,Ia=744a,Ib=1.1382ka,Ic=444.6a	Er	2021	Permanent	P	P
0.08	Due To Earth Fault	Er	2021	Temporary	T	T
0.08	Due To Earth Fault	Er	2021	Temporary	T	T
0.65	Due To Short Circuit Ia=81.11a, Ib=8.56ka, Ic=137.6a	Sc	2021	Permanent	P	P
0.3	Due To Over Current Ia=444.6a,Ib=696.6a,Ic=10.1298ka,D=7.8km	Oc	2021	Temporary	T	T
0.15	Due To Short Circuit Ia=750a,Ib=892.8a,Ic=919.8a	Sc	2021	Temporary	T	T
0.1	Due To Earh Fault	Er	2021	Temporary	T	T
0.15	Due To Earth Fault	Er	2021	Temporary	T	T
2.3333	Due To Earth Fault	Er	2021	Permanent	P	P
0.2167	Due To Earth Fault	Er	2021	Temporary	T	T
0.15	Due To Short Circuit	Sc	2021	Temporary	T	T
0.1	Due To Earth Fault	Er	2021	Temporary	T	T
0.3833	Due To Earth Fault	Er	2021	Permanent	P	P
0.0333	Due To Earth Fault	Er	2021	Temporary	T	T
0.1167	Due To 15kv Side Fault	Er	2021	Temporary	T	T
0.47	No Signal	Ns	2021	Permanent	P	P
0.63	Due To Oil Leakage Occurs On Earthing Transformer	Sm	2021	Permanent	P	P
0.2	No Signal	Ns	2021	Temporary	T	T
0.47	No Signal	Ns	2021	Permanent	P	P
0.42	Due To Earth Fault Ia=134.7a Ib=331.2a	Er	2022	Permanent	P	P

	Ic=503.7a					
0.23	Due To Earth Fault Ia=218.5a Ib=351.5a Ic=1.702ka In=1.309ka	Er	2022	Temporary	T	T
0.08	Due To Earth Fault Occurs On 15kv Load Line Side	Er	2022	Temporary	T	T
0.25	Due To Earth Fault	Er	2022	Temporary	T	T
0.42	Due To Earth Fault Ia =282.5a Ib= 1.732ka Ic= 137.0a In=1.343a	Er	2022	Permanent	P	P
744	To Transfer Load On Transformer Ii	Sm	2022	Permanent	P	P
0.23	Due To Earth Fault Ia=91.1a,Ib=18.67a,Ic=18.63a	Er	2022	Temporary	T	T
0.1	Due To 15 Kv Side Earth Fault	Er	2022	Temporary	T	T
0.07	Due To Short Circuit ,Magnitude 119.4a,	Sc	2022	Temporary	T	T
1.83	Due To Over Heat On S Phase	Sm	2022	Permanent	P	P
0.15	Due To 15 Kv Side Earth Fault	Er	2022	Temporary	T	T
0.22	Due To Short Circuit D=1.3km From Kalti Ii	Sc	2022	Temporary	T	T
520.47	For Functional Test	Sm	2022	Permanent	P	P
3.43	For Functional Test	Sm	2022	Permanent	P	P
0.17	Due To Earth Fault	Er	2022	Temporary	T	T
0.12	Due To 15kv Side Fault	Er	2022	Temporary	T	T
0.42	Due To Over Current	Oc	2022	Permanent	P	P