Performance Assessment of Power Distribution System:
(A Case of Rehabilitated Power Distribution System of Adama Town)

By:
Betel Yohannes
ID No: A/PE16418/10

A Thesis Submitted to
The Department of Electrical Power and Control Engineering
School of Electrical Engineering & Computing

Presented in Partial Fulfillment of the Requirements for the Degree of
Masters of Science in Electrical Power Engineering

Office of Post Graduate Studies

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July 2020 G.C
Adama, Ethiopia

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Approval Page

We, the undersigned , members of the Board of Examiners of the final open defense by Betel Yohannes Woldmariam have read and evaluated his thesis entitled “Performance Assessment of Power Distribution System: A Case of Rehabilitated Power Distribution System of Adama Town” and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirement of the degree of Master of Science in Electrical Power Engineering.

Name	Signature	Date
____________________ Name of Student	__________________	_______________
____________________ Advisor	__________________	_______________
____________________ External Examiner	__________________	_______________
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____________________ Chair Person	__________________	_______________
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Declaration

I, the undersigned, declare that this MSc thesis is my original work, has not been presented for fulfillment of a degree in this or other universities, and all sources of materials used for this thesis have been fully acknowledged.

Mr. Betel Yohannes
Name

____
Signature

Place: Adama Science and Technology University, Adama, Ethiopia

Date of Submission: *July 16, 2020*

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

Dr. Molla Biweta
Advisor

____
Signature

Acknowledgement

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Acronyms

A	Ampere
A'	Agree
AAC	All Aluminum Conductor
AC	Alternating Current
CT	Current Transformer
D	Disagree
DLOL	Distribution Line over Load
DPEF	Distribution Permanent Earth Fault
DPSC	Distribution Permanent Short Circuit
DTEF	Distribution Temporary Earth Fault
DTSC	Distribution Temporary Short Circuit
DUR	Duration
EC	Ethiopian Calendar
EEU	Ethiopia Electric Utility
FRQ	Frequency
GUP	Generation Unit Problem
HV	High Voltage
IC	Interconnected system
IEEE	Institute of Electrical and Electronics Engineer
Km	Kilometer
KV	Kilo Volt
KVA	Kilo Volt Ampere
KVARH	Kilo Volt Amps Reactive Hour
KWh	Kilo Watt Hour
L	Line
LV	Low Voltage
M	Mobile
MV	Mega Volt
MVA	Mega Volt Ampere
MW	Mega Watt
NK	Not Known
O&M	Operation and Maintenance
OP	Operation Problem
PTOL	Power Transformer over Load
R	Remote
SA	Strongly Agree
SCADA	Supervisory Control and Data Acquisition
SD	Strongly Disagree
SF6	Sulfur Hexafluoride
SOL	System over Load
SS	Sub-Station
TLP	Transmission Line Problem
V	Voltage
VT	Voltage Transformer

Abstract

A stable and reliable electric power supply system is a predictable prerequisite for the technological, economic and political growth of any nation. Thus, utilities must struggle to advance their system for delivering a stable and reliable electric power supply system to customers. According to power grid operation and interruption data recorded at utility, currently most power outage suffered by customers service interruption are caused due to failure in power distribution system, wherein power interruption caused by medium and low voltage distribution networks disturbance approximately account for 90% of the total power outage. In addition, according to several years statistical analysis of power supply reliability, currently 70% of reasons for power outages lie in network transformation, power expansion and the planned maintenance of distribution networks. Therefore, it is very important to do worth considering reliability performance assessment in power distribution system. This thesis work has been conducted on performance assessment of power distribution system focused on rehabilitated power distribution system of Adama Town. The study has been conducted to assess the reliability of power distribution system performance in terms of power interruption by identifying the most outstanding fault factors and root causes, and recommend a solution on the outstanding fault factors and root causes that made frequent power interruption in Adama Town distribution system. The assessment analysis has been done on eleven 15kV feeder lines and ten fault factors to predict reliability analysis for the future. The interruption frequency data of years 2009-2011 (EC) has been used as a base year for analysis. Based on interruption frequency data of the base years analysis and questionnaire on the root causes of fault factors that made frequent power interruptions, out of the ten fault factors the city feeder lines experienced highest number of outages due to by OP with 42.45%, DPSC with 21.09% and DPEF with 19.45% fault factors of the overall disturbances, and root causes for fault factors are mainly planed intentional interruptions, windy condition, tree contact, usage of improper devices, human errors and others. Finally, it has been identified that the three most significant disturbances (OP + DPSC + DPEF) that made frequent power interruption in Adama distribution system account for about 82.99% of the frequency of disturbances against customers of the EEU.

Key words: *Power Interruption, Power distribution system, Fault factors, Root causes, Feeder lines, Interruption frequency analysis, Minitab and Excel software.*

CHAPTER ONE

Introduction

1.1 Background

Electric Power distribution is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. A typical power distribution system consists of power transformers, distribution conductors, distribution feeders, service main conductors. Along with these a distribution system also consists of circuit breakers, protective devices, recloses, capacitor banks, voltage regulators, measuring equipment etc. Currently Ethiopian Electric Power Corporation power system have 400kV, 230kV, 132 kV primary transmission systems and 66kV, 45kV as sub transmission system and 33kV and 15kV as distribution system. In general the 66 or 45kV substations power transformers of various ratings like 50/ 25 /12 /6.3/3MVA are installed for step down of voltage to 15kV for feeding to distribution transformers. Most of the outgoing feeders are connected in radial fashion. Typically 33kV and 15kV overhead conductors are used for feeding 60 to 70 distribution transformers from each 33kV and 15kV feeder lines. The voltage is then further reduced by distribution transformers to the utilization voltages of 400 volts three-phase or 230 volts single-phase supply required by most users.

Substations are fenced yards with switches, transformers and other electrical equipment's. Once the voltage has been lowered at the distribution substation, the electricity flows to industrial, commercial, and residential centers through the distribution system. Conductors called feeders reach out from the distribution substation to carry electricity to customers. At key locations along the distribution system, voltage is lowered by distribution transformers to the voltage of 400volts three-phase or 230 volts single-phase supply required by most users. Figure1.1 shows the general topology of today's elements of a Substation.

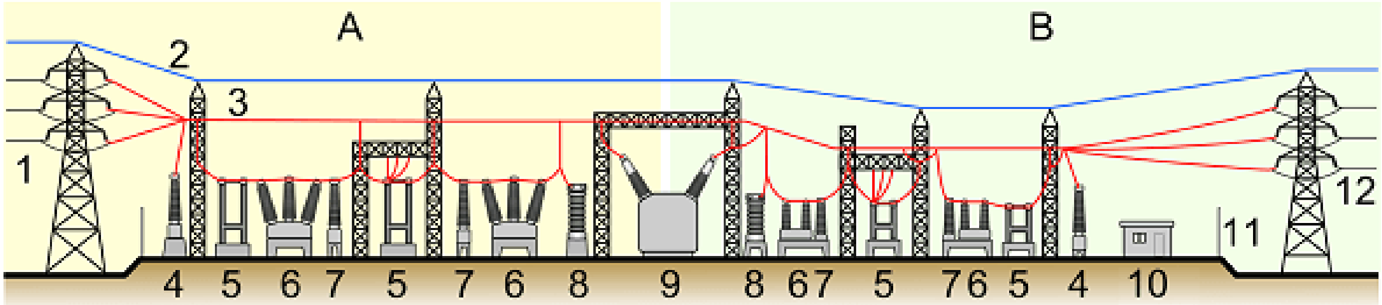

Figure 1.1: Elements of a substation A: Primary power lines' side B: Secondary power lines' side [33].

1. Primary power lines
2. Ground wire/ communication line
3. Overhead power lines
4. Transformer for measurement of electric voltage
5. Disconnect switch
6. Circuit breaker
7. Current transformer
8. Lightning arrester
9. Main transformer
10. Control building
11. Security fence
12. Secondary power lines

The goal of any power system is to deliver electricity to its customers in an economical and reliable manner. Unless this power is planned and maintained reliable, it causes adverse economic effect due to interruption costs and power outages on both the utility and its customers. [20]. With growing demand and increasing dependence on electricity supplies, the necessity to achieve an acceptable level of reliability, quality and safety at an economic price, the utility have to evolve and improve the systems continuously depending upon the requirement of the customers.

Over the past years, distribution systems have received considerably less attention devoted to reliability modeling and evaluation than the generating and the transmission systems [2]. The reasons for this are that the generating stations and the transmission systems are capital intensive and the generation and the transmission shortage can have widespread disastrous significances for both society and the environment. A distribution system, however, is relatively cheap as compared to the other two as its effects are localized. Therefore, less effort has been devoted to quantitative or qualitative assessment of the adequacy of various alternatives and reinforcements. On the other hand, analysis of the power interruption failure statistics of most utilities shows that the distribution system makes the greatest individual contribution to the unavailability of supply to a customer [2]. The distribution systems account for up to 90% of all customer reliability problems, improving distribution reliability is the key to improving customer reliability [3]. Since the primary purpose of the system is to satisfy customer requirements and the proper functioning and longevity of the system are essential requisites for continued satisfaction, it is necessary that both demand and supply considerations are appropriately viewed and included in the systems. Therefore, the distribution reliability is one of the most important in the electric power industry due to its high impact on the cost of electricity and its high correlation with customer satisfaction.

Electric distribution system power quality is a growing concern. Customers require higher quality service due to more sensitive electrical and electronic equipment’s. The effectiveness of a power distribution system is measured in terms of efficiency, service continuity or reliability, service quality in terms of voltage profile and stability and power distribution system performance.

In the context of Ethiopia, electric power interruption is becoming a day to day phenomenon. Even there are times that electric power interruption occurs several times a day, not only at the low voltage but also at the medium voltage distribution systems. The drop of the voltage, especially at the residential loads, is causing early failure of equipment’s, blackening of light bulbs, and decreased efficiency and performance of high-power appliances. Damage of electronic devices and burning of light bulbs have also occurred due to over voltages.

Electric reliability has affected social well-being, public health, water supply, communication service, and economic growth in the country. Based on the collected data from 2009 up to 2011(EC) from Adama substation, the maximum frequency of interruption and maximum duration of interruption of the Adama city grid have been estimated to be 32 interruptions per feeder line and 273.30 hours per feeder line per in these years respectively. This indicates that there is a frequent unavailability of electric power in the distribution network. The revenue loss of commercial and industrial customers as a consequence of power interruption is also huge. As frequent power interruptions are posing a huge problem to the life of the people and the economy, finding a solution to the problem is very essential.

Adama Town is now supplied from national grid that is, interconnected system (ICS). Ethiopian Electric Utility is a provider of electric power in the country. A 132 kV transmission line is stretched into the substation. Then, the distribution system in the city has a primary voltage of 33 kV and 15 kV. And also, this voltage value is stepped down to 400 volts and 230 volts to customer's level. Adama is the second largest city in Ethiopia and is located at 8.54°N 39.27°E at an elevation of 1712 meters, 99 km southeast of Addis Ababa [30]. Adama has been supplied from the national grid. With the growth of the city and the high demand of electricity, providing a reliable power supply becomes a difficult task to the power utility. Frequent power interruptions have posed serious problems to the city and mitigating the problem is very critical to improve the livelihood of the population.

Therefore, in this thesis, approaches such as electric and non-electric mitigation techniques have been recommended to find the means to minimize the causes of power interruption in distribution system.

1.2 Statement of the Problem

Power outage is a short or a long-term state of electric power loss in a given area or section of a power grid. It could affect a single house, building or an entire city, depending on the extent of the damage or cause of the outage. Power interruption becomes a serious problem in Ethiopia specifically, in Adama Town which is the study area for this thesis work. In Adama Town, mostly the grid power interrupts on average of 3 days per week and as a result most business sectors, hospitals, education sectors, factories, companies and residential houses etc. have got a lot of challenges on their profit, proper medical service, education service, day to day life and so on. Based on the extracted information from Adama substation annual interruption data of 2018/19 fiscal year, the average frequency of interruption and average duration of interruption of the Adama city grid have been estimated to be 141 interruptions per customer per year and 177 hours per customer per year respectively. This finding clearly indicates that power interruption per day is a common phenomenon in the Town and due to this problem day to day activities of the society are highly affected and hence they are strongly complaining the electric utility.

With the growing demand and increasing dependence on electricity supplies, the necessity to achieve an acceptable level of reliability and quality of power supply is needed; as a consequence the utility have to evolve and improve the systems continuously depending upon the requirement of the customers. The reason behind power interruption issues is mainly power quality problem. Hence, power quality problem can basically start at four levels of the system that delivers electric power are Power Generation, Transmission, Substation, Distribution and utility [21]. Based on the studies' findings of the past few years, distribution systems have received considerably less attention devoted to reliability assessment and evaluation than the power generating and transmission systems. The reasons for this is that the generating stations and the transmission systems are capital intensive and the generation and the transmission insufficiency can have widespread catastrophic consequences for both society and the environment. A distribution system, however, is relatively cheap as compared to the other two as its effects are localized. Therefore, less effort has been dedicated to quantitative or qualitative assessment of the capability of various alternatives and reinforcements for distribution system. On the other hand, analysis of the customer failure statistics of most utilities shows that the distribution system makes the greatest individual contribution to the unavailability of power supply to a customer. The distribution systems account for up to 90% of all customer reliability problems, improving distribution reliability is the key to improve the customer reliability.

Power distribution networks are, and will continue to be a main part of our energy infrastructure, and Adama Town EEU has the responsibility to ensure that the distribution systems are developed consistently and in a manner that meets future demands of society and customers.

This thesis work has been conducted to assess the reliability of power distribution system performance in terms of power interruption by identifying the most outstanding fault factors and root cause, and recommend electric and non-electric mitigation techniques solutions on the outstanding fault types and root causes to minimize power interruption in Adama Town distribution system reliability.

1.3 Research Questions

This study was guided by the following research questions:

1. What are the most outstanding fault factors and root causes for frequent power interruption at the existing Adama Power Distribution System?
2. Is the recommended proposed solution is valuable to the existing power distribution system from the mitigation of power interruption problem point of view?

1.4 General and Specific Objectives

1.4.1 General Objective

The general objective of the current study is to assess the reliability of rehabilitated Adama Power Distribution System to improve the system performance from the power interruption point of view.

1.4.2 Specific Objectives

The specific objectives of this thesis work are to:

- Assess the causes of power interruption at the existing Adama Power Distribution System.
- Analyze the collected data using Minitab and Excel software.
- Identify the most outstanding power interruption fault factors and root causes in the distribution system.
- Recommend a solution on outstanding power interruption fault factors and root causes.

1.5 Significance of the Study

The economic and social effects of loss of proper electric service have significant impacts on both the utility and the end users of electric device. Study shows that the impact even a small power cut can be catastrophic. Analyses from the power interruption events in some countries show that a 30 minute power cut results in an average loss of around four hundred thousand birr for medium and large industrial clients [24]. In Adama town repeated power interruption affects the distribution system both by losing large amount of electric energy and money, and end user of electrical devices by damaging the equipment, making the device to work with poor performance, and decrease the employee productivity. Therefore, maintaining a stable power supply is a very significant concern for solving the above mentioned issue and from this both EEU and end users are beneficiary.

Some of the benefits from this thesis work to EEU are:

- Reduction of frequent power interruption.
- Reduction of losing large amount of electric energy.
- Bring about customer satisfaction.
- Easley can identify the most significant causes of power interruption.

Benefits to end users are:

- Reduction of frequent power interruption and increased productivity.
- Protection of electrical devices from damage.
- Saving in electrical bill cost.
- Performance improvement of electrical load.

Results from the study provide deeper understanding of problems faced by the practitioners in managing power interruption causes and thus act as a useful guide to the formulation of realistic developmental, financial, accounting and economic policies. The finding is also useful for academician and researcher in similar areas.

The major contribution or significance of this study is to identify power interruption causes, beside this, the study is not to propose a radically renewed power interruption risk management process, but to attempt a composition of already known processes, in such a way that it can be applied by the EEU that deal with the undertaking and/or implementation of better work.

Although the power interruption causes assessment result of this research can be used as initial benchmark information in prioritizing and designing improvement action. Furthermore the same result can also be used as a baseline to compare the success of or impact of future improvement efforts. Therefore, this subject matter is so significant that its findings and recommendations help the EEU, researchers, policy makers, business operators and stakeholders.

1.6 Scope of the Study

This thesis cover; analyzing the existing frequent power interruption problem on distribution feeder lines, identifying which fault types and root cause of the electric power supply system contributes the most to the power interruption and finds recommended solution to reduce the redundancy and length of time of the electric power interruption in the future in Adama town.

Accordingly, this thesis had figure out major root causes for power interruption encountered at Adama Town based on available data (2009 up to 2011) (EC) and finds the fault types among the ten fault factors that creates frequent power interruption and recommend solutions on the outstanding problem. The findings and recommended solutions are used to manage the power interruption problems in the most redundant power failure cause section.

1.7 Outline of the Thesis

The thesis is organized into six chapters which are briefly summarized below.

Chapter one presents the introduction (background), statement of the problem, research questions, general and specific objectives, significant of the study, scope of the study has been discussed in the thesis work. In addition, it provides the outline of the thesis.

Chapter two contains exhaustive theoretical background and literature review of the study topics mainly on power interruption in general.

In Chapter three methodology and approaches of the study, data gathering and data analysis methods has been also explained.

Chapter four presents a detailed description of existing study area.

Chapter five presents detailed power interruption data demonstration, analysis and interpretation of the existing distribution system. In this chapter, detailed causes of power interruption data analysis with result with reasonable explanations has been presented on the Adama Town distribution system. Furthermore, it presents comparison of the most outstanding power interruption causes with benchmarks and recommends theoretical solutions for minimizing the most outstanding causes of power interruption on distribution system.

Finally, conclusion has been given followed by points of recommendation in Chapter Six.

CHAPTER TWO

Theoretical Background and Review of Literature

This section gives a detailed overview of the researches in the area of causes of power interruption assessment in power distribution systems.

2.1 Power Interruption

2.1.1 Definition of Power Interruption

According to IEEE100-1992, an interruption to service is the isolation of an electrical load from the system supplying that load, resulting from an abnormality in that system. The abnormality in the system can either be a malfunction of a system component, a fault or a system operation due to maintenance or repair. Interruption characteristics include duration, frequency, and time of occurrence of interruptions; whether an interruption is complete or partial, if advance warning or duration information is supplied by the utility; and whether the area affected by outage is localized or widespread.

Interruptions, independent from the cause are generally undesired as they leave energy un-served and customers without service. Most of the time, interruptions occur because the system is reacting to a fault. Most of the faults that creates power interruptions are short circuit, earth fault and over loading. A short-circuit is defined by IEEE100-1992 as an abnormal connection of relatively low impedance, whether made accidentally or intentionally, between two points of different potential [14], [15]. Earth Fault is an accidental fault between the live conductor and the earth. When earth fault occurs, the electrical system gets short-circuited and the short-circuited current flows through the system, then the fault current returns through the earth or any electrical equipment, which damages the equipment.

Power failures are particularly critical at sites where the environment and public safety are at risk. Institutions such as hospitals, sewage treatment plants and mines, will usually have backup power sources such as standby generators, which will automatically start up when electrical power is lost. Other critical systems, such as telecommunication, are also required to have emergency power.

Interruptions have their own impacts in the economic and social activities of a society and the country at large. Different industries and factories, public institutions and the likes are forced to stop their jobs due to electric power interruptions. The country's attractions for foreign investors are also affected by the electric power reliability and the consequent cost for power usage.

Reliability in power system can be divided in two basic aspects; system adequacy and system security. Adequacy relates to the capacity of the system in relation to energy demand and security relates to the dynamic response of the system to disturbances (such as faults). Since distribution systems are rarely loaded near their limits, system adequacy is of relatively small concern and reliability emphasis on system security [19]. The two main approaches applied to reliability evaluation of distribution systems are [1], [12]: Simulation methods based on drawings from statistical distributions (Monte Carlo) and Analytical methods based on solution of mathematical models. The Monte Carlo techniques are normally time consuming due to large number of drawings necessary in order to obtain accurate results [19].

Generally speaking, availability and unavailability deal strictly with interruption; they are classified as a subset of reliability. The hierarchy of power quality, reliability, and availability is shown in Figure 2.1.

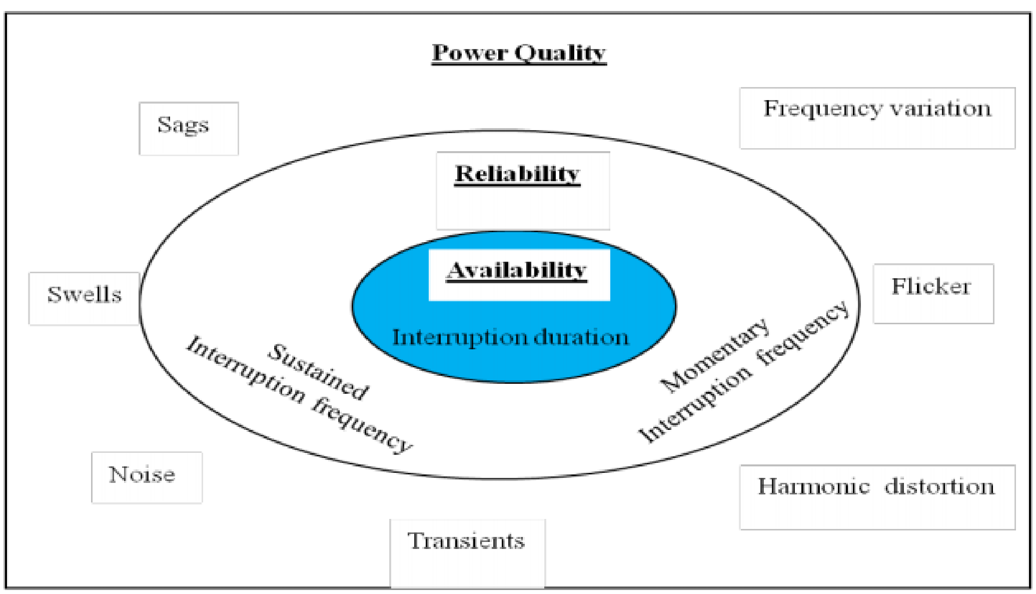

Figure 2.1: Hierarchy of power quality, reliability, and availability [8]

Hierarchy of power quality, reliability, and availability shows availability is a subset of reliability, and reliability is a subset of power quality. Power quality deals with any deviation from a perfect sinusoidal voltage source. Reliability deals with interruptions. Availability deals with the probability of being in an interrupted state [8].

2.1.2 Types of Power Interruption

Power outages are categorized into three different phenomena, relating to the duration and effect of the outage [32]:

- A transient fault is a loss of power typically caused by a fault on a power line. Power is automatically restored once the fault is cleared.
- A brownout is a drop in voltage in an electrical power supply. The term brownout comes from the dimming experienced by lighting when the voltage sags. Brownouts can cause poor performance of equipment or even incorrect operation.
- A blackout is the total loss of power to an area and is the most severe form of power outage that can occur. Blackouts which result from or result in power stations tripping are particularly difficult to recover from quickly. Outages may last from a few minutes to a few weeks depending on the nature of the blackout and the configuration of the electrical network.

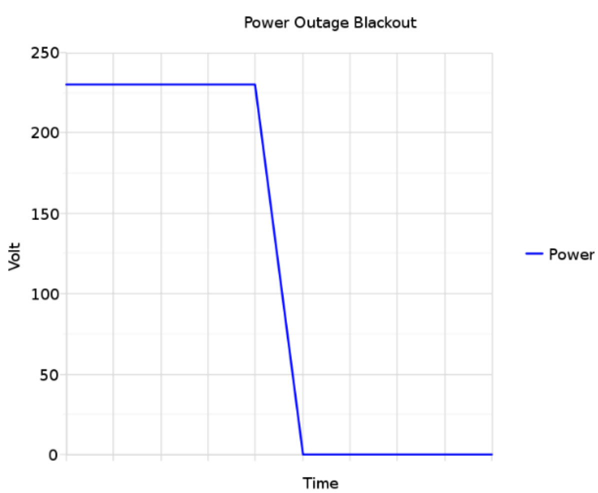

Figure 2.2: Power outage blackout [32]

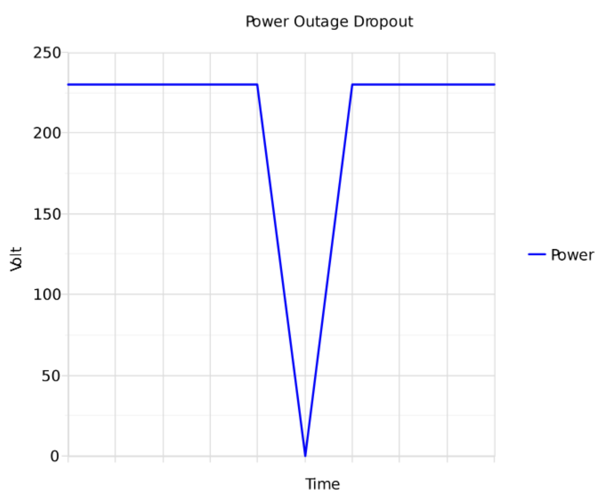

Figure 2.3: Power outage transient [32]

Generally speaking, power interruption (blackout) is classified in to two groups; Permanent and Temporary Power Interruption. It is measured in duration of time. In United States, the time for such an interruption of power is less than 5 minutes. In United Kingdom, this interruption is defined as more than 3 minutes and in Sweden it is 1 minute. A large power outage is normally referred to as a blackout affecting more than 1 million people [29]. In power distribution system; Permanent or Sustained interruptions are long-duration interruptions which last longer than 5 minutes whereas interruptions with duration of less than 5 minutes are termed as Momentary or Temporary interruptions. Usually in Adama distribution system only data on sustained interruptions was reported to the regulatory authority. Many of the distribution problems are temporary and mainly caused by overload, tree, animal contact, and whether condition and can easily be solved with little or no intervention from the system by simply reclosing the system to re-energized. But permanent faults cannot be restored by simple re-energizing. Permanent faults can be caused by Equipment malfunction, cable failure, down line or persistent tree contact [16].

Permanent (Sustained) interruptions can be classified as Planned and Unplanned Interruptions [4]. Planned interruptions (operational outages) occur mainly for the purpose of construction, preventative maintenance or repair. A planned interruption occurs at a selected time less inconvenient for the customers and the customers have been notified beforehand of the interruption. On the other hand, if the occurrence time of the interruption has not been selected, then the interruption is unplanned. Unplanned interruption occurs, for example, due to fault clearing, unwanted operation of the protection system or due to inadvertent initiation of opening operation of a switching device by a human.

2.1.3 Major Causes of Power Interruption

The main causes for interruption in power transmission could be natural disasters, adverse winds, human or technical failures, labor conflicts, terrorism, acts of war and others [22],[24]. Beside, major power outages can also be caused by combinations of electrical, computer, and human failures and developed in to cascading blackout which affect the customer [22]. Failures or disturbances have starting or initiating event which creates interruption. This event eventually leads to malfunctioning in a power system which may further lead to greater power systems failure and loss of power access to the subscriber.

Many of the distribution problems are temporary and mainly caused by overload, tree, animal contact, and whether condition. Overloading, and can be classified as power transformer overloading and distribution line overloading. Overloaded transformers are found in residential sector, commercial sector, industry, hospital, and so on. Often times rapid plant expansion without adequate capacity planning can lead to overloaded transformers. This combined with the poor power factor and high harmonic currents generated by inductive loads, can cause a transformer to become heavily loaded and cause interruption. Increasing demands for electric power supply, inadequate distribution systems and poorly designed power regulating devices have caused existing distribution system to become overloaded and create power interruption.

Faults are not evenly distributed along lines. Not all faults are inevitable "acts of nature." Most of them are from specific deficiencies at specific structures. On overhead circuits, most faults result from inadequate clearances, inadequate insulation, old equipment, or from trees or branches falling onto a line [5]. A first step in eliminating faults is to identify what is causing them. Keeping in mind that most faults result from specific structural deficiencies, field identification of fault sources is a key part of construction improvement programs. Common structural deficiencies include poor jumper clearances; old equipment (such as expulsion arresters); bushings or other equipment unprotected against animals, ground leads or grounded guys near phase conductors; poor clearances with polymer arresters; damaged insulators; damaged covered wire; and dangerous trees or branches present. When attempting to improve reliability, it is important to know the greatest contributing factors to these indices. However, predictive root cause analysis is different than historical root cause analysis which typically identifies the physical cause of faults [18] where predictive root cause analysis computes each components contribution to reliability indices. The cause of outage depends on geographical locations of the area.

This study provides an indication on identification of the most significant power interruption causes in Adama Town power distribution systems. Over-loading, earth fault and short circuits are the major cause of power interruptions in Adama distribution system and there are planned outages for operational and maintenance purpose. Those major faults can either be of temporary and permanent type.

2.2 Minitab

Minitab is a general purpose statistical software package designed for easy interactive use. It is well suited for instructional applications, but is also powerful enough to be used as a primary tool for analyzing research data. It is developed at the Pennsylvania State University by researchers. This software can do automates calculations and the creation of graphs, allowing the user to focus more on the analysis of data and the interpretation of results [31].

2.3 Review of Related Works

Electricity customers are exposed to power quality disturbances and hence could suffer from significant financial losses due to these problems. Large penetration of sensitive devices such as motor control drives in industrial and commercial facilities has substantially increased their susceptibility to power quality disturbances and frequent interruptions. Wave form distortion especially harmonics and reactive power consumption due to inductive loads are among problems posed on power system from industries while voltage variation, power frequency variation and the rest are disturbance posed on industries from power system. The drop of the voltage, especially at the residential loads is causing early failure of equipment, blackening of light bulbs, and decreased efficiency and performance of high power appliances. Damage of electronic devices and burning of light bulbs have also occurred due to over voltages.

The distribution system is part of the electric power system that links the bulk transmission system and the individual customers. Approximately 80 percent of outages experienced by the customers are due to failures in the distribution system. Therefore, the research publications which are related to power distribution system reliability enhancements are discussed in this section. Power interruption becomes a serious problem in the country, Ethiopia, and the entire nation always complains about it. Thus, distribution system automation is a must-do work by utilities to improve their system reliability, efficiency, service quality and to satisfy their customers.

In 1975, Merlin and Back [25] proposed a branch and bound type heuristic method to determine the network configuration to enhance distribution system reliability and for minimum line losses. Its solution scheme starts with a meshed network by initially closing all switches in the network. The switches are then opened one at a time until a new radial configuration is reached. In this process the switch to be opened at each stage is selected in order to enhance distribution system reliability and to minimize line losses of the resulting network.

In 2004, Joel Auernheimer [26] provides a framework for a predictive, condition-based, and cost effective maintenance optimization program for transmission and distribution systems. As system equipment continue to age and gradually deteriorate, then the probability of service interruption due to component failure increases. An effective maintenance strategy is essential in delivering safe and reliable electric power to customers economically.

In 2006, D. O. Koval and A. A. Chowdhury [9] presented a basic new restoration methodology for distribution system configurations that maximizes the amount of load that can be restored after a grid blackout, substation outage and distribution feeder line section outages and evaluates the cost of load point interruptions considering feeder islanding and substation capacity constraints. Several case studies with restoration procedures are presented and discussed to clearly reveal the impact of distribution system capacity constraints on load point reliability indices and the cost of load point interruptions.

H. Mokhtari [11], presented the results of a power quality survey in a distribution system and discussed and the power quality indices are extracted based on IEEE and IEC Standards.

In 2000, Josnicjusz Nazarko [10] discussed the application of the method of experimental design to the analysis of electrical power distribution systems. The theory of experimental design allows us to construct and experimentally verify the qualitative model of a power distribution system in order to analyze significance of each component in distribution system modeling.

In 2007, Davide L.Pepnye [23] in his two folded findings of his work on Topology and cascading outages, it has shown that; 1) a failure induced by cascading line outage with high entropy in the interconnection is less likely to happen in irregular grid topology than in regular topology, 2) once a cascade line outage is initiated, grids with more entropy or irregular grids are highly fragile leading to breaking apart in to disconnected sub-connections after fewer line failure than regular topologies. Moreover, it was found that in the scenario of cascading failure there could be two types of causes namely deterministic cause and probabilistic cause. Deterministic causes are events in the process of cascading failure that will certainly occur as a result of a single or series of events occur such as overload on certain line due to series outage of components. Probabilistic cause is defined to be the factors directly related to the actual system risk.

The probabilistic or stochastic nature of the system behavior; The component failures, for example Baldick Et Al stated that failure of protective relays on its neighboring lines of the failed one which may cause more lines to trip [13].

Cascading failure is defined as a sequence of dependent failures of individual components that successively weakens the power system. This failure comprises the physical components, software, procedure, people plus organizations that design, operate and regulate the power system. Cascading outages can be influenced by the details of the system state, such as components out for maintenance and the patterns of power transfer, and the automatic and manual system procedures. Due to complication complete enumeration of all possibilities of cascading is impossible [13], [23].

To understand what measures should be taken in planning management and operation of power systems to avoid disturbances, it is vital to know how often and to what extent disturbances occur. In a reformed electricity market with competition between the utilities, outage analysis is becoming more important. Systems for reporting incidents and disturbances can give increased knowledge on how disturbances arise and how disturbances can be avoided. There are different ways for a failure to smear out through the rest of the network during the blackout event. For example, a transmission line tripping can cause a transient, overloading of other lines, operation or disoperation of relays can contribute to system instabilities [7], [27]. But for the risk of cascading failure, these interactions become more severe when the overall system loading increases. And the cascading failure becomes more likely at the critical loading in which the probability of large blackouts and the mean blackout size start to rise quickly. The probability distribution of these blackout sizes has power law dependences.

Power grid also called electric power distribution system constitute components like generators, transformers, distribution substations (can be collectively considered as nodes) and the transmission lines. Connectivity in the random networks is statistically homogeneous and the probability of finding highly connected nodes falls exponentially [6]. It can be noticed that it is unlikely to have high degree probability in the random network. In other words, for the same number of nodes and edges, the probability of high degree nodes is less in random networks than scale free networks.

According to Watts and Strogatz (1998), regular networks such as power grid is characterized by small world property locally with high degree of clustering and globally small characteristic length. Clustering coefficient is defined as the magnitude of the connectivity extent to which neighbors of a certain node connected to it are also connected to each other. Characteristic length is also defined as the number of edges in the shortest possible path connecting two nodes averaged over all the nodes of the network. Sparsely distributed power grids have less mean degree. So, it is not difficult to guess that Ethiopian power grids have very small mean degree (not researched) because the available power supply in the country is very limited [6].

The statistics of failures can possibly depend not only on power loss but also on energy un-served. However, energy un-served is not preferable quantity to characterize the size of failure as it depends on human (technicians) time taken to restore the transmission line from malfunctioning.

CHAPTER THREE

Methodology of the Study

3.1 Research Approach

The choice of research approach depends on the degree of precision by which the original research question can be formulated, and how much knowledge exists in the area of the chosen subject. This study had used both exploratory and descriptive approaches.

a) Exploratory approach: when information is insufficient, the study is exploratory. The main purpose with exploratory studies is to collect as much knowledge about a study problem area as possible. This means that the problem is analyzed from a number of different points of view. A wealth of ideas and creativity are important elements in explorative studies because these often aim at attaining knowledge that can lay the foundation for further studies.

b) Descriptive approach: the descriptive approach is best suited to investigations where there already is knowledge. In a descriptive study, only the essential aspects of the phenomenon are looked upon.

Data has been collected as much data as possible about the study object using various sources of information, a number of journals, article and papers on power distribution system reliability assessment and study, feeder reconfiguration and other related works have been reviewed and assessment of existing physical system in the case study area, understanding and adopting the system as a whole. Secondary data has been collected with general background on a variety of views on the subject of the research. This study was used to see how reliability could be improved in the distribution system by incorporating power interruption reliability analysis through identifying the outstanding power interruption causes in the distribution system using appropriate engineering software tools (Minitab) and recommend best solution for mitigating the power interruption problems of the existing power distribution system on outstanding causes.

This study also employed qualitative approach and includes interviews, observation and document review techniques were used. The general methodologies used in this thesis are shown figure below.

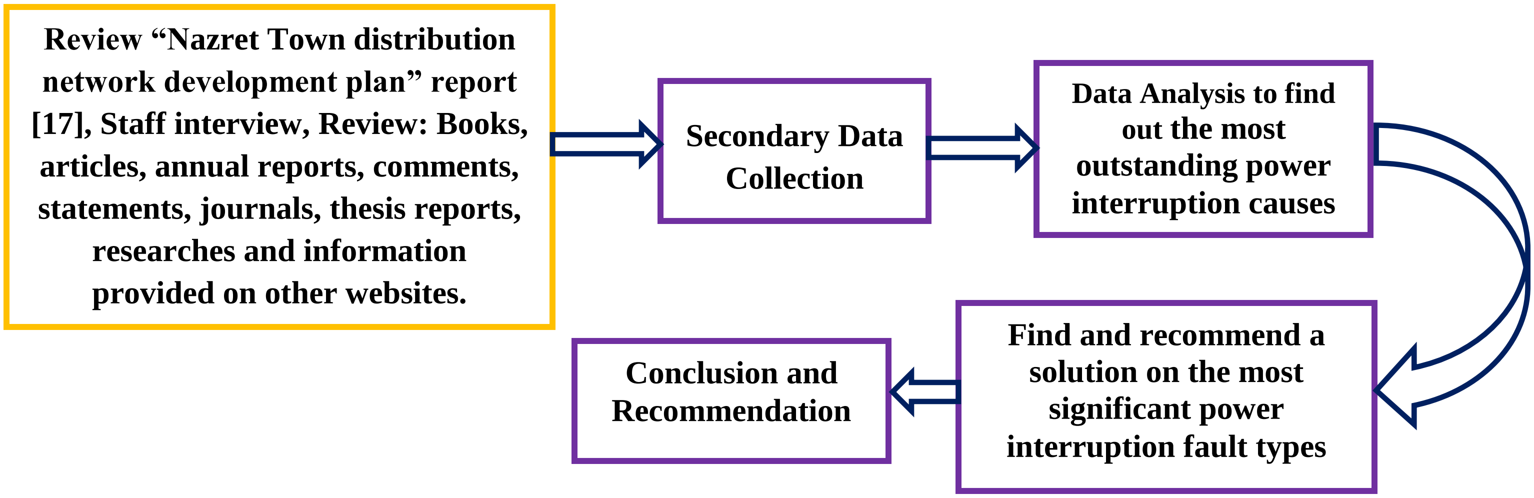

Figure 3.1: General Methodologies outline

3.2 Data Sources and Collection Methods

This part deals with the methodologies of data collection procedure that has been used for this study from the existing system. The study was based on both interview with questionnaires and secondary data. The primary data necessary for this study were the feeder information, protection system information, rating and type of each transformer, topology and layout of the system, conductor type, and topography and others. The secondary data which was very necessary for this study was manually recorded monthly power interrupted report in the station. Usually in Adama distribution system data on sustained and temporary interruptions was reported to the regulatory authority. Many of the distribution problems are temporary and mainly caused by component failure, tree, animal contact, whether condition and others causes and can easily be solved with little or no intervention from the system by simply reclosing the system to re-energized.

In Adama substation each interruption duration and frequency (number of interruption) of each feeder per hour is recorded but the causes of interruptions are not described and identified well. But to put an appropriate mitigation technique for the power interruption problem in the case study area; it is critical to know the most outstanding fault factors and sources for causes of power interruptions. To know the most outstanding causes of interruptions interviews with questioners were prepared to the employees and longtime daily workers. The questioner was prepared to describe the common sources for causes of interruptions in all feeders for the last three years and for determining the degree of contribution of each fault factors on the point assigned for the four agreement level. After selected the sources of causes of interruptions the experienced employees have been requested in order to categorize the causes according to the degree of contribution. The interview questions have been designed in a manner to find out the sources for causes of unplanned power interruption and mechanisms to solve the problems.

To determine the degree of contribution of each fault factors, agreement levels are assigned to get sources for cause information relating to unplanned power interruption problem. The allocation of the points are 5 for strongly agree (SA), 4 for agree (A), 3 for not known (NK), 2 for disagree (D) and 1 for strongly disagree (SD) using a close ended questions. The interviews questions were distributed to selected staffs and explain the purpose of the research. Considering the time of the year is appropriate, the questionnaire was sent out. The response rate indicated the recognition of the importance of the issues by the officers because 100% of the questionnaires sent were filled and returned. The questionnaire had closed-response questions on sources for causes of power interruption. The questionnaire is provided in Appendix B.

After years of having inadequate records under existing systems the implementation of recording this power interruption source of causes was difficult but not an impossible task with technology and methodologies of documentation being of a significant benefit in this process which will benefit both internal and external users of this information. Three sources of data were analyzed at different stages in this study. The interviews were conducted after the literature review and informal discussions with various staffs and power sector engineers. The questionnaires responses were analyzed properly to grasp a new finding about the gaps in solving power interruption problems in Adama Town.

Interviews

The data from the interviews were summarized in question order. Some of the summaries consisted of tables with the number of interviewees answering the questions with the same answers recorded. The results were used to identify the issues raised in the questionnaire.

Each respondent was asked similar questions designed to explore issues raised. All interviewees had more than two years work experience within the company. Each gave his/her time willingly in participating in the interviews.

Questionnaire

The suggestion was that a questionnaire which only involved ticking boxes represented more opportunity for a reasonable response rate than one which involved both ticking boxes and supplying written information. The questionnaire commenced with an explanation of how it was designed; it was divided into three parts (including the comments section). Instruction 1 was involved in determining personal profiles with marked box. Instruction 2 involved level of agreement or disagreement with each of statements regarding sources for casus of existing electric power interruptions with table. Instruction 3 sought views on problems were encountered on identification of the causes and opinions on various aspects of power interruption.

These sections were intended to generate information about the identification, valuation and reliability of infrastructure assets and other causes of interruption. The general format involved the making of a major statement followed by a series of sub-statements. Respondents were expected to give a single response on a printed scale. Close attention was given to making the statements very clear and simple to read but being able to generate the required information.

The questionnaire was one of the primary data-collection instruments in this study and this instrument would need to achieve an acceptable response rate. The materials included books, articles, annual reports, comments, statements, thesis, researches and information provided on other websites were also been taken as a data sources for this study. As the study involves analysis of the most causes of power interruption specifically of Adama Town substation, it is important for the reader to understand the role the staffs play in this process. The secondary data has been collected from reports of the substation being studied. The collected secondary data are a manually recorded monthly report data that includes type of faults factors, frequency and duration of interruption of all medium voltage (15kV) outgoing feeders of the distribution system. The collected data was a recorded data for three years and interim reports are excluded from the study.

In other words, the study is mostly based on secondary data as the data gathered from the management of Adama substation.

- **Data collection:**
  - Three years (2009-2011) (EC) interruption data has been collected from Adama SS.
  - All feeder information, type of faults, number and ratings of transformers information has been collected from the existing system.
  - Interview and questioner was prepared to identify the main root causes of fault factors and discussions with concerned workers regarding the system setting and configuration, and reliability status.
  - The collected data has been used to clearly analyze the problems of the feeder under study.

3.2.1 Sampling Design

The sample design and samples were selected using systematic random sampling techniques. This considers nearly the full use of the company in question and other randomly selected professionals. Therefore, it is necessary to interview and interrogate the staffs in engineering departments, emergency operators, distribution technicians, distribution supervisors or team leader, O&M technicians, and experienced daily laborers of EEU of Adama district station. Accordingly, the following table shows the total number of samples used for this research.

Table 3.1: Total number of samples for the study

Samples	Distribution supervisors or team leader	Engineering staffs	Distribution technicians	Emergency operators	Experienced daily laborers	Total
No. of Samples	3	5	5	7	4	24

3.2.2 Data Analysis Method

The information gathered by the questionnaire is descriptive and quantitative, so the analysis of the results will be completed using Minitab and Excel software, which incorporates appropriate detailed statistical functions. Conclusions on the consequences of current practices and recommendations for change will be developed to assist local authorities, consultants, engineers, public and private stakeholders for taking immediate action.

Therefor properly collected and organized data for effective output will be analyzed through the following methods:

- Identify and determine the essential parameters required for the study.
- Develop the analysis with Minitab® 19.1 and Excel software tools to identify the most outstanding power interruption causes out of the listed fault factors in the station.
- Based on the result of this analysis and assessment, recommend a solution that have been evaluated for potential reliability improvement on power interruption.
- Questioner respondent analysis.

CHAPTER FOUR

Description of the Study Area

4.1 Site Description

Adama is located in the Oromia region about 100 km south-east of Addis Ababa with a geographic reference of 8.54°N, 39.27°E. It is one of the larger towns of Ethiopia in a strategic location on the cross roads towards of the south-east, at an altitude of about 1700m and an estimated area of about 30 km^2 [30]. Based on Ethiopia Administrative Regions Cities and Population, the city has an estimated population of about 355,475 people and an annual population growth rate of about 4.3% [30], [17]. The households are estimated at about 60 thousand and the housing units at about 400 less than the households. The city is believed to be fully electrified with a total number of customers at about 35.7 thousand leading to the conclusion that one customer of EEU may provide electricity on average to about 1.7 households (i.e. for every 3 consumers just over 5 households are electrified) [17].

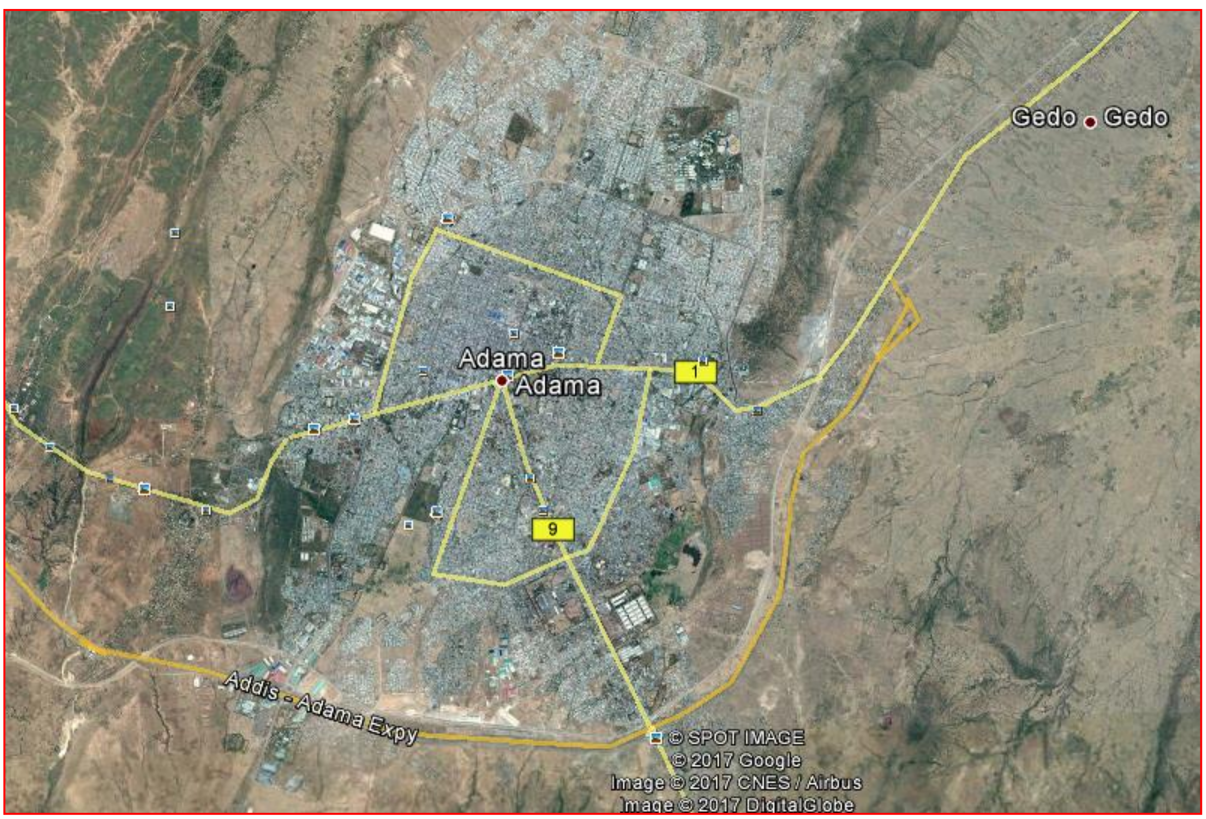

Figure 4.1: Geographical map of Adama Town [Google Map]

Adama Power Distribution System

Adama Town substation is located in South-West outskirts of the city on the way to Wonji road. The substation has been built recently (switchgear dated 2005). It is a 132/15kV substation with two transformers rated with 25MVA and one transformer rated with 50MVA each with medium voltage of 15kV. The substation receives power supplies from the 132 kV Koka substations through a132 kV Koka – Adama transmission line and another 132kV two way line connects from Awash SS. Further the nearby wind farm SS is also parallely connected to this 132kV substation. The substation supplies power to the city through six 15KV distribution feeder lines and five 15kV mobile distribution lines with no bus sectionalizes. The substation is build next to the old substation which is now unused with some of the old equipment still in the yard.

The substation has a total maximum demand of about 30 MW (about 32.5 MVA). The network topology for Adama city is a radial grid. The primary distribution system parallely takes a voltage of 132 kV from the transmission line of Koka, Awash and Adama wind farm power generation system and converts it to 15 kV by using three parallel connected transformers, and then 758 distribution transformers are used to further step-down the voltages to customer-level voltage of 400/230 volts at the load points. The distribution feeder system for the Town had a primary voltage of 15 kV, and supplies approximately 70,000 customers including residential, commercial and industrial customers. The twelve outgoing distribution feeders in the substation namely called Line 1 (peacock), Line 2 (Nazreth) which is changed to M1, Line 3 (Wolenchiti) Line 4 (Berta), Line 5 (Turk Textile), Line 6 (Mojo Cement), Line 7 (Koka Metal), Mobile 1, Mobile 2, Mobile3, Mobile 4, Mobile 5 and. The overview of the substation is shown in figure 4.2.

Figure 4.2: Overview of Adama Town substation

The simplified single line diagram for Adama substation is shown in the figure below.

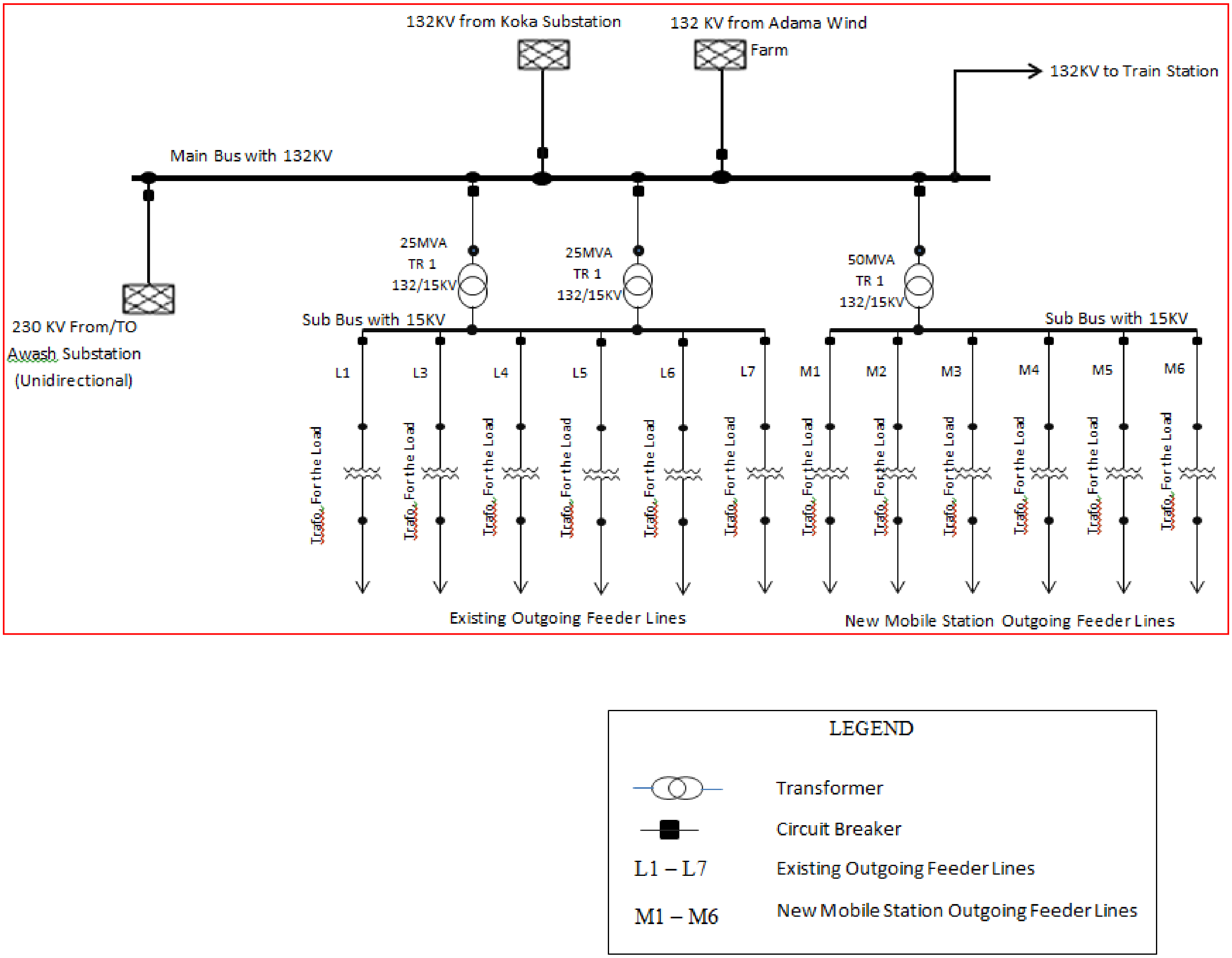

Figure 4.3: Single line diagram of Adama Town substation

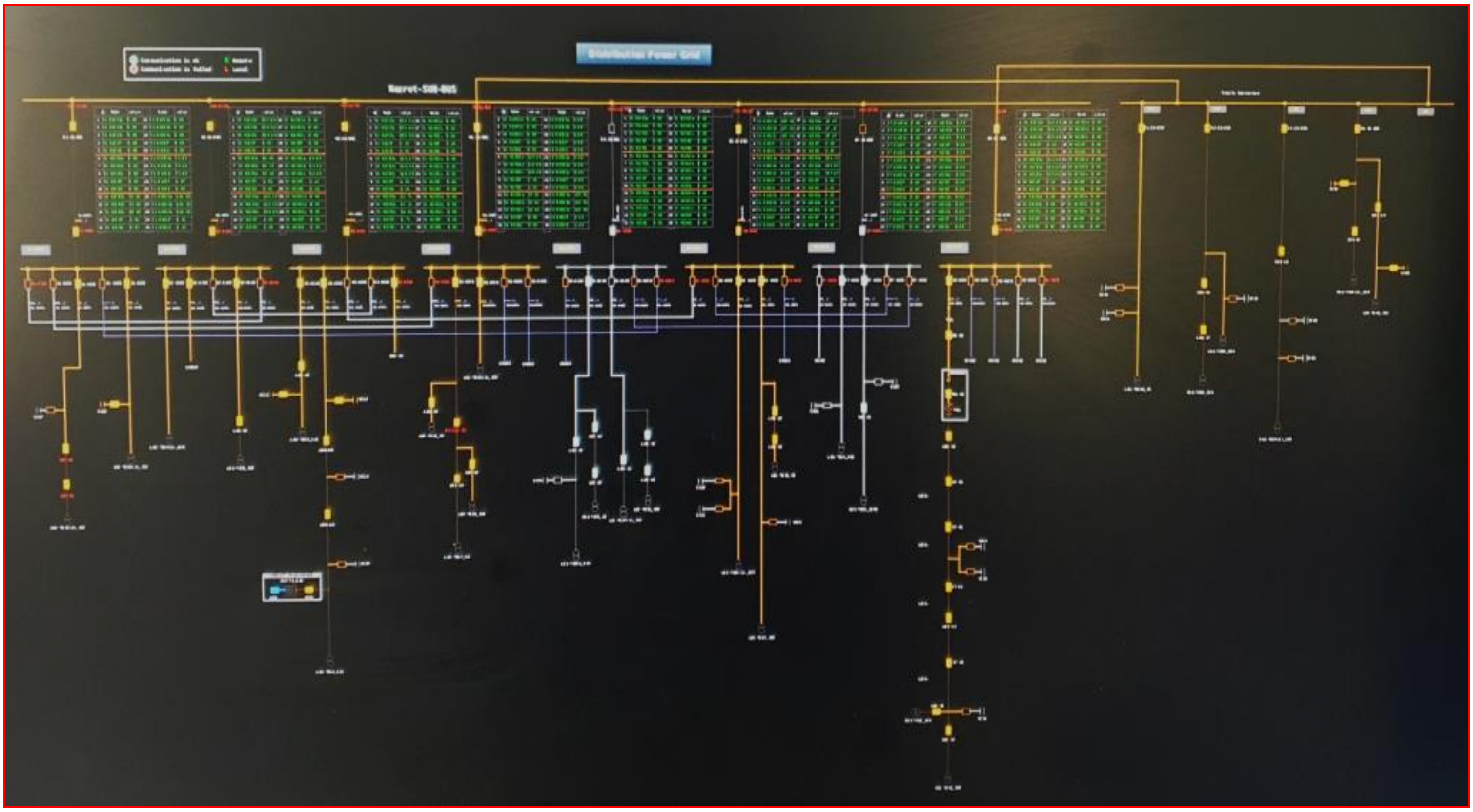

Figure 4.4: Single line diagram of Adama Town distribution line [Snap shoot from SCADA Management system]

15kv Feeder Arrangements

The 15kV switchboard at Adama (see figure 4.5 below) is a modern switchboard of Chinese construction with 630A vacuum breakers and 150-300/5/5A current transformers limiting the outgoing feeders to 7.8MVA. These CTs will most certainly require changing to meet increased loading. There are seven outgoing circuits (feeders L1 to L7) from the MV switchboard cabled to a gantry behind the substation control building but only six are active, and in addition to this there are six outgoing circuits (mobile feeders M1 to M6) from the mobile station in the substation. The constructions of the gantry make it very difficult to connect to the outgoing circuits and maintenance on the gantry may require a complete outage. This system has to be changed to a direct cabling to the outgoing circuits. Gantry isolators do not seem to be used.

The concept of the gantry is probably a leftover from the open 15kV switchyard and it now causes serious operational problems with the maintenance of the outgoing circuits and it is proposed that its use is discontinued.

From the thirteen 15KV feeders lines, eleven feeder lines are serving customers (six from existing outgoing feeder lines and five from mobile outgoing feeder lines). Commercial centers, factories, small and micro industries, banks, administrative offices, hospitals, schools, large number of residential customers and other city areas are get electricity from these feeders. These primary distribution feeders deliver power from the substation to distribution transformers. It begins with the feeder breaker at the distribution substation and exits the substation in a concrete duct bank (feeder get-away) and routed to a nearby pole. The main primary feeder branches into various primary laterals which in turn separate into several sub laterals to serve all the distribution transformers. The main feeder and sub feeders before the transformer are three phase three wire circuits and the laterals are three phase four wire or single phase two wire circuits.

Figure 4.5: Adama Substation 15kV switchboards with 630A

Figure 4.6: Seven outgoing feeders L1 to L7 (gantry)

4.2 Substation System Components and their Functions

The power substation is a network of electrical equipment which is connected in a structured way in order to supply electricity to end consumers. There are numerous electrical substation components like outgoing and incoming circuitry each of which having its circuit breakers, isolators, transformers, and bus bar system etc. for the smooth functioning of the system. The substations are entities from which consumers are getting their electrical supply to run their loads while required power quality can be delivered to the customers by changing frequency and voltage levels etc. The following are major electrical components of this substation and their functions [33].

1. **Instrument Transformers:**

The instrument transformer is a static device utilized for reduction of higher currents and voltages for safe and practical usage which are measurable with traditional instruments such as digital multi-meter etc. The value range is from 1A to 5A and voltages such as 110V etc.

The transformers are also used for actuation of AC protective relay through supporting voltage and current. Instrument transformers are shown in the figure below and its two types are also discussed below.

Figure 4.7: Instrument transformers [33]

2. **Current Transformer:**

A current transformer is a device used for the transformation of higher value currents into lower values. It is used in an analogous manner to that of AC instruments, control apparatus, and meters. These are having lower current ratings and are used for maintenance and installation of current relays for protection purpose in substations and for lower rating metering of current measurements.

Figure 4.8: Current transformer [33]

3. **Voltage Transformer:**

The Voltage transformers (VT) are similar in characteristics as current transformers but are used for converting high voltages to lower voltages for protection of relay system and for lower rating metering of voltage measurements.

Figure 4.9: Voltage transformer [33]

4. **Conductors:**

Conductors are the materials which permit flow of electrons through it. The best conductors are copper and aluminum etc. The conductors are utilized for transmission of energy from place to place over substations[33].

5. **Insulators:**

The insulators are the materials which do not permit flow of electrons through it. Insulators are resisting electric property. There are numerous types of insulators such as shackle, strain type, suspension type, and stray type etc. Insulators are used in substations for avoiding contact with humans or short circuit.

Figure 4.10: Insulator [33]

6. Isolators:

The isolators in substations are mechanical switches which are deployed for isolation of circuits when there is an interruption of current. These are also known with the name of disconnected switches operation under no-load conditions and are not fortified with arc-quenching devices. These switches have no specific current breaking value neither these have current making value. These are mechanically operated switches.

Figure 4.11: Isolator [33]

7. Bus Bars:

The bus bar is among the most important elements of the substation and is a conductor which carries current to a point having numerous connections with it. The bus bar is a kind of electrical junction which has outgoing and incoming current paths. Whenever a fault occurs in the bus bar, entire components connected to that specific section should be tripped for giving thorough isolation in a small time, for instance, 60ms for avoiding danger rising due to conductor's heat. These are of different types such as ring bus, double bus, and single bus etc. A simple bus bar is shown in the figure below which is considered as one of the most vital electrical substation components.

Figure 4.12: Bus bar in substation [33]

8. The Lightning Arresters:

The lightning arresters can be considered as the first ever components of a substation. These are having a function of protecting equipment of substation from high voltages and are also limiting the amplitude and duration of the current's flow. These are connected amid earth and line i.e. connected in line with equipment in the substation. These are meant for diversion of current to earth if any current surge appears hence by protecting insulation as well as conductor from damages. These are of various types and are distinguished based on duties.

Figure 4.13: Lightning arrester [33]

9. Circuit Breakers:

The circuit breakers are such type of switches utilized for closing or opening circuits at the time when a fault occurs within the system. The circuit breaker has 2 mobile contacts which are in OFF condition in normal situations. At the time when any fault occurs in the system, a relay is sending the tripped command to the circuit breaker which moves the contacts apart, hence avoiding any damage to the circuitry.

Figure 4.14: Circuit breaker in substation [33]

10. Relays:

Relays are a dedicated component of electrical substation equipment for the protection of system against abnormal situations e.g. faults. Relays are basically sensing devices which are devoted for sensing faults and are determining its location as well as sending interruption message of tripped command to the specific point of the circuit. A circuit breaker is falling apart its contacts after getting the command from relays. These are protecting equipment from other damages as well such as fire, the risk to human life, and removal of fault from a particular section of the substation. Following is the substation component diagram is known as a relay.

Figure 4.15: Relays [33]

11. Switchyard:

The switchyards used for the connection and disconnection of transformers and circuit breakers. These are also having lighting arrestors to protect the substation from strokes of natural lighting.

Figure 4.16: Switchyard in substation [33]

12. Metering and Indication Instruments:

There are numerous instruments for metering and indication in each substation such as watt-meters, voltmeters, ammeters, power factor meters, kWh meters, volt-ampere meters, and KVARH meters etc. These instruments are installed at different places within substation for controlling and maintaining values of current and voltages [33].

13. Equipment for Carrier Current:

The equipment of carrier current is installed in the substation for the purpose of communication, supervisory control, telemetry, and/or relaying etc. Such equipment is often mounted on a room which is known as carrier room and is connected across the power circuit of high voltages [33].

14. Prevention from Surge Voltage:

The transient of over voltages substation system is because of inherent and natural characteristics. There are several reasons for over voltages which may be caused due to a sudden alteration in conditions of the system e.g. load rejection, faults, or switching operations etc. or because of lighting etc. The types of over voltages can be classified into two i.e. switching generated or lightning generated. However, the scale of over voltages could be over maximum allowable voltage levels, hence these are required to be protected and reduced for avoiding damage to instruments, equipment, and lines of a substation. In this way, the performance of the substation system can be enhanced [33].

15. The Outgoing Feeders:

There are numerous outgoing feeders which are connected to that of substations. Basically, the connection is with a bus of the substation for carrying power from the substation to service points. The feeders can hug overhead streets, underground, underneath streets, and are carrying electrical power to that of distribution transformers at near or farther premises. The isolator in substation and breaker of the feeder are considered as entities of the substation and are of metal-clad typically. Whenever a fault is occurring in the feeder, the protection is detecting and the circuit breaker is opened. After detection of fault through manual or automatic way, there is more than one attempt for re-energizing the feeder [33].

4.3 Substation Data

For the understanding of the substation data has been collected and presented in following tables in this chapter, but data's that are going to be analyzed for this research has been presented, analyzed and interpreted in chapter five. During the site survey, the secondary data necessary for this study were the power interruption frequency and duration on each feeders and types of fault causes for interruption.

Table 4.1: Data for Adama substation

Name of substation	Lines			Trafo. Quantity	Voltage Level (KV)	Transformer Capacity (MVA)	Total capacity (MVA)
	HV	MV	LV				
Adama SS	3	0	7	2	132/15	25	50
	3	0	6	1	132/15	50	50

Below table shows the basic data of 13 feeders of the distribution network in the station.

Table 4.2: Basic data of Adama distribution feeders

Name of the feeder	Total No of distribution transformers	Total capacity of transformers (kVA)	Voltage Level in (KV)	Circuit Breaker Type	Conductor Size (AAC mm^2)
Line 1 (peacock)	61	16605	15	Vacuum	185
Line 2(Nazareth) which is changed to M1	--	--	--	--	--
Line 3(Wolenchiti)	115	32420	15	Vacuum	185
Line 4 (Berta)	59	15120	15	Vacuum	185
Line 5(Turk Textile)	33	25820	15	Vacuum	185
Line 6 (Mojo Cement)	44	22400	15	Vacuum	185
Line 7 (Koka Metal)	79	22660	15	Vacuum	185
Mobile 1	100	23605	15	SF_6	300
Mobile 2	57	23715	15	SF_6	300
Mobile 3	71	21635	15	SF_6	300
Mobile 4	50	19980	15	SF_6	300
Mobile 5	89	21385	15	SF_6	300
Mobile 6	--	--	---	--	--
Total	**758**	**245,345**			

The substation is managed and controlled by SCADA Power Grid Distribution Management System. There are 13 feeders and out of these feeders only 11 feeders are actively give a service to the Town. From the 11 feeders only 8 feeders are remotely managed and controlled by SCADA Power Grid Distribution Management System through Remote Terminal Unit (which is abbreviated by R) connection to substation. Currently the substation only made a Remote Terminal Unit connection (R-connection) at switching station to feeder lines L1, L3, L4, L7, M1, M3, M5, and M6. The R-connection for those feeder lines are L1-R5, L3-R6, L4-R3, L7-R1, M1-R2, M3-R7, M6-R4 and M5-R8. Currently from those R-connections only 6 feeder lines are properly controlled and managed from the substation using Power Grid Distribution Management System. L1-R5 and M3-R7 are out of the remote connection and needs maintenance. Figure 4.17 shows home page snap shoot of remote monitoring system using SCADA Power Grid Distribution Management System in this substation.

Figure 4.17: Home page of SCADA Power Grid Distribution Management System

Figure 4.18 shows feeder hourly loads measured with corresponding time, overall loads profile measured with total sum of load of each feeder on their corresponding time and voltage value of feeders. The hourly load of each feeder lines graph shows the incoming load current value of remotely connected active feeders on their corresponding time. The Overall Load profile shows the total sum of load power of all active feeders on their corresponding time for the past and present day and the minimum and maximum load can managed using this application. Voltage value shows the output voltage of remotely connected feeders. As you can see on the figure, feeder line L1-R5 and M3-R7 remote connection is disconnected and no output is displayed on the management system screen, so these two feeder lines could not controlled or managed from the remote system in the substation.

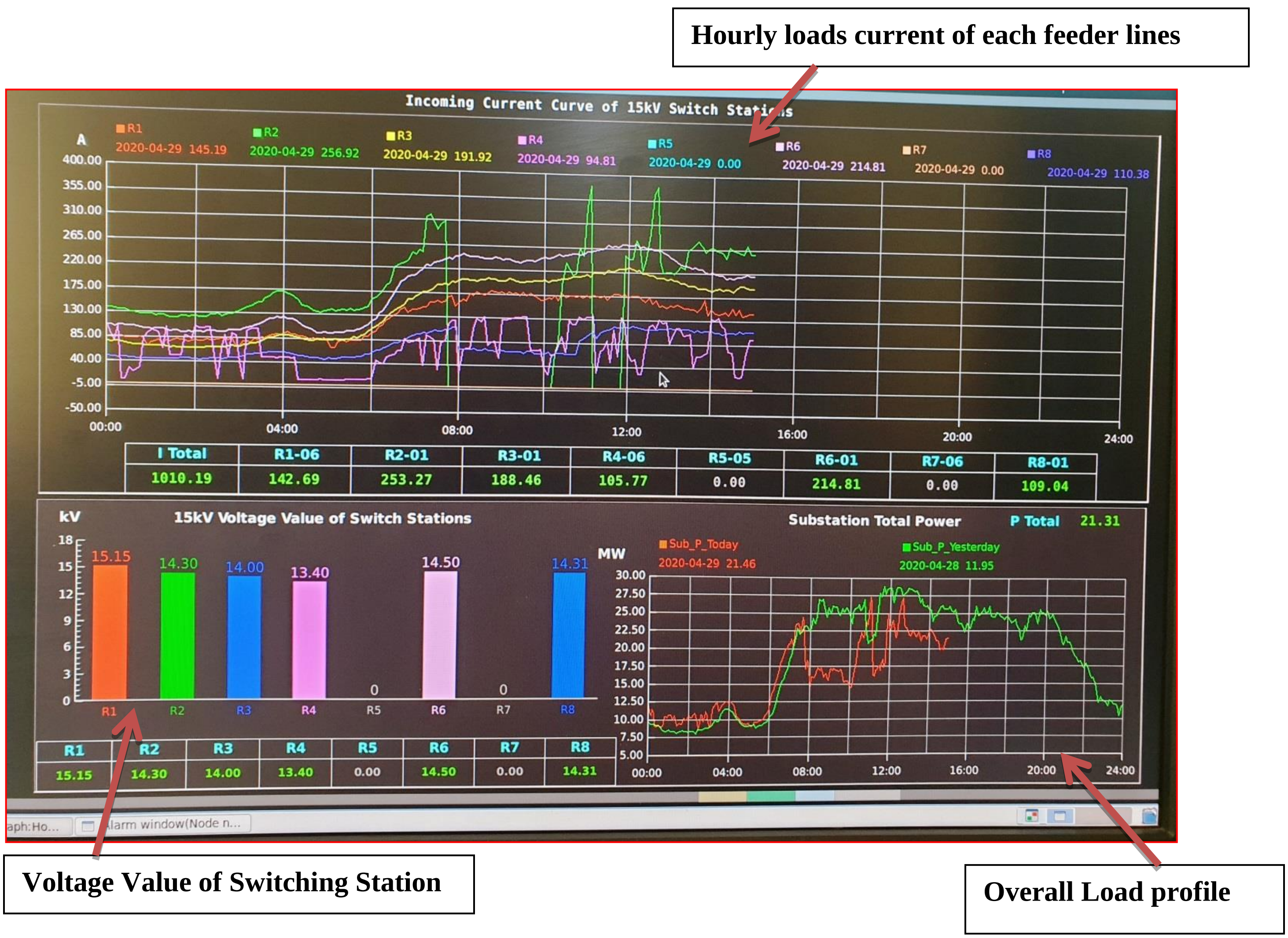

Figure 4.18: Hourly load current, overall load power and output voltage of the substation

The substation uses this SCADA Power Grid Distribution Management System application with remote controlling devices at substation and switching station respectively to control and manage all electrical parameters, switching ON and OFF all the switching station and manage all the alarm system in the substation for only remotely connected feeder lines. This management system is the most powerful application system that can control all the system remotely and can report all the fault factors for power interruption problem without sending a technician to the switching station. Currently the substation is not used this system with its full capacity, thus it needs improvement.

4.4 Fault Factors for Power Interruption in Adama Substation

In Adama substation, the fault reasons for power interruption are grouped by ten fault factors, they are:

1. DPEF (Distribution Permanent Earth Fault)
2. DPSC (Distribution Permanent Short Circuit)
3. DTEF (Distribution Temporary Earth Fault)
4. DTSC (Distribution Temporary Short Circuit)
5. TLP (Transmission Line Problem)
6. SOL (System Over Load)
7. GUP (Generation Unit Problem)
8. DLOL (Distribution Line Over Load)
9. PTOL (Power Transformer Over Load)
10. OP (Operation Problem)

Adama like many other cities in the country is suffering from power interruptions. Electric power in the country is characterized by frequent interruptions, and thus small business like the industry and electricity users at household level who have no alternative power sources are affected. Some of the major causes of power interruptions in Adama are discussed in this part.

In Adama substation, out of the ten fault types, the major faults occurring frequently are short circuit, earth fault, and there are planned or unplanned outages for operational and maintenance purpose. But those frequently fault causes are not confirmed with proper data analyze.

The major faults occurring can either be of temporary and permanent type. In this substation permanent and temporary fault termed as, permanent or sustained interruptions are long-duration interruptions which last longer than 10 minutes whereas interruptions with duration of less than 10 minutes are termed momentary or temporary interruptions. Usually in this substation only data on sustained interruptions is reported to the regulatory authority. Many of the distribution problems are temporary and mainly caused by tree, animal contact, and whether condition. They can easily be solved with little or no intervention from the system. Those temporary faults can simply solved by reclosing the system to be re-energized, but permanent faults can't be restored by simple re-energizing. Permanent faults can be caused by Equipment malfunction, cable failure, down line or persistent tree contact and so on.

In Adama substation each number and duration of interruption of each feeder per hour is recorded but the causes of interruptions are not analyzed and described well. Thus, to put an appropriate mitigation technique for the interruption problem in the case study area, it is critical to know the most significant fault factors of interruptions. To know the root causes of interruptions, discussions and questioners were prepared to the employees.

The questioner was prepared to describe the common root causes of interruptions on the feeders for the last three years. After selected the root causes of interruptions the experienced employees have been requested in order to categorize the causes according to the degree of contribution. It was very difficult to categorize the causes, at the end of the discussion respondents decided to put their agreement level. For the purpose of determining the degree of contribution of each fault factors the point is assigned for the agreement level from one up to five points. Based on their response and secondary data analysis the most outstanding fault cause has been analyzed, identified and described in the next chapter. The fault factors ranked at the top have a high degree of contribution for the electric power interruptions. From the questioner and discussion with the senior technicians, emergency operators, engineers, supervisors and experienced laborers, the most common root causes of interruptions are: trees, overload, poor and worn out electricity infrastructure, windy rain, lightning, accidents, Animals, scheduled interruptions, human error, generation outage, equipment malfunction, unknown causes of interruptions and others.

In this thesis, secondary data of DPEF, DPSC, DTEF, DTSC, TLP, SOL, GUP, DLOL, PTOL and OP fault factors are analyzed and compared to find out the most outstanding fault factors.

Table 4.3: Summary of Adama substation fault factor indexes

No	Index (fault factors)	Definition	Description
1	DPEF	Distribution Permanent Earth Fault	It is an inadvertent between any live conductor and earth and sustained more than 10 min.
2	DPSC	Distribution Permanent Short Circuit	It is a fault occurred when there is an insulation failure between phase conductors or between phase conductors and earth or both and sustained more than 10min.
3	DTEF	Distribution Temporary Earth Fault	It is an inadvertent between any live conductor and earth and sustained less than 10 min.
4	DTSC	Distribution Temporary Short Circuit	It is a fault occurred when there is an insulation failure between phase conductors or between phase conductors and earth or both and sustained more than 10min.
5	TLP	Transmission Line Problem	Faulty current and voltage signals in a transmission network.
6	SOL	System Over Load	A fault occurred when the load in the system exceed above the limit due to normal loading increment or short circuit.
7	GUP	Generation Unit Problem	Any electrical fault happened in the generating station.
8	DLOL	Distribution Line Over Load	A fault occurred when the load in the distribution line exceed above the limit due to normal loading increment or short circuit.
9	PTOL	Power Transformer Over Load	A fault occurred when the load in the power transformer exceed above the limit due to normal loading raise or short circuit.
10	OP	Operation Problem	Planned or unplanned outages problem for operational and maintenance purpose

CHAPTER FIVE

Data Collection, Analysis and Discussion

In this chapter the secondary data which has been collected from the substation is going to be presented, analyzed and discussed. The study provides an indication on identification of the most outstanding power interruption factors from the ten fault factors in the power distribution systems. The secondary data necessary for this study are the power interruption frequency and duration on eleven feeder lines and types of fault factors for interruption.

In this substation each frequency and duration of power interruption on feeder lines per hour is recorded but the causes of interruptions are not analyzed and described well, so to put an appropriate mitigation technique for the fault factors it is necessary to analyze the data using appropriate software tools. In this work, Minitab and Excel software tools have been used to do the analysis to find out the most outstanding power interruption fault factors. For the reliability problem in the case study area, it is critical knowing the causes of interruptions.

5.1 Data Collection

Interruption Data of 2009 to 2011(EC)

A detail secondary data for Adama Town distribution system has been collected and attached on Appendix A. The collected data are manually recorded by Adama substation supervisors that include only type of faults, frequency and duration of interruption of 11 medium voltage (15kV) outgoing feeder lines of the distribution system. The collected data are a manually recorded data for 3 years.

Adama Town distribution system has 11 active outgoing feeder lines, with peak load mostly around 30MW and around 70,000 customers (i.e. industrial, commercial and residential). There are no feeders dedicated for industrial, commercial and residential customers separately. The summery of collected total data for each year are shown in below Tables. The table shows that, sum of frequency of interruption for 12 months of each year and the same has been done for duration of interruption. But for this study a detail and average data have been taken to identify the most outstanding fault factors that create power interruption in the substation and all data's are attached in the appendix section. For operational problem (OP) interruption data are recorded in general, means interruption data due to operation/maintenance problem without considering planed or unplanned interruption conditions (i.e. planned and unplanned operational problem data is not recorded in the substation).

The following tables show that the sum of power interruption frequency and duration for 12 months on each feeder lines for selected years.

Table 5.1: Total interruption frequency and duration for each fault factors on 2009(EC)

Feeder Line	Month	Year	DPEF DUR. (hr.)	DPEF FRQ. (no.)	DPSC DUR. (hr.)	DPSC FRQ. (no.)	DTEF DUR. (hr.)	DTEF FRQ. (no.)	DTSC DUR. (hr.)	DTSC FRQ. (no.)	TLP DUR. (hr.)	TLP FRQ. (no.)	SOL DUR. (hr.)	SOL FRQ. (no.)	GUP DUR. (hr.)	GUP FRQ. (no.)	DLOL DUR. (hr.)	DLOL FRQ. (no.)	PTOL DUR. (hr.)	PTOL FRQ. (no.)	OP DUR. (hr.)	OP FRQ. (no.)
L1	01-12	2009	72.51	31	124.78	43	63.76	24	54.49	30	0	0	0	0	0	0	0	0	0	0	191.55	121
L3	01-12	2009	21.43	10	18.2	13	18.96	37	8.32	10	0	0	0	0	0	0	0	0	0	0	164.14	100
L4	01-12	2009	104.13	53	189.77	47	117.88	48	83.21	41	0	0	0	0	0	0	0	0	0	0	138.09	130
L5	01-12	2009	210.86	108	144.98	97	107.7	63	94.25	43	0	0	0	0	0	0	0	0	0	0	126.15	61
L6	01-12	2009	128.86	107	240.41	144	142.53	88	126.26	62	0	0	0	0	0	0	0	0	0	0	292.96	139
L7	01-12	2009	138.95	80	213	102	124.49	77	132.05	67	0	0	0	0	0	0	0	0	0	0	473.31	102
M1	01-12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M2	01-12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M3	01-12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M4	01-12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M5	01-12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5.2: Total interruption frequency and duration for each fault factors on 2010(EC)

Feeder Line	Month	Year	DPEF DUR. (hr.)	DPEF FRQ. (no.)	DPSC DUR. (hr.)	DPSC FRQ. (no.)	DTEF DUR. (hr.)	DTEF FRQ. (no.)	DTSC DUR. (hr.)	DTSC FRQ. (no.)	TLP DUR. (hr.)	TLP FRQ. (no.)	SOL DUR. (hr.)	SOL FRQ. (no.)	GUP DUR. (hr.)	GUP FRQ. (no.)	DLOL DUR. (hr.)	DLOL FRQ. (no.)	PTOL DUR. (hr.)	PTOL FRQ. (no.)	OP DUR. (hr.)	OP FRQ. (no.)
L1	01-12	2010	77.37	65	95.92	64	18.71	13	3.19	7	0	0	0	0	0	0	24.2	16	0	0	113.84	192
L3	01-12	2010	181.63	84	30.88	9	3.22	29	1.99	5	0	0	0	0	0	0	15.18	15	0	0	212.91	193
L4	01-12	2010	117.05	116	132.97	54	4.85	48	1.68	9	0	0	0	0	0	0	7.16	4	0	0	126.85	118.12
L5	01-12	2010	37.11	35	13.07	8	3.12	30	0.14	2	0	0	0	0	0	0	1.12	1	0	0	44.28	37
L6	01-12	2010	105.09	61	191.77	46	2.8	25	1.6	7	0	0	0	0	0	0	0	0	0	0	87.05	135
L7	01-12	2010	47.86	93	116.98	73	6.7	40	2.83	11	0	0	0	0	0	0	16.06	8	0	0	94.9	146
M1	01-12	2010	138.11	61	185.3	59	75.32	9	1.33	4	0	0	0	0	0	0	0	0	0	0	68.35	63
M2	01-12	2010	87.3	39	137.22	37	0.24	7	0.06	1	0	0	0	0	0	0	0	0	0	0	69.39	61
M3	01-12	2010	84.67	65	169	50	2.61	7	0.07	1	0	0	0	0	0	0	0	0	0	0	44.61	43
M4	01-12	2010	143.68	38	84.8	34	0.15	2	0.25	3	0	0	0	0	0	0	0	0	0	0	50.34	38
M5	01-12	2010	246.84	59	219.06	65	17.92	5	0.85	5	0	0	0	0	0	0	0	0	0	0	89.01	74

Table 5.3: Total interruption frequency and duration for each fault factors on 2011(EC)

Feeder Line	Month	Year	DPEF DUR. (hr.)	DPEF FRQ. (no.)	DPSC DUR. (hr.)	DPSC FRQ. (no.)	DTEF DUR. (hr.)	DTEF FRQ. (no.)	DTSC DUR. (hr.)	DTSC FRQ. (no.)	TLP DUR. (hr.)	TLP FRQ. (no.)	SOL DUR. (hr.)	SOL FRQ. (no.)	GUP DUR. (hr.)	GUP FRQ. (no.)	DLOL DUR. (hr.)	DLOL FRQ. (no.)	PTOL DUR. (hr.)	PTOL FRQ. (no.)	OP DUR. (hr.)	OP FRQ. (no.)
L1	01-12	2011	112.76	29	65.51	27	11.49	35	18.68	22	0	0	0	0	0	0	0	0	0	0	423.55	128
L3	01-12	2011	72.71	35	112.19	52	14.09	30	10.87	18.29	0	0	0	0	0	0	0	0	0	0	416.18	129
L4	01-12	2011	41.81	17	127.68	44	9.51	26	8.47	20	0	0	0	0	0	0	0	0	0	0	417.64	124
L5	01-12	2011	17.43	10	30.88	9	11.96	39	2.24	6	0	0	0	0	0	0	0	0	0	0	85.11	51
L6	01-12	2011	9.54	6	12.03	6	2.26	5	1.06	1	0	0	0	0	0	0	0	0	0	0	1.73	7
L7	01-12	2011	34.19	16	109.45	44	16.41	46	11.92	24	0	0	0	0	0	0	0	0	0	0	449.38	142
M1	01-12	2011	74.68	22	211.12	66	13.67	31	15.64	25	0	0	0	0	0	0	0	0	0	0	478.94	141
M2	01-12	2011	62.59	18	222.93	55	6.02	18	12.48	10	0	0	0	0	0	0	0	0	0	0	396.3	106
M3	01-12	2011	73.53	27	195.22	65	5.91	13	9	15	0	0	0	0	0	0	0	0	0	0	430.9	133
M4	01-12	2011	86.33	34	163.92	53	8.42	20	3.35	6	0	0	0	0	0	0	0	0	0	0	501.62	124
M5	01-12	2011	129.83	44	131.66	54	7.96	20	9.43	17	0	0	0	0	0	0	0	0	0	0	432.75	148

From the above tables we can calculate the total percentage of interruption duration and frequency effect values by taking the contribution of each type of fault factors and the total sum of all fault factors in a single feeder line (i.e. (single fault factor value on single feeder line / sum of all fault factors value on that feeder line) * 100%). This analysis has been done in data analysis section.

5.2 Data Analysis and Discussion

The calculated percentage value of each fault factors on each feeder lines for each years are shown on the following tables and all the values are taken form the above data tables. But the detail analysis for this study has been done using Minitab and Excel software tools with input of detail and average manually recorded secondary data (attached in Appendix A) and with output of statistical comparative plots, charts and graphs.

Table 5.4: Total percentage interruption frequency and duration of each fault factors on 2009(EC)

Feeder Line	Month	Year	DPEF DUR. %	DPEF FRQ. %	DPSC DUR. %	DPSC FRQ. %	DTEF DUR. %	DTEF FRQ. %	DTSC DUR. %	DTSC FRQ. %	TLP DUR. %	TLP FRQ. %	SOL DUR. %	SOL FRQ. %	GUP DUR. %	GUP FRQ. %	DLOL DUR. %	DLOL FRQ. %	PTOL DUR. %	PTOL FRQ. %	OP DUR. %	OP FRQ. %
L1	01-12	2009	14.30	12.50	24.61	17.27	12.57	9.64	10.75	12.05	0	0	0	0	0	0	0	0	0	0	37.77	48.59
L3	01-12	2009	9.28	5.88	7.88	7.65	8.21	21.76	3.60	5.88	0	0	0	0	0	0	0	0	0	0	71.04	58.82
L4	01-12	2009	16.45	16.61	29.98	14.73	18.62	15.05	13.14	12.85	0	0	0	0	0	0	0	0	0	0	21.81	40.75
L5	01-12	2009	30.83	29.03	21.20	26.07	15.75	16.94	13.78	11.56	0	0	0	0	0	0	0	0	0	0	18.44	16.40
L6	01-12	2009	13.84	19.81	25.82	26.67	15.80	16.30	13.56	11.48	0	0	0	0	0	0	0	0	0	0	31.47	25.74
L7	01-12	2009	12.84	18.69	19.69	23.83	11.51	17.99	12.21	15.65	0	0	0	0	0	0	0	0	0	0	43.75	23.83
M1	01-12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M2	01-12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M3	01-12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M4	01-12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M5	01-12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5.4 shows 2009 total percentage effect of the ten fault factors that creates power interruption on the 11 feeder lines. Thus, among the ten fault factors, frequently occurring fault factors on feeder lines at Adama substation include permanent and transient earth fault, short circuit and interruption due to operation / maintenance problem. Therefore, the most frequently fault factors that creates power interruption on L1 is OP, DPSC and DPEF; L3 is OP, DTFE and DPSC; L4 is OP, DPEF and DTEF; L5 DPEF, DPSC and DTEF; L6 is DPSC, OP and DTEF; L7 is OP, DPSC and DPEF. On this year the mobile station was not active thus no data has been recorded.

Table 5.5: Total percentage interruption frequency and duration of each fault factors on 2010(EC)

Feeder Line	Month	Year	DPEF DUR. %	DPEF FRQ. %	DPSC DUR. %	DPSC FRQ. %	DTEF DUR. %	DTEF FRQ. %	DTSC DUR. %	DTSC FRQ. %	TLP DUR. %	TLP FRQ. %	SOL DUR. %	SOL FRQ. %	GUP DUR. %	GUP FRQ. %	DLOL DUR. %	DLOL FRQ. %	PTOL DUR. %	PTOL FRQ. %	OP DUR. %	OP FRQ. %
L1	01-12	2010	23.22	18.20	28.78	17.92	5.61	3.64	0.96	1.96	0	0	0	0	0	0	7.26	4.48	0	0	34.16	53.78
L3	01-12	2010	40.74	25.07	6.93	2.69	0.72	8.66	0.45	1.49	0	0	0	0	0	0	3.41	4.48	0	0	47.76	57.61
L4	01-12	2010	29.97	33.23	34.05	15.47	1.24	13.75	0.43	2.58	0	0	0	0	0	0	1.83	1.15	0	0	32.48	33.83
L5	01-12	2010	37.55	30.97	13.22	7.08	3.16	26.55	0.14	1.77	0	0	0	0	0	0	1.13	0.88	0	0	44.80	32.74
L6	01-12	2010	27.06	22.26	49.39	16.79	0.72	9.12	0.41	72.55	0	0	0	0	0	0	0	0	0	0	22.42	49.27
L7	01-12	2010	16.77	25.07	41	19.68	2.35	10.78	0.99	2.96	0	0	0	0	0	0	5.63	2.16	0	0	33.26	39.35
M1	01-12	2010	29.48	31.12	39.56	30.10	16.08	4.59	0.28	2.04	0	0	0	0	0	0	0	0	0	0	14.59	32.14
M2	01-12	2010	29.67	26.90	46.64	25.51	0.08	4.83	0.02	0.69	0	0	0	0	0	0	0	0	0	0	23.59	42.07
M3	01-12	2010	28.13	39.16	56.15	30.12	0.86	4.22	0.023	1	0	0	0	0	0	0	0	0	0	0	14.82	25.90
M4	01-12	2010	51.46	33.04	30.37	29.57	0.054	1.74	0.089	2.61	0	0	0	0	0	0	0	0	0	0	18.03	33.04
M5	01-12	2010	43.03	28.37	38.19	3	3.12	5	0.15	5	0	0	0	0	0	0	0	0	0	0	15.51	74

Table 5.5 shows 2010 total percentage effect of the ten fault factors that creates power interruption on the 11 feeder lines. Thus, among the ten fault factors, frequently occurring fault factors on feeder lines in this substation contain permanent and transient earth fault, short circuit and interruption due to operation / maintenance problem. Therefore, the most frequently fault factors that creates power interruption on L1 is OP, DPEF and DPSC; L3 is OP, DPEF and DTEF; L4 is OP, DPEF and DPSC; L5 is OP, DPEF and DTEF; L6 is DTSC, OP and DPEF; L7 is OP, DPEF and DPSC; M1 is OP, DPEF and DPSC; M2 is OP, DPEF and DPSC; M3 is DPEF, DPSC and OP; M4 is OP, DPEF and DPSC; M5 is OP, DPEF and DTSC.

Table 5.6: Total percentage interruption frequency and duration of each fault factors on 2011(EC)

Feeder Line	Month	Year	DPEF DUR. %	DPEF FRQ. %	DPSC DUR. %	DPSC FRQ. %	DTEF DUR. %	DTEF FRQ. %	DTSC DUR. %	DTSC FRQ. %	TLP DUR. %	TLP FRQ. %	SOL DUR. %	SOL FRQ. %	GUP DUR. %	GUP FRQ. %	DLOL DUR. %	DLOL FRQ. %	PTOL DUR. %	PTOL FRQ. %	OP DUR. %	OP FRQ. %
L1	01-12	2011	17.84	12.0.3	10.37	11.20	1.82	14.52	2.96	9.13	0	0	0	0	0	0	0	0	0	0	67.02	53.11
L3	01-12	2011	11.61	13.24	17.92	19.68	2.25	11.35	1.74	6.92	0	0	0	0	0	0	0	0	0	0	66.48	48.81
L4	01-12	2011	6.91	7.36	21.10	19.05	1.57	11.26	1.40	8.66	0	0	0	0	0	0	0	0	0	0	69.02	53.68
L5	01-12	2011	11.81	8.70	20.92	7.83	8.10	33.91	1.52	5.22	0	0	0	0	0	0	0	0	0	0	57.65	44.35
L6	01-12	2011	35.84	24	45.19	24	8.49	20	3.98	4	0	0	0	0	0	0	0	0	0	0	6.50	28
L7	01-12	2011	5.50	5.88	17.61	16.18	2.64	16.91	1.92	8.82	0	0	0	0	0	0	0	0	0	0	72.32	52.21
M1	01-12	2011	9.40	7.72	26.59	23.16	1.72	10.88	1.97	8.77	0	0	0	0	0	0	0	0	0	0	60.32	49.47
M2	01-12	2011	8.94	8.70	31.83	26.57	0.86	8.70	1.78	4.83	0	0	0	0	0	0	0	0	0	0	56.59	51.21
M3	01-12	2011	10.29	10.67	27.32	25.69	0.83	5.14	1.26	5.93	0	0	0	0	0	0	0	0	0	0	60.30	52.57
M4	01-12	2011	11.31	14.35	21.47	22.36	1.10	8.44	0.44	2.53	0	0	0	0	0	0	0	0	0	0	65.69	52.32
M5	01-12	2011	18.24	15.55	18.50	19.08	1.12	7.07	1.33	6.01	0	0	0	0	0	0	0	0	0	0	60.81	52.30

Table 5.6 shows 2011 total percentage effect of the ten fault factors that creates power interruption on the 11 feeder lines. Thus, among the ten fault factors, frequently occurring fault factors on feeder lines in this substation contain permanent and transient earth fault, short circuit and interruption due to operation / maintenance problem. Therefore, the most frequently fault factors that creates power interruption for this year on L1 is OP, DTEF and DPEF; L3 is OP, DPSC and DPEF; L4 is OP, DPSC and DTEF; L5 is OP, DTEF and DPEF; L6 is OP, DPSC, and DPEF; L7 is OP, DTEF and DPSC; M1 is OP, DPSC and DTEF; M2 is OP, DPSC and DTEF ; M3 is OP, DPSC and DPEF; M4 is OP, DPSC and DPEF; M5 is OP, DPSC and DPEF.

Analysis for this thesis work has been done using two data's inputs; those are detail interruption frequency data with total of 3960 data input quantities and average interruption frequency data with total of 110 data input quantities.

To analyze the data, the Minitab software required the following index variables and coding schemes as input parameters.

- Variable Summary
- Sub-Variable Summary
- Sample Coding scheme
- Coding Focus Parameters

Table 5.7: Variable summary

Number	Variables	Code
1	Distribution Permanent Earth Faults	DPEF
2	Distribution Permanent Short Circuit	DPSC
3	Distribution Temporary Earthing Faults	DTEF
4	Distribution Temporary Short Circuit	DTSC
5	Transmission Line Problem	TLP
6	System Over Load	SOL
7	Generation Unit Problem	GUP
8	Distribution Line over Load	DLOL
9	Power Transformer Over Load	PTOL
10	Operation Problem	OP

Table 5.8: Sub-variable summary

Number	Sub-Variable	Code
1	Duration	DUR
2	Frequency	FRQ
3	Month	00
4	Year	0000

Table 5.9: Sample coding scheme

Number	Sample Coding Scheme	Example
1	Variable Name_ Sub-Variable Name, Feeder Line Code, Month and Year	DPEF_DUR, L1, 01, 2010 DPEF_FRQ, L1, 01, 2010

Table 5.10: Coding focus parameters

Focus Year (EC)
2009
2010
2011

Focus Month
1
2
3
4
5
6
7
8
9
10
11
12

Focus Station
Adama Substation

Focus Sub-Variables
Duration
Frequency

Focus Variables
Distribution Permanent Earth Faults
Distribution Permanent Short Circuit
Distribution Temporary Earthing Faults
Distribution Temporary Short Circuit
Transmission Line Problem
System Over Load
Generation Unit Problem
Distribution Line over Load
Power Transformer Over Load
Operation Problem

Focus Feeder Lines
L1
L3
L4
L5
L6
L7
M1
M2
M3
M4
M5

For the case of power interruption, the one which shows more indication on power interruption is frequency or number of interruption than duration of interruption. This is because when power interrupted repeatedly (frequent interruption) for that duration, it shows that more interruption has been occurred in the system, and if power interrupted with less number of interruptions for the same duration, it shows that interruption is less. Therefore, the effect of interruption can be shown more on the number or frequency of interruption than duration of interruption. In this thesis work interruption frequency data analysis has been done to find out the most outstanding fault factors. Figure 5.1 shows the project editor view, with the analysis page opened. Parameters used in this assessment analysis for the result of fault factors are those shown on this page.

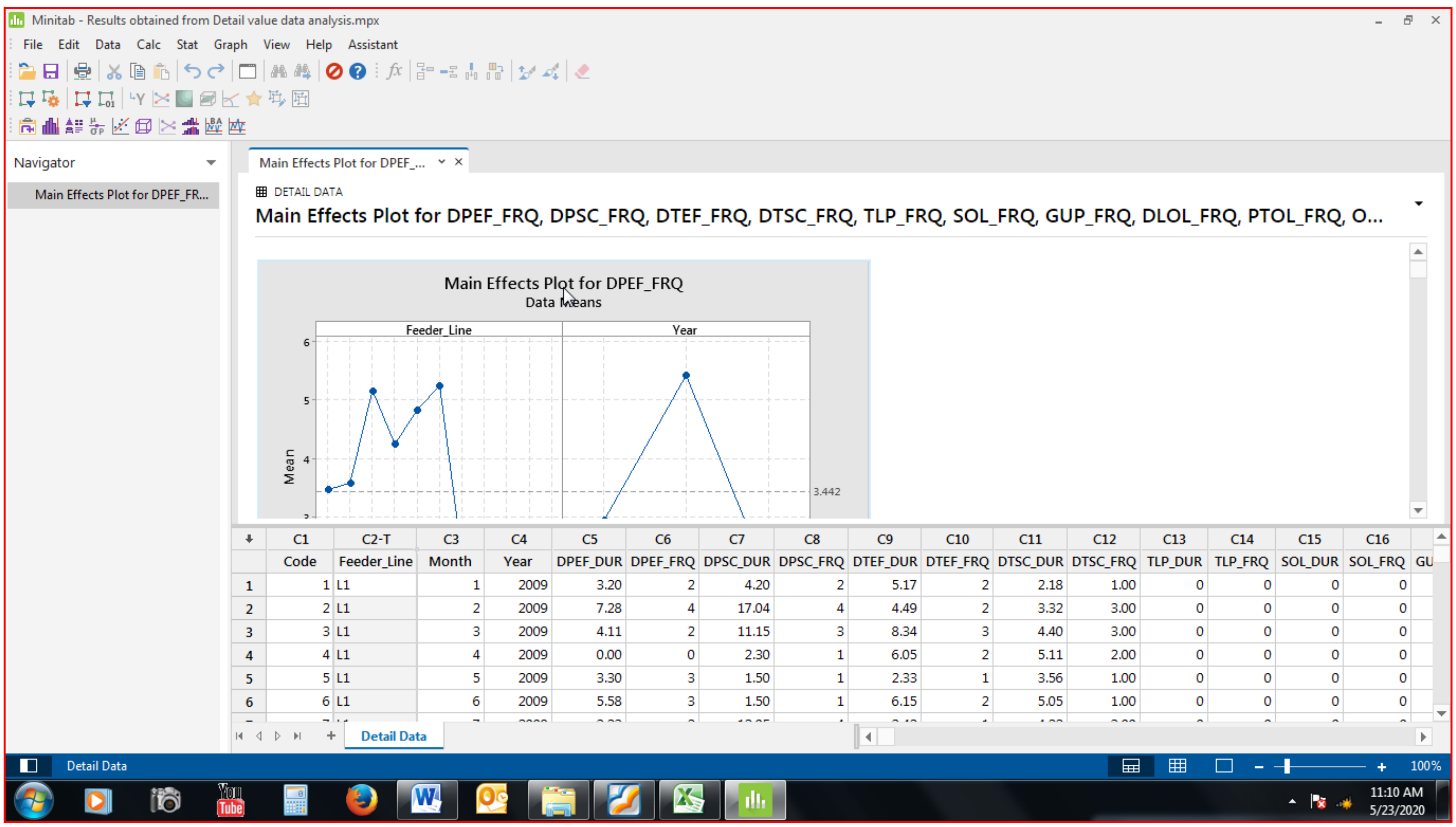

Figure 5.1: Window of Minitab® 19.1 software as analysis page opened

Therefore, frequency of interruption analysis using Detail and Average data input for the 10 fault factors on the eleven feeder lines have been analyzed and discussed with result here below.

A. Using Detail data input (Appendix A), the interruption frequency data analysis average result for single fault factor on all feeder lines in the substation is shown below.

1. Result of DPEF fault factor on power interruption from 2009 up to 2011(EC) years

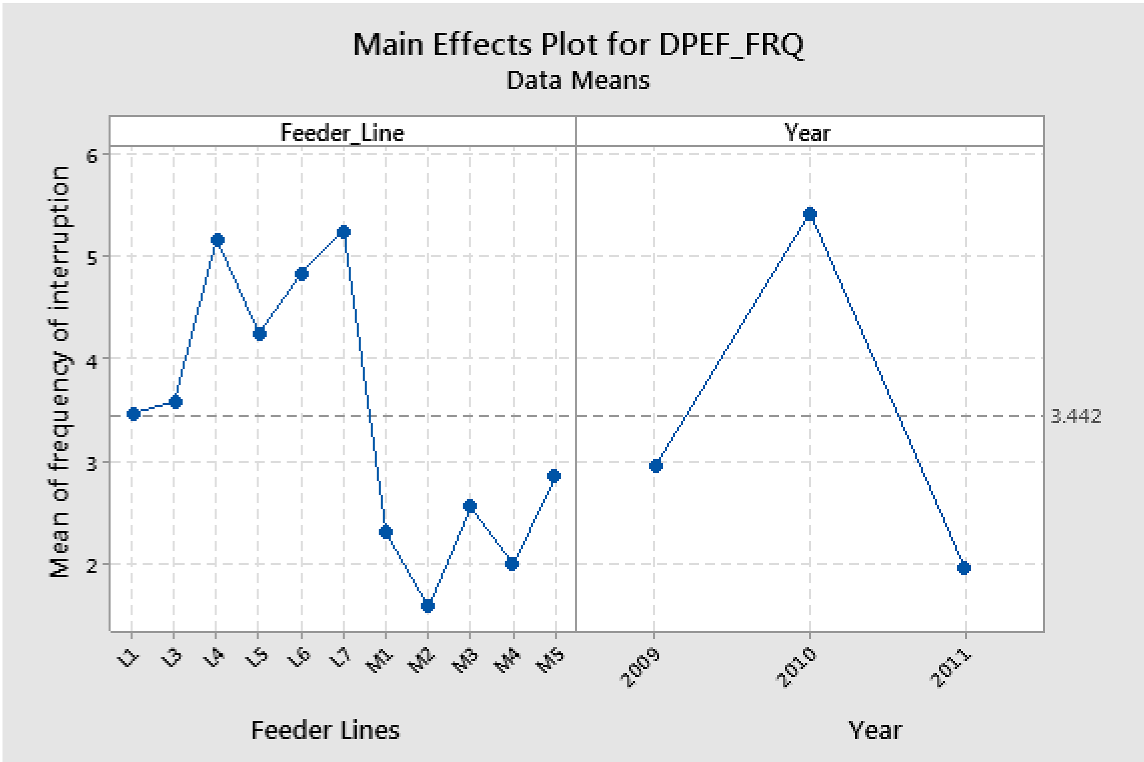

Figure 5.2: DPEF mean value for frequency of interruption

Table 5.11: DPEF total frequency of interruption for three years

Year	Feeder Line Name	Total frequency of interruption (No.)	Mean value	
2009 up to 2011	L1	125	125/36	3.4722
	L3	129	129/36	3.5833
	L4	186	186/36	5.1667
	L5	153	153/36	4.25
	L6	174	174/36	4.8333
	L7	189	189/36	5.25
	M1	83	83/36	2.3056
	M2	57	57/36	1.5833
	M3	92	92/36	2.556
	M4	72	72/36	2
	M5	103	103/36	2.861
	Total	**1363**	**1363/396**	**3.442**

Therefore, due to DPEF (Distribution Permanent Earth Fault) fault factor a total of 1363 frequency of interruption occurs in the Adama distribution system for 3 years with total mean value of 3.442.

2. Result of DPSC fault factor on power interruption from 2009 up to 2011(EC) years

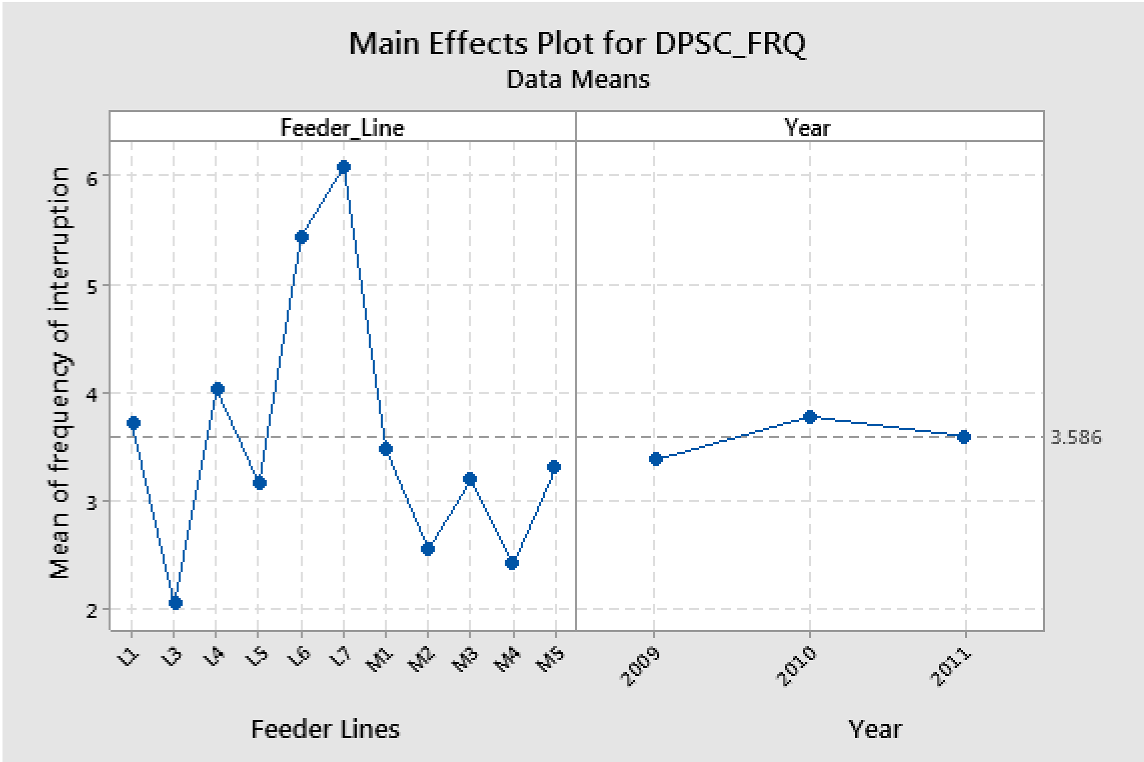

Figure 5.3: DPSC mean value for frequency of interruption

Table 5.12: DPSC total frequency of interruption for three years

Year	Feeder Line Name	Total frequency of interruption (No.)	Mean value	
2009 up to 2011	L1	134	134/36	3.7222
	L3	74	74/36	2.0555
	L4	145	145/36	4.0277
	L5	114	114/36	3.1667
	L6	196	196/36	5.4444
	L7	219	219/36	6.0833
	M1	125	125/36	3.4722
	M2	92	92/36	2.5556
	M3	115	115/36	3.1944
	M4	87	87/36	2.4167
	M5	119	119/36	3.3056
	Total	**1420**	**1420/396**	**3.5859**

Therefore, due to DPSC (Distribution Permanent Short Circuit) fault factor a total of 1420 frequency of interruption occurs in the Adama distribution system for three years with total mean value of 3.5859.

3. Result of DTEF fault factor on power interruption from 2009 up to 2011(EC) years

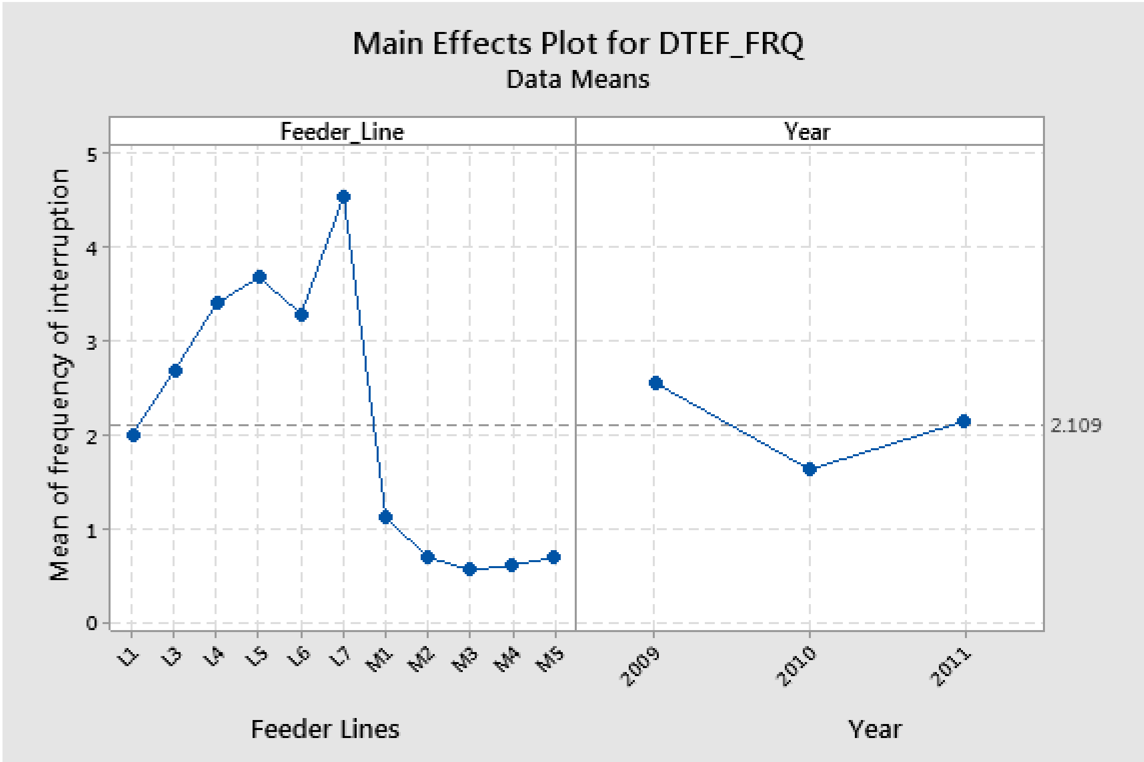

Figure 5.4: DTEF mean value for frequency of interruption

Table 5.13: DTEF total frequency of interruption for three years

Year	Feeder Line Name	Total frequency of interruption (No.)	Mean value	
2009 up to 2011	L1	72	72/36	2
	L3	96	96/36	2.6667
	L4	122	122/36	3.3889
	L5	132	132/36	3.6667
	L6	118	118/36	3.2278
	L7	163	163/36	4.5278
	M1	40	40/36	1.1111
	M2	25	25/36	0.6944
	M3	20	20/36	0.5556
	M4	22	22/36	0.6111
	M5	25	25/36	0.6944
	Total	**835**	**835/396**	**2.1085**

Therefore, due to DTEF (Distribution Temporary Earth fault) fault factor a total of 835 frequency of interruption occurs in the Adama distribution system for three years with total mean value of 2.109.

4. Result of DTSC fault factor on power interruption from 2009 up to 2011 (EC) years

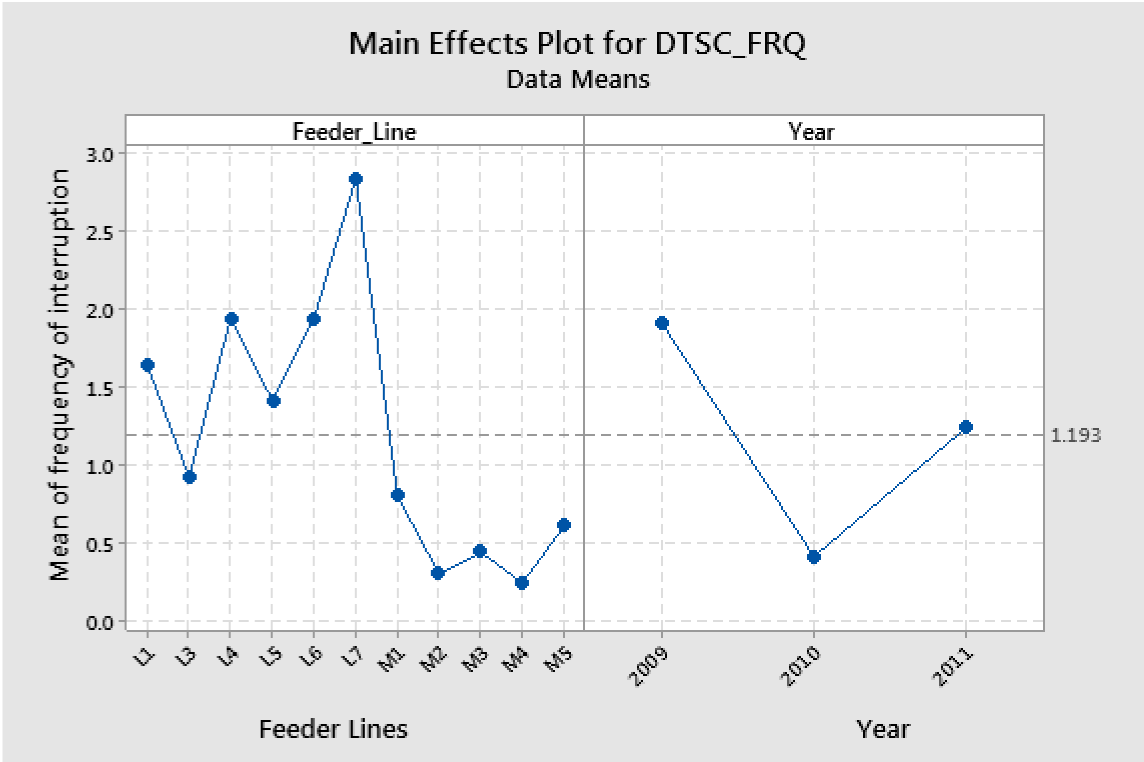

Figure 5.5: DTSC mean value for frequency of interruption

Table 5.14: DTSC total frequency of interruption for three years

Year	Feeder Line Name	Total frequency of interruption (No.)	Mean value	
2009 up to 2011	L1	59	59/36	1.6339
	L3	33.29	33.29/36	0.9247
	L4	70	70/36	1.9444
	L5	51	51/36	1.4167
	L6	70	70/36	1.9444
	L7	102	102/36	2.8333
	M1	29	29/36	0.8056
	M2	11	11/36	0.3056
	M3	16	16/36	0.4444
	M4	9	9/36	0.25
	M5	22	22/36	0.6111
	Total	**472.29**	**472.29/396**	**1.1926**

Due to DTSC (Distribution Temporary Short circuit) fault factor a total of 472.29 frequency of interruption occurs in the Adama distribution system for three years with total mean value of 1.1926.

5. Result of TLP fault factor on power interruption from 2009 up to 2011(EC) years

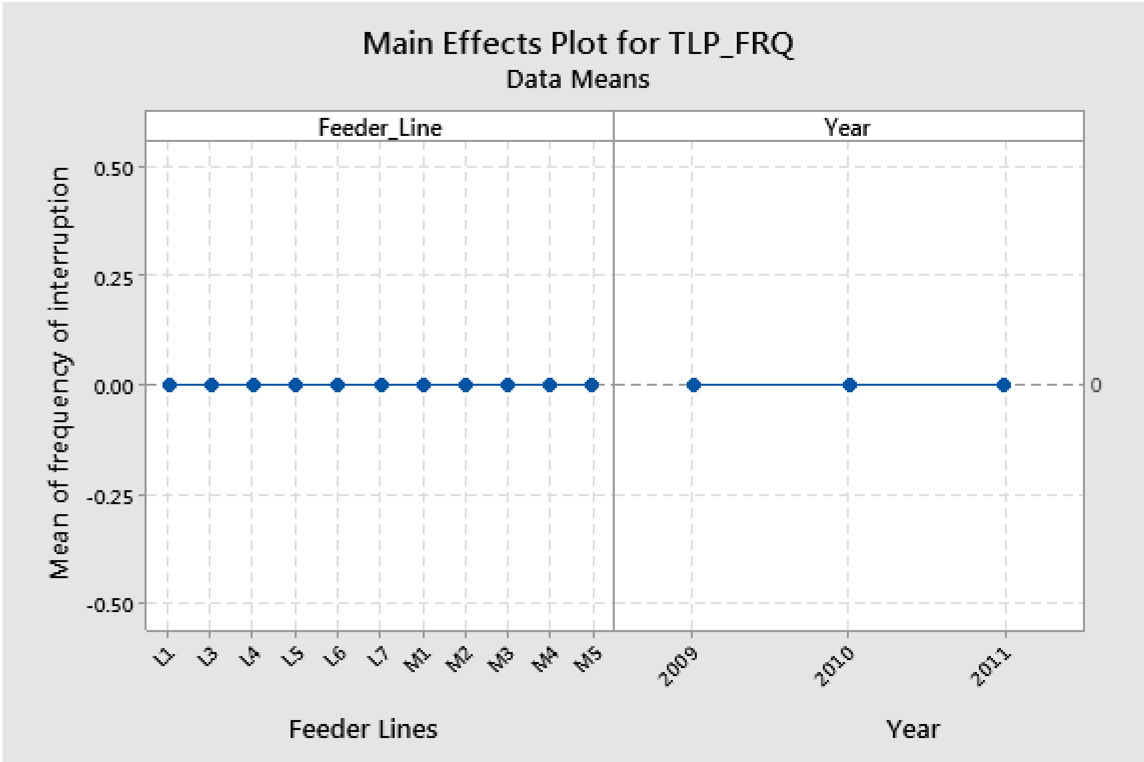

Figure 5.6: TLP mean value for frequency of interruption

Table 5.15: TLP total frequency of interruption for three years

Year	Feeder Line Name	Total frequency of interruption (No.)	Mean value	
2009 up to 2011	L1	0	0	0
	L3	0	0	0
	L4	0	0	0
	L5	0	0	0
	L6	0	0	0
	L7	0	0	0
	M1	0	0	0
	M2	0	0	0
	M3	0	0	0
	M4	0	0	0
	M5	0	0	0
	Total	**0**	**0**	**0**

Due to TLP (Transmission Line Problem) fault factor a total of 0 frequency of interruption occurs in the Adama distribution substation for three years with total mean value of 0.

6. Result of SOL fault factor on power interruption from 2009 up to 2011(EC) years

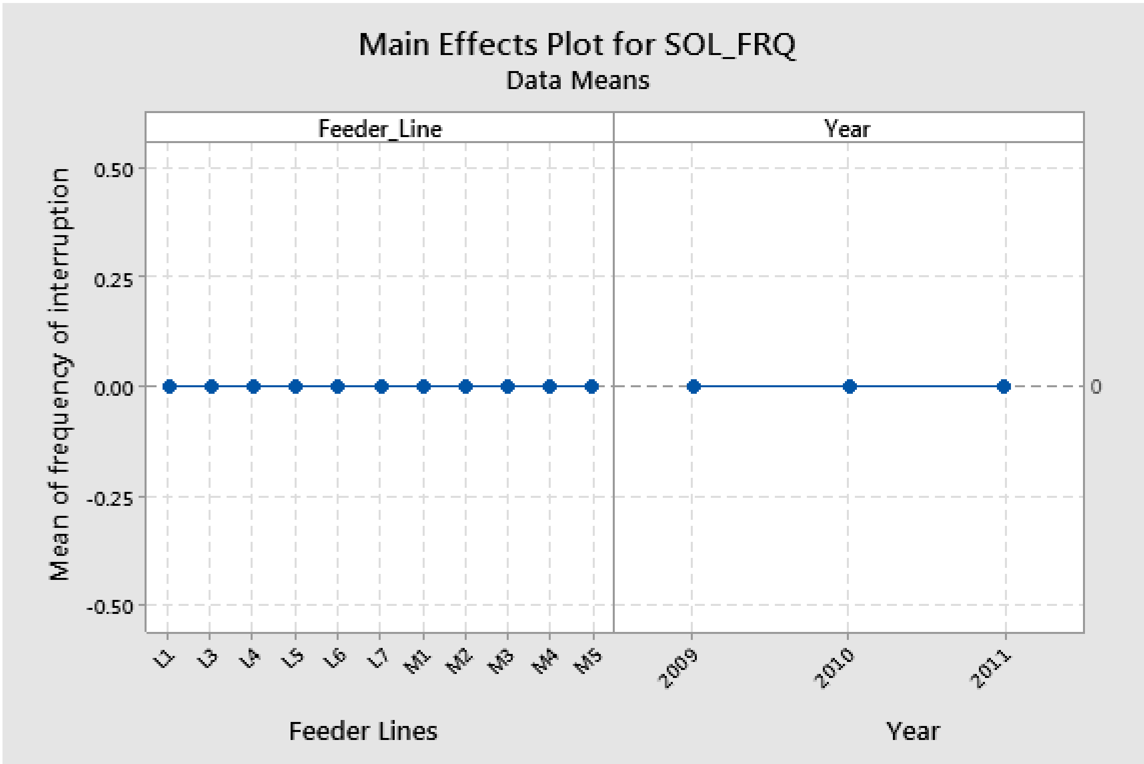

Figure 5.7: SOL mean value for frequency of interruption

Table 5.16: SOL total frequency of interruption for three years

Year	Feeder Line Name	Total frequency of interruption (No.)	Mean value	
2009 up to 2011	L1	0	0	0
	L3	0	0	0
	L4	0	0	0
	L5	0	0	0
	L6	0	0	0
	L7	0	0	0
	M1	0	0	0
	M2	0	0	0
	M3	0	0	0
	M4	0	0	0
	M5	0	0	0
	Total	**0**	**0**	**0**

Due to SOL (system Over Load) fault factors a total of 0 frequency of interruption occurs in the Adama distribution station for three years with total mean value of 0.

7. Result of GUP fault factor on power interruption from 2009 up to 2011(EC) years

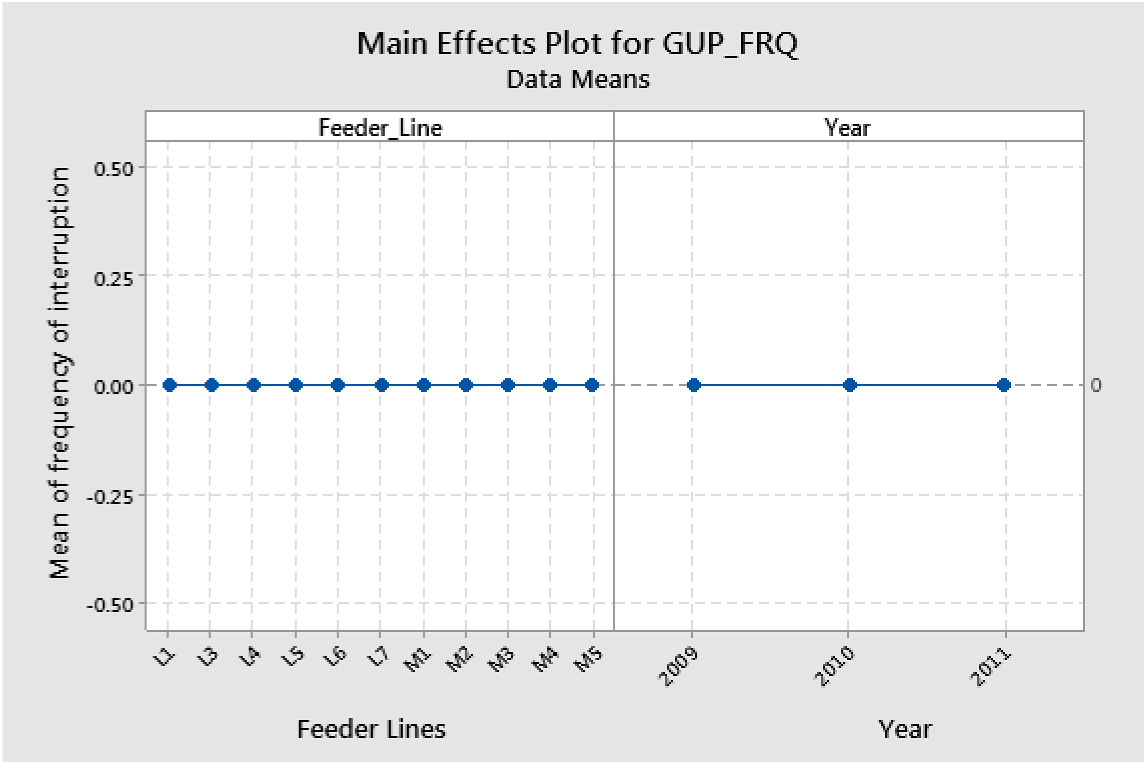

Figure 5.8: GUP mean value for frequency of interruption

Table 5.17: GUP total frequency of interruption for three years

Year	Feeder Line Name	Total frequency of interruption (No.)	Mean value	
2009 up to 2011	L1	0	0	0
	L3	0	0	0
	L4	0	0	0
	L5	0	0	0
	L6	0	0	0
	L7	0	0	0
	M1	0	0	0
	M2	0	0	0
	M3	0	0	0
	M4	0	0	0
	M5	0	0	0
	Total	**0**	**0**	**0**

Due to GUP (Generation Unit Problem) fault factors 0 frequency of interruption occurs in the Adama distribution station for three years with total mean value of 0.

8. Result of DLOL fault factor on power interruption from 2009 up to 2011(EC) years

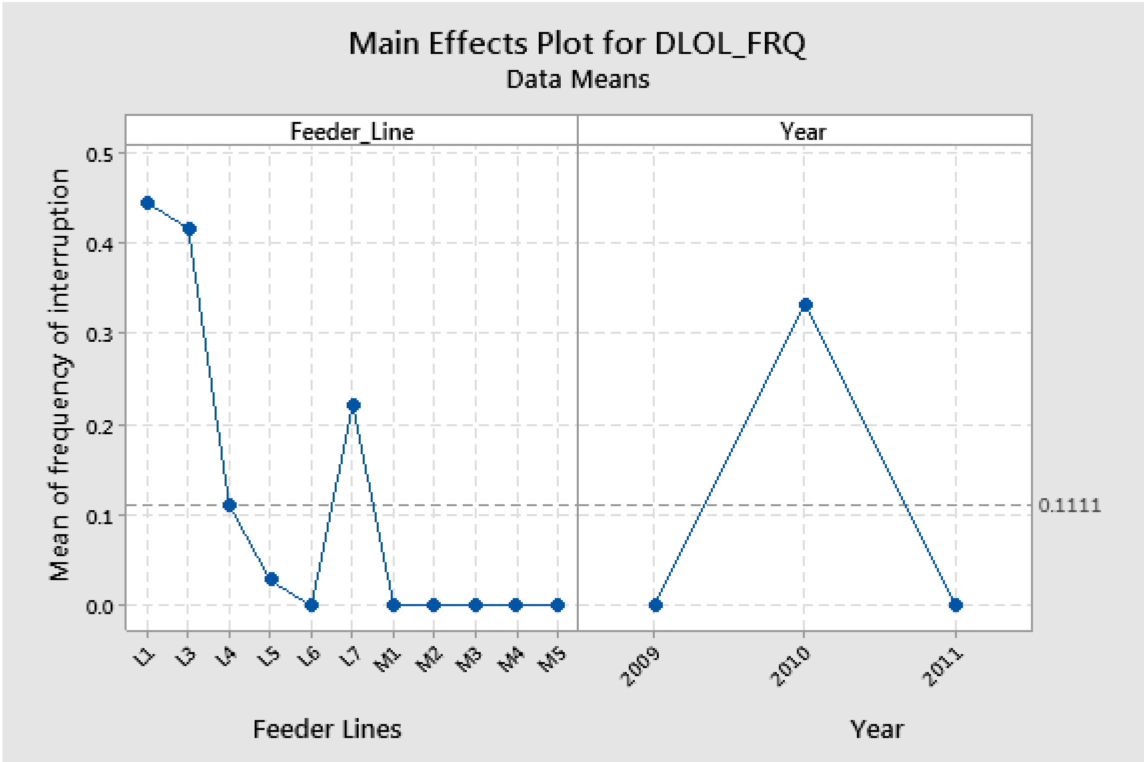

Figure 5.9: DLOL mean value for frequency of interruption

Table 5.18: DLOL total frequency of interruption for three years

Year	Feeder Line Name	Total frequency of interruption (No.)	Mean value	
2009 up to 2011	L1	16	16/36	0.4444
	L3	15	15/36	0.4167
	L4	4	4/36	0.1111
	L5	1	1/36	0.0278
	L6	0	0	0
	L7	8	8/36	0.2222
	M1	0	0	0
	M2	0	0	0
	M3	0	0	0
	M4	0	0	0
	M5	0	0	0
	Total	**44**	**44/396**	**0.1111**

Due to DLOL (Distribution Line Over Load) fault factor a total of 44 frequency of interruption occurs in the Adama distribution station for the selected three years with total mean value of 0.1111.

9. Result of PTOL fault factor on power interruption from 2009 up to 2011(EC) years

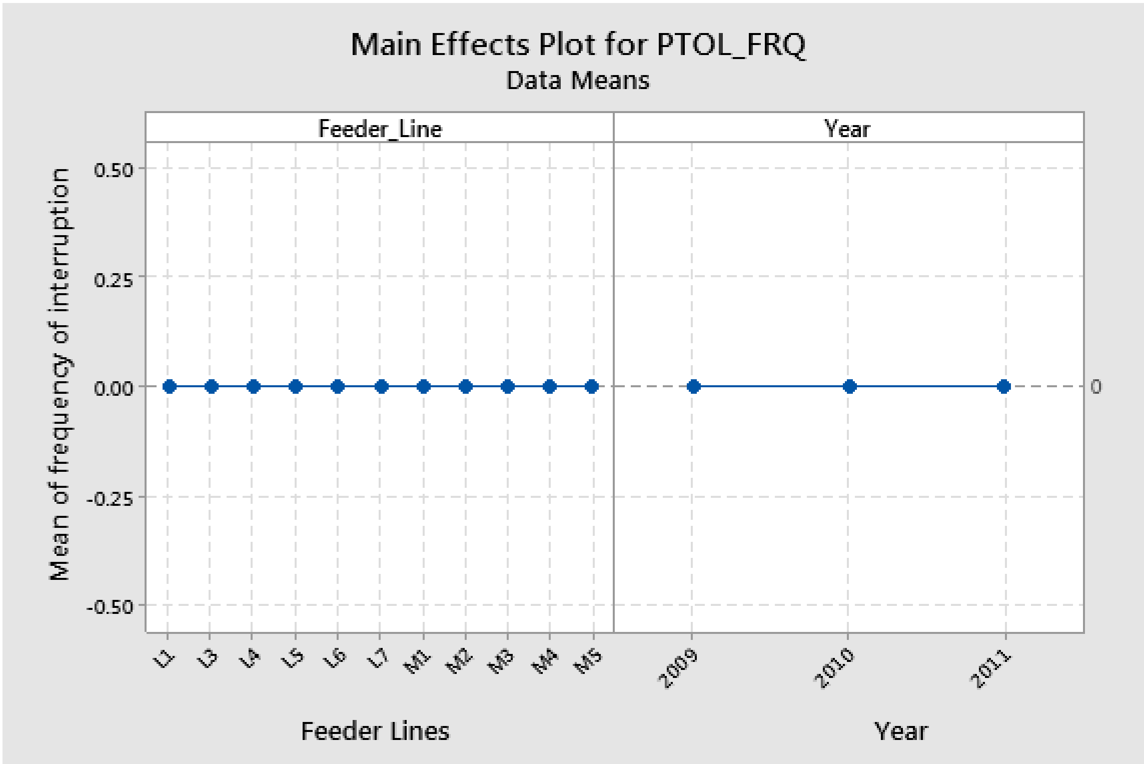

Figure 5.10: PTOL mean value for frequency of interruption

Table 5.19: PTOL total frequency of interruption for three years

Year	Feeder Line Name	Total frequency of interruption (No.)	Mean value	
2009 up to 2011	L1	0	0	0
	L3	0	0	0
	L4	0	0	0
	L5	0	0	0
	L6	0	0	0
	L7	0	0	0
	M1	0	0	0
	M2	0	0	0
	M3	0	0	0
	M4	0	0	0
	M5	0	0	0
	Total	**0**	**0**	**0**

Due to PTOL (Power Transformer Over Load) fault factor a total of 0 frequency of interruption occurs in the Adama distribution station for three years with total mean value of 0.

10. Result of OP fault factor on power interruption from 2009 up to 2011(EC) years

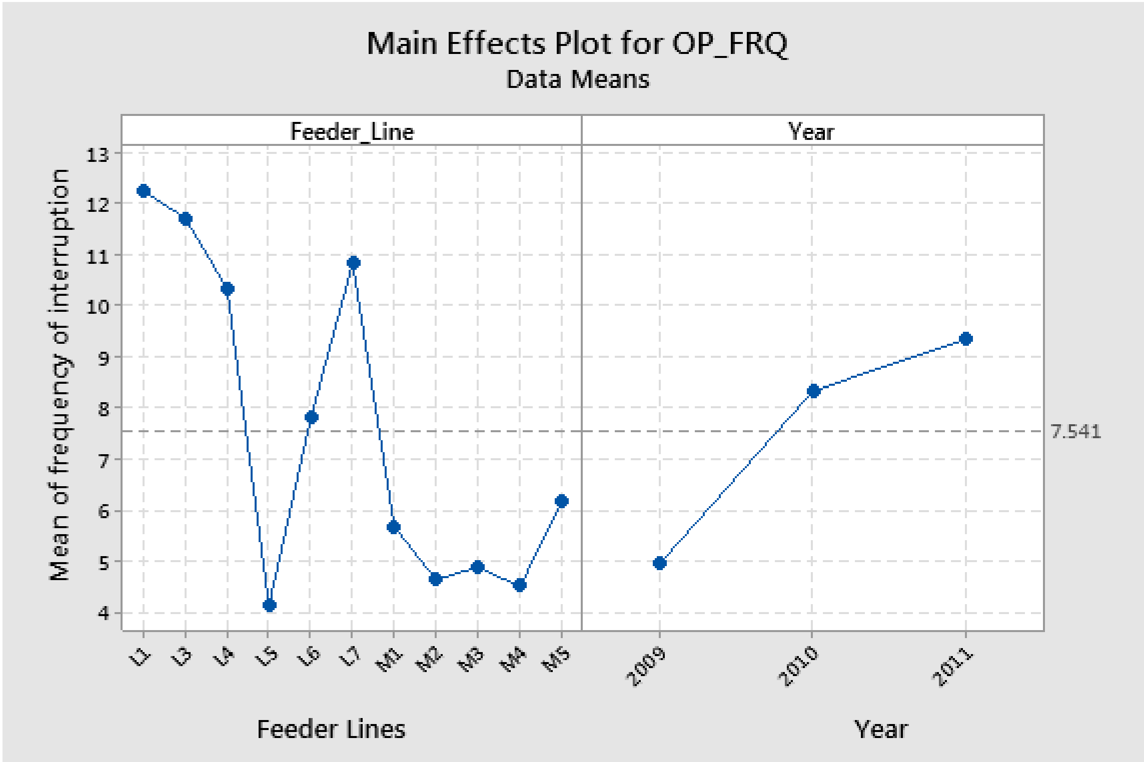

Figure 5.11: OP mean value for frequency of interruption

Table 5.20: OP total frequency of interruption for three years

Year	Feeder Line Name	Total frequency of interruption (No.)	Mean value	
2009 up to 2011	L1	441	441/36	12.25
	L3	422	422/36	11.7222
	L4	372.12	372.12/36	10.3367
	L5	149	149/36	4.1389
	L6	281	281/36	7.8056
	L7	390	390/36	10.8333
	M1	204	204/36	5.6667
	M2	167	167/36	4.6389
	M3	176	176/36	4.8889
	M4	162	162/36	4.5
	M5	222	222/36	6.1667
	Total	**2986.12**	**2986.12/396**	**7.541**

Therefore, due to OP (operational problem) fault factor a total of 2986.12 frequency of interruption occurs in the Adama distribution system for three years with total mean value of 7.541.

B. Using Average data input (on Appendix A), the frequency of interruption analysis result for all fault factors on single feeder lines in the substation is shown below.

This analysis is done using Excel software tools with input of average data value of the three years and the output approve the result in part A.

1. Effect of all fault factors on power interruption on feeder L1 from 2009 up to 2011(EC) years

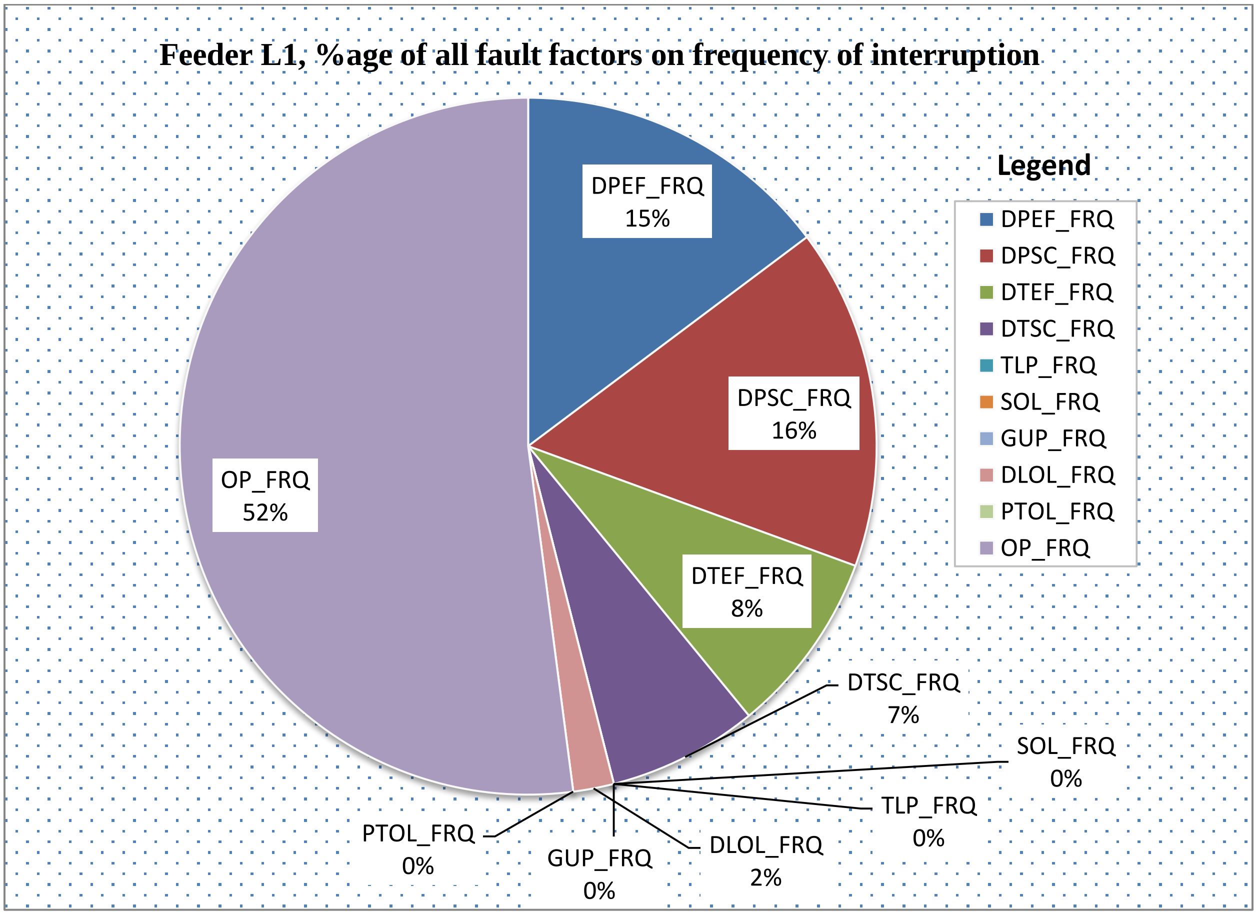

Figure 5.12: Feeder L1 percentage of all fault factors on frequency of interruption

As can be seen from the pie chart, 52% of the interruption frequency is due to operation and maintenance problem, 16% is due to permanent short circuit, 15% is due to permanent earth fault, 8% is due to temporary earth fault, 7% is due to temporary short circuit and the remaining faults recorded 0% on distribution L1. In this line the most outstanding fault factors that create frequent power interruption are ranked as below.

Table 5.21: Percentage and rank of fault factors on feeder L1

Feeder line	DPEF		DPSC		DTEF		DTSC		DLOL		OP		Others
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	
L1	3	15	2	16	4	8	5	7	6	2	1	52	0

2. Effect of all fault factors on power interruption on feeder L3 from 2009 up to 2011(EC) years

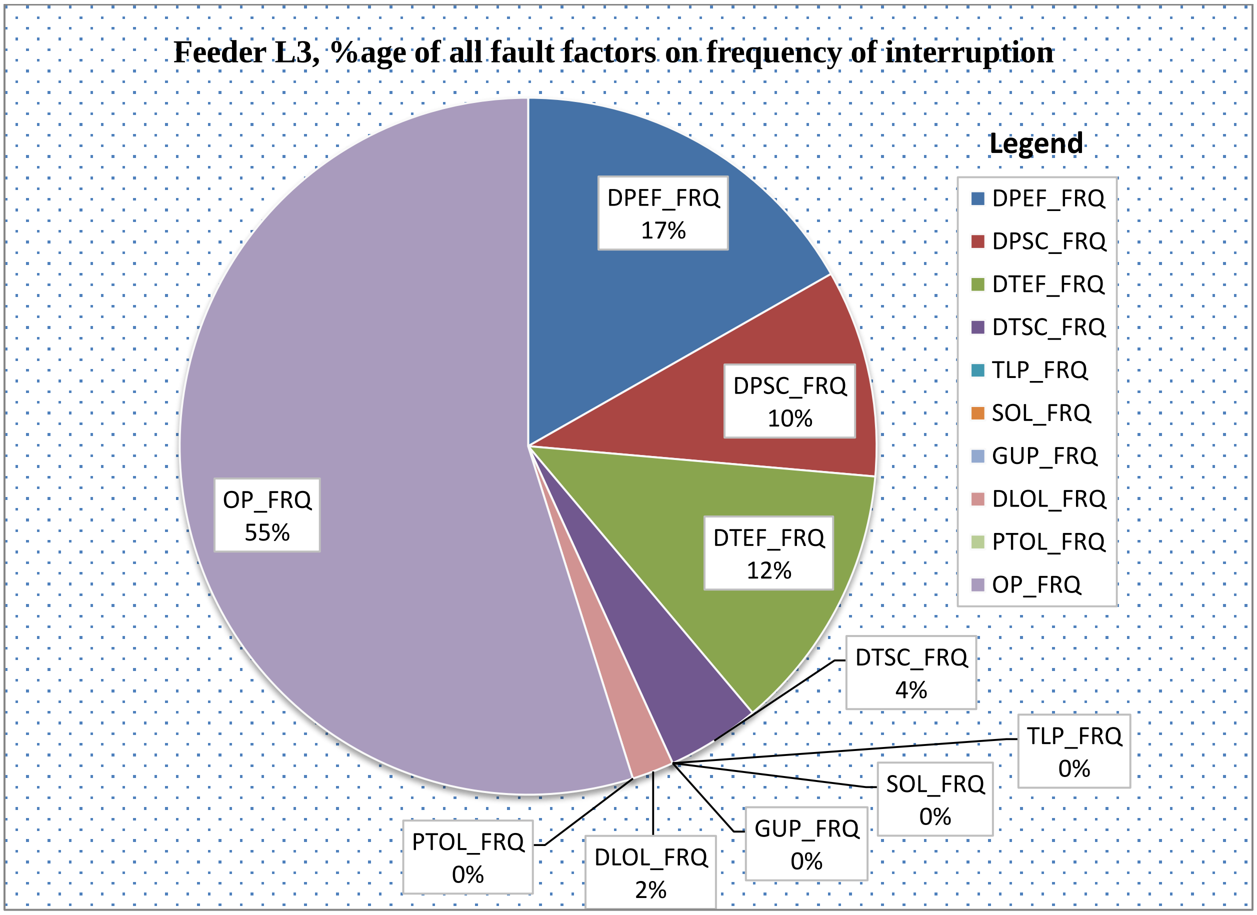

Figure 5.13: Feeder L3 percentage of all fault factors on frequency of interruption

The pie chart shows, 55% of the interruption frequency is due to operation and maintenance problem, 17% is due to permanent earth fault, 10% is due to permanent short circuit, 12% is due to temporary earth fault, 4% is due to temporary short circuit and the remaining faults recorded 0% on distribution L3. In this line the most outstanding or significant fault factors that create frequent power interruption are ranked as below.

Table 5.22: Percentage and rank of fault factors on feeder L3

Feeder line	DPEF		DPSC		DTEF		DTSC		DLOL		OP		Others
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	
L3	2	17	4	10	3	12	5	4	6	2	1	55	0

3. Effect of all fault factors on power interruption on feeder L4 from 2009 up to 2011(EC) years

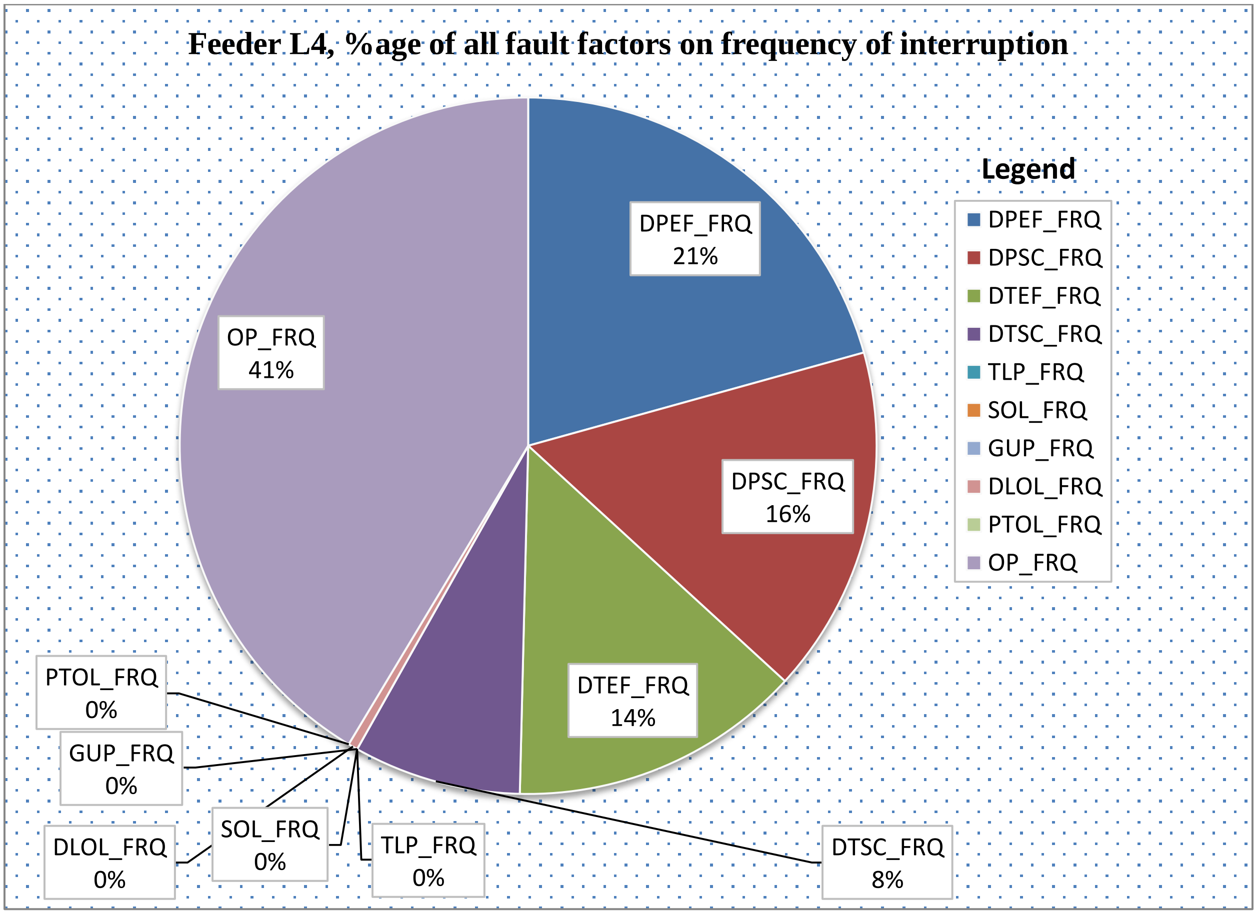

Figure 5.14: Feeder L4 percentage of all fault factors on frequency of interruption

The pie chart shows, 41% of the interruption frequency is due to operation and maintenance problem, 21% is due to permanent earth fault, 16% is due to permanent short circuit, 14% is due to temporary earth fault, 8% is due to temporary short circuit and the remaining faults recorded 0% on distribution L4. In this line the most outstanding or significant fault factors that create frequent power interruption are ranked as below.

Table 5.23: Percentage and rank of fault factors on feeder L4

Feeder line	DPEF		DPSC		DTEF		DTSC		OP		Others
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	
L4	2	21	3	16	4	14	5	8	1	41	0

4. Effect of all fault factors on power interruption on feeder L5 from 2009 up to 2011(EC) years

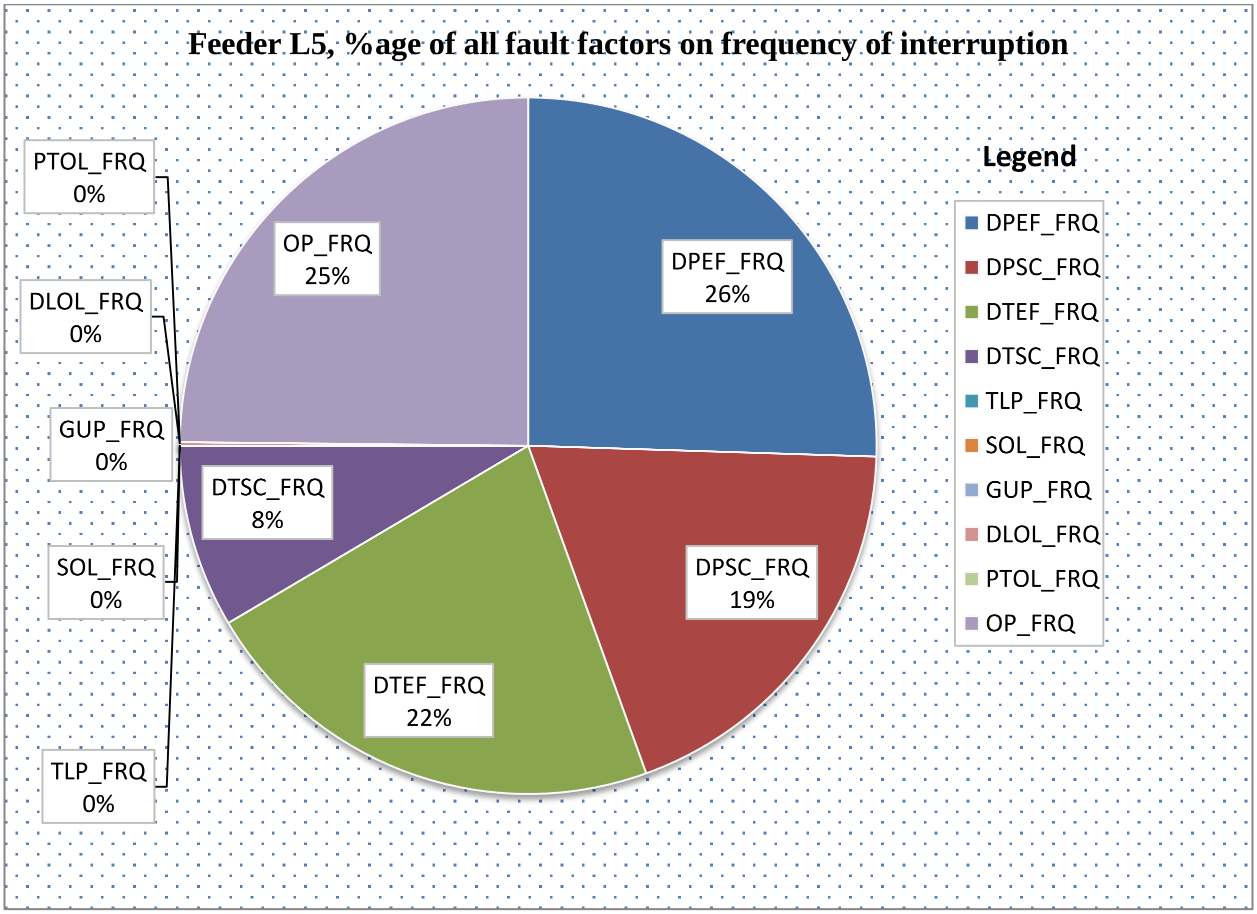

Figure 5.15: Feeder L5 percentage of all fault factors on frequency of interruption

The result in the pie chart shows, 25% of the interruption frequency is due to operation and maintenance problem, 26% is due to permanent earth fault, 19% is due to permanent short circuit, 22% is due to temporary earth fault, 8% is due to temporary short circuit and the remaining faults recorded 0% on distribution L5. In this line the most outstanding or significant fault factors that create frequent power interruption are ranked as below.

Table 5.24: Percentage and rank of fault factors on feeder L5

Feeder line	DPEF		DPSC		DTEF		DTSC		OP		Others
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	0
L5	1	26	4	19	3	22	5	8	2	25	

5. Effect of all fault factors on power interruption on feeder L6 from 2009 up to 2011(EC) years

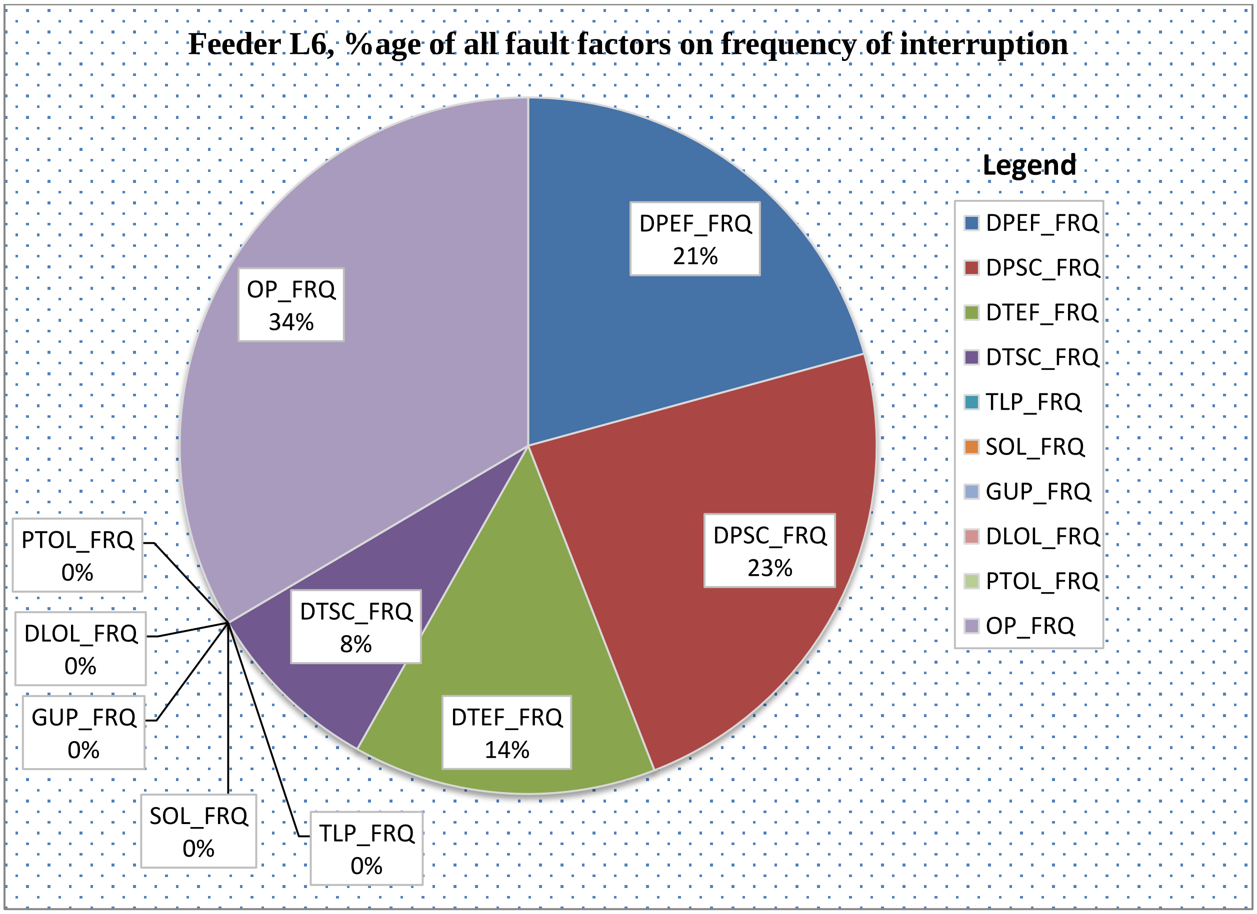

Figure 5.16: Feeder L6 percentage of all fault factors on frequency of interruption

The result in the pie chart shows, 34% of the interruption frequency is due to operation and maintenance problem, 21% is due to permanent earth fault, 23% is due to permanent short circuit, 14% is due to temporary earth fault, 8% is due to temporary short circuit and the remaining faults recorded 0% on distribution L6. In this line the most outstanding or significant fault factors that create frequent power interruption are ranked as below.

Table 5.25: Percentage and rank of fault factors on feeder L6

Feeder line	DPEF		DPSC		DTEF		DTSC		OP		Others
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	0
L6	3	21	2	23	4	14	5	8	1	34	

6. Effect of all fault factors on power interruption on feeder L7 from 2009 up to 2011(EC) years

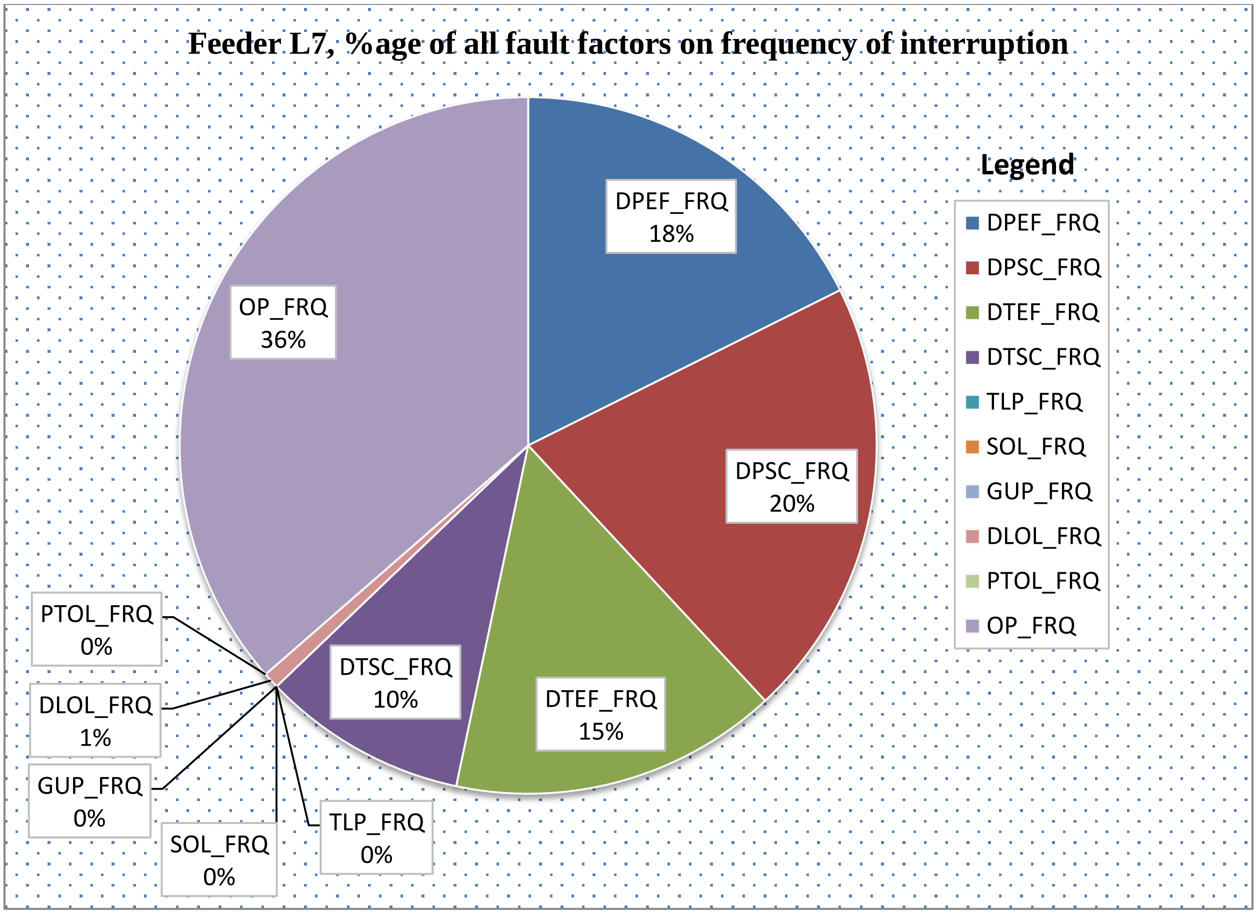

Figure 5.17: Feeder L7 percentage of all fault factors on frequency of interruption

The result in the pie chart shows, 34% of the interruption frequency is due to operation and maintenance problem, 21% is due to permanent earth fault, 23% is due to permanent short circuit, 14% is due to temporary earth fault, 8% is due to temporary short circuit and the remaining faults recorded 0% on distribution L7. In this line the most outstanding or significant fault factors that create frequent power interruption are ranked as below.

Table 5.26: Percentage and rank of fault factors on feeder L7

Feeder line	DPEF		DPSC		DTEF		DTSC		DLOL		OP		Others
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	0
L7	3	18	2	20	4	15	5	10	6	1	1	36	

7. Effect of all fault factors on power interruption on feeder M1 from 2009 up to 2011(EC) years

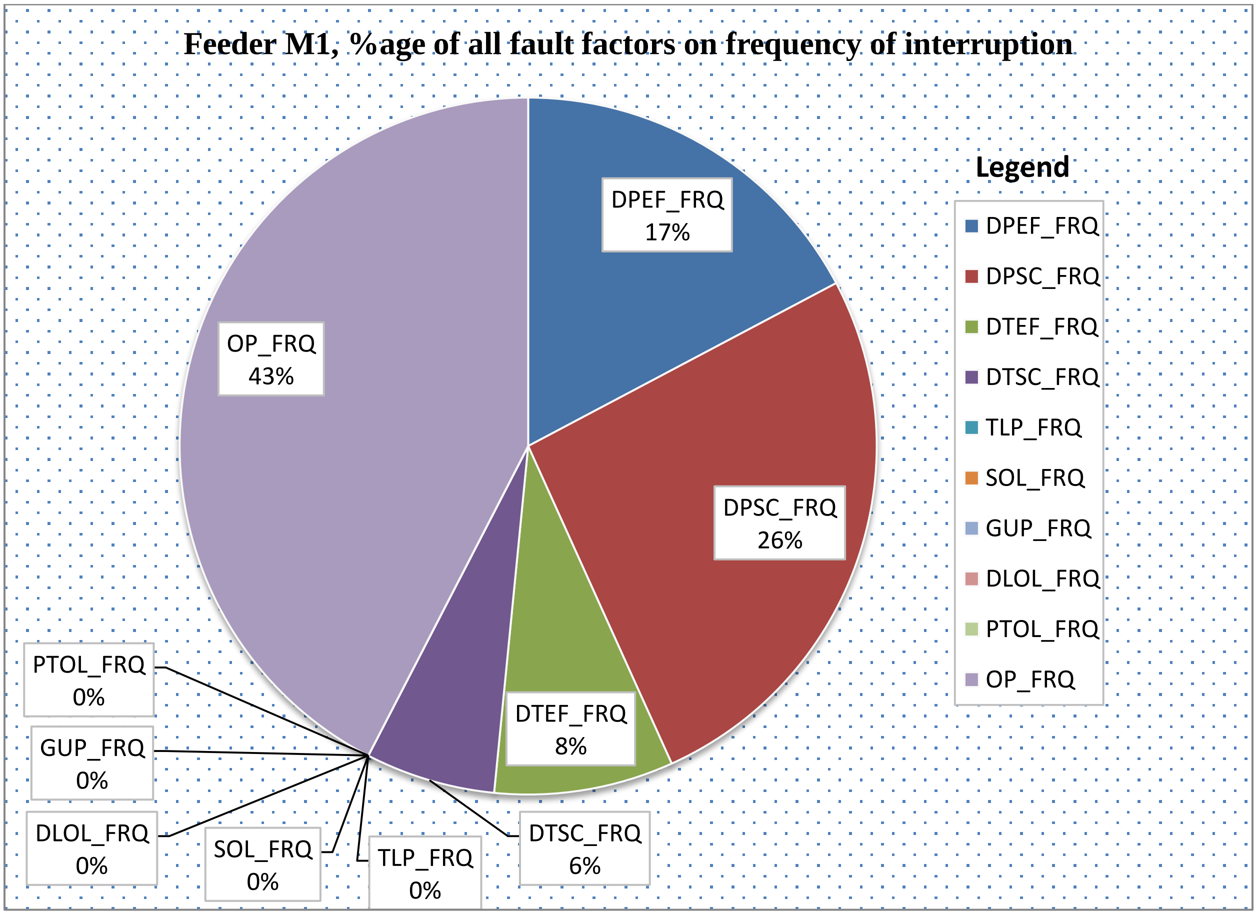

Figure 5.18: Feeder M1 percentage of all fault factors on frequency of interruption

The pie chart shows, 43% of the interruption frequency is due to operation and maintenance problem, 17% is due to permanent earth fault, 26% is due to permanent short circuit, 8% is due to temporary earth fault, 6% is due to temporary short circuit and the remaining faults recorded 0% on distribution M1. In this line the most outstanding or significant fault factors that create frequent power interruption are ranked as below.

Table 5.27: Percentage and rank of fault factors on feeder M1

Feeder line	DPEF		DPSC		DTEF		DTSC		OP		Others
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	0
M1	3	17	2	26	4	8	5	6	1	43	

8. Effect of all fault factors on power interruption on feeder M2 from 2009 up to 2011(EC) years

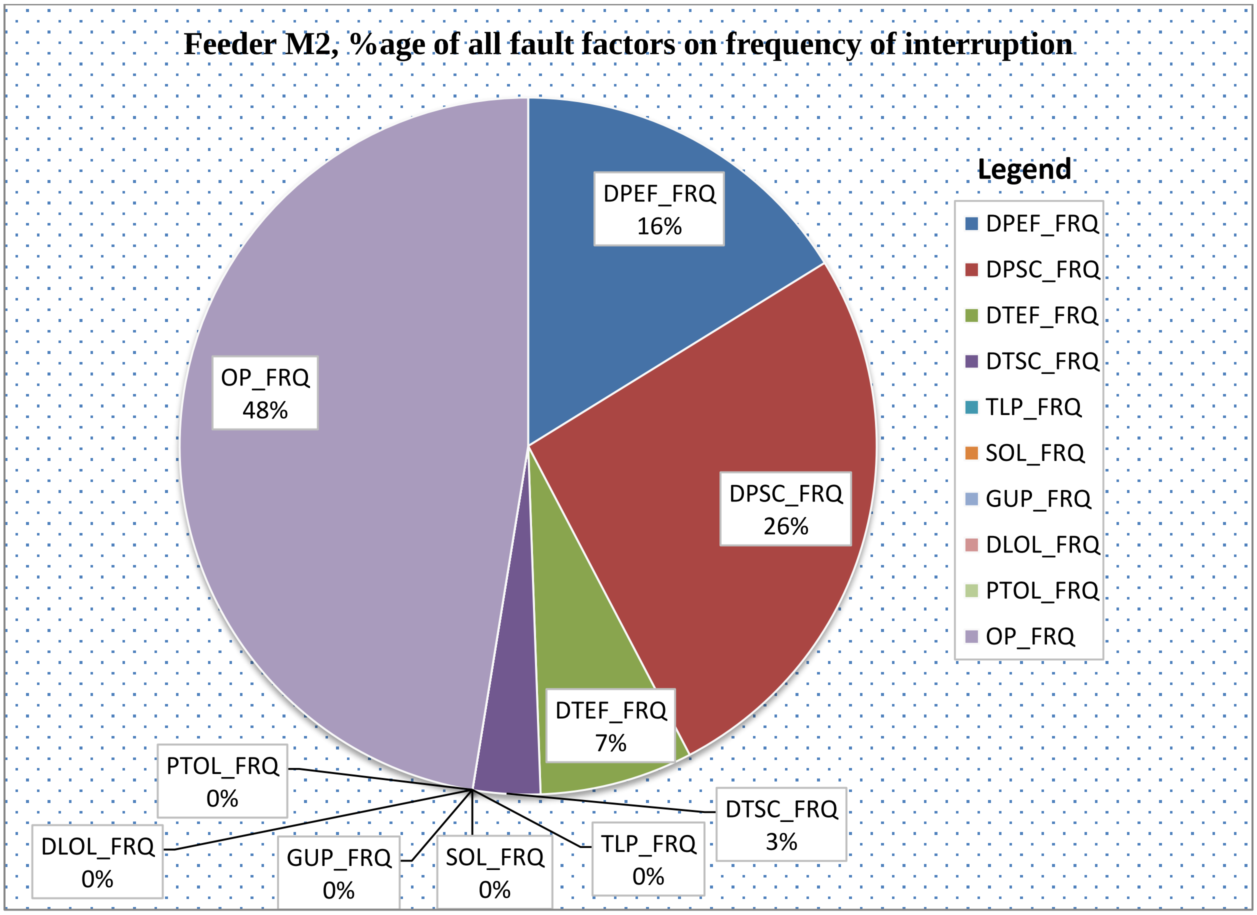

Figure 5.19: Feeder M2 percentage of all fault factors on frequency of interruption

The pie chart shows, 48% of the interruption frequency is due to operation and maintenance problem, 16% is due to permanent earth fault, 26% is due to permanent short circuit, 7% is due to temporary earth fault, 3% is due to temporary short circuit and the remaining faults recorded 0% on distribution M2. In this line the most outstanding or significant fault factors that create frequent power interruption are ranked as below.

Table 5.28: Percentage and rank of fault factors on feeder M2

Feeder line	DPEF		DPSC		DTEF		DTSC		OP		Others
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	0
M2	3	16	2	26	4	7	5	3	1	48	

9. Effect of all fault factors on power interruption on feeder M3 from 2009 up to 2011(EC) years

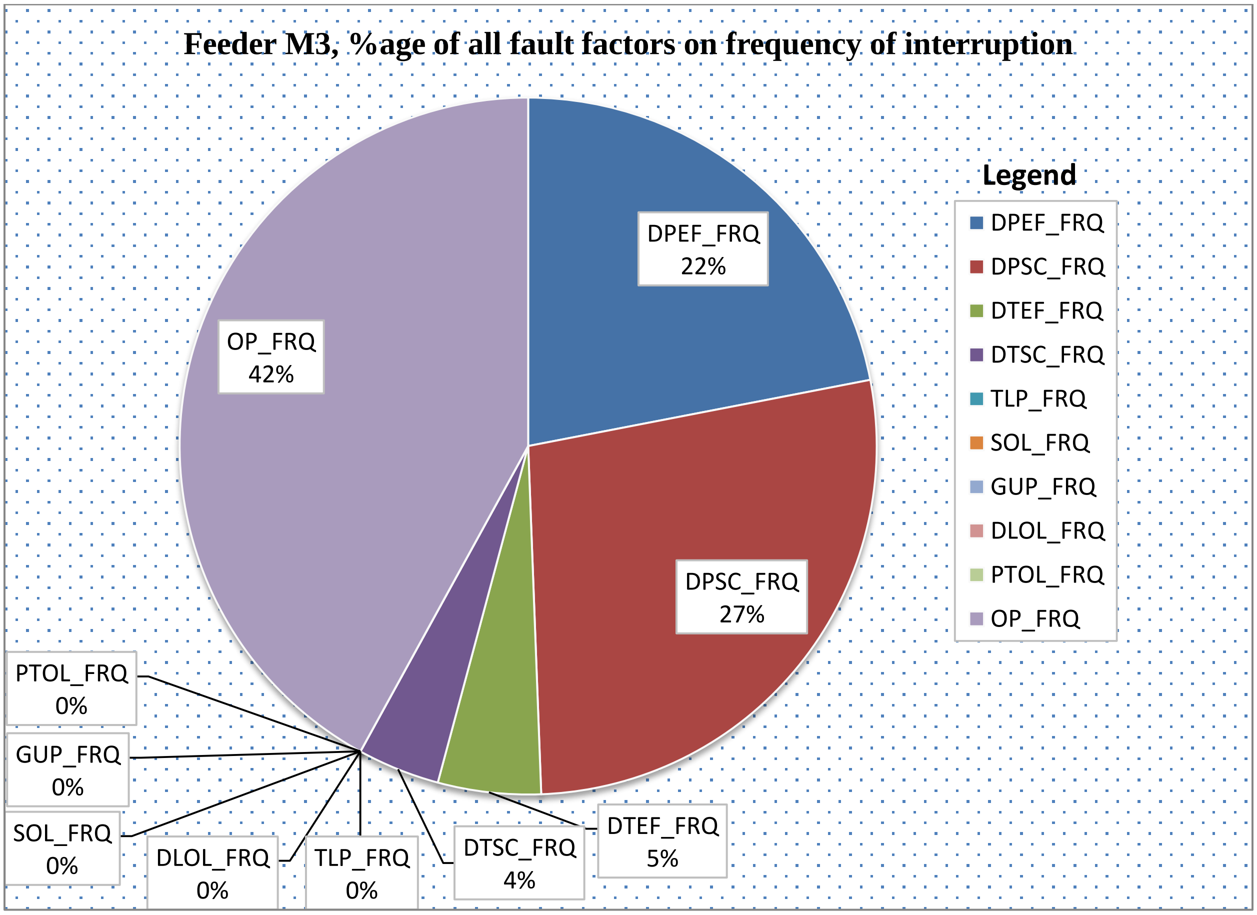

Figure 5.20: Feeder M3 percentage of all fault factors on frequency of interruption

The pie chart shows, 42% of the interruption frequency is due to operation and maintenance problem, 22% is due to permanent earth fault, 27% is due to permanent short circuit, 5% is due to temporary earth fault, 4% is due to temporary short circuit and the remaining faults recorded 0% on distribution M3. In this line the most outstanding or significant fault factors that create frequent power interruption are ranked as below.

Table 5.29: Percentage and rank of fault factors on feeder M3

Feeder line	DPEF		DPSC		DTEF		DTSC		OP		Others
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	0
M3	3	22	2	27	4	5	5	4	1	42	

10. Effect of all fault factors on power interruption on feeder M4 from 2009 up to 2011(EC) years

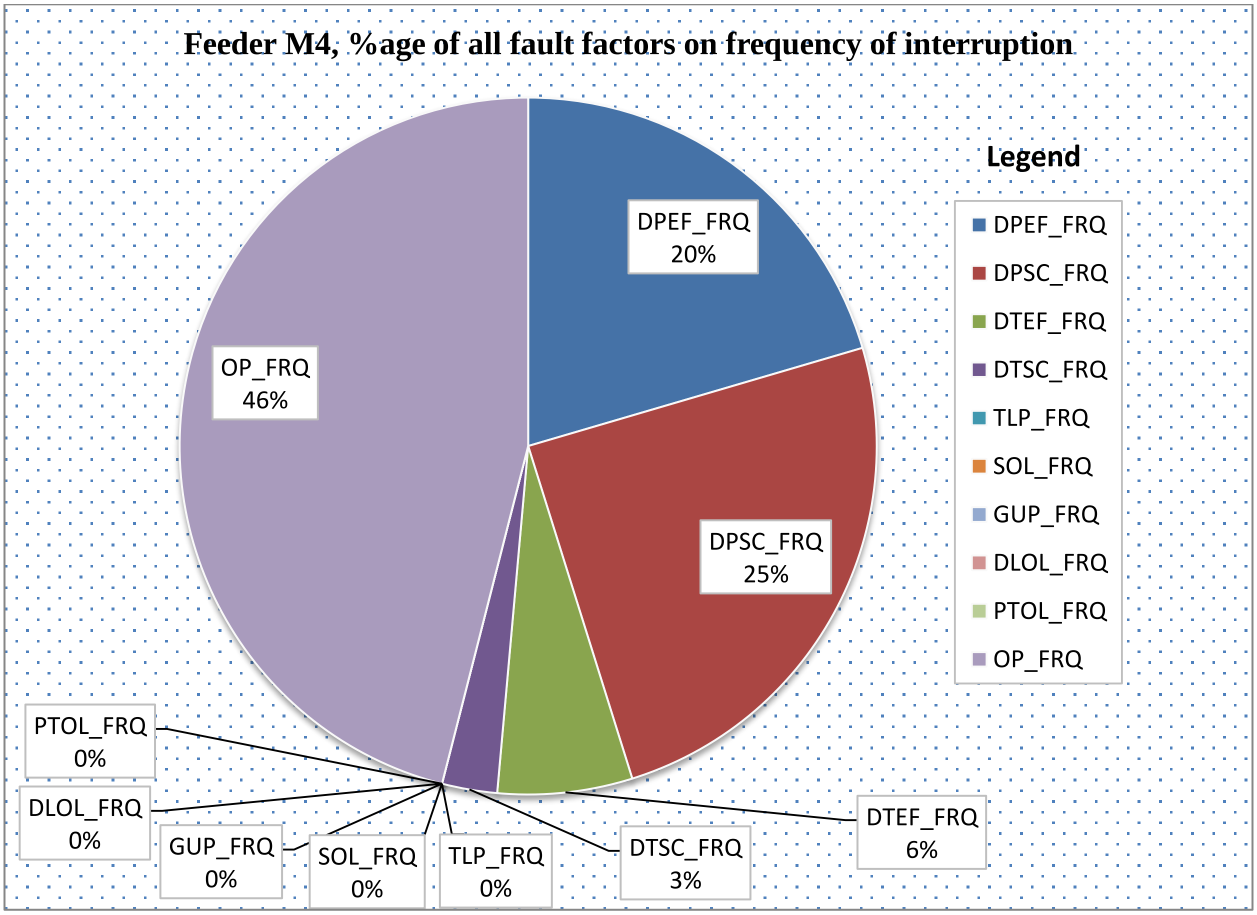

Figure 5.21: Feeder M4 percentage of all fault factors on frequency of interruption

The pie chart shows, 46% of the interruption frequency is due to operation and maintenance problem, 20% is due to permanent earth fault, 25% is due to permanent short circuit, 6% is due to temporary earth fault, 3% is due to temporary short circuit and the remaining faults recorded 0% on distribution M4. In this line the most outstanding or significant fault factors that create frequent power interruption are ranked as below.

Table 5.30: Percentage and rank of fault factors on feeder M4

Feeder line	DPEF		DPSC		DTEF		DTSC		OP		Others
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	
M4	3	20	2	25	4	6	5	3	1	46	0

11. Effect of all fault factors on power interruption on feeder M5 from 2009 up to 2011(EC) years

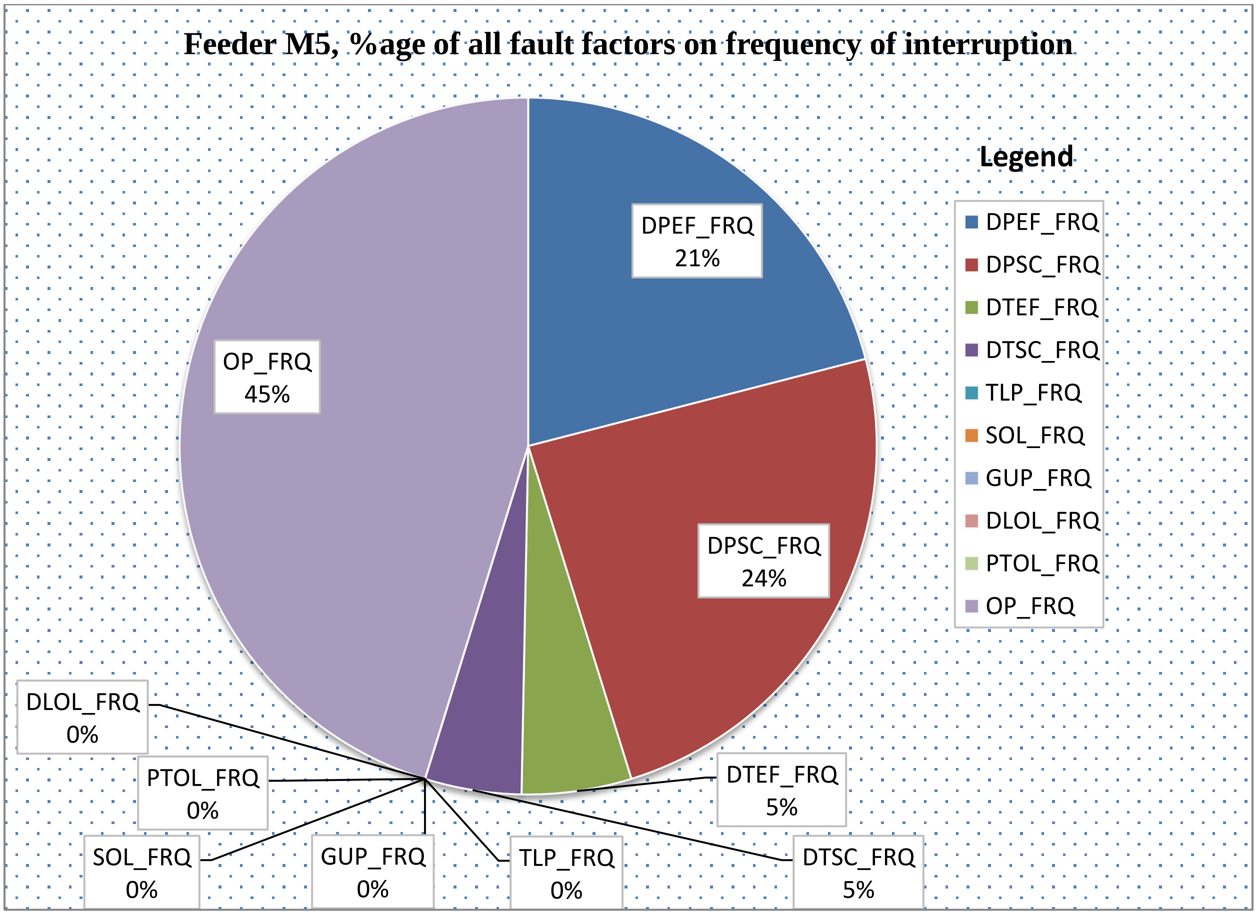

Figure 5.22: Feeder M5 percentage of all fault factors on frequency of interruption

The pie chart shows, 45% of the interruption frequency is due to operation and maintenance problem, 21% is due to permanent earth fault, 24% is due to permanent short circuit, 5% is due to temporary earth fault, 5% is due to temporary short circuit and the remaining faults recorded 0% on distribution M5. In this line the most outstanding or significant fault factors that create frequent power interruption are ranked as below.

Table 5.31: Percentage and rank of fault factors on feeder M5

Feeder line	DPEF		DPSC		DTEF		DTSC		OP		Others
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	
M5	3	21	2	24	4	5	4	5	1	45	0

From both analysis method A and B, analysis of total average result for the effect of the ten fault factors on frequency of interruption in the system has been summarized below table 5.32. The total average result in the table discovers or identifies the most outstanding fault factors that cause frequent power interruption from the ten factors with mean, percentage and rank values.

Table 5.32: Summary of comparison for total fault factors result of Adama distribution system

Feeder line	DPEF			DPSC			DTEF			DTSC			DLOL			OP			Others
	%	Mean	Rank	%	Mean	Rank	%	Mean	Rank	%	Mean	Rank	%	Mean	Rank	%	Mean	Rank	
L1	15	3.4722	3	16	3.7222	2	8	2	4	7	1.6339	5	2	0.6722	6	52	12.25	1	0
L3	17	3.5833	2	10	2.0555	4	12	2.6667	3	4	0.9247	5	2	0.4217	6	55	11.7222	1	0
L4	21	5.1667	2	16	4.0277	3	14	3.3889	4	8	1.9444	5	0	0.1989	6	41	10.3367	1	0
L5	26	4.25	1	19	3.1667	4	22	3.6667	3	8	1.4167	5	0	0.0311	6	25	4.1389	2	0
L6	21	4.833	3	23	5.444	2	14	3.2278	4	8	1.9444	5	0	0	6	34	7.8056	1	0
L7	18	5.25	3	20	6.0833	2	15	4.5278	4	10	2.8333	5	1	0.4461	6	36	10.8333	1	0
M1	17	2.3056	3	26	3.4722	2	8	1.1111	4	6	0.8056	5	0	0	6	43	5.6667	1	0
M2	16	1.5833	3	26	2.5556	2	7	0.6944	4	3	0.3056	5	0	0	6	48	4.6389	1	0
M3	22	2.556	3	27	2.5556	2	5	0.5556	4	4	0.4444	5	0	0	6	42	4.8889	1	0
M4	20	2	3	25	2.4167	2	6	0.6111	4	3	0.25	5	0	0	6	46	4.5	1	0
M5	21	2.861	3	24	3.3056	2	5	0.6944	4	5	0.6111	4	0	0	6	45	6.1667	1	0
Total Average	**19.45**	**3.442**	**3**	**21.09**	**3.5859**	**2**	**10.54**	**2.1085**	**4**	**6**	**1.1926**	**5**	**0.45**	**0.1111**	**6**	**42.45**	**7.541**	**1**	**0**

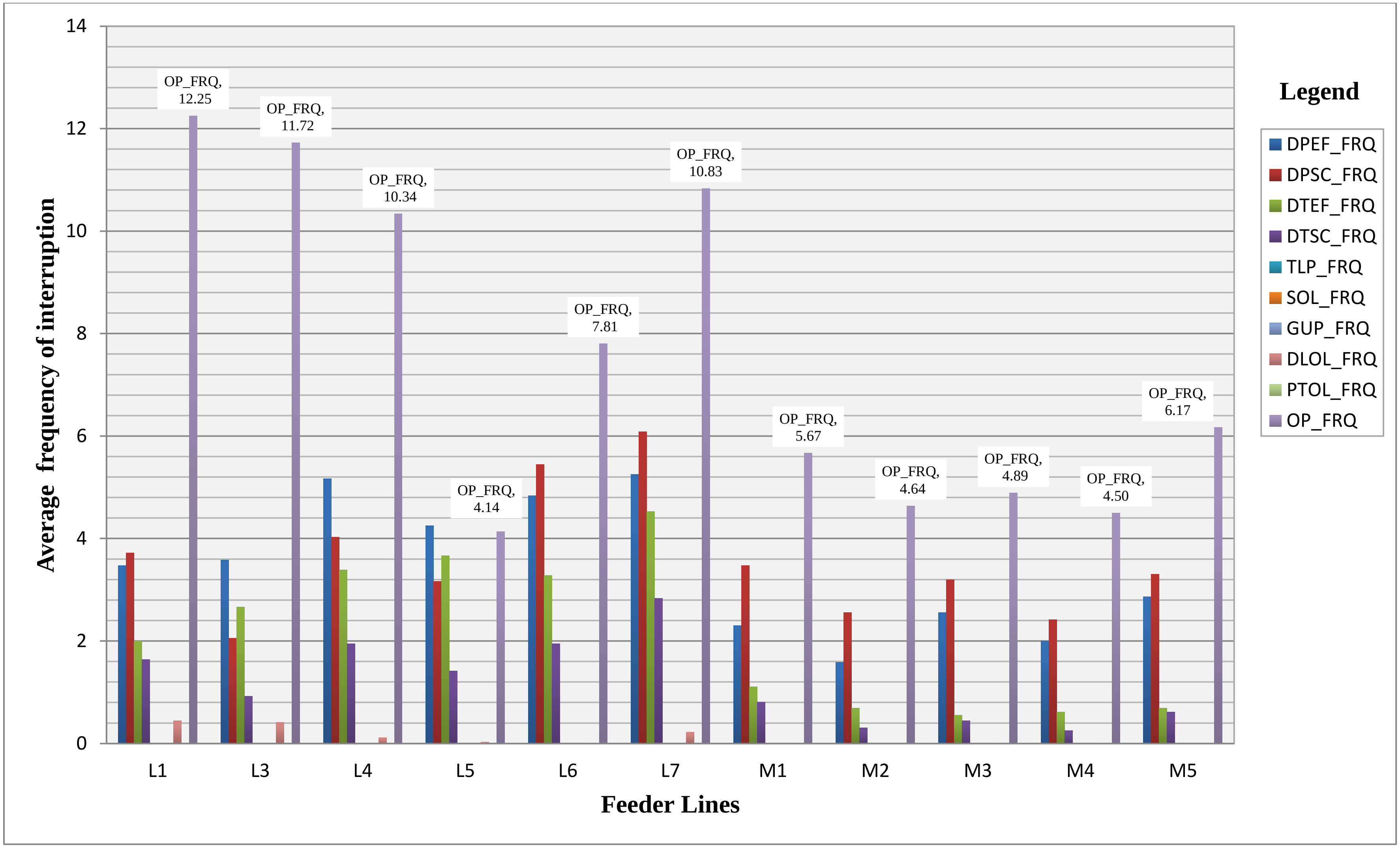

Figure 5.23: Summery of all fault factors on frequency of interruption on all feeder lines

The effect of the ten fault factors that makes frequent power interruption in Adama substation has been summarized in the above table 5.32. Therefore, based on the final comparison result in the table, planned intentional operation problem (OP) is the 1st most outstanding (significant) fault factor that causes frequent power interruption with 42.45% of the overall disturbances in Adama Town substation. Unplanned interruptions which is distribution permanent short circuit (DPSC) is the 2nd most significant fault factor that causes frequent power interruption in the station with 21.09% of the overall disturbances. The 3rd most outstanding fault factor that causes power interruption is distribution permanent earth fault (DPEF) with 19.45% of the overall disturbances. These three most significant disturbances (OP + DPSC + DPEF) account for about 82.99% of the frequency of disturbances against customers of the EEU.

Thus, in Adama substation 42.45% of interruptions frequency is caused by planned intentional operation (OP). This shows that the distribution technicians frequently did more maintenance and operational tasks in the system, as well as takes more time to locate a fault occurred during maintenance because there is no any an automatic fault locating mechanism or technology in distribution system.

A 21.09% of interruption is caused by abnormal connection of relatively low impedance whether made accidentally or intentionally between two live lines of different potential. This indicates that most of the live conductors in distribution system (service main) affected by short circuit which is result from inadequate clearance and poor insulation between conductors, old equipment, trees branches falling onto a line, wind, car accident, animals, birds and bad environmental or other conditions.

A 19.45% of interruption is caused by earth fault which is created by an accidental fault between the live conductor and the earth or neutral due to wire cut, transformer fault or tree falling onto a line. This fault was happened when the electrical system gets short-circuited and the short-circuited current flows through the system, then the fault current returns through the earth or any electrical equipment, which damages the equipment. This shows that the station has to use an upgraded automatic earth fault locating and protecting system in the distribution system.

This indicates that operational, permanent short circuit and permanent earth failure need to be taken as risks and these risks need to be addressed in calculated manner to solve the power interruption problem of the Adama city grid.

Figure 5.23 summarizes that, all feeder lines are facing power interruption problem more due to OP+DPSC+DPEF fault factor and feeder L1, L7 L3, and L4 are the main feeders experiencing much more frequent power interruption problem due to OP fault factors with high rank respectively. So, it is better to locate an automatic fault locating mechanism in distribution system at these feeders to locate or identify any fault as quickly as possible for immediate maintenances.

Field personnel can be trained to spot pole structures where faults have occurred or might likely occur. Common structural deficiencies include poor jumper clearances, poor jumper cables used as fuses; old equipment such as expulsion arresters; bushings or other equipment unprotected against animals, ground leads or grounded guys near phase conductors; poor clearances with polymer arresters; damaged insulators; damaged covered wire; and dangerous trees or branches present.

When attempting to improve reliability, it is important to know the greatest contributing factors to these indices. However, predictive root cause analysis is different than historical root cause analysis which typically identifies the physical cause of faults where predictive root cause analysis computes each components contribution to reliability improvement. The cause of outage also depends on geographical locations of the area. This is a very important research that found the most outstanding fault factor that causes frequent power interruption at Adama city grid power distribution and further assessed the gaps that exist in the EEU as utility provider. Therefore, from the result of fault factors that cause frequent power interruption in Adama substation, the EEU requires assessment of the whole power interruption risk identification system of the EEU.

5.3 Questioner Respondent Analysis

Major sources for cause of fault factors

In Adama substation, data for frequency and duration of interruption are recorded but data for major root sources for causes of fault factors that creates power interruption in the system did not recorded at all. Therefore, it is critical knowing and recording data of root sources for the causes of interruptions. To know the sources for causes of interruptions discussions and questioners were prepared to the employees and longtime daily workers.

The questioner was prepared to describe the common root causes of interruptions in the feeder for the last three years. After selected the causes of interruptions the experienced employees have been requested in order to categorize the causes according to the degree of contribution. It was very difficult to categorize the causes, at the end of the discussion respondents decided to put their agreement level. For the purpose of determining the degree of contribution of each fault factor the point is assigned for the agreement level from one up to five points. The allocation of the point is 5 for strongly agree, 4 for agree, 3 for neutral, 2 for disagree and 1 for strongly disagree. Accordingly table was prepared and employees (i.e. emergency operators, distribution technicians and engineers, customer center technicians, some distribution supervisors worked in the distribution) and experienced daily laborers have given their response. So based on their response as shown in Table 5.33, the root causes are ranked according with their respond values in the questioner. The root causes ranked at the top have a high degree of contribution for the electric power interruptions. From the questioner and discussion with the senior technicians, emergency operators, supervisor and experienced laborers, the most common sources for causes of interruptions are: trees, windy, vehicles accidents, animals, planed intentional interruptions, human error, equipment malfunction, customers transformer overload, poor conductor insulation, equipment ageing, improper jumper cable used as fuse, unknown causes of interruptions and others. An effective maintenance program should aim to minimize these effects.

Tree

As per the discussion with line technicians, trees are identified as root cause of fault factors that creates power interruption. They may fall on power lines regardless of weather conditions and in some cases may destroy a span of lines and tear down supporting structures. Tree trimming, periodically cutting adjacent to power lines to ensure safe and reliable clearances, is a critical utility activity. Many customers have extremely negative responses to tree trimming. Tree trimming should always be performed by a trained crew to ensure safety, maintain tree health and direct re-growth away from conductor location. But in Adama area trimming is performed by the community and it is not done as per standard. EEU has to making routine tree and vegetation maintenance on regular cycles to minimize the possible future interruptions.

Wind, Vehicles and Animals

Usually Adama is a windy Town, thus mostly strong winds swing sagged power lines together and trigger a short circuit. Winds also blow tree limbs or entire trees onto power lines. Severe winds can destroy extensive sections of lines and utility poles. This is a problem in Adama distribution system. A sagged 15kV overhead distribution lines get moved due to wind and the sagged distribution line may be easily reached with trucks. Traffic accidents involving utility poles are a common cause of power outages. Poles may be severely damaged, causing power lines to touch objects or collapse. Vehicles loaded with height above the line clearance also causes conductors to damage, to swing together and poles to knock over. Therefore, to protect this, EEU has to use some danger signs to show there is an electrical power.

Animals periodically cause power outages by climbing onto or inside energized equipment. They can cause a short circuit that interrupts the flow of power to customers. The switching stations have to be protected from animals.

Planed Intentional Interruptions

It is sometimes necessary to interrupt customer service when performing work on radial distribution systems. Since this work is scheduled in advance, customers can be notified as to the time and expected duration of the interruption. Certain types of distribution maintenance require equipment to be de-energized and grounded. During maintenance, all customers downstream of the maintenance location will experience interruptions unless they can be fed from an alternate path. Even if the system can be reconfigured to restore certain customers, short interruptions may be necessary since many switches can only be switched while de-energized. Even if all switches are capable of making and breaking load, operating the system as a temporary network may be unacceptable and customer interruptions may be required. Feeder expansions also require scheduled interruptions. Since the expansion location must be de-energized before a feeder extension can be connected, all customers downstream of this point (on the original feeder) may need to be interrupted. The use of live-line construction techniques can avoid these types of interruptions

Human Error

Mistakes, carelessness and inexperienced works (Daily labors and junior technicians) by utility workers often result in customer interruptions. The utility workers who have informal relationship with some factory interrupt the line when they need. Carelessly cut down of trees and dropping heavy branch over power distribution lines causes long time power interruptions. Another contributing factor for electricity interruptions in Adama is theft of electric energy by peoples who are working privately (such as welding house, metal work house and others) which continues to pose serious problem in Adama energy sector. These illegal connections may cause overload on customer transformers and even insufficient supply as supply becomes smaller than the demand. These practices often lead to huge revenue loss to EEU which affects effective delivery of electricity. When there is less income, services become worse and customers experience more interruptions in power supply. EEU has to install some un-theft technology or controlling system to protect this problem.

Usage of Equipment and Devices

Equipment used in electrical power distribution system must be installed depending on their name plate or their manufacturing policy. Manufacturers set the operating conditions like temperature, voltage and current level and medium of cooling and arc extinguishing. In this study, some customer transformers are found to be over loaded due to many customers being installed on a single transformer covering wide area and HRC fuses being installed beyond the rating of the transformer and improper jumper cables used as fuse. This over loading is mainly due to the improvement of the living standard of the customers. Improper jumper cables used as drop out fuse, feeder line output and customer transformer output mostly creates power interruption in the substation. Equipment ageing leads to equipment malfunction, poor conductor insulation, poor infrastructures contributes to either low productivity or technical and non-technical losses of electricity. These technical and non-technical breakdowns lead to power interruption within the country.

From interview and questioner respondent analysis, the major root causes of fault factors that create frequent power interruption in the system is being evaluated by giving a points from one up to five agreement level and shown in Table 5.33.

Table 5.33: Evaluation of questionnaires on root causes of fault factors for power interruption

No.	Root causes of fault factors on power interruption	Agreement levels					Total result	Rank
		Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**		
1	Windy condition	20	4	0	1	0	118	2
2	Tree contact	15	8	3	0	0	116	3
3	Human Error	8	7	5	0	0	83	8
4	Usage of Equipment and Devices	16	3	2	0	0	98	7
5	Planed Intentional Interruptions	20	3	2	1	0	120	1
6	Vehicles accidents	3	4	6	8	3	68	9
7	Animals and birds	2	5	15	2	0	79	10
8	Unknown and others	12	8	3	3	0	107	6
9	Preventive maintenance	15	7	4	0	0	115	4
10	Other Natural phenomena	16	5	4	0	0	112	5

From the evaluation of questioner total result, summery of root causes for fault factors on power interruption has been illustrated in figure 5.24.

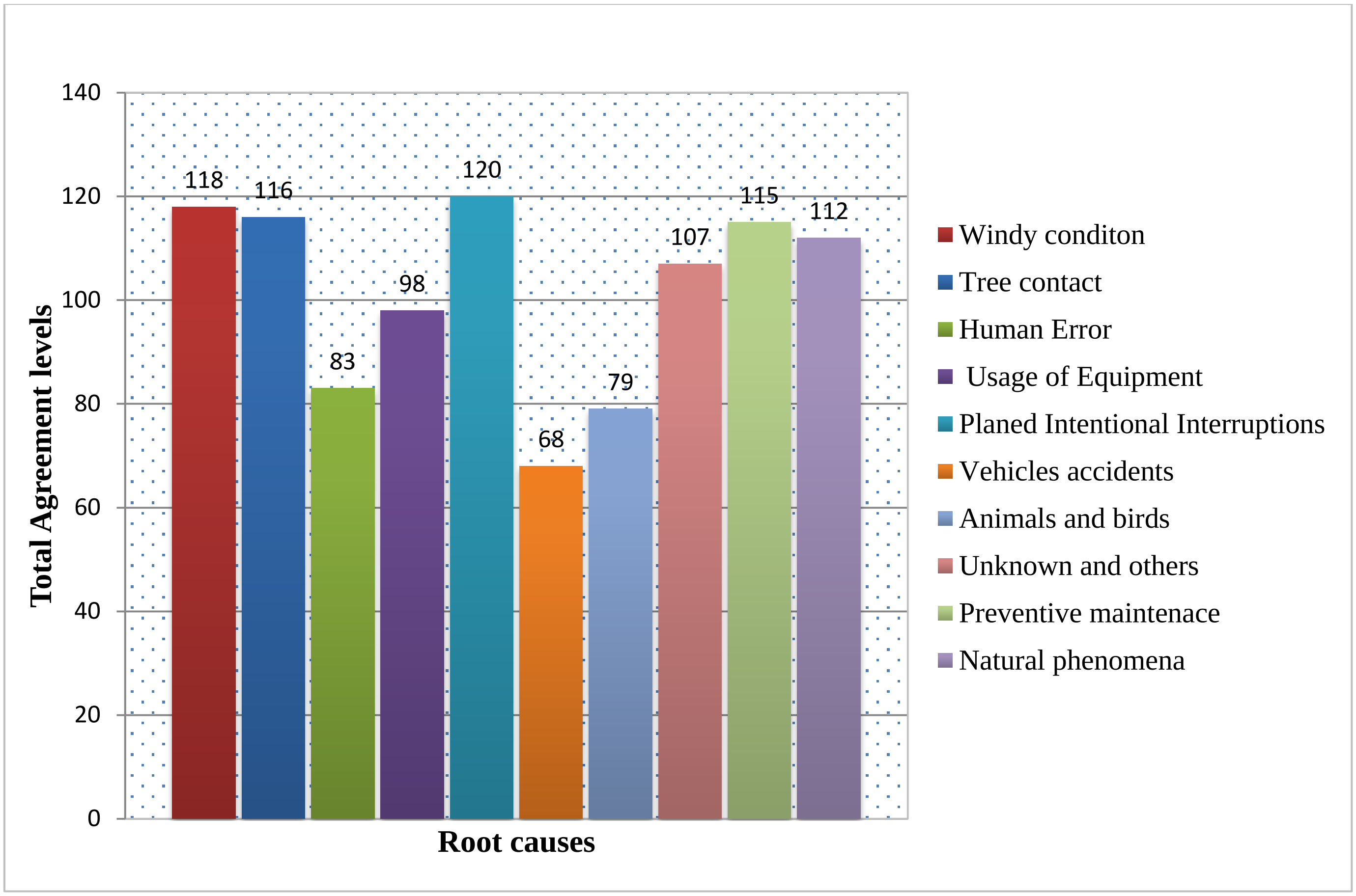

Figure 5.24: Summery of root causes for fault factors on power interruption

From the above figure it is understood that the maximum number of faults are caused mainly due to planed intentional interruption, wind, vegetation and preventive maintenance which needs to be mitigated to improve the reliability in the system. We can see from the figure that there are number of outages which could have been easily mitigated by creating organized maintenance plan and awareness among the public regarding vegetation as well as safety precautions on electricity to various consumers, so could take preventive measure to avoid damage to electric lines and equipment, thus reducing interruptions.

Furthermore, many reasons for maintenance of the outage durations were observed. Some of them are: lack of automatic fault detectors, shortage of maintenance tools, shortage of protective devices like dropout fuse, transformer fuse, automatic sectionalizer, communication gap between substation operators and distribution workers, unnecessary scheduled outages.

CHAPTER SIX

Conclusion and Recommendation

Based on the results obtained from the frequency of interruption data analysis and evaluation of Adama power distribution system on all feeder lines with the ten fault factors, the following conclusions and recommendation have been made and the possible future works are proposed.

6.1 Conclusion

This thesis work was conducted in Adama Town distribution system, in which frequent power interruption is the main reliability problem for power quality in the distribution system. Analysis on identification of the most outstanding fault factors that made power interruption and the root source for cause of this fault factors have been studied. The Study is carried out on the eleven 15kV distribution feeder lines and on the ten fault factors that made power interruption to assess the performance of the present system and also to recommend predictive reliability analysis for the future. The interruption data of years 2009-2011(EC) has been used as a base years.

Based on interruption frequency data of the base years analysis and the questionnaire about the root sources for causes of fault factors that made power interruptions, it can be seen that City feeder lines experienced highest number of outages by OP with 42.45%, DPSC with 21.09% and DPEF with 19.45% fault factors of the overall disturbances, and the outages root sources are mainly Planed intentional interruptions, windy condition, tree contact, usage of improper equipment and devices, and human errors and others. These three most significant disturbances (OP + DPSC + DPEF) that made frequent power interruption in Adama distribution system account for about 82.99% of the frequency of disturbances against customers of the EEU. This indicates that operational, permanent short circuit and permanent earth failure need to be taken as risks and these risks need to be addressed in calculated manner to reduce the power interruption problem of the Adama city grid.

In Adama power distribution system, 42.45% of interruption frequency is caused by planned intentional operation (OP). This shows that the distribution technicians frequently did more maintenance and operational tasks in the system, as well as takes more time to locate a fault occurred during maintenance because there is no any an automatic fault locating or detectors mechanism or technology in distribution system.

There are ten fault factors that cause power interruption, but not all these factors mostly made power interruption in the distribution system. So far, analysis has not been done to determine which fault factor creates frequent power interruption in the distribution system. Thus, this study has tried to show how to analyze and determine the most outstanding fault factors that creates frequent power interruption in the distribution system. Therefore, the outcome of this work can help the utilities for improving reliability in terms of interruption, effective preparation on scheduled preventive maintenance, for proper protective device installation, to minimize maintenance cost, for spare part order, for proper report on causes of power interruption, to manage the causes of power interruption, coping strategies on customers electric power use, to control illegal usage of electric power (electric theft) of the study area, for further research study and others.

In Adama substation, duration and frequency of interruption of each feeder line per hour has been only recorded, but the most frequent fault causes for this interruption were not analyzed, described and identified well for further fault verification. Thus, to put an appropriate mitigation technique for the interruption problem in the case study area, it is critical to know the most significant fault causes of interruptions and this thesis work provide a solution how to determine the most significant fault factor that creates frequent power interruption.

The effect of the ten fault factors on power interruption has been identified on each feeder lines. Effect of single fault factor on all feeder lines by mean value using Main effect plot with Minitab software and effect of all fault factors on single feeder line by %age value using Pei and Column chart with Excel software tools have been analyzed and determined.

Data for major root sources for the causes of fault factors that creates power interruption is not recorded in the station. EEU of Adama district has no modern technology to record and analyze black out data rather they were using the traditional way of recording and analyzing blackout data which could result loss of important data used for further study purpose, so due to this reason, it was difficult to find long time recorded data to investigate the overall properties of blackout. However, it has been tried to investigate the statistical analysis with the available data at hand.

6.2 Recommendation and Future work

In order to achieve better results for predictive reliability analysis, to judge the present performance and to improve the reliability in terms of power interruption in the system the following recommendations are drawn.

- Nowadays automatic fault locating or detectors mechanism are widely used in distribution system for their positive impact on system reliability and power system loss reduction. So, to minimize long time taken by distribution technicians to detect and locate faults in distribution system during maintenance and operational tasks in the system, better to install an automatic fault detecting and locating mechanism in distribution system.
- The recorded interruption data in the distribution system was simply documented in station and not analyzed for further fault identification, instead trying and error fault identification method has been used in the district. So, it is strongly recommend that proper advanced fault analysis mechanism has to be used to identify the most outstanding fault factors that cause frequent power interruption.
- Maintenance has to be done by proper fault factors identification mechanism using the recorded data.
- The data recording has to be made in organized and efficient way, meaning that all individual component failure data, localized fault data, root sources for cause of fault factor data have to be precisely recorded and documented well if future system analysis should represent true state of the system.
- The switching and the sectionalizing time have to be maintained for different locations of switches. Auto re-closure time has to be maintained and enabled to trigger the main circuit breaker automatic operation in the system (Here in this substation Auto re-closure has been disabled in order to maximize the age of the main circuit breaker).
- Data for non-notified and notified outages has to be maintained separately. The reason for outage has to be detailed and precise. The present data recording system has to be changed from manual to computer aided system so that the reliability problems can be identified easily and solutions can be easily suggested as well.

- EEU of Adama district has to build modern technology to record and analyze black out data avoid traditional way of recording and analyzing blackout data which could result loss of important data used for further study purpose.
- Scheduled tree trimming and cutting program has to be made for distribution system reliability enhancement and to minimize the failure rate of overhead lines. Another way to reduce number of vegetation related failure is to replace bare 15kv overhead conductor with insulated conductor, which can have significant negative effect on DPSC and DPEF fault factors.
- Avoid jumper cables, which are used as a fuse at customer transformer output and feeder line output at distribution terminal (gantry). It is strongly recommend that Adama district EEU has to use a correct rated fuse, automatic sectionalisers, auto reclosers, circuit breakers, relays and other protective devices to reduce frequent outage and improve reliability and maintenance operation.
- There are no feeder lines which are separately dedicated for industrial, commercial and residential customers, and this causes a problem on controlling power interruption. So it is better to re-construct (re-configure) a separate feeder lines (gantry) for each customer.

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Appendix: A

Detail Power Interruption Data of year 2009 – 2011(EC)

Code	Feeder _Line	Month	Year	DPEF _DUR	DPEF _FRQ	DPSC _DUR	DPSC _FRQ	DTEF _DUR	DTEF _FRQ	DTSC _DUR	DTSC _FRQ	TLP_ DUR	TLP_ FRQ	SOL_ DUR	SOL_ FRQ	GUP_ DUR	GUP_ FRQ	DLOL _DUR	DLOL _FRQ	PTOL _DUR	PTOL _FRQ	OP_DUR	OP_ FRQ
1	L1	1	2009	3.2	2	4.2	2	5.17	2	2.18	1	0	0	0	0	0	0	0	0	0	0	12.28	5
2	L1	2	2009	7.28	4	17.04	4	4.49	2	3.32	3	0	0	0	0	0	0	0	0	0	0	15.36	6
3	L1	3	2009	4.11	2	11.15	3	8.34	3	4.4	3	0	0	0	0	0	0	0	0	0	0	11.29	4
4	L1	4	2009	0	0	2.3	1	6.05	2	5.11	2	0	0	0	0	0	0	0	0	0	0	4.54	3
5	L1	5	2009	3.3	3	1.5	1	2.33	1	3.56	1	0	0	0	0	0	0	0	0	0	0	6.33	3
6	L1	6	2009	5.58	3	1.5	1	6.15	2	5.05	1	0	0	0	0	0	0	0	0	0	0	4.32	5
7	L1	7	2009	3.23	2	12.05	4	3.42	1	4.22	3	0	0	0	0	0	0	0	0	0	0	11.42	6
8	L1	8	2009	20.31	6	25.01	7	4.52	1	6.29	4	0	0	0	0	0	0	0	0	0	0	10.16	9
9	L1	9	2009	11.03	2	15.35	4	3.23	2	4.07	3	0	0	0	0	0	0	0	0	0	0	40.28	32
10	L1	10	2009	7.03	3	6.12	3	2.01	1	5.28	3	0	0	0	0	0	0	0	0	0	0	21.02	30
11	L1	11	2009	4.42	1	20.36	9	8.03	3	3.54	2	0	0	0	0	0	0	0	0	0	0	37.33	10
12	L1	12	2009	3.02	3	8.2	4	10.02	4	7.47	4	0	0	0	0	0	0	0	0	0	0	17.22	8
13	L1	1	2010	3.56	5	12.11	8	0.01	1	0	0	0	0	0	0	0	0	12.1	8	0	0	3.91	12
14	L1	2	2010	3.56	4	12.11	7	0.01	1	0	0	0	0	0	0	0	0	12.1	8	0	0	3.91	12
15	L1	3	2010	3.5	5	11.23	8	0.5	2	0	0	0	0	0	0	0	0	0	0	0	0	3.45	13
16	L1	4	2010	2.76	4	1.31	2	0.06	1	0.03	1	0	0	0	0	0	0	0	0	0	0	7.35	16
17	L1	5	2010	10.3	7	2.05	3	0	0	0.03	1	0	0	0	0	0	0	0	0	0	0	13.41	27
18	L1	6	2010	6.41	5	0.17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17.08	25
19	L1	7	2010	5	1	4.68	4	0	0	0.13	1	0	0	0	0	0	0	0	0	0	0	36.08	31
20	L1	8	2010	0.05	4	14.15	5	13.73	1	0	0	0	0	0	0	0	0	0	0	0	0	5.63	7
21	L1	9	2010	31.18	16	4.25	3	0.2	2	0	0	0	0	0	0	0	0	0	0	0	0	12	12
22	L1	10	2010	3.5	5	11.23	8	0.5	2	0	0	0	0	0	0	0	0	0	0	0	0	3.45	13
23	L1	11	2010	4.05	4	11.4	7	3.2	1	2.5	2	0	0	0	0	0	0	0	0	0	0	4.12	11
24	L1	12	2010	3.5	5	11.23	8	0.5	2	0.5	2	0	0	0	0	0	0	0	0	0	0	3.45	13
25	L1	1	2011	0	0	2.2	2	0.18	1	0.17	1	0	0	0	0	0	0	0	0	0	0	2.28	3

26	L1	2	2011	20.04	2	6.28	3	1.32	4	0.49	2	0	0	0	0	0	0	0	0	0	0	11.36	5
27	L1	3	2011	1.15	1	5.11	3	1.4	4	1.34	2	0	0	0	0	0	0	0	0	0	0	1.29	4
28	L1	4	2011	0	0	0	0	0.11	1	0	0	0	0	0	0	0	0	0	0	0	0	4.54	6
29	L1	5	2011	0.01	1	4.3	3	0.56	3	0.33	1	0	0	0	0	0	0	0	0	0	0	2.33	3
30	L1	6	2011	1.1	1	2.58	2	0.05	1	0.15	1	0	0	0	0	0	0	0	0	0	0	4.32	5
31	L1	7	2011	11.42	3	2.23	1	1.22	4	2.42	6	0	0	0	0	0	0	0	0	0	0	13.42	13
32	L1	8	2011	30.01	5	19.31	5	0.29	1	0.52	1	0	0	0	0	0	0	0	0	0	0	41.16	18
33	L1	9	2011	13.35	3	10.03	2	2.07	4	1.23	2	0	0	0	0	0	0	0	0	0	0	55.28	28
34	L1	10	2011	4.12	3	8.03	2	1.28	2	0	0	0	0	0	0	0	0	0	0	0	0	213.02	29
35	L1	11	2011	25.36	7	3.42	1	0.54	3	1.03	2	0	0	0	0	0	0	0	0	0	0	67.33	11
36	L1	12	2011	6.2	3	2.02	3	2.47	7	11	4	0	0	0	0	0	0	0	0	0	0	7.22	3
37	L3	1	2009	6.25	3	1.06	1	3.4	4	2.36	2	0	0	0	0	0	0	0	0	0	0	11.2	6
38	L3	2	2009	1.4	1	1.04	1	2.08	1	2.03	1	0	0	0	0	0	0	0	0	0	0	11.04	8
39	L3	3	2009	3.46	1	2.03	2	4.09	3	1.05	1	0	0	0	0	0	0	0	0	0	0	11.3	6
40	L3	4	2009	0	0	1.83	1	1.45	2	0.32	1	0	0	0	0	0	0	0	0	0	0	10.02	5
41	L3	5	2009	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10.23	6
42	L3	6	2009	2	1	0	0	0.54	2	1	1	0	0	0	0	0	0	0	0	0	0	9.01	7
43	L3	7	2009	0	0	0.28	1	1.01	2	0	0	0	0	0	0	0	0	0	0	0	0	17.26	10
44	L3	8	2009	0	0	5.73	3	1.46	6	1	1	0	0	0	0	0	0	0	0	0	0	12.45	9
45	L3	9	2009	1.03	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40.13	26
46	L3	10	2009	0	0	0	0	1.23	3	0.31	1	0	0	0	0	0	0	0	0	0	0	15.4	8
47	L3	11	2009	0	0	5.23	3	1.32	6	0.07	1	0	0	0	0	0	0	0	0	0	0	16.1	9
48	L3	12	2009	7.29	3	0	0	2.38	8	0.18	1	0	0	0	0	0	0	0	0	0	0	0	0
49	L3	1	2010	19.53	8	4.05	2	0.21	3	0	0	0	0	0	0	0	0	7.31	7	0	0	13.35	15
50	L3	2	2010	19.53	8	0	0	0.21	3	0	0	0	0	0	0	0	0	7.31	7	0	0	13.35	15
51	L3	3	2010	19.23	7	0	0	0.34	5	0.13	1	0	0	0	0	0	0	0	0	0	0	13.45	16
52	L3	4	2010	12.73	10	0	0	0.03	1	0	0	0	0	0	0	0	0	0.56	1	0	0	0	0
53	L3	5	2010	12.3	4	0	0	0.2	2	0	0	0	0	0	0	0	0	0	0	0	0	24.43	23
54	L3	6	2010	9.06	9	2.5	2	0	0	0.1	1	0	0	0	0	0	0	0	0	0	0	17.48	28
55	L3	7	2010	5.9	4	1	1	0.08	1	0	0	0	0	0	0	0	0	0	0	0	0	44.09	29
56	L3	8	2010	19.85	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41.9	9

57	L3	9	2010	9.81	6	0	0	0.13	1	0	0	0	0	0	0	0	0	0	0	0	0	7.73	12
58	L3	10	2010	19.23	7	1.26	1	0.34	5	0.13	1	0	0	0	0	0	0	0	0	0	0	13.45	16
59	L3	11	2010	15.23	5	19.06	2	1.34	3	1.5	1	0	0	0	0	0	0	0	0	0	0	10.23	14
60	L3	12	2010	19.23	7	3.01	1	0.34	5	0.13	1	0	0	0	0	0	0	0	0	0	0	13.45	16
61	L3	1	2011	1.4	1	17.07	6	2.11	3	4	3.29	0	0	0	0	0	0	0	0	0	0	6.11	10
62	L3	2	2011	5.54	3	16.56	8	0.4	3	0	0	0	0	0	0	0	0	0	0	0	0	24	10
63	L3	3	2011	0.07	1	9.06	5	2.03	6	0.53	2	0	0	0	0	0	0	0	0	0	0	2.34	5
64	L3	4	2011	1.43	2	3.35	2	0.44	3	0.13	1	0	0	0	0	0	0	0	0	0	0	2	4
65	L3	5	2011	5.32	4	10.21	4	0.5	4	0	0	0	0	0	0	0	0	0	0	0	0	0.22	2
66	L3	6	2011	0	0	3.45	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.02	9
67	L3	7	2011	4.48	10	17.5	7	7.24	3	0.42	2	0	0	0	0	0	0	0	0	0	0	12.06	6
68	L3	8	2011	18.43	6	23.17	4	0.58	2	0	0	0	0	0	0	0	0	0	0	0	0	28.15	11
69	L3	9	2011	12.55	2	5.39	4	0.29	2	3.14	4	0	0	0	0	0	0	0	0	0	0	53.11	27
70	L3	10	2011	9.16	3	3.24	2	0.15	1	0	0	0	0	0	0	0	0	0	0	0	0	212.22	28
71	L3	11	2011	3.16	1	2.17	6	0.15	2	2.02	5	0	0	0	0	0	0	0	0	0	0	68.4	14
72	L3	12	2011	11.17	2	1.02	1	0.2	1	0.63	1	0	0	0	0	0	0	0	0	0	0	1.55	3
73	L4	1	2009	6.2	6	13.51	6	12.36	6	10.03	4	0	0	0	0	0	0	0	0	0	0	17.86	10
74	L4	2	2009	5.3	5	22.51	5	10.36	5	20.03	8	0	0	0	0	0	0	0	0	0	0	27.86	18
75	L4	3	2009	8.1	7	11.4	4	14.34	5	14.03	6	0	0	0	0	0	0	0	0	0	0	16.32	11
76	L4	4	2009	1.04	1	11.58	2	11.04	6	10.04	4	0	0	0	0	0	0	0	0	0	0	10.04	6
77	L4	5	2009	0	0	6.36	1	0	0	11.04	7	0	0	0	0	0	0	0	0	0	0	9.09	10
78	L4	6	2009	9.49	2	20.38	2	9.08	4	5.09	3	0	0	0	0	0	0	0	0	0	0	7.4	7
79	L4	7	2009	8.73	5	8.46	5	8.04	0	10.4	5	0	0	0	0	0	0	0	0	0	0	18.43	9
80	L4	8	2009	32.73	4	27.16	7	0	0	1.04	1	0	0	0	0	0	0	0	0	0	0	4.23	5
81	L4	9	2009	10.11	4	7.56	4	10.23	4	0	0	0	0	0	0	0	0	0	0	0	0	6.9	8
82	L4	10	2009	7.2	7	21.4	4	14.34	5	0.03	1	0	0	0	0	0	0	0	0	0	0	6.32	16
83	L4	11	2009	8.03	5	18.05	3	14.75	6	1.45	1	0	0	0	0	0	0	0	0	0	0	7.32	14
84	L4	12	2009	7.2	7	21.4	4	13.34	7	0.03	1	0	0	0	0	0	0	0	0	0	0	6.32	16
85	L4	1	2010	7.76	12	15.61	3	0.43	7	0.11	1	0	0	0	0	0	0	3.58	2	0	0	11.26	11
86	L4	2	2010	7.76	11	15.61	4	0.43	7	0.11	1	0	0	0	0	0	0	3.58	2	0	0	11.26	11
87	L4	3	2010	6.54	12	15.63	3	0.34	6	0.11	1	0	0	0	0	0	0	0	0	0	0	11.12	11.12

88	L4	4	2010	2.78	5	3.98	5	0.08	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89	L4	5	2010	4.43	10	3.04	4	0.1	1	0	0	0	0	0	0	0	0	0	0	0	0	15.29	20
90	L4	6	2010	13.25	5	1.43	2	0.21	4	0	0	0	0	0	0	0	0	0	0	0	0	17.3	12
91	L4	7	2010	1.98	3	5.65	4	0	0	0.08	1	0	0	0	0	0	0	0	0	0	0	14.46	9
92	L4	8	2010	36.5	12	22.31	11	0.1	2	0	0	0	0	0	0	0	0	0	0	0	0	2.9	4
93	L4	9	2010	17.96	12	7	6	0.18	3	0.16	1	0	0	0	0	0	0	0	0	0	0	9.9	5
94	L4	10	2010	6.54	12	15.63	3	0.34	6	0.11	1	0	0	0	0	0	0	0	0	0	0	11.12	12
95	L4	11	2010	5.01	10	11.45	6	2.3	5	0.89	2	0	0	0	0	0	0	0	0	0	0	11.12	11
96	L4	12	2010	6.54	12	15.63	3	0.34	6	0.11	1	0	0	0	0	0	0	0	0	0	0	11.12	12
97	L4	1	2011	4.35	3	26.4	5	3.13	7	0.17	1	0	0	0	0	0	0	0	0	0	0	2.1	6
98	L4	2	2011	1.1	1	4.44	4	0.34	2	0	0	0	0	0	0	0	0	0	0	0	0	9.23	4
99	L4	3	2011	0	0	3.32	2	0.35	3	1.31	2	0	0	0	0	0	0	0	0	0	0	3.34	6
100	L4	4	2011	0	0	4.14	4	0	0	0.41	3	0	0	0	0	0	0	0	0	0	0	3.16	6
101	L4	5	2011	1.34	1	19.37	4	0	0	0.48	1	0	0	0	0	0	0	0	0	0	0	1.21	1
102	L4	6	2011	0	0	1.4	1	0	0	0.2	2	0	0	0	0	0	0	0	0	0	0	6.27	6
103	L4	7	2011	10.54	2	12.54	2	1.33	4	1.07	3	0	0	0	0	0	0	0	0	0	0	8.54	6
104	L4	8	2011	11.46	3	27	7	1.55	2	3.11	3	0	0	0	0	0	0	0	0	0	0	25.1	13
105	L4	9	2011	0	0	5.17	3	0.41	3	0.4	1	0	0	0	0	0	0	0	0	0	0	61.39	26
106	L4	10	2011	4.59	3	10.36	5	0.35	1	0.3	1	0	0	0	0	0	0	0	0	0	0	223.25	30
107	L4	11	2011	7.26	3	2.41	2	1.01	2	0.57	2	0	0	0	0	0	0	0	0	0	0	70.54	15
108	L4	12	2011	1.17	1	11.13	5	1.04	2	0.45	1	0	0	0	0	0	0	0	0	0	0	3.51	5
109	L5	1	2009	13.55	12	17.26	9	9.56	6	10.15	5	0	0	0	0	0	0	0	0	0	0	11.2	4
110	L5	2	2009	14.55	11	7.26	5	10.56	7	10.15	5	0	0	0	0	0	0	0	0	0	0	12.04	5
111	L5	3	2009	103.44	12	10.13	7	8.45	4	12.03	6	0	0	0	0	0	0	0	0	0	0	10.3	4
112	L5	4	2009	15.05	8	12.9	10	10.15	7	8.04	4	0	0	0	0	0	0	0	0	0	0	5.04	3
113	L5	5	2009	11.32	8	8.34	7	10.13	8	1.14	2	0	0	0	0	0	0	0	0	0	0	6.23	2
114	L5	6	2009	10.12	9	14.54	10	8.24	8	5.07	2	0	0	0	0	0	0	0	0	0	0	0	0
115	L5	7	2009	11.71	7	9.46	6	9.03	8	5.08	2	0	0	0	0	0	0	0	0	0	0	17.26	10
116	L5	8	2009	14.53	8	15.31	9	7.23	2	8.09	3	0	0	0	0	0	0	0	0	0	0	12.45	5
117	L5	9	2009	5.16	6	24.48	12	0	0	10.05	6	0	0	0	0	0	0	0	0	0	0	40.13	24
118	L5	10	2009	3.44	10	8.13	8	10.45	5	12.3	6	0	0	0	0	0	0	0	0	0	0	5.4	2

119	L5	11	2009	4.55	9	9.04	9	13.45	3	2.03	1	0	0	0	0	0	0	0	0	0	0	6.1	2
120	L5	12	2009	3.44	8	8.13	5	10.45	5	10.12	1	0	0	0	0	0	0	0	0	0	0	0	0
121	L5	1	2010	1.28	2	0	0	0.2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
122	L5	2	2010	1.28	2	0	0	0.2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
123	L5	3	2010	1.28	3	0	0	0.2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
124	L5	4	2010	0.86	3	1.83	1	0.88	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	L5	5	2010	0.39	2	0	0	0	0	0	0	0	0	0	0	0	0	1.12	1	0	0	7.52	8
126	L5	6	2010	0.11	1	0	0	0.01	1	0	0	0	0	0	0	0	0	0	0	0	0	7.58	9
127	L5	7	2010	1	1	0.28	1	0.05	2	0	0	0	0	0	0	0	0	0	0	0	0	17.88	12
128	L5	8	2010	23.37	7	5.73	3	0.63	6	0.11	1	0	0	0	0	0	0	0	0	0	0	1.16	1
129	L5	9	2010	2.95	4	0	0	0.35	4	0	0	0	0	0	0	0	0	0	0	0	0	4.01	3
130	L5	10	2010	1.28	3	0	0	0.2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
131	L5	11	2010	2.03	4	5.23	3	0.2	3	0.03	1	0	0	0	0	0	0	0	0	0	0	6.13	4
132	L5	12	2010	1.28	3	0	0	0.2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
133	L5	1	2011	5.25	3	4.05	2	2.4	4	1.36	2	0	0	0	0	0	0	0	0	0	0	1.2	4
134	L5	2	2011	0.4	1	0	0	0.08	2	0	0	0	0	0	0	0	0	0	0	0	0	1.04	2
135	L5	3	2011	1.46	1	0	0	1.09	4	0	0	0	0	0	0	0	0	0	0	0	0	1.3	1
136	L5	4	2011	0	0	0	0	0.45	2	0.32	1	0	0	0	0	0	0	0	0	0	0	0	0
137	L5	5	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.23	1
138	L5	6	2011	2	1	2.5	2	0.54	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
139	L5	7	2011	0	0	1	1	1.01	2	0	0	0	0	0	0	0	0	0	0	0	0	17.26	10
140	L5	8	2011	0	0	0	0	1.46	6	0	0	0	0	0	0	0	0	0	0	0	0	12.45	5
141	L5	9	2011	1.03	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40.13	24
142	L5	10	2011	0	0	1.26	1	1.23	3	0.31	1	0	0	0	0	0	0	0	0	0	0	5.4	2
143	L5	11	2011	0	0	19.06	2	1.32	6	0.07	1	0	0	0	0	0	0	0	0	0	0	6.1	2
144	L5	12	2011	7.29	3	3.01	1	2.38	8	0.18	1	0	0	0	0	0	0	0	0	0	0	0	0
145	L6	1	2009	13.55	10	10.04	5	11.11	7	10.03	4	0	0	0	0	0	0	0	0	0	0	12.81	5
146	L6	2	2009	13.55	12	12.04	6	10.52	5	12.03	4	0	0	0	0	0	0	0	0	0	0	17.02	7
147	L6	3	2009	23.44	14	10.01	5	10.3	8	20.03	8	0	0	0	0	0	0	0	0	0	0	11.54	5
148	L6	4	2009	14.05	8	13.02	7	11.2	8	11.05	6	0	0	0	0	0	0	0	0	0	0	15.33	5
149	L6	5	2009	11.32	12	13.51	5	12.33	9	12.08	5	0	0	0	0	0	0	0	0	0	0	11.56	4

150	L6	6	2009	10.12	11	13.55	5	10.07	8	14.3	5	0	0	0	0	0	0	0	0	0	0	10.5	5
151	L6	7	2009	11.71	12	21.61	10	10.45	7	8.09	6	0	0	0	0	0	0	0	0	0	0	13.31	5
152	L6	8	2009	14.53	5	32.61	18	10.15	6	5.06	4	0	0	0	0	0	0	0	0	0	0	33.02	14
153	L6	9	2009	5.16	4	15.15	19	18.09	11	2.08	1	0	0	0	0	0	0	0	0	0	0	72.07	28
154	L6	10	2009	3.44	8	32.61	21	10.7	5	10.03	5	0	0	0	0	0	0	0	0	0	0	27.26	31
155	L6	11	2009	4.55	6	33.65	28	12.4	6	11.45	8	0	0	0	0	0	0	0	0	0	0	56.33	21
156	L6	12	2009	3.44	5	32.61	15	15.21	8	10.03	6	0	0	0	0	0	0	0	0	0	0	12.21	9
157	L6	1	2010	7.2	7	20.51	5	0.36	4	0.03	1	0	0	0	0	0	0	0	0	0	0	7.86	17
158	L6	2	2010	7.2	7	20.51	5	0.36	4	0.03	1	0	0	0	0	0	0	0	0	0	0	7.86	17
159	L6	3	2010	7.2	7	21.4	4	0.34	3	0.03	1	0	0	0	0	0	0	0	0	0	0	6.32	16
160	L6	4	2010	0	0	4.58	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
161	L6	5	2010	0	0	0.36	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.09	10
162	L6	6	2010	9.49	3	20.38	2	0.08	3	0	0	0	0	0	0	0	0	0	0	0	0	7.4	7
163	L6	7	2010	8.73	6	8.46	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18.43	9
164	L6	8	2010	32.73	8	27.16	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.23	5
165	L6	9	2010	10.11	4	7.56	4	0.23	1	0	0	0	0	0	0	0	0	0	0	0	0	5.9	8
166	L6	10	2010	7.2	7	21.4	4	0.34	3	0.03	1	0	0	0	0	0	0	0	0	0	0	6.32	16
167	L6	11	2010	8.03	5	18.05	3	0.75	4	1.45	2	0	0	0	0	0	0	0	0	0	0	7.32	14
168	L6	12	2010	7.2	7	21.4	4	0.34	3	0.03	1	0	0	0	0	0	0	0	0	0	0	6.32	16
169	L6	1	2011	0	0	2.47	2	0	0	1.06	1	0	0	0	0	0	0	0	0	0	0	0.17	1
170	L6	2	2011	9.54	6	9.56	4	2.26	5	0	0	0	0	0	0	0	0	0	0	0	0	1.56	6
171	L6	3	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
172	L6	4	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
173	L6	5	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
174	L6	6	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
175	L6	7	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176	L6	8	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
177	L6	9	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
178	L6	10	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
179	L6	11	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180	L6	12	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

181	L7	1	2009	13.28	8	32.02	8	11.52	7	11.44	4	0	0	0	0	0	0	0	0	0	0	12.54	4
182	L7	2	2009	10.04	6	15.2	10	10.07	8	10.58	5	0	0	0	0	0	0	0	0	0	0	13.29	5
183	L7	3	2009	5.41	2	10.07	7	10.2	9	11.47	7	0	0	0	0	0	0	0	0	0	0	13.01	6
184	L7	4	2009	8.09	4	12.07	6	10.48	9	11.27	6	0	0	0	0	0	0	0	0	0	0	13.41	4
185	L7	5	2009	10.07	5	14.17	6	10.11	1	12.01	8	0	0	0	0	0	0	0	0	0	0	12.18	5
186	L7	6	2009	11.48	7	17.18	7	10.3	4	10.23	6	0	0	0	0	0	0	0	0	0	0	6.42	4
187	L7	7	2009	10.07	6	13.3	8	11.25	4	11.25	5	0	0	0	0	0	0	0	0	0	0	9.2	5
188	L7	8	2009	11.5	5	1.01	1	10.11	7	11.31	5	0	0	0	0	0	0	0	0	0	0	16.09	8
189	L7	9	2009	8.09	4	19.48	10	10.22	8	10.07	4	0	0	0	0	0	0	0	0	0	0	22.01	19
190	L7	10	2009	12.23	8	11.2	8	12.16	9	11.19	4	0	0	0	0	0	0	0	0	0	0	231.51	21
191	L7	11	2009	22.17	13	32.06	15	0	0	10.88	6	0	0	0	0	0	0	0	0	0	0	62.22	11
192	L7	12	2009	16.52	12	35.24	16	18.07	11	10.35	7	0	0	0	0	0	0	0	0	0	0	61.43	10
193	L7	1	2010	3.55	11	7.26	6	0.56	6	0.15	2	0	0	0	0	0	0	8.03	4	0	0	4.98	13
194	L7	2	2010	3.55	11	7.26	6	0.56	6	0.15	2	0	0	0	0	0	0	8.03	4	0	0	4.98	13
195	L7	3	2010	3.44	11	8.13	5	0.45	5	0.12	1	0	0	0	0	0	0	0	0	0	0	5.12	12
196	L7	4	2010	3.05	4	2.9	3	0.15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
197	L7	5	2010	1.32	2	3.34	7	0.13	2	0.14	2	0	0	0	0	0	0	0	0	0	0	11.35	20
198	L7	6	2010	0.12	1	15.54	9	0.24	4	0	0	0	0	0	0	0	0	0	0	0	0	24.14	23
199	L7	7	2010	1.71	3	7.46	6	0.03	1	0	0	0	0	0	0	0	0	0	0	0	0	23.1	23
200	L7	8	2010	14.53	5	15.31	5	0.23	2	0	0	0	0	0	0	0	0	0	0	0	0	3.7	3
201	L7	9	2010	5.16	9	24.48	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.15	5
202	L7	10	2010	3.44	11	8.13	5	0.45	5	0.12	1	0	0	0	0	0	0	0	0	0	0	5.12	12
203	L7	11	2010	4.55	14	9.04	6	3.45	3	2.03	2	0	0	0	0	0	0	0	0	0	0	5.14	10
204	L7	12	2010	3.44	11	8.13	5	0.45	5	0.12	1	0	0	0	0	0	0	0	0	0	0	5.12	12
205	L7	1	2011	0	0	22.05	7	0.33	2	0.5	1	0	0	0	0	0	0	0	0	0	0	2.56	5
206	L7	2	2011	1.11	1	2.17	2	1.03	4	1.11	3	0	0	0	0	0	0	0	0	0	0	8.15	5
207	L7	3	2011	0	0	2.19	2	0.2	1	0.34	1	0	0	0	0	0	0	0	0	0	0	3.21	6
208	L7	4	2011	0	0	3.21	2	0.51	4	0.47	1	0	0	0	0	0	0	0	0	0	0	9.02	13
209	L7	5	2011	1.2	1	3.32	2	1.11	4	0	0	0	0	0	0	0	0	0	0	0	0	3.39	4
210	L7	6	2011	2.49	1	7.01	5	1.28	6	0	0	0	0	0	0	0	0	0	0	0	0	3.23	7
211	L7	7	2011	1.33	1	16.15	5	2.27	7	2.22	4	0	0	0	0	0	0	0	0	0	0	17.26	10

212	L7	8	2011	14.33	4	25.02	6	1.41	3	2.42	4	0	0	0	0	0	0	0	0	0	0	25.47	17
213	L7	9	2011	1.14	1	1.3	1	1.16	6	1.12	2	0	0	0	0	0	0	0	0	0	0	68.18	28
214	L7	10	2011	0	0	11.56	6	2.22	4	1.09	3	0	0	0	0	0	0	0	0	0	0	236.53	32
215	L7	11	2011	9.24	4	11.14	4	4.4	2	1.3	3	0	0	0	0	0	0	0	0	0	0	71.18	12
216	L7	12	2011	3.35	3	4.33	2	0.49	3	1.35	2	0	0	0	0	0	0	0	0	0	0	1.2	3
217	M1	1	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0
218	M1	2	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
219	M1	3	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
220	M1	4	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
221	M1	5	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
222	M1	6	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
223	M1	7	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
224	M1	8	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
225	M1	9	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
226	M1	10	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
227	M1	11	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
228	M1	12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
229	M1	1	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
230	M1	2	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
231	M1	3	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
232	M1	4	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
233	M1	5	2010	9.09	8	3.51	4	0.14	2	0	0	0	0	0	0	0	0	0	0	0	0	12.01	7
234	M1	6	2010	5.08	7	13.55	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5.36	12
235	M1	7	2010	6.35	7	21.61	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15.93	8
236	M1	8	2010	22.38	7	32.61	8	0.05	1	0	0	0	0	0	0	0	0	0	0	0	0	6.28	7
237	M1	9	2010	30.33	12	15.15	9	0.03	1	0.28	3	0	0	0	0	0	0	0	0	0	0	12.18	9
238	M1	10	2010	22.38	7	32.61	8	0.05	1	0	0	0	0	0	0	0	0	0	0	0	0	6.28	7
239	M1	11	2010	20.12	6	33.65	7	75	2	1.05	1	0	0	0	0	0	0	0	0	0	0	4.03	6
240	M1	12	2010	22.38	7	32.61	8	0.05	1	0	0	0	0	0	0	0	0	0	0	0	0	6.28	7
241	M1	1	2011	12.43	4	14.17	6	1.11	3	3.55	4	0	0	0	0	0	0	0	0	0	0	2.81	3
242	M1	2	2011	1.1	1	23.15	6	0.52	1	1.18	3	0	0	0	0	0	0	0	0	0	0	7.02	7

243	M1	3	2011	19.21	3	21.4	7	0.3	2	2.89	3	0	0	0	0	0	0	0	0	0	0	1.54	5
244	M1	4	2011	0.56	1	7.2	1	1.2	2	0	0	0	0	0	0	0	0	0	0	0	0	5.33	4
245	M1	5	2011	1.36	1	6.03	3	2.33	5	0.3	1	0	0	0	0	0	0	0	0	0	0	1.56	4
246	M1	6	2011	8.08	2	8.33	3	0	0	0.35	1	0	0	0	0	0	0	0	0	0	0	0.5	3
247	M1	7	2011	1.55	1	28.53	9	0.45	3	1.1	2	0	0	0	0	0	0	0	0	0	0	13.31	12
248	M1	8	2011	6.16	3	24.3	4	0.15	1	2.22	4	0	0	0	0	0	0	0	0	0	0	33	14
249	M1	9	2011	3.45	1	2.58	2	0	0	1.31	2	0	0	0	0	0	0	0	0	0	0	72.07	28
250	M1	10	2011	1.25	1	3.01	2	0	0	0.5	1	0	0	0	0	0	0	0	0	0	0	273.26	31
251	M1	11	2011	17.03	3	37.35	13	2.4	5	1.11	2	0	0	0	0	0	0	0	0	0	0	56.33	21
252	M1	12	2011	2.5	1	35.07	10	5.21	9	1.13	2	0	0	0	0	0	0	0	0	0	0	12.21	9
253	M2	1	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
254	M2	2	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
255	M2	3	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
256	M2	4	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
257	M2	5	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
258	M2	6	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
259	M2	7	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
260	M2	8	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
261	M2	9	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
262	M2	10	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
263	M2	11	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
264	M2	12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
265	M2	1	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
266	M2	2	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
267	M2	3	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
268	M2	4	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
269	M2	5	2010	6.32	4	2.43	1	0.05	1	0	0	0	0	0	0	0	0	0	0	0	0	8.55	8
270	M2	6	2010	12.31	8	6.38	2	0.05	1	0	0	0	0	0	0	0	0	0	0	0	0	3	6
271	M2	7	2010	12.05	6	13.86	6	0	0	0.06	1	0	0	0	0	0	0	0	0	0	0	19.15	10
272	M2	8	2010	13.71	5	23.98	5	0.03	1	0	0	0	0	0	0	0	0	0	0	0	0	8.95	8
273	M2	9	2010	3.03	2	18.63	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.68	6

274	M2	10	2010	13.71	5	23.98	5	0.03	1	0	0	0	0	0	0	0	0	0	0	0	0	8.95	8
275	M2	11	2010	12.46	4	23.98	5	0.05	2	0	0	0	0	0	0	0	0	0	0	0	0	7.16	7
276	M2	12	2010	13.71	5	23.98	5	0.03	1	0	0	0	0	0	0	0	0	0	0	0	0	8.95	8
277	M2	1	2011	3.28	2	42.02	8	1.52	4	0.15	1	0	0	0	0	0	0	0	0	0	0	2.54	4
278	M2	2	2011	0	0	15.2	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.29	3
279	M2	3	2011	5.41	3	0	0	0.2	1	8.49	2	0	0	0	0	0	0	0	0	0	0	3	5
280	M2	4	2011	0	0	2.07	1	0.48	1	0	0	0	0	0	0	0	0	0	0	0	0	3.41	4
281	M2	5	2011	0	0	14.17	6	0.11	1	1.55	2	0	0	0	0	0	0	0	0	0	0	2.18	5
282	M2	6	2011	11.48	3	17.18	7	0.3	4	0	0	0	0	0	0	0	0	0	0	0	0	6.42	7
283	M2	7	2011	0	0	13.3	1	1.25	4	2.05	4	0	0	0	0	0	0	0	0	0	0	9.2	5
284	M2	8	2011	11.5	5	41.01	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26.09	15
285	M2	9	2011	0	0	9.48	4	0	0	0.24	1	0	0	0	0	0	0	0	0	0	0	42.01	19
286	M2	10	2011	2.23	1	1.2	1	2.16	3	0	0	0	0	0	0	0	0	0	0	0	0	231.51	21
287	M2	11	2011	22.17	2	32.06	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60.22	11
288	M2	12	2011	6.52	2	35.24	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.43	7
289	M3	1	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
290	M3	2	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
291	M3	3	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
292	M3	4	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
293	M3	5	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
294	M3	6	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
295	M3	7	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
296	M3	8	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
297	M3	9	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
298	M3	10	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
299	M3	11	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	M3	12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
301	M3	1	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
302	M3	2	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
303	M3	3	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
304	M3	4	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

305	M3	5	2010	6.17	3	6.12	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.37	3
306	M3	6	2010	10.33	10	6.59	2	0	0	0.07	1	0	0	0	0	0	0	0	0	0	0	10.24	13
307	M3	7	2010	3.1	2	13.4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13.81	8
308	M3	8	2010	11.89	10	28.83	7	0.25	2	0	0	0	0	0	0	0	0	0	0	0	0	1.1	3
309	M3	9	2010	16.95	9	25.65	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10.21	6
310	M3	10	2010	11.89	10	28.83	7	0.25	2	0	0	0	0	0	0	0	0	0	0	0	0	1.1	3
311	M3	11	2010	12.45	11	30.75	6	1.86	1	0	0	0	0	0	0	0	0	0	0	0	0	2.68	4
312	M3	12	2010	11.89	10	28.83	7	0.25	2	0	0	0	0	0	0	0	0	0	0	0	0	1.1	3
313	M3	1	2011	9.36	3	23.04	9	1	1	1.1	1	0	0	0	0	0	0	0	0	0	0	0.35	2
314	M3	2	2011	9.55	3	18.44	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.23	6
315	M3	3	2011	7.45	4	15.12	4	1.23	2	1.29	2	0	0	0	0	0	0	0	0	0	0	4.02	6
316	M3	4	2011	4.02	3	4.44	3	0.35	1	0.5	1	0	0	0	0	0	0	0	0	0	0	3.56	8
317	M3	5	2011	1.03	1	7.33	5	0.43	2	0.15	1	0	0	0	0	0	0	0	0	0	0	5.07	8
318	M3	6	2011	3.23	2	5.49	8	0.1	1	0	0	0	0	0	0	0	0	0	0	0	0	2.36	3
319	M3	7	2011	0	0	23.06	6	0.45	2	3.12	6	0	0	0	0	0	0	0	0	0	0	11.42	10
320	M3	8	2011	6.02	2	24.03	4	0	0	0.56	1	0	0	0	0	0	0	0	0	0	0	43.16	19
321	M3	9	2011	0	0	8.3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63.47	23
322	M3	10	2011	2.05	2	21.33	7	0	0	1.1	1	0	0	0	0	0	0	0	0	0	0	211.31	27
323	M3	11	2011	21.25	5	15.29	5	1.25	2	0	0	0	0	0	0	0	0	0	0	0	0	78.45	15
324	M3	12	2011	9.57	2	29.35	6	1.1	2	1.18	2	0	0	0	0	0	0	0	0	0	0	4.5	6
325	M4	1	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
326	M4	2	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
327	M4	3	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
328	M4	4	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
329	M4	5	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
330	M4	6	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
331	M4	7	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
332	M4	8	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
333	M4	9	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
334	M4	10	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
335	M4	11	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

336	M4	12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
337	M4	1	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
338	M4	2	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
339	M4	3	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
340	M4	4	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
341	M4	5	2010	3.55	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.28	7
342	M4	6	2010	1.59	2	13.46	6	0.05	1	0	0	0	0	0	0	0	0	0	0	0	0	10.01	9
343	M4	7	2010	2.46	2	13.11	5	0.1	1	0	0	0	0	0	0	0	0	0	0	0	0	23.85	8
344	M4	8	2010	30.05	6	7.83	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.08	1
345	M4	9	2010	14.88	7	26.18	10	0	0	0.25	3	0	0	0	0	0	0	0	0	0	0	6.88	10
346	M4	10	2010	30.05	6	7.83	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.08	1
347	M4	11	2010	31.05	7	8.56	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.08	1
348	M4	12	2010	30.05	6	7.83	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.08	1
349	M4	1	2011	13.5	4	30.04	8	1.05	1	0.55	1	0	0	0	0	0	0	0	0	0	0	2.25	4
350	M4	2	2011	8.52	4	27.33	8	0.06	1	0.55	1	0	0	0	0	0	0	0	0	0	0	6.18	3
351	M4	3	2011	14.43	6	7.02	4	1.29	3	0	0	0	0	0	0	0	0	0	0	0	0	2.29	7
352	M4	4	2011	0	0	4.22	3	0.35	2	0	0	0	0	0	0	0	0	0	0	0	0	1.14	2
353	M4	5	2011	5.25	3	12.52	6	1.09	3	0.47	1	0	0	0	0	0	0	0	0	0	0	0.3	1
354	M4	6	2011	1.05	1	3.13	2	0.2	1	0.58	1	0	0	0	0	0	0	0	0	0	0	4.58	2
355	M4	7	2011	8.25	2	19.24	6	1.03	2	0	0	0	0	0	0	0	0	0	0	0	0	12.59	4
356	M4	8	2011	8.37	3	13.06	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62.35	19
357	M4	9	2011	4.3	2	9.56	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70.39	28
358	M4	10	2011	1.4	1	13.1	4	1.28	2	1	1	0	0	0	0	0	0	0	0	0	0	240.4	30
359	M4	11	2011	9.25	4	17.42	2	1.02	2	0	0	0	0	0	0	0	0	0	0	0	0	83	14
360	M4	12	2011	12.01	4	7.28	2	1.05	3	0.2	1	0	0	0	0	0	0	0	0	0	0	16.15	10
361	M5	1	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
362	M5	2	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
363	M5	3	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
364	M5	4	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
365	M5	5	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
366	M5	6	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

367	M5	7	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
368	M5	8	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
369	M5	9	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
370	M5	10	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
371	M5	11	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
372	M5	12	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
373	M5	1	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
374	M5	2	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
375	M5	3	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
376	M5	4	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
377	M5	5	2010	8.09	4	8.47	6	0.17	3	0	0	0	0	0	0	0	0	0	0	0	0	3.54	7
378	M5	6	2010	24.24	4	24.42	10	0.1	1	0	0	0	0	0	0	0	0	0	0	0	0	12.5	11
379	M5	7	2010	7.15	2	0.06	1	0	0	0.33	1	0	0	0	0	0	0	0	0	0	0	28.7	14
380	M5	8	2010	53.2	11	39.41	8	0	0	0.08	0	0	0	0	0	0	0	0	0	0	0	6.18	6
381	M5	9	2010	0.08	7	35.05	12	17.65	1	0.08	1	0	0	0	0	0	0	0	0	0	0	18.08	16
382	M5	10	2010	51.4	10	38.21	9	0	0	0.09	1	0	0	0	0	0	0	0	0	0	0	6.18	6
383	M5	11	2010	51.28	11	35.23	10	0	0	0.18	1	0	0	0	0	0	0	0	0	0	0	7.65	8
384	M5	12	2010	51.4	10	38.21	9	0	0	0.09	1	0	0	0	0	0	0	0	0	0	0	6.18	6
385	M5	1	2011	15.02	4	17.52	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.05	9
386	M5	2	2011	4.42	2	20.09	7	0	0	0.58	1	0	0	0	0	0	0	0	0	0	0	13.09	15
387	M5	3	2011	13.03	6	4.34	1	0.17	1	1.47	2	0	0	0	0	0	0	0	0	0	0	1.31	3
388	M5	4	2011	7.2	5	11.57	6	0.34	3	1.27	2	0	0	0	0	0	0	0	0	0	0	3.38	8
389	M5	5	2011	6.05	3	10.01	5	0	0	2.01	2	0	0	0	0	0	0	0	0	0	0	2.55	6
390	M5	6	2011	5.37	4	5.01	3	1.24	5	0	0	0	0	0	0	0	0	0	0	0	0	1.23	9
391	M5	7	2011	18.27	6	15.24	7	0.35	2	1.25	2	0	0	0	0	0	0	0	0	0	0	7.07	5
392	M5	8	2011	29.25	5	19.39	11	1.15	3	1.31	3	0	0	0	0	0	0	0	0	0	0	29.27	13
393	M5	9	2011	0	0	4.58	3	0.46	3	0	0	0	0	0	0	0	0	0	0	0	0	49.46	23
394	M5	10	2011	2.39	2	12.38	2	3.25	2	1.19	4	0	0	0	0	0	0	0	0	0	0	212.53	29
395	M5	11	2011	26.27	5	9.31	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	84.56	18
396	M5	12	2011	2.56	2	2.22	1	0	0	0.35	1	0	0	0	0	0	0	0	0	0	0	26.25	10

Average Power Interruption Data of year 2009 – 2011(EC)

Feeder_ Line	Years	DPEF_ DUR	DPEF_ FRQ	DPSC_ DUR	DPSC_ FRQ	DTEF_ DUR	DTEF_ FRQ	DTSC_ DUR	DTSC_ FRQ	TLP_ DUR	TLP_ FRQ	SOL_ DUR	SOL_ FRQ	GUP_ DUR	GUP_ FRQ	DLOL_ DUR	DLOL_ FRQ	PTOL_ DUR	PTOL_ FRQ	OP_ DUR	OP_ FRQ
L1	2009 up to 2011	7.30	3.47	7.95	3.72	2.61	2.00	2.12	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.44	0.00	0.00	20.25	12.25
L3	2009 up to 2011	7.66	3.58	4.48	2.06	1.01	2.67	0.59	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.42	0.00	0.00	22.03	11.72
L4	2009 up to 2011	7.31	5.17	12.51	4.03	3.67	3.39	2.59	1.94	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.11	0.00	0.00	18.96	10.34
L5	2009 up to 2011	4.79	4.25	5.25	3.17	3.41	3.67	2.68	1.42	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	7.10	4.14
L6	2009 up to 2011	6.76	4.83	12.34	5.44	4.10	3.28	3.58	1.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.60	7.81
L7	2009 up to 2011	6.14	5.25	12.21	6.08	4.10	4.53	4.08	2.83	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.22	0.00	0.00	28.27	10.83
M1	2009 up to 2011	5.91	2.31	11.01	3.47	2.47	1.11	0.47	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.20	5.67
M2	2009 up to 2011	4.16	1.58	10.00	2.56	0.17	0.69	0.35	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.94	4.64
M3	2009 up to 2011	4.39	2.56	10.12	3.19	0.24	0.56	0.25	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.21	4.89
M4	2009 up to 2011	6.39	2.00	6.91	2.42	0.24	0.61	0.10	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.33	4.50
M5	2009 up to 2011	10.46	2.86	9.74	3.31	0.72	0.69	0.29	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.49	6.17

Appendix: B

Questionnaires about Root Causes of Power Interruptions

This study is a part of partial fulfillment of the requirements for the Degree of Masters of Science in Electrical Power Engineering program in Adama Science and Technology University. The area of the research is selected on studies of "Performance Assessment of Power Distribution System in Adama power distribution system".

The objective of the questionnaire is for collecting relevant data in relation to Assessment of Power Interruption in Adama Town power distribution system city feeder, for the purpose of identifying the root source for cause of fault factors that creates frequent power interruptions and to recommend proper mitigation solutions for those potentially identified problems. Through this participation, your answers are helpful in enhancing the reliability performance of the power distribution system in Adama Town. Your response is only be used for research analysis purposes and I confirm your response is confidential. Thank you very much for your time and suggestions.

Instruction-1: Put "X" mark in the box of your answer, you can mark more than one box for one question.

1) In which areas of responsibility you involved?

☐ In technical areas ☐ in non-technical areas ☐ Laborer

2) About your educational level

☐ Reading & Writing ☐ Up to grade 4 ☐ Grade 5 to 9

☐ Grade 10/12 complete ☐ Collage Diploma ☐ Bachelor Degree

☐ 2nd Degree ☐ Doctorate (PHD) ☐ If other

3) How many years of experience in the company

☐ Up to 2 years ☐ 3-8 years ☐ 9-14 years

☐ 15–19 years ☐ Above 20

Instruction-2: Please indicate your level of agreement or disagreement with each of these statements regarding factors contribute for the existing electric power interruptions. Place an "X" mark in the table of your answer.

No.	Root causes of fault factors on power interruption	Agreement levels					Total result	Rank
		Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**		
1	Windy condition							
2	Tree contact							
3	Human Error							
4	Usage of Equipment and Devices							
5	Planed Intentional Interruptions							
6	Vehicles accidents							
7	Animals and birds							
8	Unknown and others							
9	Preventive maintenance							
10	Other Natural phenomena							

Instruction-3: Any Other Comment

1) If you have any other ideas regarding the causes of the power interruptions in Adama town distribution system, City feeder, please specify it here under.

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2) If you have any reasons for prolongation of the power outage durations please mention it

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3) If you have any suggestion about the solutions of the power interruption problems in Adama town power distributions system, city feeder, please specify it

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Thank you for taking the time to complete this questionnaire.