ASSESSMENT OF ELECTRIC POWER DISTRIBUTION FEEDER RELIABILITY:

(Case Study of Adama City Feeders Before and After Rehabilitation)

By

Hamza Ali Adem

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A Thesis Summited to

The Department of Electrical Power and Control Engineering

School of Electrical Engineering and Computing

Presented in Partial Fulfilment of the Requirement for the Degree of Master of Science in Electrical Power Engineering

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July 2020 G.C

Adama, Ethiopia

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Approved Page

We, the undersigned, members of the Board of Examiners of the final open defence by Hamza Ali Adem have read and evaluated his thesis entitled ”assessment of electric power distribution feeder reliability:(case study of Adama city feeders before and after rehabilitation)" and Examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfilment of the requirement of the degree of Master of Science in Electrical Power Engineering

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CANDIDATES DECLARATION

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

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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. Tefera. T.Y. ________________

Advisor Signature

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Hamza Ali

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

ACCI – Average Customer Curtailment Index

AENS – Average Energy Not Supplied

ASAI – Average Service Availability Index

ASUI – Average Service Unavailability Index

CAIDI – Customer Average Interruption Duration Index

DBN – Dynamic Bayesian Networks

DPEF- Distribution Permanent Earth Fault.

DPSC- Distribution Permanent Short Circuit

DTEF - Distribution Temporary Earth Fault

DTSC- Distribution Temporary Short Circuit

ENS – load- and energy-orientated indices such as Energy Not Supplied

FMEA – Failure mode and effect analysis

kV – kilo volt

KVA- kilo volt ampere

OP - Operation

SAIDI – System Average Interruption Duration Index

SAIFI – System Average Interruption Duration Index

r – Average repair rate

U – Average unavailability

λ – Average failure rate

Abstract

A stable and reliable electric power supply system is an inevitable pre-requisite for the technological and economic growth for any nation. Due to this, utilities must strive and ensure that the customer's reliability requirements are met and the regulator's requirements satisfied at the lowest possible cost. It is a known that the fact around the world that 90% of the customer service interruptions is caused due to failure in the distribution system. Therefore, this thesis covered assessment of electric power distribution feeder reliability: case study of Adama city feeders before and after rehabilitation. Based on data taken for three years and nine month from 2009 up to 2012 E.c the maximum interruption fault types are operational fault, permanent short circuit fault and permanent earthling fault. The minimum faults are happened due to temporary short circuit fault and temporary earthling fault. to evaluate of distribution feeder's interruption reliability indices before and after rehabilitated Adama distribution network by taking eight months of before and after rehabilitated network. Before rehabilitation total outage duration system average interruption duration index is 12506.18-minute, system average interruption frequency index is 91 times, the customer average duration customer average interruption duration index is 137.42 and unsold electricity is 38,012,835.00 birr This is too far from the after rehabilitated feeders outages after rehabilitation the Reliability of the 15kV system could be further improved by the installed eight switching stations, auto recloser, and rehabilitated fifty five transformers consider load and low voltage installed by insulated wire and constructed a concrete pole up to customer service drop. Additionally, fifty five transformers connected with installed SCADA station, after rehabilitated the reliability index of system average interruption duration index is 8163.22, system average interruption frequency index is 49 and customer average interruption duration of index is 166.59 and unsold electric city is 25,986,615.00 birr base on this value after rehabilitated is more reliable than before rehabilitated

.***keywords: reliability, rehabilitation, duration, frequency***

CHAPTER 1

INTRODUCTION

1.1. Thesis Background

Power distribution network system established mainly to provide adequate electricity supply to customers as economically as possible with reasonable assurance of reliability. Nowadays, the power distribution networks have grown exponentially in term of size and technology over the past few years. As a result, utility company must strive to ensure that the customer's reliability requirements are met with optimum strategic planning and lowest possible cost. The ability of the system to provide adequate supply of electricity energy determine by the term reliability. Reliability analysis of distribution network is not a new topic in electric power industries, a lot of studies and research have been carried out due to the increasing cost of blackouts and fault outages. Over the past, distribution network system have received less attention devoted to reliability studies compared to generation and transmission system [1]. The reasons being is the generation and transmission systems are capital intensive and the inadequacy can have widespread consequences for both society and environment. However, a distribution system is slightly cheaper compare to the other two because its effects are localized. Analysis of the customer failure statistics of most utilities shows that distribution system makes the greatest individual contribution to the unavailability of electrical supply to customer. It is very important to assess and evaluate the reliability of power system networks in order to obtain the most accurate and effective way in decision making especially in planning, operation, and maintenance.

Historical assessment and predictive methods are normally used to evaluate the reliability of a distribution network. Most utilities focus more on historical assessment rather than predictive methods. Predictive methods are categorized into analytical and simulation methods. Reliability assessment method for distribution system fall into two classes: simulation and analytical [2]. Simulation is the most flexible method but require extensive time in computational and also uncertainty in precision. Analytical method can be further divided into network modelling and Markov modelling. Network modelling has been the most popular technique for distribution system reliability analysis due to the simplicity of the method and natural similarities between network model and the distribution topology. The difference between simulation and analytical method is the way in which the system reliability indices are evaluated. By applying both analytical and simulation method, the reliability indices for distribution systems will be determined such as System Average Interruption Frequency Index

(SAIFI) and System Average Interruption Duration Index (SAIDI). The probability distribution of SAIFI and SAIDI which give information about the variability of the indices also need to obtain in order to improve in decision making.

1.2. Statement of the Problem

There are many factors that contribute to the failure of distribution network system. In distribution system planning, reliability aspects are an important part of the decision base. Thus, to be able to assess and evaluate, reliability is needed in the planning process. The data obtained from Adama substation and Adama district office showed that the distribution network contribute the highest SAIDI and SAIFI for three-year from 2009 to 2012 E.C.

The main problem facing is the power demand is rapidly increased whilst supply growth is constrained by limited source, environmental problem and other social concerns. According to Ethiopian Electric Agency statistic, about 80% of power interruptions result from power distribution system failure [3]. Historical assessment and predictive methods are normally used to evaluate the reliability of a distribution network. Most utilities focus more on historical assessment rather than predictive methods. Hence, it is vital in design and development of distribution network to study and analyse the reliability. Enhance knowledge in reliability analysis of distribution network will contribute to the measurement of how far the system meet the performance criteria, to help quantify comparison between various options, and to help in term of economic decision [4]. Besides that, reliability analysis result will determine the failure rate and mean failure duration for particular equipment or group of equipment's, thus with more detail in databases, the information gained may be important for utilities operators, such as the most frequent cause of failures, areas of greatest amount of undelivered energy [5] or the most weakness area of protection system which contribute to interruptions and fault. In this thesis, the most challenging and difficult aspect will be on the analytical part where details concentration are required to acquire input data from utilities and industries and calculation to obtained useful reliability indices which will be used for comparison with the historical assessment. Incorrect input data will of course lead to false result [6].

1.3. Objectives

1.3.1. General Objectives

The major objective of this thesis is assessment of electric power distribution feeder reliability: case study of Adama city feeders before and after rehabilitation

1.3.2. Specific Objectives

- Study was to identify causes of interruptions and suggest possible solutions to the Adama distribution system.
- To determine the reliability assessment of System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI) and Customer Average Interruption Duration Index (CAIDI), unsold electric city of distribution network system of Adama network.
- Analysis and evaluated Adama distribution feeder interruption finally give an overview of the measures necessary in order to decrease interruption indices.
- Compare the reliability index after and before rehabilitation which is done by CET Company.

1.4. Scope

The most challenging and difficult aspect will be on the analytical part where details concentration required to acquire input data from Adama distribution system calculation to obtained useful reliability indices which will be used for comparison with the historical assessment. Due to broadness of the network for taking the data it is difficult to cover all utilities. Due to this, the study will focus on assess of 15kV distribution network in feeders of Adama distribution network. The parameter used to determine the reliability indices are failure rate, repair rate and unavailability. The scopes of this Thesis are:

a) In Adama there are eleven feeders, among them only ten feeders are rehabilitated. The un rehabilitated network is the feeder line is line five. So the scope of this thesis is assess the distribution feeders and compare the reliability index of after rehabilitation of network which is done by Chines Company with before rehabilitation network.

b) To determine the reliability assessment of System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI) and Customer Average Interruption Duration Index (CAIDI), unsold electric city of Adama city network

CHAPTER 2

LITERATURE REVIEW

2.1. Theoretical Background

Electrical power is vitally important to our modern society nowadays in line with the challenges to provide the most efficient and cost-effective way of supplying electricity from the industrial area up until residential consumers. The availability of reliable power supply at a reasonable cost is crucial for the economic growth and development of a country [6]. Power Utility Company nowadays tries to enhance and develop their own strategies based on experience, trending, research, and studies to meet customer demands as economically as possible at reasonable service of reliability. Analysis throughout the word shows that around 90% of all customer reliability problems are due to the problem in the distribution system. Thus, improving distribution reliability is the key to improving customer reliability [7]. The concept of power-reliability is extremely broad and covers all aspects of the ability of the system to satisfy customer requirements. There is a reasonable subdivision of the concern designated as system reliability which is shown in Figure 1.

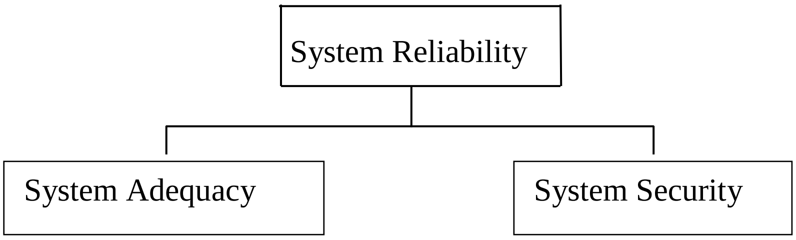


Figure 1 System Reliability Subdivision

Figure 1 represents two basic aspects of a power system: system adequacy and security. Adequacy relates to the existence of sufficient facilities within the system to satisfy the consumer load demand. These include the facilities necessary to generate sufficient energy and the associated transmission and distribution facilities required to transport the energy to the actual consumer load points. Security relates to the ability of the system to respond to disturbances arising within that system. Security is therefore associated with the response of the system to whatever perturbations it is subject to [8]. The most common methods of assessing electric power distribution network reliability deal with percentage availability, number of power outage, the outage frequency, the duration of those outages over a specified time.

2.2. Review of other works

2010 the author M.R Emjedi, K.Awodele, S.Chowdhury, S.P Chowdhury Case Study of Distribution Network Reliability Analysis Based on Probabilistic Method using Fuzzy Logic The fuzzy logic concept is used to evaluate the reliability distribution network. The basic concept underlying fuzzy logic is that of a linguistic variable whose values are words rather than numbers. The use of fuzzy logic as an evaluation tool has distinguish characteristic, this technique aims at exploiting the tolerance for imprecision and uncertainty to achieve tractability, robustness and low solution cost [8]. The fuzzy logic method was used to predict the reliability as there was no mathematic function describing the relationship between subsystems and the network reliability. The advantage of fuzzy logic method is its enabling the possibility of adding new fuzzy systems to the existing model, in order to account for factors that were not included in the model. These new fuzzy level can be added into fuzzy level 1 or 2. The reason is that all subsystems are assumed to be independent to each other. Furthermore, fuzzy logic is more flexible thus it allow for its application to simplify complex models. Due the simplification, the computation time is reduced and larger model could be easily evaluated with minimal computation time.

In 2012 Aoxue Su, Mingtian FAN, Zhonglai LI . The Reliability Analysis of Distribution System Based on Dynamic Bayesian Network Dynamic Bayesian network is a time extension of the static Bayesian network, which consists of the initial network and transfer network. Based on Dynamic Bayesian networks, the actual value of the component failure rates and repair rates can be accurately reflected and failure frequency and duration of distribution system can be calculated. Bayesian network method permits not only computing the reliability indices of a distribution system but also presenting the effect of each component or some components on the system reliability.

This method can't calculate the situation with time, which not only can't calculate outage frequency index and outage time index, but also can't exactly reflect the actual value of the failure rate and repair rate of components. In order to solve these problems, an approximate Bayesian network inference algorithm for time-sequence simulation is presented [9]. But this method is similar to the Monte Carlo simulation method, which simulate the events using the sampling, and suffer in computation time and uncertainty of precision. Dynamic Bayesian Network inherits the advantages of static Bayesian Networks, and it can be able to describe the dynamic evolution process of the distribution system due to the disconnect switches and protection devices.

This advantage constructs the topological relationship of distribution system on influence of each component on the systems. this method not considers the impact of time factor to the variables, but reflect the probabilistic dependencies between variables and time varying of variables and this able to describe the dynamic evolution process of distribution system due to disconnect switches and protection devices.

In 2007, Davide L.Pepnye [35] 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 [11].

2.3. Reliability and reliability index

Power system, Reliability is defined in many ways. This is true particularly for electric power distribution systems. According to Bhavaraju et.al. 2005, Reliability of an electric power system is defined as the probability that the power system will perform the function of delivering electric energy to customers on a continuous basis and With acceptable service quality [12]Reliability with regard to Power Distribution Systems is the probability that an item or collection of items(feeders, transformer, insulation, feeder pillar, distribution line, Poles, fuse, isolator, connections etc) will perform satisfactorily, under all conditions during a given period of time. Quantitatively, Reliability is the probability of success or availability of supply [13].

Another approach taken is to define reliability through indices. Reliability indices are parametric quantity use to assess the performance levels of electrical power distribution systems so as to make it suitable for scientific analysis [14]. Reliability indices typically consider such aspects as the number of customers interrupted, the duration of the interruption measured in minutes or hours and the frequency of interruptions For example, the reliability of a distribution system is said to be described by a complete set of indices such as SAIFI (frequency of outage), SAIDI (duration of outage), CAIDI (required time to restore supply), ASAI (percentage availability). Others are MAIFI, ASIFI, ASIDI etc. One of these indices is not sufficient to completely measure reliability of power supply since each focus on specific aspect of reliability[15].

Quantitative reliability evaluation of a distribution system can be divided into two basic segments; measuring of the past performance and predicting the future performance.

Below are some of the basic indices that have been used to assess the past performance;

- System Average Interruption Frequency Index (SAIFI). It is designed to give information about the average frequency of sustained interruption per customer over predefined area.

$$SAIFI = \frac{\text{TOTAL NUMBER OF CUSTOMER INTERRUPTIONS}}{\text{TOTAL NUMBER OF CUSTOMER SERVED}} = \frac{\sum \lambda_i N_i}{\sum N_i} \qquad (2.1)$$

- System Average Interruption Duration Index (SAIDI). It is commonly referred to as customer minutes of interruption or customer hours, and is designed to provide information about the average time that the customers are interrupted.

$$SAIDI = \frac{\text{TOTAL NUMBER OF CUSTOMER DURATION}}{\text{TOTAL NUMBER OF CUSTOMER SERVED}} = \frac{\sum U_i N_i}{\sum N_i} \qquad (2.2)$$

Past performance statistics provide valuable reliability profile of the existing system However, distribution planning involves the analysis of future systems and evaluation of system reliability when there are changes in; configuration, operation conditions or in protection schemes. This estimates the future performance of the system based on system topology and failure data of the components. Due to stochastic nature of failure occurrence and outage duration, it is generally based on probabilistic models. The basic indices associated with system load points are; failure rate, average outage duration and annual unavailability.

For instance, the Adama substation exists an expansion of its wheeling capacity beyond the present level of 50MW addition mobile substation 50MW by 2015 and 2018 respectively. Quantitative reliability evaluation of a distribution system can be divided into two basic segments; measuring of the past performance and predicting the future performance.

2.4. Feeders Interruption Fault

Distribution reliability primarily means continuation of power supply without interruption. IEEE 1366 standard defines distribution reliability as measurement of keeping lights on Simply, reliability is the measurement of equipment outage rates and power interruption duration. There are various events that disrupt normal operation of the distribution system leading to power outages. However, some key descriptions pertaining to distribution system reliability are explained below. Faults are characterized by an enormous current flowing in the circuit in an abnormal way and can cause equipment insulation failure leading to power outages. In the distribution system, normally there are two types of faults, temporary and sustained. Temporary faults clear themselves in a short time once after the path is de-energized and customers will see a momentary interruption [16].A permanent fault remains for long time and needs manual switching to clear it.

Temporary or Momentary Interruptions

According to IEEE 1366 standard, faults lasting less than 5 minutes are categorized as momentary interruptions [16], Most momentary faults may not necessarily lead to a power outage. For example, the falling of a tree branch on power lines may not lead to a fault. Besides faults, the operation of automatic switches also results in momentary interruption. The study doesn't account for momentary interruptions as most utility companies do not consider a momentary interruption in a reliability study due to the difficulty knowing when it happened [17].

Sustained Interruption

Sustained interruptions occur when customers are out of power for a long time. IEEE 1366 standard classifies faults lasting more than 5 minutes as sustained faults [16] [18]. Sustained faults are generally characterized by open circuits and will result in power outage.

Planned Interruption

This happens when deliberate action is taken on a component by removing it from service in order to carry out maintenance work or construction. This interruption usually accompanies scheduled outage. It is usually planned and the customers are aware of the loss of supply that ensues.

Unplanned Interruption

This type of interruption is basically as a result of faults and failures which makes a component to be unavailable to perform its function. In addition, the two major factors that affect the reliability of power distribution system are Capacity shortages and Faults and failures

2.5. Availability of supply indices

Customer, the interruptions are classified in planned and unplanned interruptions, as well as, in short and long interruptions. Long interruptions are considered as those longer than 3 minutes. In order to quantify the effects of long interruption, interruption indices are defined as Interruption Frequency, Supply Unavailability and Interruption Duration. Interruption frequency represents the number of interruptions on average per year per customer. Supply unavailability describes the number of minutes without supply on average per year per customer, and interruption duration is the average duration of customer interruptions.

The three methodologies for calculation interruption indices are based on the number of customers, the connected power and the number of substations (transformers). UNIPEDE [16] and IEEE [17] have defined acronyms for indices calculated by one of the specific methodologies. Several national regulators in Europe have defined their own acronyms for the interruption indices. All of these methodologies are well-known and are exposed in the following references: [19]-[22].

2.6. Availability in Europe

In Europe, every country applies their own criteria in order to calculate the supply indices; there are differences in the methodology, voltage level and proportion of network included. In many cases, the indices are calculated by distribution companies, and in other cases, company indices are confidential. In general, it can be said that the data in not homogeneous; few years are represented; and the quality of data is questionable. Therefore, the values available should be taken with caution and benchmarking these crude values could lead to inaccurate conclusions. But they are providing a point of reference from which to compare different practices etc. in different countries. Table 1 compares the national mean values of the interruption frequency and unavailability [23] in different European countries, the city of Barcelona is also included in these statistics.

Table 1: European availability bench mark

County	Interruption frequency[min/a]	Unavailability [min/a]
Austria	0.59	35.23
Barcelona city	2.28	107.60
Belgium	0.90	42.25
Finland	4.06	182.67
France	1.21	53.33
Germany	0.27	37.00

Great Britain	0.77	70.09
Ireland	1.34	235.67
Italy	3.83	202.85
Norway	2.73	218.00
Spain	2.98	153.00
Sweden	2.07	99.00
The Netherlands	0.38	27.50

Generally, it could be said that the values of interruption indices have a great dispersion and there is a great variety between different countries. It has been shown [24] that even when distribution networks have very similar networks, there can be significant differences in interruption indices. Therefore, a range of influential factors can be determined which may explain the variations of indices. In short, these factors can be separated into two classes: inherited and inherent factors [25].

The most important inherited factors are:

- Feeder length
- Voltage level in MV
- Percentage of underground network
- Sectionalizing
- Rate of automatization
- Rate of interconnection between feeders

The most important inherent factors are:

- Lightning
- Air pollution and salt contamination
- Climatic factors, like storms, ice storms, extreme temperatures, strong precipitations and floods
- Animals
- Vegetation
- Customer density

2.7. Distribution Network Reliability

Until now, the objectives of network design have been to minimize distribution losses. However, by introducing interruption indices, the design criteria will change to include optimal network configuration, which will guarantee lower interruption indices. There are three possible strategies for decreasing interruption indices:

- Reduction of the number of faults
- Reduction of time of interruption
- Reduction of number of affected customers

2.7.1. Reduction of the number of faults

The reduction of the interruption frequency is possible by decreasing failure rates of the network component. For example, the reduction of the number of faults in an overhead line can be reached by a tree trimming program, which ensures the clearance distance. This will reduce the failure rate, and increase the system reliability and reduce interruption. A reduction of the number of interruptions leads to lower interruption indices. In summary, the reduction of the number of faults causes a decrease of the frequency of interruptions and unavailability. In the following list, we can find the most important measures for reducing failure rates.

- Preventive maintenance
- Monitoring critical components
- Preventive replacement of components which have reached the end of their useful life
- Isolated or tree wires in overhead lines to prevent tree contact with the conductor
- Tree trimming and periodical trimming of the adjacent vegetation to prevent contact with the conductors
- Protection against animals contact with conductors

2.7.2. Reduction of time of interruption

The time of interruption is the time required to restore the power supply. A fault affected zone in the distribution network can be isolated from the healthy part of the network by disconnecting the affected sector. It is important that the switching actions of the restoring process are optimized in order to isolate the smallest possible section of network affected by the fault. This process does not reduce the time interruption in the fault affected zone, but it will provide a substantial improvement in the sector of the network that is not affected by the fault. Furthermore, automated sectioning points will provide a timelier restoration of the power supply. If the restoration of the supply takes place in less than three minutes, the interruption is not considered as long interruption. Time reduction of the time processes lead to a reduction in the unavailability indices, but do not show effects on interruption frequency.

2.7.3. Reduction of number of affected customers

Finally, due to the reduction of the number of customers affected customers by a fault it is possible to reduce the interruption frequency and the unavailability of a supply region. Possible reduction measures include:

- Permanent reconfiguration of the distribution network
- More protective elements (recloser etc.)
- Resonant transformer grounding.

Permanent reconfiguration is the reduction of the number of customers per feeder by adding more and shorter feeders per substation. More protective elements, such as reclosers, separate the fault affected network section from the healthy one and reduce the number of customers interrupted. Finally, resonant grounding with arc suppression coils in transformer stations reduces the number of temporary phase to earth faults in overhead networks. The perceived power quality can be divided into five parts: commercial quality of the utility, availability of supply, waveform quality, customer installation and compatibility levels of the customer's apparatus. It is very important to consider that the customer apparatus and installation are influential on the power quality. System reliability is expressed by interruption indices, which are applied in different ways around Europe; therefore, an international comparison of availability of supply should be viewed with reservation. In the future, when the quality of data is increased, the comparison should have more substance. The variation of the interruption indices between countries and companies led us to the conclusion that the factors of influence on these indices and inherited and inherent. Finally, decreasing fault rates, restoration time and number of affected customers will result in lower interruption indices and increase distribution system [25].

CHAPTER 3

METHODOLOGY

3.1. Thesis Methodology

This thesis is adopting methods involving analysis and evaluation of reliability of the distribution network in Adama network to see how reliability could be improved in the distribution system by incorporating reliability analysis in the systematic planning approach so that optimum reliability is achieved. The reliability indices of the present system shall be evaluated assessed and compared and sees how risk of failure could be mitigated.The reliability of a distribution system is said to be described by a complete set of indices such as SAIFI (frequency of outage), SAIDI (duration of outage), CAIDI (required time to restore supply), ASAI (percentage availability). Other are MAIFI, ASIFI, ASIDI etc. One of these indices is not sufficient to completely measure Reliability of power supply since each focus on specific aspect of reliability. In this thesis, four are used to assess and quantify Reliability of electric power supply in Adama.

3.2. Data collection

By using Secondary data collection is done directly at Adama substation each of primary distribution feeders. The purpose of this data collection is to obtain data to analysis and assessment reliability of after and before rehabilitation Adama city.

- Three years and nine month from 2009 and nine month of 2012 EC interruption data collected from Adama substation.
- Each feeder data, number of transformers and type of faults information has been collected from the existing network
- The collected data has been used to clearly analyze the problems of the feeder under study.

3.3. Data Analysis Method

Based on the data obtained in this thesis, will be analysed to get the value of SAIDI, SAIFI and CAIDI to find out how much reliability the existing network and after and before rehabilitation the level of reliability of power distribution system on each feeders 15 kv in Adama substation and compare the standard value of reliability index which is used in this thesis. Standard index values used are

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 from secondary data.
- Based on the result of this analysis and assessment, recommend a solution that have been evaluated for potential reliability improvement on power interruption.

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

Figure 2 :-Geographical map of Adama Town [Google Map]

CHAPTER 4

Study Sites description

4.1. Site description

Sites selected for this thesis are Adama city distribution feeders. The selection and the station description are presented as follow.

4.1.1. Adama substation

Adama substation is in the South-West of the city with new housing developments not far from the substation. The substation has been built recently (switchgear dated 2005). It is a 132/15kV substation with two transformers 2x25MVA and 50MVA mobile substation total 100MVA. The 15kV switchboard has two incoming circuits and eleven outgoing feeders with bus sectionalized. Adama 132kV substation receives power supplies from the 132 kV Koka substations through a single 132 kV Koka – Adama line. Another 132kV line connects to Awassa melkasa. Further the nearby wind farm is also connected to the 132kV substation. Mobile Substation – substation that have primary circuit breaker or fuse, a transformer and secondary switchgear mounted on a trailer. These are used to temporary replace permanent substation following sever events such as the lot multiple power transformers. Mobile Substation can be used to support multiple substations but are typically limited to a maximum capacity of MVA due to size and weight constraints [26].

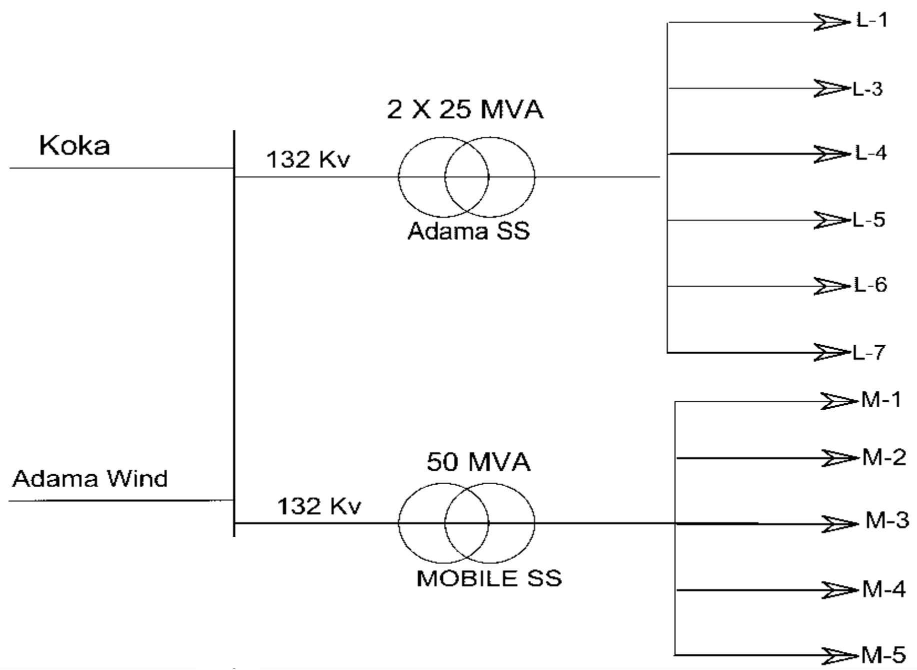


Figure 3: Details of 15kV Feeders before rehabilitation from Each Substation

4.1.2. SCADA system

ETAP ESCADA is a model-driven electrical SCADA platform that provides a real-time monitoring and control software applications integrated with data acquisition and control hardware to offer intuitive visualization and analyses via intelligent graphical user interface, one-line diagram, geospatial view, and digital dashboards. Model-driven electrical SCADA means the inherent integration of SCADA platform with the state-of-the-art ETAP power system analytical applications to provide intelligent situational awareness and diagnostics. ETAP Situational Intelligent (SI) predicts system behaviour in response to operator actions and events while proactively recommends / implements decisions to improve operations [26]. In Adama SCADA substation integrated with 55 distribution transformers and 8 switching station switching station but R7 and R8 not finished so far.

Table 2: Details of 15kV Feeders after rehabilitated sectionalized by switching station

No	New Switching station		
	New existing feeder	Switching station feeder	Specific location
1	Line 7	ST-R1-3,R1-5	Kebele 09 Wonji mazoria
2	Mobile 1	ST-R2-2,R2-3,R2-5	Kebele 16/05 tractor factory
3	Line 4	ST-R3-2,R3-3	Kebele 01 Medhanialem church
4	Mobile 6	ST-R4-2,R4-3	Lekeadi Aba geda
5	Line 1	ST-R5-2,R5-3	Kebele 15 Around post office
6	Line 3	ST-R6-4,R6-5	Kebele 04 In front of ASTU
7	Mobile 3	ST-R7-2,R7-3	Kebele 13 Amede gibrena
8	Mobile 5	ST-R6-2,R8-5	Boku shenen Mikael church

On the above table show that from Adama distribution substation has eight outgoing feeders and the remaining three are existing feeders. A switching station is a substation without transformers and operating only at a single voltage level. Switching stations are sometimes used as collector express feeder. Sometimes they are used for switching the current to back-up lines or for parallelizing circuits in case of failure and all switching station are controlling by SCADA room.

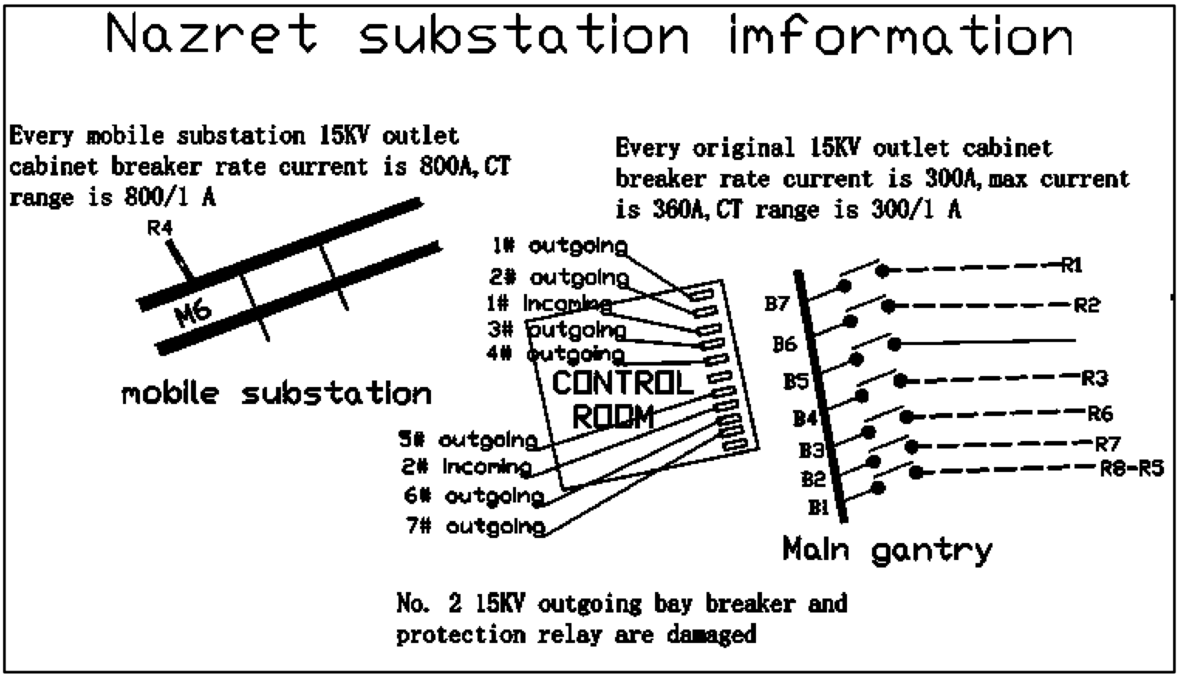


Figure 4: Detail of 15kV main gantry from Each Substation

4.2. Major Components of Feeder

Poles- poles support overhead distribution equipment and are an important of all over header system. Most poles are treated wood, but concrete and steel are also used. Typically distribution pole are construction.

Sectionalizing Switches devices that can be opened and closed to reconfigure a primary distribution system. Like substation disconnect switches, they are rated as either load break or no-load break

Recloser self-contained protection devices with fault interrupting capability and reclosing relays. Interruption capability is lower than for a circuit breaker, and applicable are typically away from substation where fault current is lower. Most recloser utilized one or two instantaneous operation that clear a fault without any intentional time relays.

Capacitors device used to provide reactive current to counteract inductive load such as motors, properly applying capacitors will reduce losses, improve voltage regulation and allow a distribution system to deliver increased kilowatts. Typical distribution system utilized fixed capacitors (unable to be switched on and off) during light loading conditions and turn on switched capacitors during heavy loading conditions. Switched capacitor are typically turned on and off automatically based on temperature, timers, current, voltage, reactive power or power factor measurements.

Voltage Regulators transformers with load tap changers used on feeders to support voltage. They are becoming less common as the use of higher voltages, large wire and capacitors becomes more common.

Distribution transformer or service transformer is a transformer that provides the final voltage transformation in the electric power distribution system, stepping down the voltage used in the distribution lines to the level used by the customer. Adama town has more than 700 total distribution transformers.

Sectionalizes are (beside overcurrent relays, recloser and fuses) one of the most used for distribution system protection. Sectionalizes count the number of operations of the recloser during fault conditions. After a preselected number of recloser openings, and while the recloser is open, the sectionalize opens and isolates the faulty section of line. This permits the recloser to close and re-establish supplies to those areas free of faults. If the fault is temporary, the operating mechanism of the sectionalized is reset [27].

Feeder Automation refers to SCADA and locally controlled devices on feeders. Intelligent electronic devices (IEDs), automatic meter reading (AMR), capacitor control, automatic reconfiguration and a host of other functions. In the context of distribution reliability, feeder automation usually refers to switches that can automatically open and close after a fault has occurred.

Lightning arrester (alternative spelling lightning arrestor) (also called lightning diverter) is a device used on systems and systems to protect the and conductors of the system from the damaging effects of. The typical lightning arrester has a terminal and a ground terminal. When a lightning surge (or switching surge, which is very similar) travels along the power line to the arrester, the current from the surge is diverted through the arrester, in most cases to earth [21].

On the above fig: 4Under Electricity Network Reinforcement and Expansion Project (ENREP), 8 Major Cities Distribution Network Rehabilitation and Upgrading Project is consisting of one contract, finance d by The World Bank and Ethiopian Electric Utility (EEU). The construction contractor is China Electric Power Equipment and Technology Co. Ltd. (CET) -(CHINA)).This Project is Distribution Network Rehabilitation and Upgrading in eight (8) major Cities, consists of one city which is Adama rehabilitation MV and LV networks at some selected Areas. By Chines Company the following activities are done [28].

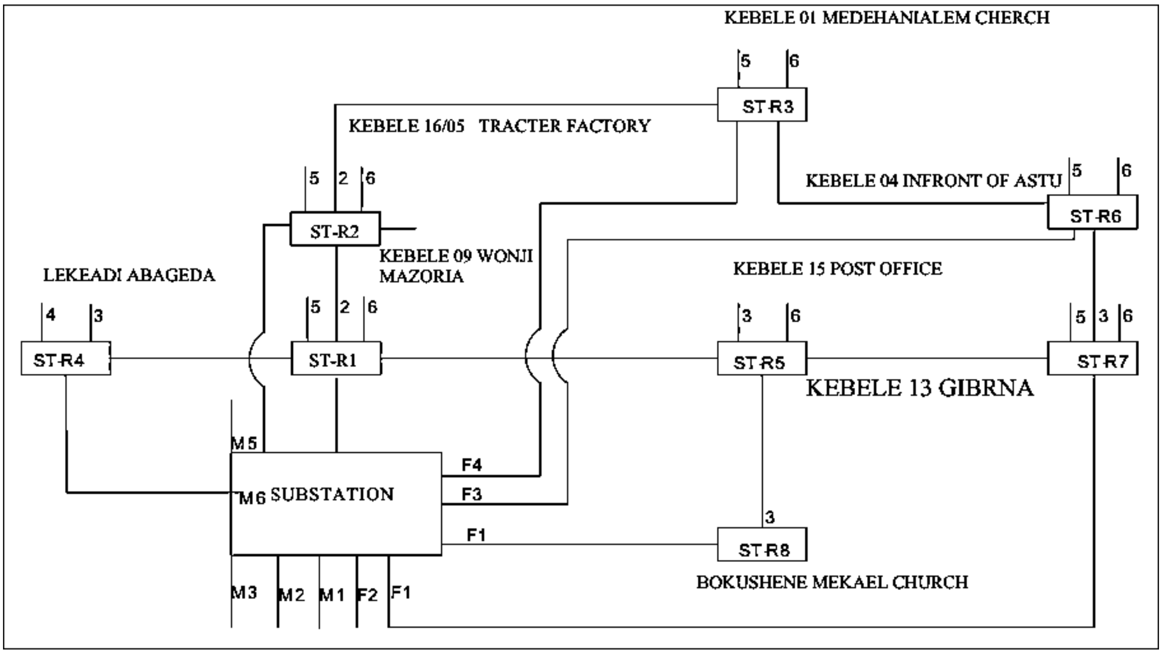


Figure 5: Details of 15kv line switching station

Reinforce the MV network back bone constructed 15 kV Express feeder lines the lines from Substation to Switching stations, the 15 kV outgoing lines from switching stations that will be connected to the existing 15 kV load lines and this also includes replacement of existing 15 kV lines that are very old network configuration: includes, Interconnection of Switching stations for load sharing so that to improve reliability of power supply, Installation of Switched capacitors and Voltage boosters to improve voltage profile and power quality, Installation of Autorecloser, Automatic sectionalizes and Load break switches.

Additionally to improve reliability of power supply, Implementation of SCADA system for better control of distribution system and replacement of parts some selected areas of LV network with ABC in phase-1: This is replacing of existing LV networks at some selected areas with new AB cables 95 mm2

- Rehabilitate /add new Distribution Transformers: This is rehabilitation of existing distribution transformers and addition of new distribution transformers under the LV networks indicated above.

CHAPTER 5

DATA PRESENTATION, ANALYSIS AND ASSESSMENT

For this study data are collected from Adama district, Adama distribution substation (EEU) and from the customers of the town. The collected data are a recorded data that includes peak load, type of faults, frequencies, lightning causes temporary faults on distribution circuits; neither the lightning arcs externally across insulation but neither the lightning nor the fault arc permanently damages any equipment. Normally, less than 20% of lightning strikes cause permanent damage. and duration of interruption of medium voltage (15kV) outgoing feeders of the distribution system. Primary data are obtained through inspection on site, direct observation and Participating with the maintenance team. Secondary data are collected from yearly power interruption report of Adama substation office. Based on the secondary data Analytical method is applied to assess the overall behaviour of the distribution system reliability indices. The company is the Ethiopia electricity utility serving the whole of Ethiopia the Companies providing electricity distribution services in Ethiopia.

The data collected include:

1. Numbers of feeders (15KV)
2. Numbers of outages on each feeder
3. Duration and frequency of each outages
4. Causes of outages
5. Number of transformers on each feeder
6. Peak Load in Ampere (A)
7. Peak Load in MW

This data which covered from 2009 to nine month of 2012 E.C, are on the eleven feeders (15kV lines) supplying the town. Reliability indices like SAIDI, CAIDI, CAIFI and ASAI are used to assess reliability performance of the distribution's feeders.

5.1. Major Causes of Interruption feeders

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 [29]. 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. Field personnel can be trained to spot pole structures where faults have occurred or might likely occur. 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 [30] where Predictive root Couse analysis computes each components contribution to reliability indices. The cause of outage depends on geographical locations of the area. From historical data of the past years, major cause of outages in the system is being evaluated.

Faults caused by trees

A freshly cut tree branch will not cause if it is placed across two distribution phase conductors. The resistance of the branch typically limits current flow to several amps. Similarly, a desiccated branch will not cause a fault if it is even higher. Regardless, Faults often but not always occur after a branch falls across two conductors. Understanding the physical responsible for determining whether fault occurs or not is important and can help when making tree-related distribution reliability decisions.

When a branch breaks off a tree and bridges two conductors, fault does not occur immediately because a moisture tree branch has substantial resistance. Even though has not immediately occurred, the following two process initiate: (1) a small current begins flow and stats to dry out the wood fibres, (2) the electric initiates' carbonization of cellulose near each conductor [31].

There are several strategies to prevent faults due to tree branch contact: line construction can reduce faults by utilizing lower distribution voltage, by avoiding compact designs with high phase –to –phase voltage gradient branch contact/ insulation wire can be effective, but fault tend to result in conductor burn down since they will not motor (move themselves along the conductor) like fault on bare conductor. A basic understanding of tree characteristics is helpful for ensuring reliability during distribution planning, engineering and operations, tree trimming, periodically pruning vegetation adjacent to power lines to ensure safe and reliability clearance.is critical utility activity for a variety of reasons

Faults caused by birds

Birds are the most common cause of animal faults on distribution systems, and air insulation substations. Different type of birds cause different type of problems, but can generally be classified as nesting bird, roosting birds, raptors, and woodpeckers.

Nesting birds commonly building their homes on lattice towers, poles and in substations, nesting materials can cause faults, and bird excrement can contaminate insulators. Removing nesting sites can be difficult since the instinctual nature of certain birds will cause them to rebuilding nests in the same location. To further complicated matters, nesting birds can attract predators (e.g raccoons, snakes, cats) that can be a worsen reliability problem than the birds themselves.

Transformer failure

Transformer impact distribution system reliability in two related ways: failures and overloads. Catastrophic transformer failures can result in interruptions to thousands of customers. When this happened, another transformer are called upon to pick up the interrupted load. If there is not enough pare transformer capacity, addition must be made whether or not t overload in-service transformers and accept the resulting ;loss-of- life accepting loss- of –life will improve reliability of for the moment, but will increase the probability that the overloaded transformer will fail at future date. On Adama distribution network on and the most cause failures interrupted feeder is transformer failed.

Lightning caused faults (overhead line)

In the majority of case Lightning causes most damage by directly striking an overhead phase wire and injecting an enormous current surge that creates a very large voltage. The voltage impulse easily breaks down most distribution-class insulation unless it is protected with a surge arrester. Almost all direct lightning strokes cause flashovers. In addition, the lightning current may start a pole fire or burn through conductors. Also, nearby lightning strokes that don't hit the line may couple damaging voltages to the line. These induced voltages may fail equipment or cause flashovers

Thesis the detail reliability of 15kV system for the purposed of the study, we will consider the distribution feeder for supply direct to customer or feeders that interconnect between substations Adama. Here we will also look at the after and before rehabilitated performance of the distribution system reliability when there are changes in the configuration, operation condition and or protection schemes, and expansion in the network. In this thesis, the predictive reliability analysis shall be carried out in 15kV feeder and a number of alternatives shall be evaluated. Further evaluation and study on the existing network will be conducted to determine type of network modelling configuration either radial parallel [31].

5.2. Modelling of Adama distribution feeder's reliability index

Network modelling is the use of series-parallel combinations to reduce the network. But Adama distribution system network is series or radial combination so this modelling focused the reliability index. A radial system basically consists of set of series components like; breakers, lines, switches, transformers and at the end a "Customers". In the series structure both components must be intact for the system to function, "a chain is no stronger than its part" while in the parallel structure both must fail for the system to stop

Functioning In this case, all the components are connected in series as shown in Figure 6 and the equations needed to evaluate the basic indices are as follows

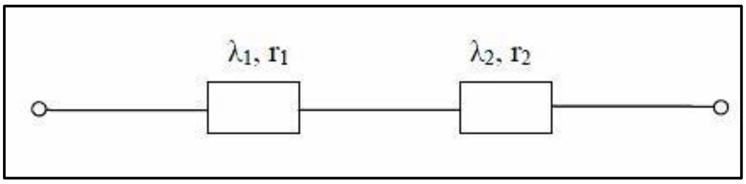


Figure 6: Series Structure

Load based indices are conventional indices which typically represent the data of each connected individual customer. The load point indices used in this thesis are represented below.

a. Average Failure rate of the system

$$\lambda_s = \lambda_1 + \lambda_2 = \sum_{i}^{2} = \lambda_i \qquad 4.1)$$

b. Average outage time of the system:

$$rs = \frac{\lambda_1 r_1 + \lambda_2 r_2 + \lambda_1 r_1 \lambda_2 r_2}{\lambda_1 + \lambda_1} = \frac{\sum \lambda_1 r_i}{\sum \lambda_i r_i} = \frac{U_s}{\lambda_s} \qquad (4.2)$$

If $\lambda 1 \lambda 2\, \mathrm{r}_1\, \mathrm{r}_2 << \lambda 1\, \mathrm{r}_1 \mathrm{or}\, \lambda_2\, \mathrm{r}_1 \mathrm{r}_2$

c. Average Annual Outage time of the system:

$$Us = f_s x r_s = \lambda_s x r_s \qquad (4.3)$$

Where λi the failure rate at node i, ri is the outage time at node I Where λi the failure rate at node i, ri is the outage time at node i. In parallel system, the failure modes of the load point involve overlapping outages, i.e. two or more components must be on outage at the same time in order to interrupt a load point as shown in Figure 7 It is assumed that the failures are independent and that restoration involves repair or replacement, the equations used to evaluate the indices of the overlapping outage are as shown below.

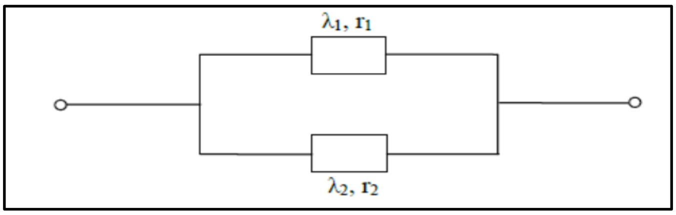


Figure 7: parallel structure

(d)Average Failure rate of the system:

$$\lambda_p = \frac{\lambda_1\lambda_2(r_1 + r_2) + \lambda_1 r_1 \lambda_2 r_2}{1 + \lambda_1 r_1 + \lambda_2 r_2 \lambda_1} = \lambda_2\lambda_1\lambda_2(r_1 + r_2) \qquad (4.4)$$

Where $\lambda 1 \mathrm{r}_1$ and λ_2 r_2 usually $<< 1$

(e) Average outage time of the system:

$$\mathrm{r_p} = (\mathrm{r_1\ r_2})/(\mathrm{r_1} + \mathrm{r_2}) \qquad (4.5)$$

(f) Average Annual Outage time of the system:

$$\mathrm{U_p} = \lambda_\mathrm{p}\mathrm{r_p} \qquad (4.6)$$

These are adequate for simple radial systems and more extended indices have to be used for general distribution systems (mixed radial and meshed systems). In this thesis, the following alternatives which may improves reliability in the system shall be considered:

i) Assessment of the existing network

ii) Evaluated the performance of after and before rehabilitated and what are done during rehabilitated including Change in the network configuration

iii) Recommended the improvement and development in distribution network

In this Thesis, we will assume that the distribution system are design and construct as single radial systems Adama distribution network is installed radial system therefore to evacuated the performance and analysis the distribution feeder by using Single radial system 15kV feeder supply direct to customer

Three basic reliability parameters require for analysis:

Average failure rate: $\lambda s = \sum_i \lambda_i$ (4.7)

Average annual outage time $= U_s = \sum_i \lambda_i r_i$ (4.8)

Average outage time: $r_s = \frac{U_s}{\lambda_s} = \frac{\sum_i \lambda_i r_i}{\sum_i \lambda_i}$ (4.9)

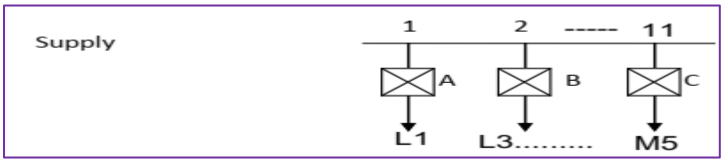


Figure 8: Simple 3-load point radial system

A radial system consists of a set of series components, including lines, cables, disconnects (or isolator), bus bar, breaker, earth switch and etc [32]. A customer or substation connected to any load point of such system requires all components between himself and the supply point to be operating. Simple radial system shown in Figure 8 The assume failure rates and repair times of each line A, B and C are shown in Table 4 and the load point reliability indices are shown in Table 4. Data shown is the typical and general feature of radial system. The assumption made is perfect isolation of faults on line element A, B and C by the circuit breaker.

Table 3: Component data for system

Line	λ (f/yr)	r (hours)
A	17	365.52
B	28	535.31
C	32	621.27
D	22	297.82
E	32	602.74
F	38	761.67
G	21	544.80
H	15	447.20
I	17	453.01
J	16	452.41
K	18	506.44
Total	256	5588.18

Table 4: Load Point reliability indices for the system

Load Point	λ (f/yr)	r (hours)	UL(hours/yr)	Number of Transformer	Average Load Demand (KW)
Line 1	17	365.52	6162.45	85	8
Line 3	28	535.31	14882.50	101	8
Line 4	32	621.27	19654.75	59	8
Line 5	22	297.82	6684.85	16	8
Line 6(M6)	32	602.74	19566.58	40	8
Line 7	38	761.67	28855.47	108	8
M1	21	544.80	11184.19	98	10
M2	15	447.20	6859.50	70	5
M3	17	453.01	7921.99	49	9
M4	16	452.41	7268.39	41	9
M5	18	506.44	9057.40	98	5
Total	256	5588.18	1432791.38	765	86

5.3. Calculation of Reliability Indices

Reliability indices are simply statistical aggregations of reliability data of well-defined loads, equipment and power users [33]. The electrical distribution system is basically analysed based on its reliability and reliability can be evaluated using reliability indices. In the14-distribution system, the reliability is basically represented by load-based indices and overall system-based indices. Load based indices are conventional indices which typically represent the data of each connected individual customer. The load point indices used in this thesis are represented below

System based indices are most widely used indices by utility companies for the reliability improvement targets. In other words, system-based indices often serve as benchmarks for reliability improvement. The main advantage of system-based indices is that it treats all type of customers equally despite its size [34]. Some commonly used system indices are described below.

Load base reliability indices two of the oldest distribution reliability indices weight customers based on connected KVA instead of weighting each customer equally. Because of this, the following are referred to as load- based indices.

System Average Interruption Frequency Index (SAIFI) represents the total number of sustained interruptions in a system over a year it is the ratio of the total mean failure rate of each element and the total customers served in the system. Total mean failure rate for an element is the total number of interruptions that a customer on that segment is expected to experience in a year SAIFI can be reduced by reducing the number of sustained interruptions.

$$SAIFI = \frac{\text{Connected KVA Interrupted}}{\text{Total Connected KVA Served}} / yr \qquad (4.7)$$

System Average Interruption Duration Index (SAIDI) is the annual outage duration an average customer will experience over a year. The sum of the annual outage duration represents the total number of annual customer hours interrupted due to all possible faults. SAIDI can be reduced by reducing the number of interruptions or by reducing the duration of interruptions.

$$SAIDI = \frac{\text{Connected KVA Interrupted}}{\text{Total Connected KVA Served}} hr / yr \qquad (4.8)$$

Customer Average Interruption Duration Index (CAIDI) is the measure of the average time to restore service to customers per interruption. CAIDI can be improved by increasing the number of momentary interruptions or decreasing the duration of sustained interruptions. Due to this, CAIDI might not be that useful to describe reliability as compare to SAIDI and SAIFI. Customer Average Interruption Duration Index is calculated as

$$CAIDI = \frac{ASIDI}{ASIFI} \qquad (4.9)$$

Average Service Availability Index (ASAI) provides the same information as SAIDI and represents the customer weighted availability of system over a year. Usually ASAI has a value of more than 0.999. ASAI is the customer –weighted availability of the system and provides the same information as SAIDI –high ASAI value reflects higher level of reliability. Some less commonly used reliability indices are not based on the total number of customers served. The customer average interruption frequency index

$$ASAI = \frac{8760 - ASIDI}{8760} \qquad (4.10)$$

The reason for load –based indices predating customer-based indices is pragmatic. In the past. Knew the size of distribution feeders but did not know how many customers were connected to each feeder. Interrupted feeders KVA was easily determined while interrupted customers required estimation. Today, customer information systems (CIS) associated customer with feeders and allow customer-based indices to be easily computed. From a utility perspective, ASIFI AND ASIDI probably represent better measures of reliability than SAIFI and SAIDI larger KVA corresponds to higher revenue and should be weighted higher making investment decisions.

The above illustration is the basic evaluation technique for basic radial system. For the purpose of this study, further operating philosophy will be apply such as additional of isolation (disconnects), additional protection and automation, transferrable load and others system configuration that might affect the reliability indices. It shall be observed that, when the additional features applied on the evaluation, there will be changes and improvement in the reliability indices [35].

5.4. Type of Interruptions

The faults in the electricity network may have various forms as illustrated These faults could be mainly of two types, namely, transient (temporary) and permanent faults. Usually, transient faults occur when phase conductors electrically contact other phase conductors or ground momentarily due to trees, birds or other animals, high winds, lightning, flashovers, and so on. Transient faults are cleared by a service interruption of sufficient length of time to extinguish the power arc or electric discharge. Here, the fault duration is minimized and unnecessary fuse blowing is prevented by using instantaneous or high-speed tripping and automatic reclosing of a relay-controlled power circuit breaker or the automatic tripping and reclosing of a circuit Reclose. The breaker speed, relay settings and recloser characteristics are selected in a manner to interrupt the fault current before a series fuse is blown, which would cause the transient fault to become permanent. Permanent faults are those which require repairs by repair crew in terms of [34]: Replacing burned-down conductors, blown fuses, or any other damaged apparatus removing tree limbs from the line manually reclosing a circuit breaker or recloser to restore service

There are different types of interruption and they are as discussed below.

- ❖ (DPEF) Distribution Permanent Earth Fault.
- ❖ (DPSC) Distribution Permanent Short Circuit
- ❖ (DTEF) Distribution Temporary Earth Fault
- ❖ (DTSC) Distribution Temporary Short Circuit
- ❖ Distribution Line Over Load (DLOL)

- ❖ (OP) Operational (When Medium Voltage feeders are interrupted Voluntary for maintenance, Load transfer, new transformer erecting, etc.)

The rest are due to others like generation, transmission problems and operational or intentional isolation.

- ❖ (TLP) Transmission Line Problem (Failure on 45 KV,66KV,132Kv ,230Kv and 400KV)
- ❖ (SOL) System Over Load (When Generated power is below the total Demand)
- ❖ (GUP) Generating Unit Problem (Generation Unit Failure)
- ❖ (DLOL) Distribution Line Overload (When Medium Voltage Feeders are loaded beyond their capacity or CT ratio)
- ❖ (PTOL) Power transformer Overload (When the load is beyond the capacity of Substation transformer)

5.5. Assessment of cause study Adama distribution primary feeders existing network

Power distribution network in Adama is effected at a primary voltage of 15kV consisting entirely of 3-phases, 3-wire feeders and is stepped down to a utilization voltage of 380/220V (3-phase, 4 wire) The distribution system in Adama consists of 220 km of 15 of 380/220V lines and above 750 distribution transformers[37]. Even though, there are many efforts and launched projects to modernize Adama underground electric cable installation, the medium voltage (MV) and Low Voltage (LV) networks are still dominated by overhead lines. In the radial distribution network structure of Adama, there are manually controlled three phase switches (MCOS) or section switches located on the beginning of each branch circuit that can interrupt the supply for planned outages like maintenance or unplanned outages of various disturbances. But the network is not suited with additional equipment's such as remote-controlled switches, automatic recloser, sectionalizes, remotely controlled fault passage indicators, etc. which would contribute a lot in improving the overall reliability. In a radial distribution system, only one path is connected between each customer and the substations. i.e. The electrical power flows from the substation to the customer along a single path which if interrupted results in complete loss of power to the customer. Such system has only one power source for a group of customers and is usually suitable for. Sparsely populated for a city like Adama, with a population density of 7,374.82/km2 and with a huge power demand such kind of network configuration is unsuccessful and that was exactly what has been witnessed for the past years. On top of this, the whole system can only be operated manually which makes it difficult to monitor the system state as well as to take any action. Knowing this, Ethiopian Electric Utility, EEU planned to modify the system to a ring system by installing several switching stations in between various Substations [37]. However, only few of the total number of feeders per substation, which are believed to encounter many faults, have been made to interconnect to other substations. In the existing distribution system, pinpointing the exact or even approximate location of faults is difficult, even though fault passage indicators are installed in various switching stations. Dispatchers still depend on telephone calls from customers and substation Operators. Customers‟ calls only provide an approximate location of the outage. Once the approximate location of outages is known, line crews are dispatched to drive along the lines to look for damage. After the damaged area is located, it has to be isolated from the rest of the system if the fuse protecting that line has not operated. This is done by first opening the substation breaker and then manually operating the switches or removing the fuses. Coordination between the line crews and dispatchers is maintained via portable radio to perform this task properly or via mobile telephone. The next step is to restore power to those parts of the system which are undamaged but have lost power because of problems elsewhere in the system. The power to these parts may be provided from alternates routes. The dispatchers determine such possible routes and ask the line crew to operate the isolators. Most of the isolators cannot be operated under load; therefore, the substation breaker is opened before operating the isolators. Since the whole process is done manually, it takes a long time. For instance, the Adama substation is an expansion of its wheeling capacity beyond the present level of 50MW addition mobile substation 50MW by 2015 and 2018 respectively. Adama district to assess feeder is line, to evaluate and analysis reliability index by compared with others feeders first consider and calculated the availability of interruption fault type data. A few step restoration scenarios were identified in Adama feeder’s line outages in the year 2009 and nine-month of 2012 E.c. From the data given by Adama district office and Adama substation, there were no recorded outages before 2009 E.c Adama substations. Further break down on calculation of fault type below Table 5 the calculation of frequency and duration of interruption which involves eleven feeders. Thus, in this calculation, it is finding out the total number of frequency and duration of hour of for take period of time

Table 5:-Adama distribution availability of interruption fault type data existing system.

Item No.	Substation Name	Feeder Name	Voltage Level	Frequency and Duration of Interruption										Frequency of Interruption (No.)	Duration of Interruption (Hr.)
				DPEF		DPSC		DTEF		DTSC		OP			
				F	D [Hr.]	F	D [Hr.]	F	D [Hr.]	F	D [Hr.]	F	D [Hr.]		
1	ADAMA SUBSTATION	Line 1	15 kv	86	254.35	83	171.12	56	35.87	30	22.31	255	521.53	510	1005.17
2		Line 3	15 kv	140	297.94	82	172.85	107	107.00	34	34.00	478	860.31	841	1472.10
3		Line 4	15 kv	192	272.40	166	499.75	131	133.66	77	97.69	391	705.00	957	1708.50
4		Line 5	15 kv	168	198.40	128	125.05	162	125.05	56	103.63	165	266.87	679	818.99
5		Line 6	15 kv	192	285.32	253	670.54	172	170.51	71	129.34	294	401.82	982	1657.53
6		Line 7	15 kv	205	249.42	244	503.18	181	150.95	107	148.05	409	1043.01	1146	2094.60
7		M1	15 kv	114	287.62	156	473.75	59	96.91	37	19.80	255	620.12	621	1498.20
8		M2	15 kv	84	226.72	126	472.57	33	10.44	14	22.96	207	497.11	464	1229.80
9		M3	15 kv	117	236.37	139	438.39	38	31.10	18	10.74	217	529.18	529	1245.77
10		M4	15 kv	97	288.18	120	318.55	35	14.24	17	7.10	217	616.04	486	1244.11
11		M5	15 kv	115	420.67	131	400.88	34	29.80	23	10.45	238	530.93	541	1392.72
		Sum		1181	2072.16	1238	3088.81	901	830.38	426	577.78	2454	4915.76	7756	15367.50

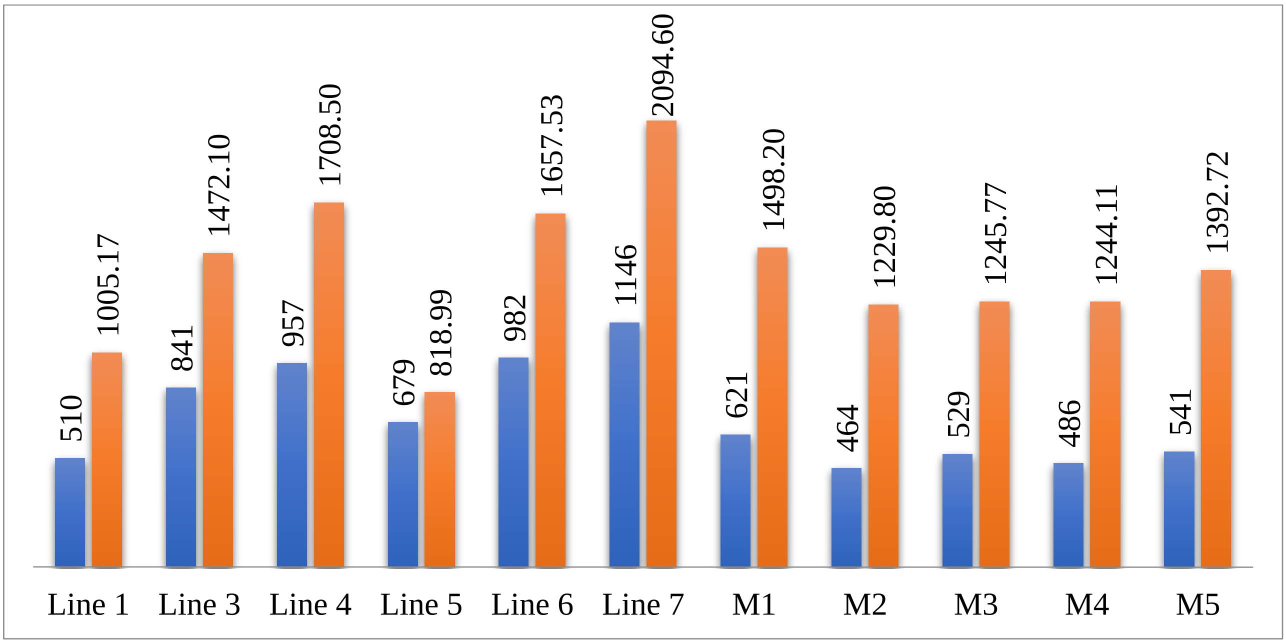


Figure 9:- Frequency and Duration of interruption by feeders existing network

On the Figure 9 it is clearly shown that the value frequency and duration of interruption the duration of interrupted maximum on feeders L7and L4 and the minimum. Feeders line 5 and line 1 the maximum frequency line 7 and line 4the minimum frequency feeders are M2 and M4

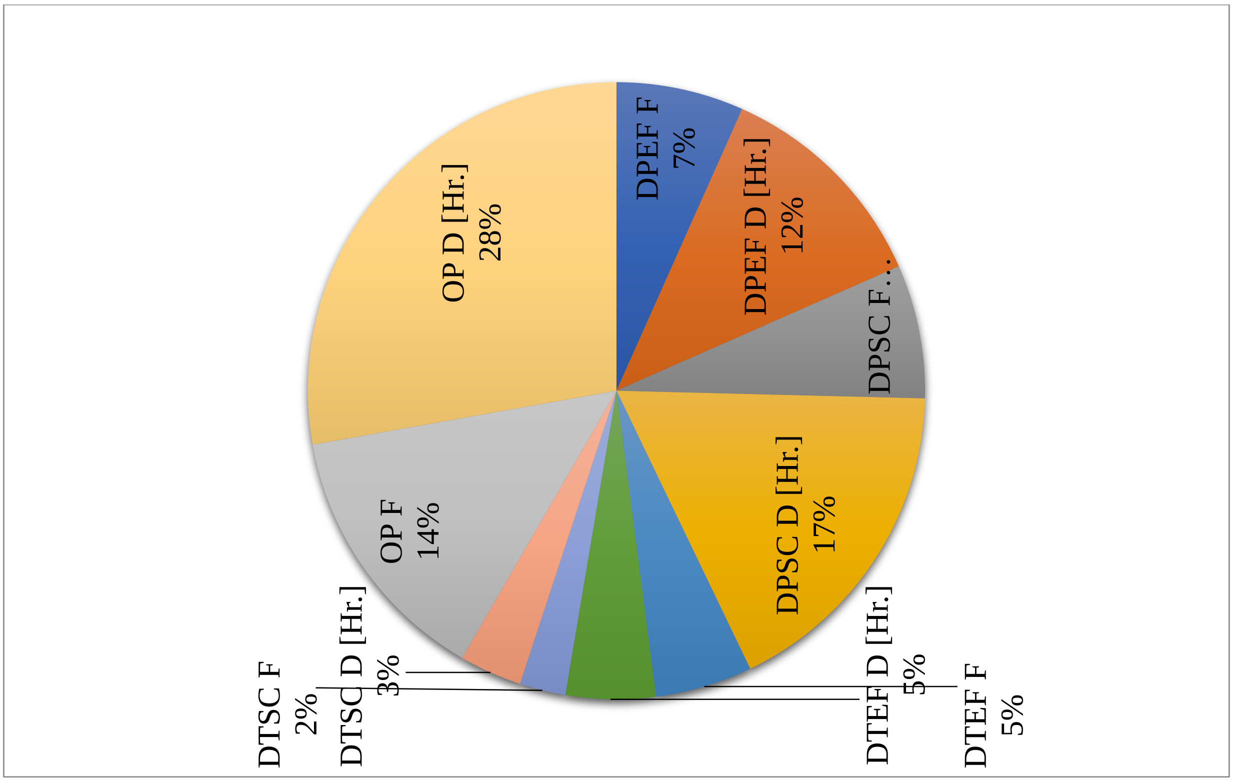


Figure 10 **:-** Frequency and Duration of interruption by fault type existing network

On the Figure 10 it is clearly shown that frequency and duration high value score interruption fault type is Operational (When Medium Voltage feeders are interrupted Voluntary for maintenance, Load transfer, new transformer erecting, etc. the second maximum interruption fault type is distribution permanent short circuit or DPSC and DPEF. The minimum faults types are DTSC and DTEF.

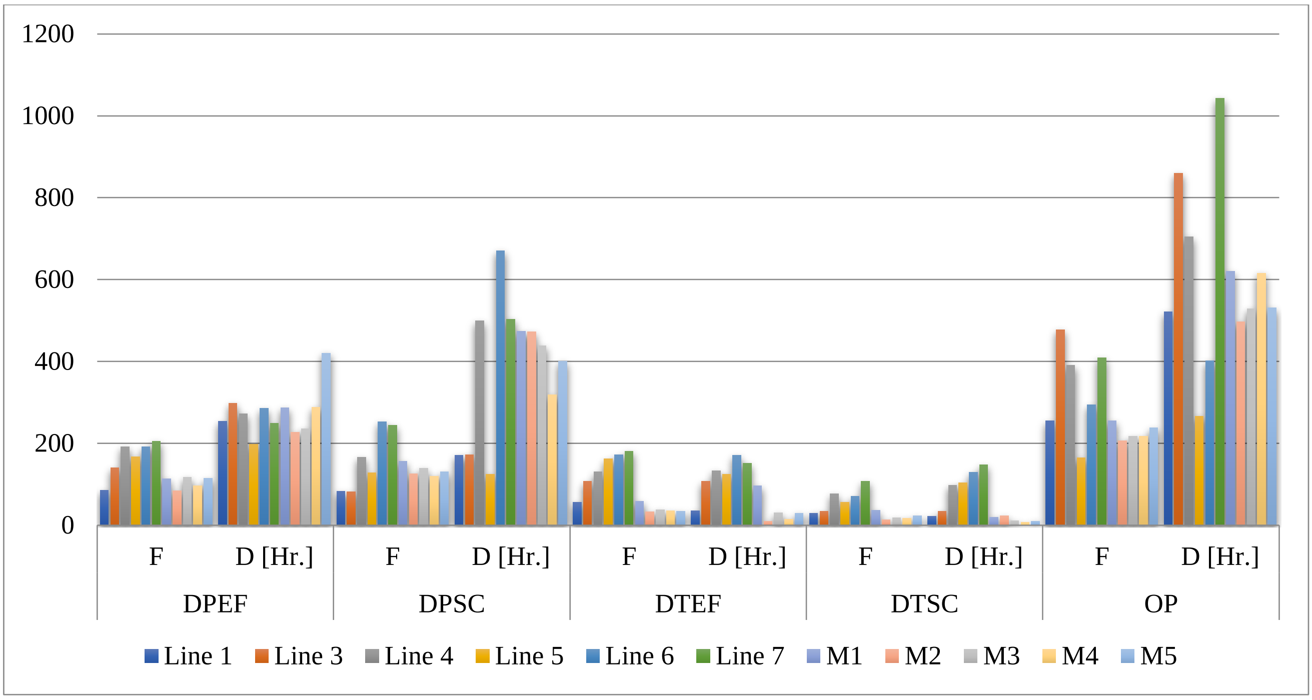


Figure 11: Frequency and Duration of interruption by fault type and feeder existing network

On the Figure 11 it is clearly shown that the operational type of interruption has maximum duration and frequency compared to others type of interruption type of fault. The minimum interruptions are DTEF and DTSC. For all feeders line the maximum occurrence of fault types are OP, DPSC and DPEF.

There are several types of outages that should not be included when calculating the indices, such as [24]:

- Interruptions that occur as a result of outage on customer – owned facilities
- Loss of supply from another utility
- Planned interruptions
- Momentary interruptions

To assess reliability, index the interruption data collected from Adama substation and utility office these interruptions data are used to calculation is done to review and analysis current performance of unplanned events and calculated the SAIFI, SAIDI and CAID indices values gives the system frequency and duration of Interruptions per year per transformers basis. The indices will be helpful to evaluated reliability indices compared with after rehabilitated network performance and unsold electricity

Table 6: Adama distribution feeder’s three years and nine-month reliability index

Item No.	Substation Name	Feeder Name	Voltage Level	Total Frequency of Interruption (No.)	Total Duration of Interruption (Hr.)	Momentary Total Frequency of Interruption (No.)	Momentary Total Duration of Interruption (Hr.)	Sustained Total Frequency of Interruption (No.)	Sustained Total Duration of Interruption (Hr.)	Peak Load in A	Peak Load in MW	Unsold Electricity	Number of Transformer	KVA of Transformer	Number of Transformer	Transformer Interupted	SAIDI (minute)	SAIFI	CAIDI
1	ADAMA SUBSTATION	Line 1	15 kv	510.00	1005.17	86.00	58.18	169.00	425.47	360.00	8	12062094.00	85.00	17680.00	85.00	43350.00	3056.19	20.23	151.05
2		Line 3	15 kv	841.00	1472.10	141.00	141.00	222.00	470.79	370.00	8	17665228.80	101.00	24070.00	101.00	84941.00	4018.29	31.58	127.24
3		Line 4	15 kv	957.00	1708.50	208.00	231.35	358.00	772.15	360.00	8	20501940.00	59.00	15600.00	59.00	56463.00	3849.87	29.75	129.41
4		Line 5	15 kv	679.00	818.99	218.00	228.68	296.00	323.45	255.00	8	9827915.16	16.00	10560.00	16.00	10864.00	437.33	6.67	65.56
5		Line 6	15 kv	982.00	1657.53	243.00	299.84	445.00	955.86	190.00	8	19890364.80	40.00	15040.00	40.00	39280.00	3231.09	25.07	128.88
6		Line 7	15 kv	1146.00	2094.60	288.00	299.00	449.00	752.60	450.00	8	25135231.20	108.00	23615.00	108.00	123768.00	6868.77	68.30	100.57
7		M1	15 kv	621.00	1498.20	96.00	116.71	270.00	761.37	180.00	10	22473072.00	98.00	16490.00	98.00	60858.00	6305.45	37.27	169.19
8		M2	15 kv	464.00	1229.80	47.00	33.40	210.00	699.29	396.00	5	9223463.03	70.00	20280.00	70.00	32480.00	4136.64	20.70	199.80
9		M3	15 kv	529.00	1245.77	56.00	41.84	256.00	674.75	380.00	9	16817854.50	49.00	9090.00	49.00	25921.00	2794.04	17.67	158.14
10		M4	15 kv	486.00	1244.11	52.00	21.34	217.00	606.73	158.00	9	16795544.40	41.00	8480.00	41.00	19926.00	2102.19	12.53	167.76
11		M5	15 kv	541.00	1392.72	57.00	40.24	246.00	821.55	198.00	5	10445409.75	43.00	16290.00	98.00	23263.00	2985.36	14.90	200.38
Total Sum				7756.00	15367.50	1492.00	1511.58	3138.00	7264.01	3297.00	86	180838117.64	710.00	177195.00	765.00	521114.00	39785.23	284.67	1597.99

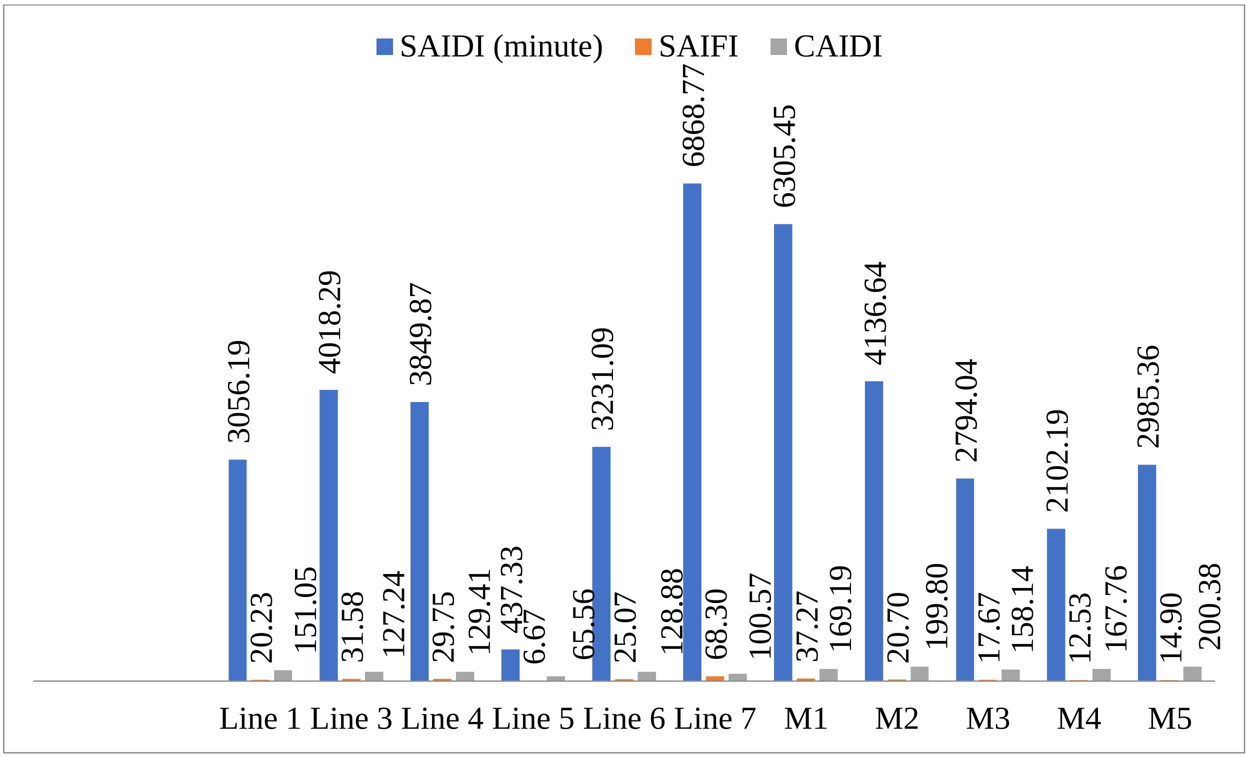


Figure 12: compared reliability index feeder line 5 with other feeders existing network.

On the figure 12 it is clearly shown that the reliability index of feeder L5 minimum compared to others feeder’s line. The reason of reliability index of feeder L5 minimum SAIDI, SAIFI and CAIDI compared to other distribution feeders this reason is the line 5 by concert pole and feed energy utilized dedicated power customer.

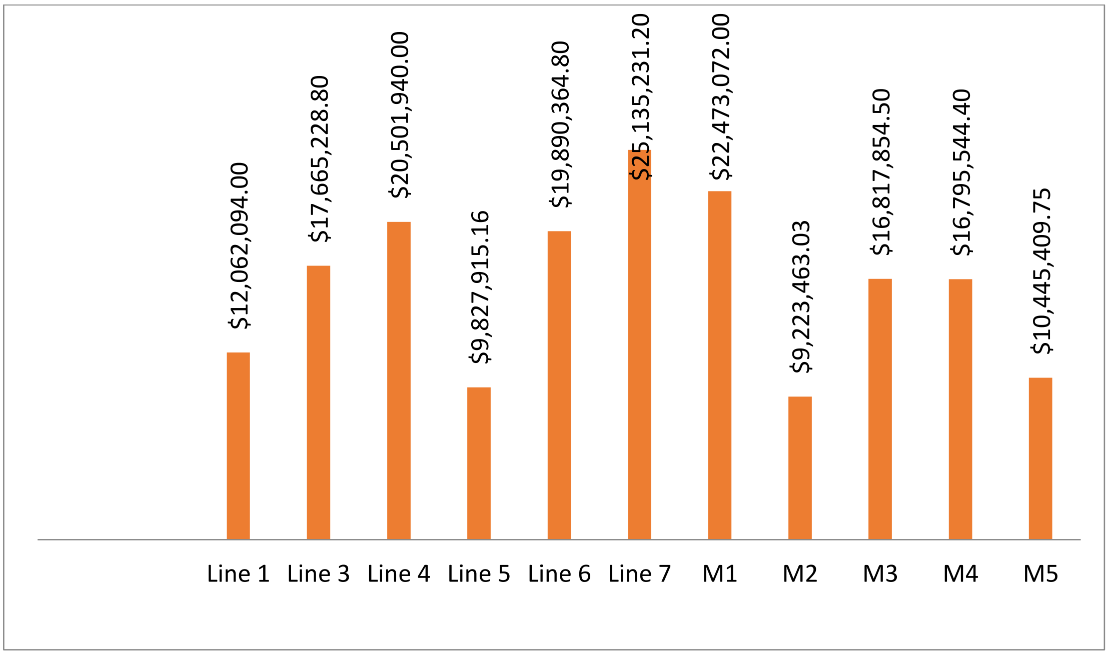


Figure 13: compared unsold electricity un- rehabilitated feeder line 5 with other feeders existing network

On the figure 13 it is clearly shown that the highest unsold electric city is line the minimum unsold electric city cost line 5, mobile 5 and mobile 2

5.5.1. Adama distribution network before rehabilitated

Table 7: Adama distribution feeders before rehabilitation interruption fault data

Item No.	Substation Name	Feeder Code	Feeder Name	Voltage Level	Frequency and Duration of Interruption										Frequency of Interruption (No.)	Duration of Interruption (Hr.)
					DPEF		DPSC		DTEF		DTSC		OP			
					F	D [Hr.]	F	D [Hr.]	F	D [Hr.]	F	D [Hr.]	F	D [Hr.]		
1	ADAMA SUBSTATION	Line 1	Line 1	15 kv	40	53.69	36	57.11	8	18.13	5	3.13	112	81.81	201	213.87
2		Line 3	Line 3	15 kv	51	110.61	7	26.83	17	17.00	4	4.00	147	172.76	226	331.20
3		Line 4	Line 4	15 kv	76	92.21	39	82.14	27	3.57	6	1.35	85	93.21	233	272.48
4		Line 5	Line 5	15 kv	25	32.41	7	1.64	22	1.64	2	0.14	37	44.28	93	80.11
5		Line 6	Line 6	15 kv	40	83.49	30	124.77	14	1.74	4	1.51	85	65.01	173	276.52
6		Line 7	Line 7	15 kv	56	34.27	53	91.43	22	4.98	6	2.41	108	79.82	245	212.91
7		M1	M1	15 kv	61	138.11	59	185.30	9	75.32	4	1.33	63	68.35	196	468.41
8		M2	M2	15 kv	39	87.30	37	137.22	7	0.24	1	0.06	61	69.39	145	294.21
9		M3	M3	15 kv	65	84.67	50	169.00	7	2.61	1	0.07	43	44.61	166	300.96
10		M4	M4	15 kv	38	143.68	34	84.80	2	0.15	3	0.25	38	50.34	115	279.22
11		M5	M5	15 kv	59	246.84	65	219.06	5	17.92	5	0.85	74	89.01	208	573.68
	Sum				388	632.09	268	706.44	126	122.62	32	13.93	698	674.63	2001	3303.57

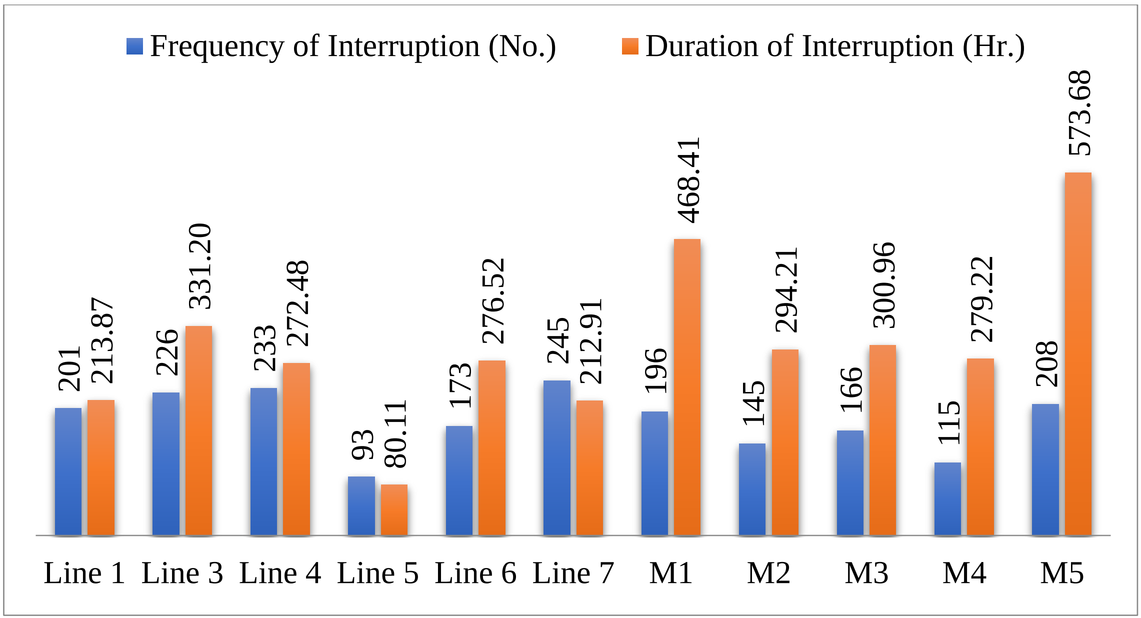


Figure 14:- Before Rehabilitation Frequency and Duration of interruption by feeder

On the Figure 14 it is clearly shown that after rehabilitation the maximum restore duration of time M1and M5 and the minimum duration to restore time line 1 and line 5 feeders the maximum feeders interrupted frequency line 7 and line 3 and minimum line 5 and M4.

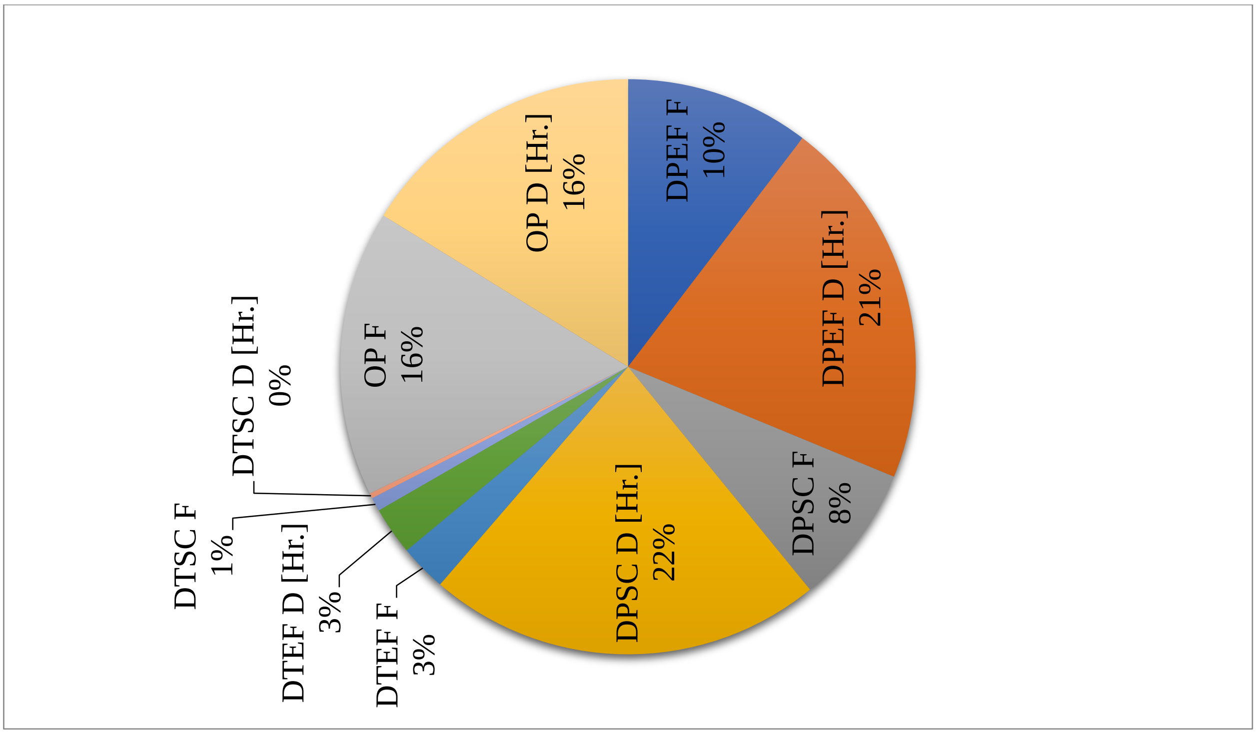


Figure 15: Before Rehabilitation Frequency and Duration of interruption by fault type

From figure 15 show that the interruption fault type the maximum faults types are DPEF, DPSC, and OP the highest frequency fault types DPEF and the minimum DTSC and DTEEF.

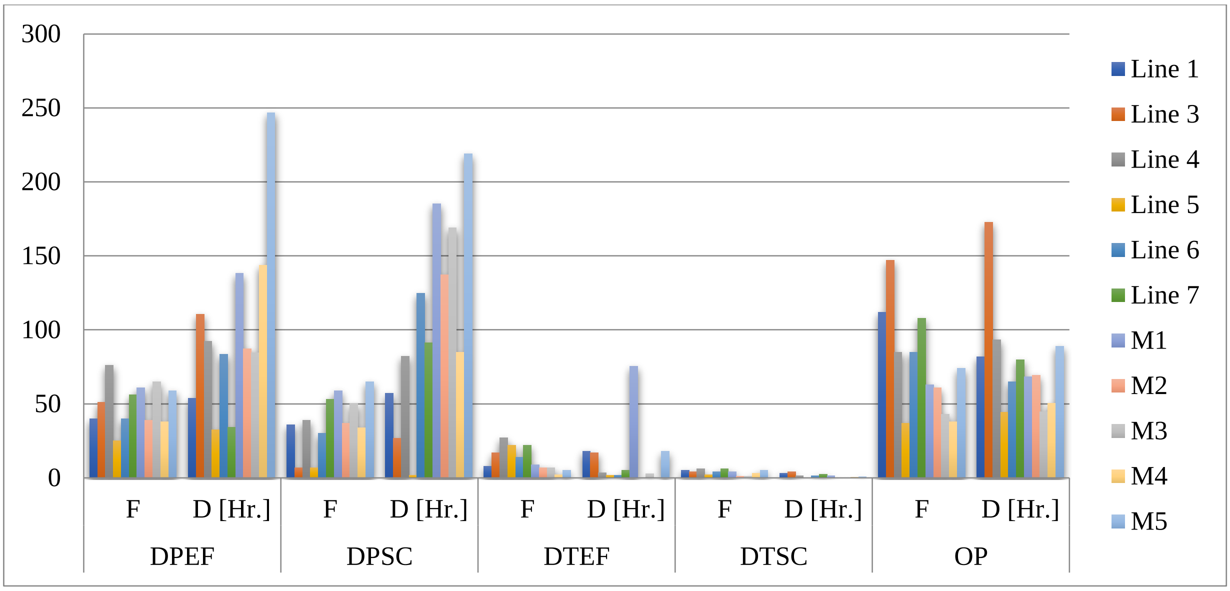


Figure 16: -Before Rehabilitation Frequency and Duration of interruption by fault type and feeders

Observed from figure 16 The duration of before rehabilitated the distribution permanent earthling fault, distribution permanent short circuit fault, and operating interruption very high on the all feeders happened compared to with temporary earthling and short circuit fault due interruption fault type.

Adama distribution network before rehabilitated reliability index assessment The interruptions data are used to calculation is done to review and analysis current performance of unplanned events and calculated the SAIFI, SAIDI and CAID indices values gives the system frequency and duration of Interruptions per year per transformers basis. The indices will be helpful to evaluated reliability indices compared with before rehabilitated network performance and unsold electricity the data taking from the last eight month of 2010 E.C

Table 8:- Adama distribution network before rehabilitated reliability index assessment

				Momentary		Sustained										
Item No.	Substation Name	Feeder Name	Voltage Level	Total Frequency of Interruption (No.)	Total Duration of Interruption (Hr.)	Total Frequency of Interruption (No.)	Total Duration of Interruption (Hr.)	Peak Load in A	Peak Load in MW	Number of Transformer	KVA of Transformer	Number of Transformer Interrupted	SAIDI (minute)	SAIFI	CAIDI	Unsold Electricity
1	ADAMA SUBSTATION	Line 1	15 kv	13.00	21.26	76.00	110.80	360.00	8	80.00	17680.00	80.00	791.43	9.05	87.47	2566440.00
2		Line 3	15 kv	21.00	21.00	58.00	137.44	370.00	8	95.00	24070.00	95.00	1165.79	8.20	142.18	3974400.00
3		Line 4	15 kv	33.00	4.92	115.00	174.35	360.00	8	50.00	15600.00	50.00	778.35	8.56	90.97	3269760.00
4		Line 5	15 kv	24.00	1.78	32.00	34.05	255.00	8	16.00	10560.00	16.00	48.64	0.76	63.84	961320.00
5		Line 6	15 kv	18.00	3.25	70.00	208.26	190.00	8	40.00	15040.00	40.00	743.79	4.17	178.51	3318240.00
6		Line 7	15 kv	28.00	7.39	109.00	125.70	450.00	8	90.00	23615.00	108.00	1010.09	14.60	69.19	2554920.00
7		M1	15 kv	13.00	76.65	120.00	323.41	180.00	10	98.00	16490.00	98.00	2829.84	17.50	161.71	7026150.00
8		M2	15 kv	8.00	0.30	76.00	224.52	396.00	5	70.00	20280.00	70.00	1403.25	7.92	177.25	2206575.00
9		M3	15 kv	8.00	2.68	115.00	253.67	380.00	9	49.00	9090.00	49.00	1109.81	8.39	132.35	4062960.00
10		M4	15 kv	5.00	0.40	72.00	228.48	158.00	9	41.00	8480.00	41.00	836.40	4.39	190.40	3769470.00
11		M5	15 kv	10.00	18.77	124.00	465.90	198.00	5	43.00	16290.00	98.00	1788.72	7.93	225.44	4302600.00
		Sum		181.00	158.40	967.00	2286.58	3297.00	86.00	672.00	177195.00	745.00	12506.10	91.46	136.74	38012835.00

All the indices are with respect to customer load point of view, Table 8 shows the results of practical Adama distribution feeder performance. When compared with the before rehabilitated and after rehabilitated, performance of the practical feeder is not good. The performance can be improved by proper planning management in the distribution system which includes switches, sectionalizes and other protective devices at appropriate places.

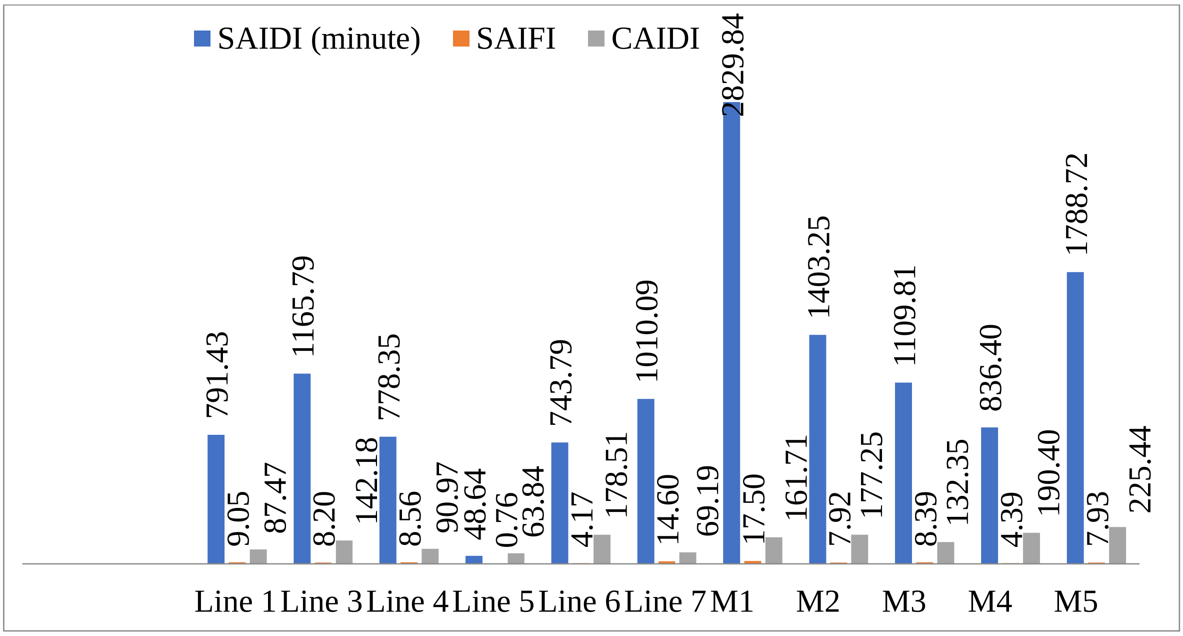


Figure 17: :- Adama distribution feeders network before rehabilitation reliability indices

From the SAIDI values obtained from figure 17, above, it can be observed that SAIDI value is highest when the first batch of feeder M1 and M5 customers restore Meanwhile, when the remaining feeders of customers are restored small each restoration time, In conclusion, when the distribution of customers restored and the number of customers restored at each restoration time are known, it can be seen that, the SAIDI value lies more towards the time when the largest number of customers are restored at.

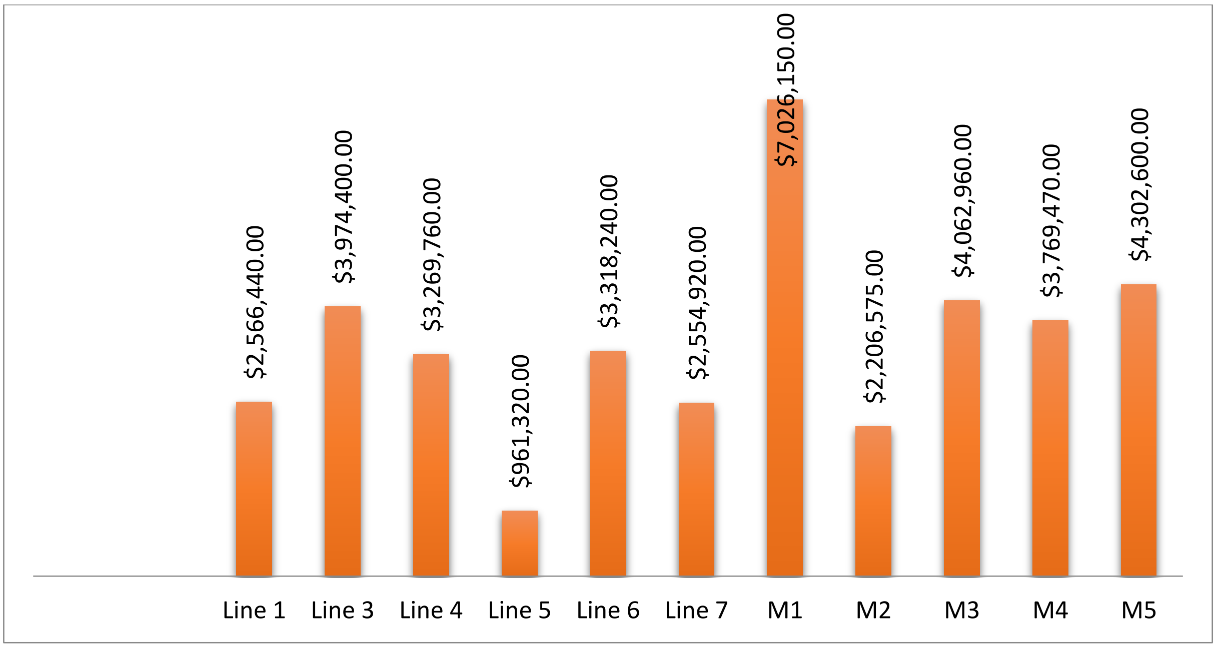


Figure 18: Adama Distribution Feeders Before Rehabilitation Unsold Electricity

On the Figure 18 it is clearly shown that before rehabilitation to compared and evaluated all unsold electricity on each feeders the feeders M1 and M5 very maximum other the L5 and M2 unsold electricity are small .

5.5.2. Adama distribution network after rehabilitation

Under Electricity Network Reinforcement and Expansion Project (ENREP), 8 Major Cities Distribution Network Rehabilitation and Upgrading Project is consisting of one contract, financed by The World Bank and Ethiopian Electric Utility (EEU). The construction contractor is China Electric Power Equipment and Technology Co. Ltd. (CET) - (CHINA)). This Project is Distribution Network Rehabilitation and Upgrading in eight (8) major Cities, consists of three lots: namely; Lot 1- Addis Ababa (only rehabilitation of LV networks at some selected Areas), Lot 2-Bahirdar, Mekelle and Dessie sites, and Lot 3-Dredawa,Adama, Hawasa and Jimma sites[28].

In Adama city the distribution network was very poor reliability and very high interruption frequency and duration of interruption the chine construction company including the the following activity working to rehabilitated the distribution network.

- Design, Supply and installation of twelve (12) 15kV Express feeders, eight (8) 15kV Interconnection lines, sixteen (16) 15kV Outgoing feeders and five (5) replacement of 15kV existing line segments
- Design, Supply and Installation of 15 kV distribution line control equipment (8 Switching Stations, 1 Auto re closure, 3 Auto Sectionalizes, 40 Load break witches, 22 Switched Capacitors and 1 Voltage boosters)
- Design, Supply and installation of SCADA system for 15 kV distribution network
- Design, Supply and installation of 16 new distribution transformers, one new compact Substations, rehabilitation of 38 existing distribution transformers and replacing of existing LV networks under these distribution transformers with new AB cable. Quantitative reliability evaluation of a distribution system can be divided into two basic segments; measuring of the past before rehabilitated and rehabilitated performance taken data Date 2010 E.C the last eight month interruption data from Adama district office and Adama substation

One of the objective of this thesis is compared the distribution network feed's before and after rehabilitated by show on table 9 data taken the interruption data from Adama substation the first eight month 2011 E.c for evaluated the reliability index of after and before rehabilitated take only eight month both duration and frequency data.

Table 9: Adama distribution after rehabilitated interruptions data

Item No.	Substation Name	Feeder Name	Voltage Level	Frequency and Duration of Interruption										Frequency of Interruption (No.)	Duration of Interruption (Hr.)
				DPEF		DPSC		DTEF		DTSC		OP			
				F	D [Hr.]	F	D [Hr.]	F	D [Hr.]	F	D [Hr.]	F	D [Hr.]		
1	ADAMA SUBSTATION	Line 1	15 kv	13	63.730	19	42.010	19	5.130	14	5.420	57	80.700	122	196.99
2		Line 3	15 kv	27	36.670	39	100.370	24	24.000	9	9.000	57	80.900	156	250.94
3		Line 4	15 kv	10	28.790	29	98.610	18	6.700	15	6.750	48	58.950	120	199.80
4		Line 5	15 kv	6	9.110	5	7.030	22	7.030	3	1.680	23	33.480	59	58.33
5		Line 6	15 kv	6	9.540	6	12.030	5	2.260	1	1.060	7	1.730	25	26.62
6		Line 7	15 kv	8	20.460	31	81.120	31	8.140	14	7.060	67	72.290	151	189.07
7		M1	15 kv	16	50.450	39	133.110	17	6.060	18	11.590	52	65.070	142	266.28
8		M2	15 kv	13	31.670	41	144.950	15	3.860	9	12.240	48	56.130	126	248.85
9		M3	15 kv	18	40.660	43	120.950	9	3.560	12	6.720	62	73.170	144	245.06
10		M4	15 kv	23	59.370	40	116.560	13	5.070	4	2.150	42	91.680	122	274.83
11		M5	15 kv	35	98.610	45	103.170	14	3.250	12	7.890	68	59.950	174	272.87
		Total		99	250.42	209	619.23	151	63.18	83	54.80	359	449.25	1341	2229.64

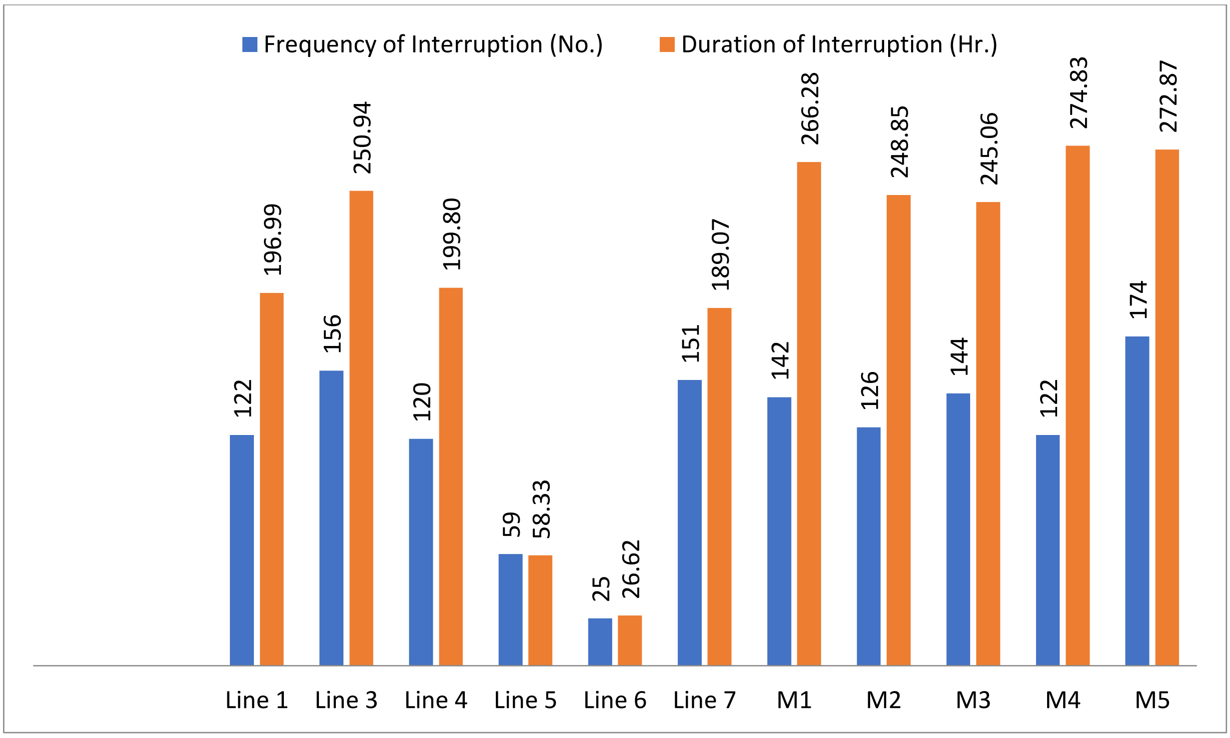


Figure 19: After Rehabilitation Frequency and Duration of interruption by feeders

On the Figure 19 it is clearly shown that after rehabilitation the maximum restore duration of time M4, M1, L3 and M5 compared to other feeders L5 and L6 frequency and duration.

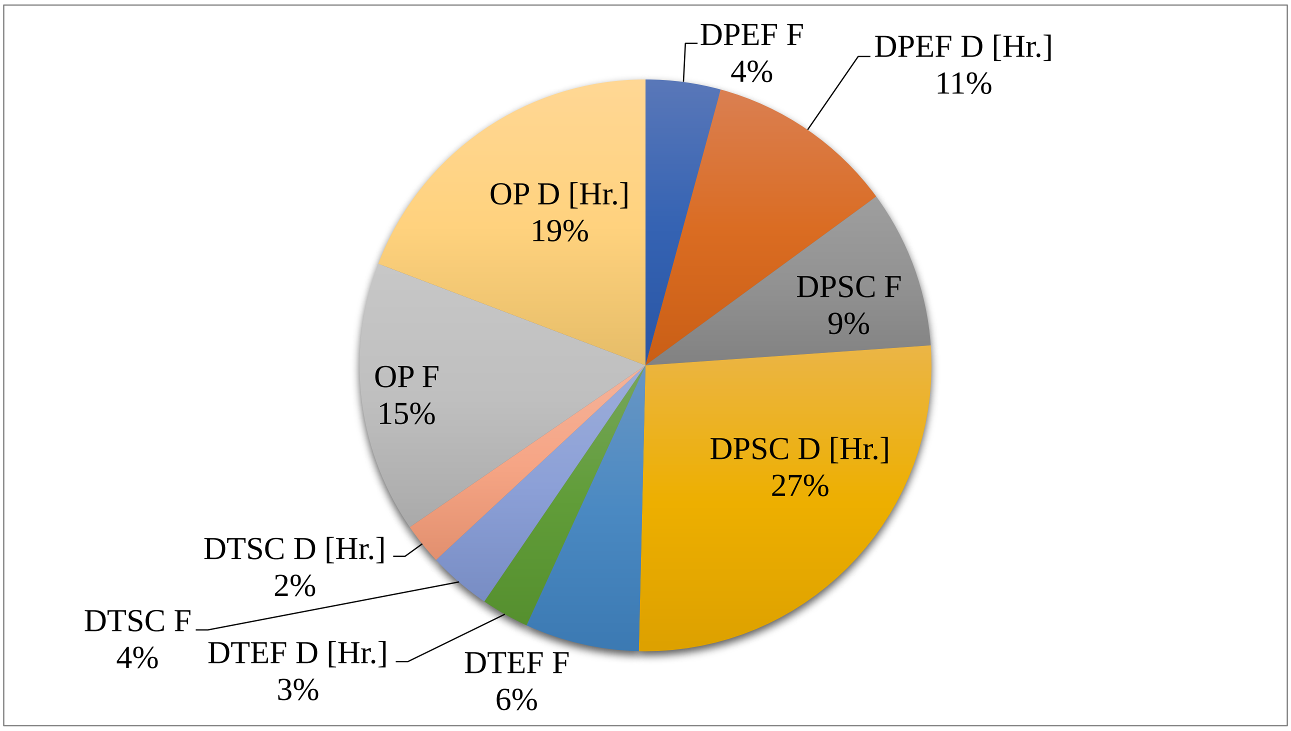
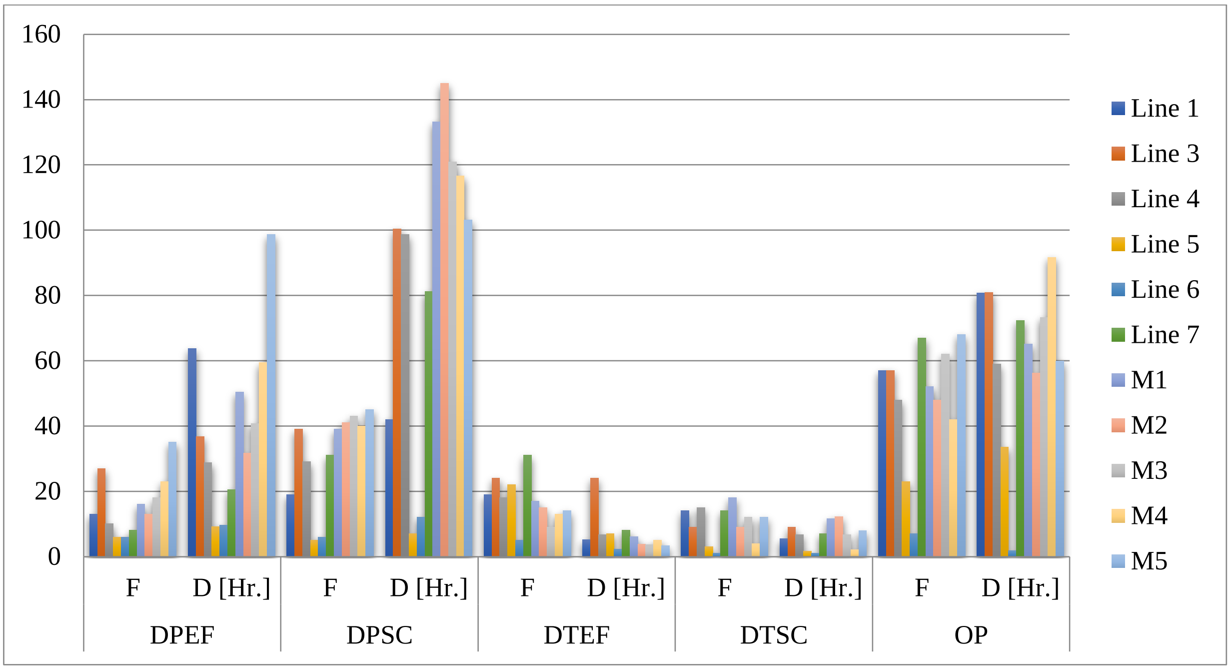


Figure 20: After Rehabilitation Frequency and Duration of interruption by fault type

From figure 20 show that the fault DPSC and OP the fault amount for the given duration of are the highest duration of interruption frequency the minimum fault type are DTEF and DTSC.



`Figure 21: Frequency and Duration of interruption by fault type and feeder

Observed from above figure 21 the duration of after rehabilitated maximum fault occurred for all feeders happened by DPSC, and OP and minimum cause of interruption for each feeder temporary earthling and short circuit fault.

In below table 10 the data given by Adama district office and Adama substation, there were no recorded outages enough data there for this thesis only taken data eight month after and before rehabilitated primary distribution system and calculation of interruption fault type used to calculation of frequency and duration of interruption addition to evaluated or compared reliability index.

Table 10: - Adama distribution network after rehabilitated reliability index assessment

				Momentary	Sustained													
Item No.	Substation Name	Feeder Name	Voltage Level	Total Frequency of Interruption (No.)	Total Duration of Interruption (Hr.)	Total Frequency of Interruption (No.)	Total Duration of Interruption (Hr.)	Total Frequency of Interruption (No.)	Total Duration of Interruption (Hr.)	Peak Load in A	Peak Load in MW	Interruption Cost	Number of Transformer	KVA of Transformer	SAIDI (minute)	SAIFI	CAIDI	Unsold Electricity
1	ADAMA SUBSTATION	Line 1	15 kv	122.00	196.99	33.00	10.55	32.00	105.74	360.00	8	2363880.00	85.00	17680.00	759.54	4	198.26	2,363,880.00
2		Line 3	15 kv	156.00	250.94	33.00	33.00	66.00	137.04	370.00	8	3011280.00	101.00	24070.00	1169.67	9	124.58	3,011,280.00
3		Line 4	15 kv	120.00	199.80	33.00	13.45	39.00	127.40	360.00	8	2397600.00	59.00	15600.00	635.21	3	196.00	2,397,600.00
4		Line 5	15 kv	59.00	58.33	25.00	8.71	11.00	16.14	255.00	8	699960.00	16.00	10560.00	21.82	0	88.04	699,960.00
5		Line 6	15 kv	25.00	26.62	6.00	3.32	12.00	21.57	190.00	8	319440.00	40.00	15040.00	72.91	1	107.85	319,440.00
6		Line 7	15 kv	151.00	189.07	45.00	15.20	39.00	101.58	450.00	8	2268840.00	108.00	23615.00	927.10	6	156.28	2,268,840.00
7		M1	15 kv	142.00	266.28	35.00	17.65	55.00	183.56	180.00	10	3994200.00	98.00	16490.00	1520.19	8	200.25	3,994,200.00
8		M2	15 kv	126.00	248.85	24.00	16.10	54.00	176.62	396.00	5	1866375.00	70.00	20280.00	1044.79	5	196.24	1,866,375.00
9		M3	15 kv	144.00	245.06	21.00	10.28	61.00	161.61	380.00	9	3308310.00	49.00	9090.00	669.20	4	158.96	3,308,310.00
10		M4	15 kv	122.00	274.83	17.00	7.22	63.00	175.93	158.00	9	3710205.00	41.00	8480.00	609.56	4	167.55	3,710,205.00
11		M5	15 kv	174.00	272.87	26.00	11.14	80.00	201.78	198.00	5	2046525.00	43.00	16290.00	733.23	5	151.34	2,046,525.00
	Total			1341.00	2229.64	298.00	146.62	512.00	1408.97	3297.00	86.00	25986615.00	710.00	177195.00	8163.22	49	166.85	25,986,615.00

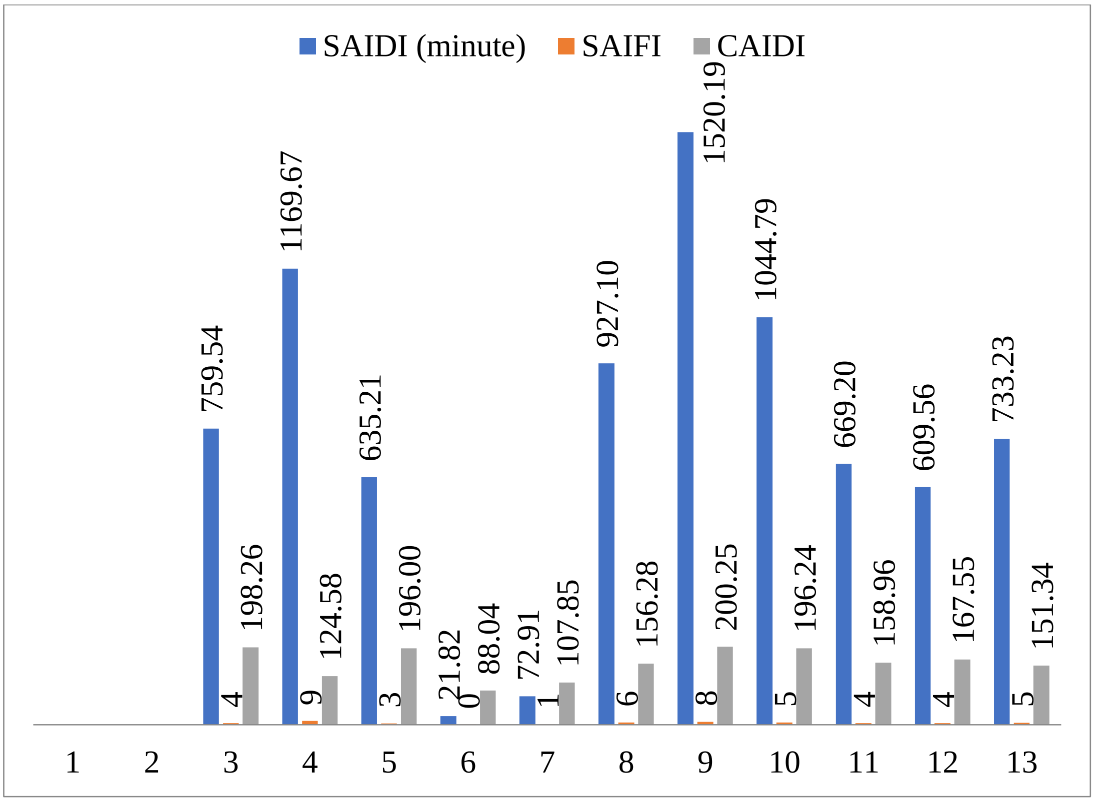


Figure 22: After rehabilitation SAIDI, SAIFI and CAIDI reliability index

From the SAIDI values obtained from figure 22 on the above, it can be observed that SAIDI value is highest when the first batch of feeder M1 and L3 customers restore Meanwhile, when the remaining feeders of customers are restored small each restoration time, In conclusion, when the distribution of customers restored and the number of customers restored at each restoration time are known, it can be seen that, the SAIDI value lies more towards the time when the largest number of customers are restored at.

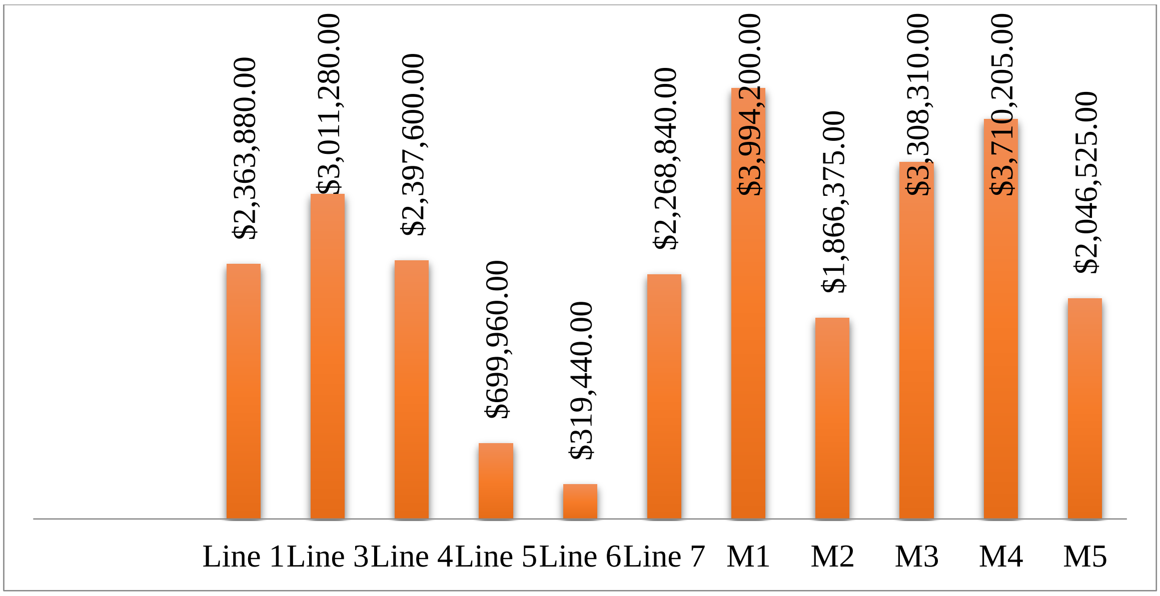


Figure 23: Adama Distribution Feeders After Rehabilitation Unsold Electricity

On the Figure 23 it is clearly shown that before rehabilitation to compared and evaluated all unsold electricity on each feeders the feeders M1 and M4 very maximum other the L5 and L6 unsold electricity are minimum.

5.6. Compared and analysis of interruption and reliability index before and after rehabilitated of Adama distribution feeders.

Table 11: after rehabilitated and before rehabilitated reliability index of Adama distribution feeders

			REHABLITATED			UN REHABLITATED		
Item No.	Substation Name	Feeder Name	SAIDI (minute)	SAIFI	CAIDI	SAIDI (minute)	SAIFI	CAIDI
1	ADAMA SUBSTATION	Line 1	760	4	198	791	9	87
2		Line 3	1170	9	125	1166	8	142
3		Line 4	635	3	196	778	9	91
4		Line 5	22	0	88	49	1	64
5		Line 6	73	1	108	744	4	179
6		Line 7	927	6	156	1010	15	69
7		M1	1520	8	200	2830	18	162
8		M2	1045	5	196	1403	8	177
9		M3	669	4	159	1110	8	132
10		M4	610	4	168	836	4	190
11		M5	733	5	151	1789	8	225
	Sum		8163	49	167	12506	91	137

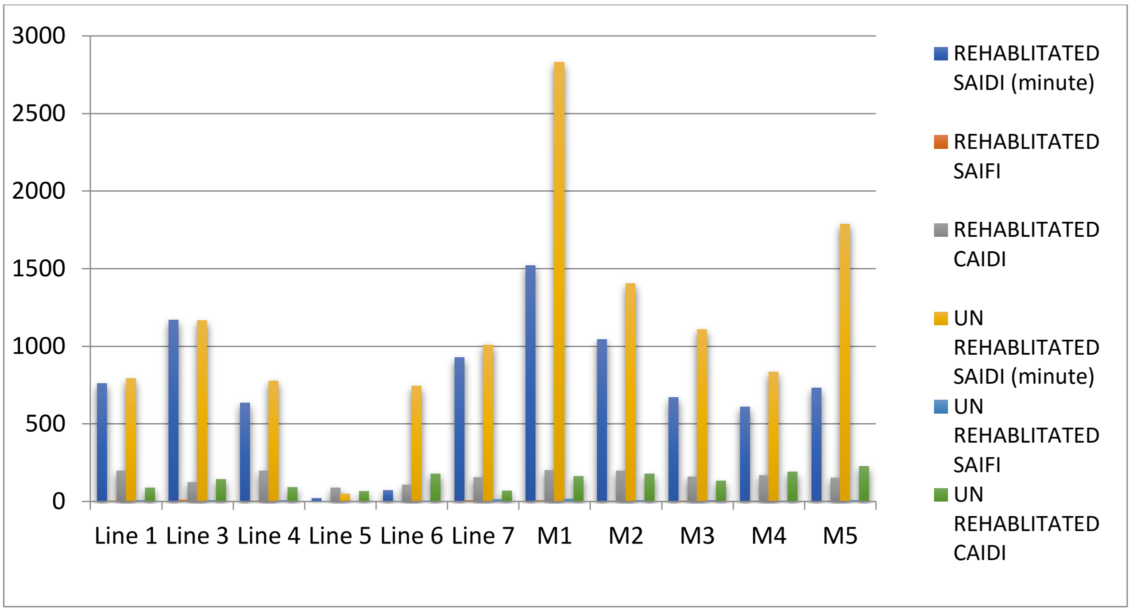


Figure 24: After rehabilitation and before rehabilitation reliability index

Table 12: After and before rehabilitation unsold electricity Adama distribution line

Item No.	Substation Name	Feeder Name	Rehablitated Unsold Electricity	Un rehablitated Unsold Electricity
1	ADAMA SUBSTATION	Line 1	2,363,880.00	2566440.00
2		Line 3	3,011,280.00	3974400.00
3		Line 4	2,397,600.00	3269760.00
4		Line 5	699,960.00	961320.00
5		Line 6	319,440.00	3318240.00
6		Line 7	2,268,840.00	2554920.00
7		M1	3,994,200.00	7026150.00
8		M2	1,866,375.00	2206575.00
9		M3	3,308,310.00	4062960.00
10		M4	3,710,205.00	3769470.00
11		M5	2,046,525.00	4302600.00
	Sum		25,986,615.00	38,012,835.00

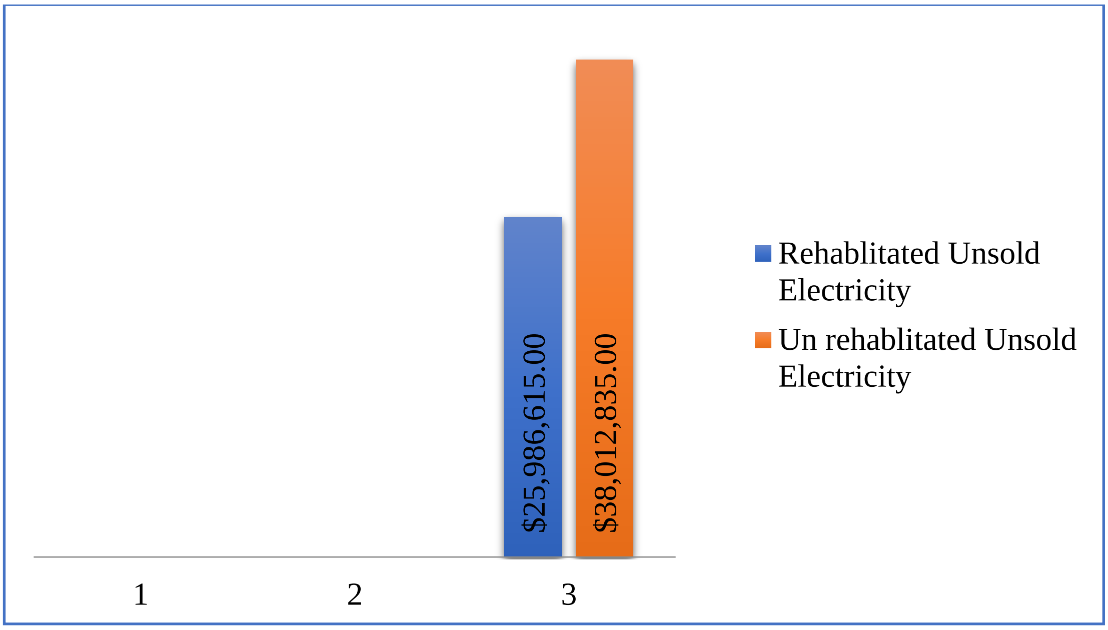


Figure 25: compared after and before rehabilitated Adama distribution network

On the above figure 25 show that compared after and before rehabilitated by taken only eight-month data in both of after and before rehabilitated after rehabilitated the unsold electricity save 12,026,220 birrs to spend.

After evaluated and discus the reliability index of Adama distribution feeders' line with the advent of performance-based rates, utilities are taking a closer look at their Reliability data and working to improve their indices. Studies have shown that reliability is greatly affected by rehabilitated by china company. There is an almost direct correlation between rehabilitated and as well as circuit length, with longer circuits have more interruptions. Some data also suggests that utilities with higher system voltages tend to have more outages, but this may be related to the length of the circuit more than the voltage. Circuit configuration also has an impact on system reliability. Simple overhead radial systems have the worst reliability. Auto-looped overhead systems and underground systems have an about equal degree of reliability, and a well-coordinated overhead system with multiple protective devices usually results in the highest degree of reliability. Of course, network systems provide a level of service reliability that is an order of magnitude better than any standard distribution configuration.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The result of this Thesis is true reflection of power distribution in the study area. The value of reliability obtained from the analysis of the feeders show that outage duration, outage frequency and time taken to restore supply are very high. On the other assessment, evaluated and comparison of distribution feeder’s interruption reliability indices before and after rehabilitated Adama distribution network by taken eight months before and after rehabilitated network

- Before the total outage duration (SAIDI) for the period is12506.18-minute, outage frequency (SAIFI) is ninety one times and the customer average duration CAIDI is 137.42 and unsold electricity is 38,012,835.00 birr. This is too far from the after rehabilitated feeders values Reliability of the 15kV system could be further improved by the installed eight switching stations, auto recloser, and rehabilitated 55 transformers consider load and low voltage installed by insulated wire and constructed a concrete pole up to customer service drop. Additionally, fifty five transformers and eight switching station connected with installed SCADA station, this china constructed company after rehabilitated the reliability index for SAIDI is 8163.22, SAIFI is 49 and CAIDI is 166.59 and unsold electricity is 25,135.231.2 birr base on this value after rehabilitated is more reliable than before rehabilitated.
- The Adama distribution system is mainly made up of radial network which is making things worse in case of line tripping. So, it is better to convert radial networks to ring network for better reliability. Distribution transformers are without surge arrestors at the majority of locations. So, it is better the distribution transformer with their accessories are equipped with surge arresters. For better distribution reliability, low voltages feeders should be undergrounded.
- Timely maintenance of distribution lines is necessary, particularly trimming and cutting of trees which causes earth fault by bridging line to earth or bridging two or three phases
- Out of much different type interruption duration, natural or unplanned faultsare very minimum when compared with operation or maintenance interruption duration are very high. Therefore, thy have to work in for the minimization of operation or maintenance interruption duration

- Reduction of faults — trimming of trees, animal guards, arresters.

- Finding and replacing faults quicker — faulted circuit indicators, management system for the outages, crew staffing, cable fault finding.
- Limit the number of interrupted customers — increase the number of fuses, recloser and sectionalizes.
- Interrupt customers only in the case of permanent faults — use recloser Instead of fuses and implement fuse saving schemes
- To increase the reliability of distribution network system just like previously constructed by chines company on distribution feeders which are not fully rehabilitated it is better to do more researches and projects on un-rehabilitated distribution Networks.

6.2. Recommendations

Based on this thesis study many problems are observed and out of that it can be tried to solve interruption related problems. But still now many problems are not addressed. So, this study can also recommend many different methods for reduction of long-duration interruptions for concerned body.

- Reliability analysis requires: total number of customers, number of customers served, number of customers interrupted, loads connected, number of transformers and their ratings, and so on. So, power system faults, power system devices (lines, buses, transformers on each feeder, circuit breakers, and disconnects) and total number of customers served and interrupted should be correctly documented information are more necessary things for the next researches.
- In this thesis interruption data of substation are studied but the SCADA can control eight switching stations so that this thesis couldn’t include those SCADA interruption data. For the others researchers I recommend it is better to include all switching station data and it is better to simulate by using software.

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Appendix

Appendix 1A

Adama distribution network district three month and nine month interruption from 2009 up to 2012

Code	Feeder_Line	Month	Year	DPEF_DUR	DPEF_FRQ	DPSC_DUR	DPSC_FRQ	DTEF_DUR	DTEF_FRQ	DTSC_DUR	DTSC_FRQ	OP_DUR	OP_FRQ	Frequency Of Intrruption(No.)	Duration Of Intrruption (Hr.)
1	L1	1	2009	3.2	2	4.2	2	5.17	2	2.18	1	12.28	5	12	27.03
2	L1	2	2009	7.28	4	17.04	4	4.49	2	3.32	3	15.36	6	19	47.49
3	L1	3	2009	4.11	2	11.15	3	8.34	3	4.40	3	11.29	4	15	39.29
4	L1	4	2009	0	0	2.3	1	6.05	2	5.11	2	4.54	3	8	18
5	L1	5	2009	3.3	3	1.5	1	2.33	1	3.56	1	6.33	3	9	17.02
6	L1	6	2009	5.58	3	1.5	1	6.15	2	5.05	1	4.32	5	12	22.6
7	L1	7	2009	3.23	2	12.05	4	3.42	1	4.22	3	11.42	6	16	34.34
8	L1	8	2009	20.31	6	25.01	7	4.52	1	6.29	4	10.16	9	27	66.29
9	L1	9	2009	11.03	2	15.35	4	3.23	2	4.07	3	40.28	32	43	73.96
10	L1	10	2009	7.03	3	6.12	3	2.01	1	5.28	3	21.02	30	40	41.46
11	L1	11	2009	4.42	1	20.36	9	8.03	3	3.54	2	37.33	10	25	73.68
12	L1	12	2009	3.02	3	8.2	4	10.02	4	7.47	4	17.22	8	23	45.93
13	L1	1	2010	3.56	5	12.11	8	0.01	1	0	0	3.91	12	26	19.59
14	L1	2	2010	3.56	4	12.11	7	0.01	1	0	0	3.91	12	24	19.59
15	L1	3	2010	3.5	5	11.23	8	0.5	2	0	0	3.45	13	28	18.68
16	L1	4	2010	2.76	4	1.31	2	0.06	1	0.03	1	7.35	16	24	11.51
17	L1	5	2010	10.3	7	2.05	3	0	0	0.03	1	13.41	27	38	25.79
18	L1	6	2010	6.41	5	0.17	1	0	0	0	0	17.08	25	31	23.66
19	L1	7	2010	5	1	4.68	4	0	0	0.13	1	36.08	31	37	45.89
20	L1	8	2010	0.05	4	14.15	5	13.73	1	0	0	5.63	7	17	33.56
21	L1	9	2010	31.18	16	4.25	3	0.2	2	0	0	12	12	33	47.63
22	L1	10	2010	3.5	5	11.23	8	0.5	2	0	0	3.45	13	28	18.68
23	L1	11	2010	4.05	4	11.4	7	3.2	1	2.5	2	4.12	11	25	25.27
24	L1	12	2010	3.5	5	11.23	8	0.5	2	0.5	2	3.45	13	30	19.18
25	L1	1	2011	0	0	2.2	2	0.18	1	0.17	1	2.28	3	7	4.83
26	L1	2	2011	20.04	2	6.28	3	1.32	4	0.49	2	11.36	5	16	39.49
27	L1	3	2011	1.15	1	5.11	3	1.4	4	1.34	2	1.29	4	14	10.29
28	L1	4	2011	0	0	0	0	0.11	1	0	0	4.54	6	7	4.65
29	L1	5	2011	0.01	1	4.3	3	0.56	3	0.33	1	2.33	3	11	7.53
30	L1	6	2011	1.1	1	2.58	2	0.05	1	0.15	1	4.32	5	10	8.2
31	L1	7	2011	11.42	3	2.23	1	1.22	4	2.42	6	13.42	13	27	30.71
32	L1	8	2011	30.01	5	19.31	5	0.29	1	0.52	1	41.16	18	30	91.29
33	L1	9	2011	13.35	3	10.03	2	2.07	4	1.23	2	55.28	28	39	81.96
34	L1	10	2011	4.12	3	8.03	2	1.28	2	0	0	213.02	29	36	226.45
35	L1	11	2011	25.36	7	3.42	1	0.54	3	1.03	2	67.33	11	24	97.68
36	L1	12	2011	6.2	3	2.02	3	2.47	7	11	4	7.22	3	20	28.91
37	L2	1-6	2012	26.4	8	29.9163	15	2.2497	9	0.25	1	5.8327	10	43	64.6487
38	L2	7-9	2012	61.5	9	18.5834	5	3.9997	4	0.25	2	10.3327	5	25	94.6658
				254.35	86	171.1197	83	35.8694	56	22.31	30	521.5254	255	*442*	*935.6245*

Code	Feeder_Line	Month	Year	DPEF_DUR	DPEF_FRQ	DPSC_DUR	DPSC_FRQ	DTEF_DUR	DTEF_FRQ	DTSC_DUR	DTSC_FRQ	OP_DUR	OP_FRQ	Frequency Of Intrruption(No.)	Duration Of Intrruption (Hr.)
1	L3	1	2009	6.25	3	1.06	1	3.4	4	2.36	2	11.2	6	16	24.27
2	L3	2	2009	1.4	1	1.04	1	2.08	1	2.03	1	11.04	8	12	17.59
3	L3	3	2009	3.46	1	2.03	2	4.09	3	1.05	1	11.3	6	13	21.93
4	L3	4	2009	0	0	1.83	1	1.45	2	0.32	1	10.02	5	9	13.62
5	L3	5	2009	0	0	1	1	0	0	0	0	10.23	6	7	11.23
6	L3	6	2009	2	1	0	0	0.54	2	1	1	9.01	7	11	12.55
7	L3	7	2009	0	0	0.28	1	1.01	2	0	0	17.26	10	13	18.55
8	L3	8	2009	0	0	5.73	3	1.46	6	1	1	12.45	9	19	20.64
9	L3	9	2009	1.03	1	0	0	0	0	0	0	40.13	26	27	41.16
10	L3	10	2009	0	0	0	0	1.23	3	0.31	1	15.4	8	12	16.94
11	L3	11	2009	0	0	5.23	3	1.32	6	0.07	1	16.1	9	19	22.72
12	L3	12	2009	7.29	3	0	0	2.38	8	0.18	1	0	0	12	9.85
13	L3	1	2010	19.53	8	4.05	2	0.21	3	0	0	13.35	15	28	37.14
14	L3	2	2010	19.53	8	0	0	0.21	3	0	0	13.35	15	26	33.09
15	L3	3	2010	19.23	7	0	0	0.34	5	0.13	1	13.45	16	29	33.15
16	L3	4	2010	12.73	10	0	0	0.03	1	0	0	0	0	11	12.76
17	L3	5	2010	12.3	4	0	0	0.2	2	0	0	24.43	23	29	36.93
18	L3	6	2010	9.06	9	2.5	2	0	0	0.1	1	17.48	28	40	29.14
19	L3	7	2010	5.9	4	1	1	0.08	1	0	0	44.09	29	35	51.07
20	L3	8	2010	19.85	9	0	0	0	0	0	0	41.9	9	18	61.75
21	L3	9	2010	9.81	6	0	0	0.13	1	0	0	7.73	12	19	17.67
22	L3	10	2010	19.23	7	1.26	1	0.34	5	0.13	1	13.45	16	30	34.41
23	L3	11	2010	15.23	5	19.06	2	1.34	3	1.5	1	10.23	14	25	47.36
24	L3	12	2010	19.23	7	3.01	1	0.34	5	0.13	1	13.45	16	30	36.16
25	L3	1	2011	1.4	1	17.07	6	2.11	3	3.29	4	6.11	10	24	29.98
26	L3	2	2011	5.54	3	16.56	8	0.4	3	0	0	24	10	24	46.5
27	L3	3	2011	0.07	1	9.06	5	2.03	6	0.53	2	2.34	5	19	14.03
28	L3	4	2011	1.43	2	3.35	2	0.44	3	0.13	1	2	4	12	7.35
29	L3	5	2011	5.32	4	10.21	4	0.5	4	0	0	0.22	2	14	16.25
30	L3	6	2011	0	0	3.45	3	0	0	0	0	6.02	9	12	9.47
31	L3	7	2011	4.48	10	17.5	7	7.24	3	0.42	2	12.06	6	28	41.7
32	L3	8	2011	18.43	6	23.17	4	0.58	2	0	0	28.15	11	23	70.33
33	L3	9	2011	12.55	2	5.39	4	0.29	2	3.14	4	53.11	27	39	74.48
34	L3	10	2011	9.16	3	3.24	2	0.15	1	0	0	212.22	28	34	224.77
35	L3	11	2011	3.16	1	2.17	6	0.15	2	2.02	5	68.4	14	28	75.9
36	L3	12	2011	11.17	2	1.02	1	0.2	1	0.63	1	1.55	3	8	14.57
37	L3	1-6	2012	22.167	11	6.8333	6	2.2497	11	0	0	62.3318	53	81	93.582
38	L3	7-9	2012	0	0	4.75	2	0	0	0	0	4.7503	3	5	9.5003
				297.94	**140**	**172.853**	**82**	**38.52**	**107**	**20.5**	**34**	**860.312**	**478**	**841**	**1390**

Code	Feeder_Line	Month	Year	DPEF_DUR	DPEF_FRQ	DPSC_DUR	DPSC_FRQ	DTEF_DUR	DTEF_FRQ	DTSC_DUR	DTSC_FRQ	OP_DUR	OP_FRQ	Of Intrruptio	Duration Of Intrruption
1	L4	1	2009	6.2	6	13.51	6	12.36	6	10.03	4	17.86	10	32	59.96
2	L4	2	2009	5.3	5	22.51	5	10.36	5	20.03	8	27.86	18	41	86.06
3	L4	3	2009	8.1	7	11.4	4	14.34	5	14.03	6	16.32	11	33	64.19
4	L4	4	2009	1.04	1	11.58	2	11.04	6	10.04	4	10.04	6	19	43.74
5	L4	5	2009	0	0	6.36	1	0	0	11.04	7	9.09	10	18	26.49
6	L4	6	2009	9.49	2	20.38	2	9.08	4	5.09	3	7.4	7	18	51.44
7	L4	7	2009	8.73	5	8.46	5	8.04	0	10.4	5	18.43	9	24	54.06
8	L4	8	2009	32.73	4	27.16	7	0	0	1.04	1	4.23	5	17	65.16
9	L4	9	2009	10.11	4	7.56	4	10.23	4	0	0	6.9	8	20	34.8
10	L4	10	2009	7.2	7	21.4	4	14.34	5	0.03	1	6.32	16	33	49.29
11	L4	11	2009	8.03	5	18.05	3	14.75	6	1.45	1	7.32	14	29	49.6
12	L4	12	2009	7.2	7	21.4	4	13.34	7	0.03	1	6.32	16	35	48.29
13	L4	1	2010	7.76	12	15.61	3	0.43	7	0.11	1	11.26	11	34	35.17
14	L4	2	2010	7.76	11	15.61	4	0.43	7	0.11	1	11.26	11	34	35.17
15	L4	3	2010	6.54	12	15.63	3	0.34	6	0.11	1	11.12	8	30	33.74
16	L4	4	2010	2.78	5	3.98	5	0.08	1	0	0	0	0	11	6.84
17	L4	5	2010	4.43	10	3.04	4	0.1	1	0	0	15.29	20	35	22.86
18	L4	6	2010	13.25	5	1.43	2	0.21	4	0	0	17.3	12	23	32.19
19	L4	7	2010	1.98	3	5.65	4	0	0	0.08	1	14.46	9	17	22.17
20	L4	8	2010	36.5	12	22.31	11	0.1	2	0	0	2.9	4	29	61.81
21	L4	9	2010	17.96	12	7	6	0.18	3	0.16	1	9.9	5	27	35.2
22	L4	10	2010	6.54	12	15.63	3	0.34	6	0.11	1	11.12	12	34	33.74
23	L4	11	2010	5.01	10	11.45	6	2.3	5	0.89	2	11.12	11	34	30.77
24	L4	12	2010	6.54	12	15.63	3	0.34	6	0.11	1	11.12	12	34	33.74
25	L4	1	2011	4.35	3	26.4	5	3.13	7	0.17	1	2.1	6	22	36.15
26	L4	2	2011	1.1	1	4.44	4	0.34	2	0	0	9.23	4	11	15.11
27	L4	3	2011	0	0	3.32	2	0.35	3	1.31	2	3.34	6	13	8.32
28	L4	4	2011	0	0	4.14	4	0	0	0.41	3	3.16	6	13	7.71
29	L4	5	2011	1.34	1	19.37	4	0	0	0.48	1	1.21	1	7	22.4
30	L4	6	2011	0	0	1.4	1	0	0	0.2	2	6.27	6	9	7.87
31	L4	7	2011	10.54	2	12.54	2	1.33	4	1.07	3	8.54	6	17	34.02
32	L4	8	2011	11.46	3	27	7	1.55	2	3.11	3	25.1	13	28	68.22
33	L4	9	2011	0	0	5.17	3	0.41	3	0.4	1	61.39	26	33	67.37
34	L4	10	2011	4.59	3	10.36	5	0.35	1	0.3	1	223.25	30	40	238.85
35	L4	11	2011	7.26	3	2.41	2	1.01	2	0.57	2	70.54	15	24	81.79
36	L4	12	2011	1.17	1	11.13	5	1.04	2	0.45	1	3.51	5	14	17.3
37	L4	1-6	2012	5.83	3	35.8326	14	1.333	8	2.333	3	18.333	18	46	63.6616
38	L4	7-9	2012	3.5767	3	13.5	7	0.0833	1	1.9997	4	4.0837	4	19	23.2434
SUM				272.3967	192	499.7526	166	133.6563	131	97.6927	77	704.9967	391	957	1708.495

Code	Feeder_Li	Month	Year	DPEF_DU	DPEF_FRQ	DPSC_DU	DPSC_FRQ	DTEF_DU	DTEF_FRQ	DTSC_DU	DTSC_FRQ	OP_DUR	OP_FRQ	Frequency Of Intrruption(No.)	Duration Of Intrruption (Hr.)
1	L5	1	2009	13.55	12	17.26	9	9.56	6	10.15	5	11.2	4	36	61.72
2	L5	2	2009	14.55	11	7.26	5	10.56	7	10.15	5	12.04	5	33	54.56
3	L5	3	2009	13.44	12	10.13	7	8.45	4	12.03	6	10.3	4	33	54.35
4	L5	4	2009	15.05	8	12.9	10	10.15	7	8.04	4	5.04	3	32	51.18
5	L5	5	2009	11.32	8	8.34	7	10.13	8	1.14	2	6.23	2	27	37.16
6	L5	6	2009	10.12	9	14.54	10	8.24	8	5.07	2	0	0	29	37.97
7	L5	7	2009	11.71	7	9.46	6	9.03	8	5.08	2	17.26	10	33	52.54
8	L5	8	2009	14.53	8	15.31	9	7.23	2	8.09	3	12.45	5	27	57.61
9	L5	9	2009	5.16	6	24.48	12	0	0	10.05	6	40.13	24	48	79.82
10	L5	10	2009	3.44	10	8.13	8	10.45	5	12.3	6	5.4	2	31	39.72
11	L5	11	2009	4.55	9	9.04	9	13.45	3	2.03	1	6.1	2	24	35.17
12	L5	12	2009	3.44	8	8.13	5	10.45	5	10.12	1	0	0	19	32.14
13	L5	1	2010	1.28	2	0	0	0.2	2	0	0	0	0	4	1.48
14	L5	2	2010	1.28	2	0	0	0.2	2	0	0	0	0	4	1.48
15	L5	3	2010	1.28	3	0	0	0.2	3	0	0	0	0	6	1.48
16	L5	4	2010	0.86	3	1.83	1	0.88	1	0	0	0	0	5	3.57
17	L5	5	2010	0.39	2	0	0	0	0	0	0	7.52	8	10	7.91
18	L5	6	2010	0.11	1	0	0	0.01	1	0	0	7.58	9	11	7.7
19	L5	7	2010	1	1	0.28	1	0.05	2	0	0	17.88	12	16	19.21
20	L5	8	2010	23.37	7	5.73	3	0.63	6	0.11	1	1.16	1	18	31
21	L5	9	2010	2.95	4	0	0	0.35	4	0	0	4.01	3	11	7.31
22	L5	10	2010	1.28	3	0	0	0.2	3	0	0	0	0	6	1.48
23	L5	11	2010	2.03	4	5.23	3	0.2	3	0.03	1	6.13	4	15	13.62
24	L5	12	2010	1.28	3	0	0	0.2	3	0	0	0	0	6	1.48
25	L5	1	2011	5.25	3	4.05	2	2.4	4	1.36	2	1.2	4	15	14.26
26	L5	2	2011	0.4	1	0	0	0.08	2	0	0	1.04	2	5	1.52
27	L5	3	2011	1.46	1	0	0	1.09	4	0	0	1.3	1	6	3.85
28	L5	4	2011	0	0	0	0	0.45	2	0.32	1	0	0	3	0.77
29	L5	5	2011	0	0	0	0	0	0	0	0	0.23	1	1	0.23
30	L5	6	2011	2	1	2.5	2	0.54	2	0	0	0	0	5	5.04
31	L5	7	2011	0	0	1	1	1.01	2	0	0	17.26	10	13	19.27
32	L5	8	2011	0	0	0	0	1.46	6	0	0	12.45	5	11	13.91
33	L5	9	2011	1.03	1	0	0	0	0	0	0	40.13	24	25	41.16
34	L5	10	2011	0	0	1.26	1	1.23	3	0.31	1	5.4	2	7	8.2
35	L5	11	2011	0	0	19.06	2	1.32	6	0.07	1	6.1	2	11	26.55
36	L5	12	2011	7.29	3	3.01	1	2.38	8	0.18	1	0	0	13	12.86
37	L5	1-6	2012	21.99903	14	25.082	10	1.6827	28	0	0	7.249	12	64	56.01273
38	L5	7-9	2012	1	1	20.0833	4	0.5834	2	6.9997	5	4.083	4	16	32.7494
	Sum			198.399	168	234.1	128	125.05	162	103.63	56	266.9	165	679	928.04213

Code	Feeder_Li	Month	Year	DPEF_DU	DPEF_FR	DPSC_DU	DPSC_FR	DTEF_DU	DTEF_FR	DTSC_DU	DTSC_FR	OP_DUR	OP_FRQ	Frequency Of Intrrupti	Duration Of Intrrupti
1	L6	1	2009	13.55	10	10.04	5	11.11	7	10.03	4	12.81	5	31	57.54
2	L6	2	2009	13.55	12	12.04	6	10.52	5	12.03	4	17.02	7	34	65.16
3	L6	3	2009	23.44	14	10.01	5	10.3	8	20.03	8	11.54	5	40	75.32
4	L6	4	2009	14.05	8	13.02	7	11.2	8	11.05	6	15.33	5	34	64.65
5	L6	5	2009	11.32	12	13.51	5	12.33	9	12.08	5	11.56	4	35	60.8
6	L6	6	2009	10.12	11	13.55	5	10.07	8	14.3	5	10.5	5	34	58.54
7	L6	7	2009	11.71	12	21.61	10	10.45	7	8.09	6	13.31	5	40	65.17
8	L6	8	2009	14.53	5	32.61	18	10.15	6	5.06	4	33.02	14	47	95.37
9	L6	9	2009	5.16	4	15.15	19	18.09	11	2.08	1	72.07	28	63	112.55
10	L6	10	2009	3.44	8	32.61	21	10.7	5	10.03	5	27.26	31	70	84.04
11	L6	11	2009	4.55	6	33.65	28	12.4	6	11.45	8	56.33	21	69	118.38
12	L6	12	2009	3.44	5	32.61	15	15.21	8	10.03	6	12.21	9	43	73.5
13	L6	1	2010	7.2	7	20.51	5	0.36	4	0.03	1	7.86	17	34	35.96
14	L6	2	2010	7.2	7	20.51	5	0.36	4	0.03	1	7.86	17	34	35.96
15	L6	3	2010	7.2	7	21.4	4	0.34	3	0.03	1	6.32	16	31	35.29
16	L6	4	2010	0	0	4.58	2	0	0	0	0	0	0	2	4.58
17	L6	5	2010	0	0	0.36	1	0	0	0	0	9.09	10	11	9.45
18	L6	6	2010	9.49	3	20.38	2	0.08	3	0	0	7.4	7	15	37.35
19	L6	7	2010	8.73	6	8.46	5	0	0	0	0	18.43	9	20	35.62
20	L6	8	2010	32.73	8	27.16	7	0	0	0	0	4.23	5	20	64.12
21	L6	9	2010	10.11	4	7.56	4	0.23	1	0	0	5.9	8	17	23.8
22	L6	10	2010	7.2	7	21.4	4	0.34	3	0.03	1	6.32	16	31	35.29
23	L6	11	2010	8.03	5	18.05	3	0.75	4	1.45	2	7.32	14	28	35.6
24	L6	12	2010	7.2	7	21.4	4	0.34	3	0.03	1	6.32	16	31	35.29
25	L6	1	2011	0	0	2.47	2	0	0	1.06	1	0.17	1	4	3.7
26	L6	2	2011	9.54	6	9.56	4	2.26	5	0	0	1.56	6	21	22.92
27	L6	3	2011	0	0	0	0	0	0	0	0	0	0	0	0
28	L6	4	2011	0	0	0	0	0	0	0	0	0	0	0	0
29	L6	5	2011	0	0	0	0	0	0	0	0	0	0	0	0
30	L6	6	2011	0	0	0	0	0	0	0	0	0	0	0	0
31	L6	7	2011	0	0	0	0	0	0	0	0	0	0	0	0
32	L6	8	2011	0	0	0	0	0	0	0	0	0	0	0	0
33	L6	9	2011	0	0	0	0	0	0	0	0	0	0	0	0
34	L6	10	2011	0	0	0	0	0	0	0	0	0	0	0	0
35	L6	11	2011	0	0	0	0	0	0	0	0	0	0	0	0
36	L6	12	2011	0	0	0	0	0	0	0	0	0	0	0	0
37	L6	1-6	2012	31.25	14.00	3.58	3.00	3.25	11.00		0.00	19.50	11.00	39.00	57.58
38	L6	7-9	2012	10.58	4.00	222.75	54.00	19.67	43.00	0.42	1.00	0.58	2.00	104.00	254.00
	sum			***285.32***	***192.00***	***670.54***	***253.00***	***170.51***	***172.00***	***129.34***	***71.00***	***401.82***	***294.00***	***982.00***	***1657.53***

Code	Feeder_Line	Month	Year	DPEF_DUR	DPEF_FRQ	DPSC_DUR	DPSC_FRQ	DTEF_DUR	DTEF_FRQ	DTSC_DUR	DTSC_FRQ	OP_DUR	OP_FRQ	Intrruption(No.)	Duration Of Intrruption (Hr.)
1	L7	1	2009	13.28	8	32.02	8	11.52	7	11.44	4	12.54	4	31	80.8
2	L7	2	2009	10.04	6	15.2	10	10.07	8	10.58	5	13.29	5	34	59.18
3	L7	3	2009	5.41	2	10.07	7	10.2	9	11.47	7	13.01	6	31	50.16
4	L7	4	2009	8.09	4	12.07	6	10.48	9	11.27	6	13.41	4	29	55.32
5	L7	5	2009	10.07	5	14.17	6	10.11	1	12.01	8	12.18	5	25	58.54
6	L7	6	2009	11.48	7	17.18	7	10.3	4	10.23	6	6.42	4	28	55.61
7	L7	7	2009	10.07	6	13.3	8	11.25	4	11.25	5	9.2	5	28	55.07
8	L7	8	2009	11.5	5	1.01	1	10.11	7	11.31	5	16.09	8	26	50.02
9	L7	9	2009	8.09	4	19.48	10	10.22	8	10.07	4	22.01	19	45	69.87
10	L7	10	2009	12.23	8	11.2	8	12.16	9	11.19	4	231.51	21	50	278.29
11	L7	11	2009	22.17	13	32.06	15	0	0	10.88	6	62.22	11	45	127.33
12	L7	12	2009	16.52	12	35.24	16	18.07	11	10.35	7	61.43	10	56	141.61
13	L7	1	2010	3.55	11	7.26	6	0.56	6	0.15	2	4.98	13	38	16.5
14	L7	2	2010	3.55	11	7.26	6	0.56	6	0.15	2	4.98	13	38	16.5
15	L7	3	2010	3.44	11	8.13	5	0.45	5	0.12	1	5.12	12	34	17.26
16	L7	4	2010	3.05	4	2.9	3	0.15	1	0	0	0	0	8	6.1
17	L7	5	2010	1.32	2	3.34	7	0.13	2	0.14	2	11.35	20	33	16.28
18	L7	6	2010	0.12	1	15.54	9	0.24	4	0	0	24.14	23	37	40.04
19	L7	7	2010	1.71	3	7.46	6	0.03	1	0	0	23.1	23	33	32.3
20	L7	8	2010	14.53	5	15.31	5	0.23	2	0	0	3.7	3	15	33.77
21	L7	9	2010	5.16	9	24.48	10	0	0	0	0	2.15	5	24	31.79
22	L7	10	2010	3.44	11	8.13	5	0.45	5	0.12	1	5.12	12	34	17.26
23	L7	11	2010	4.55	14	9.04	6	3.45	3	2.03	2	5.14	10	35	24.21
24	L7	12	2010	3.44	11	8.13	5	0.45	5	0.12	1	5.12	12	34	17.26
25	L7	1	2011	0	0	22.05	7	0.33	2	0.5	1	2.56	5	15	25.44
26	L7	2	2011	1.11	1	2.17	2	1.03	4	1.11	3	8.15	5	15	13.57
27	L7	3	2011	0	0	2.19	2	0.2	1	0.34	1	3.21	6	10	5.94
28	L7	4	2011	0	0	3.21	2	0.51	4	0.47	1	9.02	13	20	13.21
29	L7	5	2011	1.2	1	3.32	2	1.11	4	0	0	3.39	4	11	9.02
30	L7	6	2011	2.49	1	7.01	5	1.28	6	0	0	3.23	7	19	14.01
31	L7	7	2011	1.33	1	16.15	5	2.27	7	2.22	4	17.26	10	27	39.23
32	L7	8	2011	14.33	4	25.02	6	1.41	3	2.42	4	25.47	17	34	68.65
33	L7	9	2011	1.14	1	1.3	1	1.16	6	1.12	2	68.18	28	38	72.9
34	L7	10	2011	0	0	11.56	6	2.22	4	1.09	3	236.53	32	45	251.4
35	L7	11	2011	9.24	4	11.14	4	4.4	2	1.3	3	71.18	12	25	97.26
36	L7	12	2011	3.35	3	4.33	2	0.49	3	1.35	2	1.2	3	13	10.72
37	L7	1-6	2012	28.4163	16	41.0003	20	1.6827	8	0.25	2	20.8337	17	63	92.183
38	L7	7-9	2012	0	0	22.7503	5	1.6666	10	0.9997	3	4.583	2	20	29.9996
		Sum		249.416	205	503.181	244	150.949	181	148.05	107	1043.007	409	1146	2094.6026

Code	Feeder_Lin	Month	Year	DPEF_DUR	DPEF_FRQ	DPSC_DU	DPSC_FRQ	DTEF_DUR	DTEF_FRQ	DTSC_DUR	DTSC_FRQ	OP_DUR	OP_FRQ	Frequency Of Intrruption (No.)	Duration Of Intrruption (Hr.)
1	M1	1	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	M1	2	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	M1	3	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	M1	4	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	M1	5	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	M1	6	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	M1	7	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	M1	8	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	M1	9	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	M1	10	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	M1	11	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	M1	12	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	M1	1	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	M1	2	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	M1	3	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	M1	4	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	M1	5	2010	9.09	8.00	3.51	4.00	0.14	2.00	0.00	0.00	12.01	7.00	21.00	24.75
18	M1	6	2010	5.08	7.00	13.55	5.00	0.00	1.00	0.00	0.00	5.36	12.00	25.00	23.99
19	M1	7	2010	6.35	7.00	21.61	10.00	0.00	0.00	0.00	0.00	15.93	8.00	25.00	43.89
20	M1	8	2010	22.38	7.00	32.61	8.00	0.05	1.00	0.00	0.00	6.28	7.00	23.00	61.32
21	M1	9	2010	30.33	12.00	15.15	9.00	0.03	1.00	0.28	3.00	12.18	9.00	34.00	57.97
22	M1	10	2010	22.38	7.00	32.61	8.00	0.05	1.00	0.00	0.00	6.28	7.00	23.00	61.32
23	M1	11	2010	20.12	6.00	33.65	7.00	75.00	2.00	1.05	1.00	4.03	6.00	22.00	133.85
24	M1	12	2010	22.38	7.00	32.61	8.00	0.05	1.00	0.00	0.00	6.28	7.00	23.00	61.32
25	M1	1	2011	12.43	4.00	14.17	6.00	1.11	3.00	3.55	4.00	2.81	3.00	20.00	34.07
26	M1	2	2011	1.10	1.00	23.15	6.00	0.52	1.00	1.18	3.00	7.02	7.00	18.00	32.97
27	M1	3	2011	19.21	3.00	21.40	7.00	0.30	2.00	2.89	3.00	1.54	5.00	20.00	45.34
28	M1	4	2011	0.56	1.00	7.20	1.00	1.20	2.00	0.00	0.00	5.33	4.00	8.00	14.29
29	M1	5	2011	1.36	1.00	6.03	3.00	2.33	5.00	0.30	1.00	1.56	4.00	14.00	11.58
30	M1	6	2011	8.08	2.00	8.33	3.00	0.00	0.00	0.35	1.00	0.50	3.00	9.00	17.26
31	M1	7	2011	1.55	1.00	28.53	9.00	0.45	3.00	1.10	2.00	13.31	12.00	27.00	44.94
32	M1	8	2011	6.16	3.00	24.30	4.00	0.15	1.00	2.22	4.00	33.00	14.00	26.00	65.83
33	M1	9	2011	3.45	1.00	2.58	2.00	0.00	0.00	1.31	2.00	72.07	28.00	33.00	79.41
34	M1	10	2011	1.25	1.00	3.01	2.00	0.00	0.00	0.50	1.00	273.26	31.00	35.00	278.02
35	M1	11	2011	17.03	3.00	37.35	13.00	2.40	5.00	1.11	2.00	56.33	21.00	44.00	114.22
36	M1	12	2011	2.50	1.00	35.07	10.00	5.21	9.00	1.13	2.00	12.21	9.00	31.00	56.12
37	M1	1-6	2012	63.83	23.00	74.33	29.00	5.08	11.00	2.83	8.00	30.25	23.00	94.00	176.33
38	M1	7-9	2012	11.00	8.00	3.00	2.00	2.83	8.00	0.00	0.00	42.58	28.00	46.00	59.42
				287.62	114.00	473.75	156.00	96.91	59.00	19.80	37.00	620.12	255.00	621.00	1498.20

Code	Feeder_Line	Month	Year	DPEF_DUR	DPEF_FRQ	DPSC_DUR	DPSC_FRQ	DTEF_DUR	DTEF_FRQ	DTSC_DUR	DTSC_FRQ	OP_DUR	OP_FRQ	Frequency Of Intrruption(No.)	Duration Of Intrruption (Hr.)
1.00	M2	1.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	M2	2.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	M2	3.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	M2	4.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	M2	5.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	M2	6.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	M2	7.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	M2	8.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	M2	9.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.00	M2	10.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11.00	M2	11.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.00	M2	12.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.00	M2	1.00	2010.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14.00	M2	2.00	2010.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	M2	3.00	2010.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.00	M2	4.00	2010.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17.00	M2	5.00	2010.00	6.32	4.00	2.43	1.00	0.05	1.00	0.00	0.00	8.55	8.00	14.00	17.35
18.00	M2	6.00	2010.00	12.31	8.00	6.38	2.00	0.05	1.00	0.00	0.00	3.00	6.00	17.00	21.74
19.00	M2	7.00	2010.00	12.05	6.00	13.86	6.00	0.00	0.00	0.06	1.00	19.15	10.00	23.00	45.12
20.00	M2	8.00	2010.00	13.71	5.00	23.98	5.00	0.03	1.00	0.00	0.00	8.95	8.00	19.00	46.67
21.00	M2	9.00	2010.00	3.03	2.00	18.63	8.00	0.00	0.00	0.00	0.00	4.68	6.00	16.00	26.34
22.00	M2	10.00	2010.00	13.71	5.00	23.98	5.00	0.03	1.00	0.00	0.00	8.95	8.00	19.00	46.67
23.00	M2	11.00	2010.00	12.46	4.00	23.98	5.00	0.05	2.00	0.00	0.00	7.16	7.00	18.00	43.65
24.00	M2	12.00	2010.00	13.71	5.00	23.98	5.00	0.03	1.00	0.00	0.00	8.95	8.00	19.00	46.67
25.00	M2	1.00	2011.00	3.28	2.00	42.02	8.00	1.52	4.00	0.15	1.00	2.54	4.00	19.00	49.51
26.00	M2	2.00	2011.00	0.00	0.00	15.20	10.00	0.00	0.00	0.00	0.00	3.29	3.00	13.00	18.49
27.00	M2	3.00	2011.00	5.41	3.00	0.00	0.00	0.20	1.00	8.49	2.00	3.00	5.00	11.00	17.10
28.00	M2	4.00	2011.00	0.00	0.00	2.07	1.00	0.48	1.00	0.00	0.00	3.41	4.00	6.00	5.96
29.00	M2	5.00	2011.00	0.00	0.00	14.17	6.00	0.11	1.00	1.55	2.00	2.18	5.00	14.00	18.01
30.00	M2	6.00	2011.00	11.48	3.00	17.18	7.00	0.30	4.00	0.00	0.00	6.42	7.00	21.00	35.38
31.00	M2	7.00	2011.00	0.00	0.00	13.30	1.00	1.25	4.00	2.05	4.00	9.20	5.00	14.00	25.80
32.00	M2	8.00	2011.00	11.50	5.00	41.01	8.00	0.00	0.00	0.00	0.00	26.09	15.00	28.00	78.60
33.00	M2	9.00	2011.00	0.00	0.00	9.48	4.00	0.00	0.00	0.24	1.00	42.01	19.00	24.00	51.73
34.00	M2	10.00	2011.00	2.23	1.00	1.20	1.00	2.16	3.00	0.00	0.00	231.51	21.00	26.00	237.10
35.00	M2	11.00	2011.00	22.17	2.00	32.06	3.00	0.00	0.00	0.00	0.00	60.22	11.00	16.00	114.45
36.00	M2	12.00	2011.00	6.52	2.00	35.24	6.00	0.00	0.00	0.00	0.00	6.43	7.00	15.00	48.19
37.00	M2	1-6	2012.00	38.67	16.00	65.50	26.00	0.68	3.00	10.42	3.00	24.67	28.00	76.00	139.93
38.00	M2	7-9	2012.00	38.17	11.00	46.92	8.00	3.50	5.00	0.00	0.00	6.75	12.00	36.00	95.33
		Sum		***226.72***	***84.00***	***472.57***	***126.00***	***10.44***	***33.00***	***22.96***	***14.00***	***497.11***	***207.00***	***464.00***	***1229.80***

Code	Feeder_Line	Month	Year	DPEF_DUR	DPEF_FRQ	DPSC_DUR	DPSC_FRQ	DTEF_DUR	DTEF_FRQ	DTSC_DUR	DTSC_FRQ	OP_DUR	OP_FRQ	Frequency Of Intrruption(No.)	Duration Of Intrruption (Hr.)
1	M3	1	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	M3	2	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	M3	3	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	M3	4	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	M3	5	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	M3	6	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	M3	7	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	M3	8	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	M3	9	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	M3	10	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	M3	11	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	M3	12	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	M3	1	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	M3	2	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	M3	3	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	M3	4	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	M3	5	2010	6.17	3.00	6.12	3.00	0.00	0.00	0.00	0.00	4.37	3.00	9.00	16.66
18	M3	6	2010	10.33	10.00	6.59	2.00	0.00	0.00	0.07	1.00	10.24	13.00	26.00	27.23
19	M3	7	2010	3.10	2.00	13.40	5.00	0.00	0.00	0.00	0.00	13.81	8.00	15.00	30.31
20	M3	8	2010	11.89	10.00	28.83	7.00	0.25	2.00	0.00	0.00	1.10	3.00	22.00	42.07
21	M3	9	2010	16.95	9.00	25.65	13.00	0.00	0.00	0.00	0.00	10.21	6.00	28.00	52.81
22	M3	10	2010	11.89	10.00	28.83	7.00	0.25	2.00	0.00	0.00	1.10	3.00	22.00	42.07
23	M3	11	2010	12.45	11.00	30.75	6.00	1.86	1.00	0.00	0.00	2.68	4.00	22.00	47.74
24	M3	12	2010	11.89	10.00	28.83	7.00	0.25	2.00	0.00	0.00	1.10	3.00	22.00	42.07
25	M3	1	2011	9.36	3.00	23.04	9.00	1.00	1.00	1.10	1.00	0.35	2.00	16.00	34.85
26	M3	2	2011	9.55	3.00	18.44	4.00	0.00	0.00	0.00	0.00	3.23	6.00	13.00	31.22
27	M3	3	2011	7.45	4.00	15.12	4.00	1.23	2.00	1.29	2.00	4.02	6.00	18.00	29.11
28	M3	4	2011	4.02	3.00	4.44	3.00	0.35	1.00	0.50	1.00	3.56	8.00	16.00	12.87
29	M3	5	2011	1.03	1.00	7.33	5.00	0.43	2.00	0.15	1.00	5.07	8.00	17.00	14.01
30	M3	6	2011	3.23	2.00	5.49	8.00	0.10	1.00	0.00	0.00	2.36	3.00	14.00	11.18
31	M3	7	2011	0.00	0.00	23.06	6.00	0.45	2.00	3.12	6.00	11.42	10.00	24.00	38.05
32	M3	8	2011	6.02	2.00	24.03	4.00	0.00	0.00	0.56	1.00	43.16	19.00	26.00	73.77
33	M3	9	2011	0.00	0.00	8.30	4.00	0.00	0.00	0.00	0.00	63.47	23.00	27.00	71.77
34	M3	10	2011	2.05	2.00	21.33	7.00	0.00	0.00	1.10	1.00	211.31	27.00	37.00	235.79
35	M3	11	2011	21.25	5.00	15.29	5.00	1.25	2.00	0.00	0.00	78.45	15.00	27.00	116.24
36	M3	12	2011	9.57	2.00	29.35	6.00	1.10	2.00	1.18	2.00	4.50	6.00	18.00	45.70
37	M3	1-6	2012.00	52.67	17.00	57.58	18.00	19.08	15.00	1.00	1.00	42.83	28.00	79.00	173.16
38	M3	7-9	2012.00	25.50	8.00	16.58	6.00	3.50	3.00	0.67	1.00	10.83	13.00	31.00	57.08
		Sum		236.37	117.00	438.39	139.00	31.10	38.00	10.74	18.00	529.18	217.00	529.00	1245.77

Code	Feeder_Line	Month	Year	DPEF_DUR	DPEF_FRQ	DPSC_DUR	DPSC_FRQ	DTEF_DUR	DTEF_FRQ	DTSC_DUR	DTSC_FRQ	OP_DUR	OP_FRQ	Frequency Of Intrruption(No.)	Duration Of Intrruption (Hr.)
1	M4	1	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	M4	2	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	M4	3	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	M4	4	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	M4	5	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	M4	6	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	M4	7	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	M4	8	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	M4	9	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	M4	10	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	M4	11	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	M4	12	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	M4	1	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	M4	2	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	M4	3	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	M4	4	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	M4	5	2010	3.55	2.00	0.00	0.00	0.00	0.00	0.00	0.00	5.28	7.00	9.00	8.83
18	M4	6	2010	1.59	2.00	13.46	6.00	0.05	1.00	0.00	0.00	10.01	9.00	18.00	25.11
19	M4	7	2010	2.46	2.00	13.11	5.00	0.10	1.00	0.00	0.00	23.85	8.00	16.00	39.52
20	M4	8	2010	30.05	6.00	7.83	3.00	0.00	0.00	0.00	0.00	1.08	1.00	10.00	38.96
21	M4	9	2010	14.88	7.00	26.18	10.00	0.00	0.00	0.25	3.00	6.88	10.00	30.00	48.19
22	M4	10	2010	30.05	6.00	7.83	3.00	0.00	0.00	0.00	0.00	1.08	1.00	10.00	38.96
23	M4	11	2010	31.05	7.00	8.56	4.00	0.00	0.00	0.00	0.00	1.08	1.00	12.00	40.69
24	M4	12	2010	30.05	6.00	7.83	3.00	0.00	0.00	0.00	0.00	1.08	1.00	10.00	38.96
25	M4	1	2011	13.50	4.00	30.04	8.00	1.05	1.00	0.55	1.00	2.25	4.00	18.00	47.39
26	M4	2	2011	8.52	4.00	27.33	8.00	0.06	1.00	0.55	1.00	6.18	3.00	17.00	42.64
27	M4	3	2011	14.43	6.00	7.02	4.00	1.29	3.00	0.00	0.00	2.29	7.00	20.00	25.03
28	M4	4	2011	0.00	0.00	4.22	3.00	0.35	2.00	0.00	0.00	1.14	2.00	7.00	5.71
29	M4	5	2011	5.25	3.00	12.52	6.00	1.09	3.00	0.47	1.00	0.30	1.00	14.00	19.63
30	M4	6	2011	1.05	1.00	3.13	2.00	0.20	1.00	0.58	1.00	4.58	2.00	7.00	9.54
31	M4	7	2011	8.25	2.00	19.24	6.00	1.03	2.00	0.00	0.00	12.59	4.00	14.00	41.11
32	M4	8	2011	8.37	3.00	13.06	3.00	0.00	0.00	0.00	0.00	62.35	19.00	25.00	83.78
33	M4	9	2011	4.30	2.00	9.56	5.00	0.00	0.00	0.00	0.00	70.39	28.00	35.00	84.25
34	M4	10	2011	1.40	1.00	13.10	4.00	1.28	2.00	1.00	1.00	240.40	30.00	38.00	257.18
35	M4	11	2011	9.25	4.00	17.42	2.00	1.02	2.00	0.00	0.00	83.00	14.00	22.00	110.69
36	M4	12	2011	12.01	4.00	7.28	2.00	1.05	3.00	0.20	1.00	16.15	10.00	20.00	36.69
	M4	1-6	2012	45.67	18.00	34.92	23.00	4.76	10.00	2.75	6.00	54.25	42.00	99.00	142.34
	M4	7-9	2012	12.50	7.00	34.92	10.00	0.92	3.00	0.75	2.00	9.83	13.00	35.00	58.92
Sum				288.18	97.00	318.55	120.00	14.24	35.00	7.10	17.00	616.04	217.00	486.00	1244.11

Code	Feeder_Line	Month	Year	DPEF_DUR	DPEF_FRQ	DPSC_DUR	DPSC_FRQ	DTEF_DUR	DTEF_FRQ	DTSC_DUR	DTSC_FRQ	OP_DUR	OP_FRQ	Frequency Of Intrruption(No.)	Duration Of Intrruption (Hr.)
1.00	M5	1.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	M5	2.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	M5	3.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	M5	4.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	M5	5.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	M5	6.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	M5	7.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	M5	8.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	M5	9.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.00	M5	10.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11.00	M5	11.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.00	M5	12.00	2009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.00	M5	1.00	2010.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14.00	M5	2.00	2010.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	M5	3.00	2010.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.00	M5	4.00	2010.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17.00	M5	5.00	2010.00	8.09	4.00	8.47	6.00	0.17	3.00	0.00	0.00	3.54	7.00	20.00	20.27
18.00	M5	6.00	2010.00	24.24	4.00	24.42	10.00	0.10	1.00	0.00	0.00	12.50	11.00	26.00	61.26
19.00	M5	7.00	2010.00	7.15	2.00	0.06	1.00	0.00	0.00	0.33	1.00	28.70	14.00	18.00	36.24
20.00	M5	8.00	2010.00	53.20	11.00	39.41	8.00	0.00	0.00	0.08	0.00	6.18	6.00	25.00	98.87
21.00	M5	9.00	2010.00	0.08	7.00	35.05	12.00	17.65	1.00	0.08	1.00	18.08	16.00	37.00	70.94
22.00	M5	10.00	2010.00	51.40	10.00	38.21	9.00	0.00	0.00	0.09	1.00	6.18	6.00	26.00	95.88
23.00	M5	11.00	2010.00	51.28	11.00	35.23	10.00	0.00	0.00	0.18	1.00	7.65	8.00	30.00	94.34
24.00	M5	12.00	2010.00	51.40	10.00	38.21	9.00	0.00	0.00	0.09	1.00	6.18	6.00	26.00	95.88
25.00	M5	1.00	2011.00	15.02	4.00	17.52	5.00	0.00	0.00	0.00	0.00	2.05	9.00	18.00	34.59
26.00	M5	2.00	2011.00	4.42	2.00	20.09	7.00	0.00	0.00	0.58	1.00	13.09	15.00	25.00	38.18
27.00	M5	3.00	2011.00	13.03	6.00	4.34	1.00	0.17	1.00	1.47	2.00	1.31	3.00	13.00	20.32
28.00	M5	4.00	2011.00	7.20	5.00	11.57	6.00	0.34	3.00	1.27	2.00	3.38	8.00	24.00	23.76
29.00	M5	5.00	2011.00	6.05	3.00	10.01	5.00	0.00	0.00	2.01	2.00	2.55	6.00	16.00	20.62
30.00	M5	6.00	2011.00	5.37	4.00	5.01	3.00	1.24	5.00	0.00	0.00	1.23	9.00	21.00	12.85
31.00	M5	7.00	2011.00	18.27	6.00	15.24	7.00	0.35	2.00	1.25	2.00	7.07	5.00	22.00	42.18
32.00	M5	8.00	2011.00	29.25	5.00	19.39	11.00	1.15	3.00	1.31	3.00	29.27	13.00	35.00	80.37
33.00	M5	9.00	2011.00	0.00	0.00	4.58	3.00	0.46	3.00	0.00	0.00	49.46	23.00	29.00	54.50
34.00	M5	10.00	2011.00	2.39	2.00	12.38	2.00	3.25	2.00	1.19	4.00	212.53	29.00	39.00	231.74
35.00	M5	11.00	2011.00	26.27	5.00	9.31	3.00	1.00	1.00	0.00	0.00	84.56	18.00	27.00	121.14
36.00	M5	12.00	2011.00	2.56	2.00	2.22	1.00	0.00	0.00	0.35	1.00	26.25	10.00	14.00	31.38
37.00	M5	1-6	2012.00	25.08	5.00	30.83	10.00	2.58	5.00	0.17	1.00	4.58	8.00	29.00	63.25
38.00	M5	7-9	2012.00	18.92	7.00	19.33	2.00	1.33	4.00			4.58	8.00	21.00	44.17
		Sum		***420.67***	***115.00***	***400.88***	***131.00***	***29.80***	***34.00***	***10.45***	***23.00***	***530.93***	***238.00***	***541.00***	***1392.72***

Substation Name		ADAMA DISTRIBUTION FEEDERS RELIABILITY ASSESSMENT INTRUPTION AND RELIABILITY INDEX FROM 2009 UP TO 9 MONTH OF 2012 E.C											
Feeder Code		Line 1	Line 3	Line 4	Line 5	Line 6	Line 7	M1	M2	M3	M4	M5	SUM
Feeder Name		Line 1	Line 3	Line 4	Line 5	Line 6	Line 7	M1	M2	M3	M4	M5	
Voltage Level		15 kv	15 kv	15 kv	15 kv	15 kv	15 kv	15 kv	15 kv	15 kv	15 kv	15 kv	
Frequency and Duration of Interruption DPEF	F	86.00	140.00	192.00	168.00	192.00	205.00	114.00	84.00	117.00	97.00	115.00	1510.00
	D [Hr.]	254.35	297.94	272.40	198.40	285.32	249.42	287.62	226.72	236.37	288.18	420.67	3017.38
DPSC	F	83.00	82.00	166.00	128.00	253.00	244.00	156.00	126.00	139.00	120.00	131.00	1628.00
	D [Hr.]	171.12	172.85	499.75	125.05	670.54	503.18	473.75	472.57	438.39	318.55	400.88	4246.64
DTEF	F	56.00	107.00	131.00	162.00	172.00	181.00	59.00	33.00	38.00	35.00	34.00	1008.00
	D [Hr.]	35.87	107.00	133.66	125.05	170.51	150.95	96.91	10.44	31.10	14.24	29.80	905.52
DTSC	F	30.00	34.00	77.00	56.00	71.00	107.00	37.00	14.00	18.00	17.00	23.00	484.00
	D [Hr.]	22.31	34.00	97.69	103.63	129.34	148.05	19.80	22.96	10.74	7.10	10.45	606.06
OP	F	255.00	478.00	391.00	165.00	294.00	409.00	255.00	207.00	217.00	217.00	238.00	3126.00
	D [Hr.]	521.53	860.31	705.00	266.87	401.82	1043.01	620.12	497.11	529.18	616.04	530.93	6591.91
Total Frequency of		510.00	841.00	957.00	679.00	982.00	1146.00	621.00	464.00	529.00	486.00	541.00	7756.00
Total Duration of Interruption		1005.17	1472.10	1708.50	818.99	1657.53	2094.60	1498.20	1229.80	1245.77	1244.11	1392.72	15367.50
Total Frequency of		86.00	141.00	208.00	218.00	243.00	288.00	96.00	47.00	56.00	52.00	57.00	1492.00
Total Duration of Interruption		58.18	141.00	231.35	228.68	299.84	299.00	116.71	33.40	41.84	21.34	40.24	1511.58
Total Frequency of		169.00	222.00	358.00	296.00	445.00	449.00	270.00	210.00	256.00	217.00	246.00	3138.00
Total Duration of Interruption		425.47	470.79	772.15	323.45	955.86	752.60	761.37	699.29	674.75	606.73	821.55	7264.01
Average Frequency of		0.52	0.85	0.97	0.69	0.99	1.16	0.63	0.47	0.53	0.49	0.55	7.83
Average Duration of		1.02	1.49	1.73	0.83	1.67	2.12	1.51	1.24	1.26	1.26	1.41	15.52
Peak Load in A		360.00	370.00	360.00	255.00	190.00	450.00	180.00	396.00	380.00	158.00	198.00	3297.00
Peak Load in MW		8	8	8	8	8	8	10	5	9	9	5	86.00
Unsold Electricity		12062094.00	17665228.80	20501940.00	9827915.16	19890364.80	25135231.20	22473072.00	9223463.03	16817854.50	16795544.40	10445409.75	180838117.64
Number of Transformer		85.00	101.00	59.00	16.00	40.00	108.00	98.00	70.00	49.00	41.00	43.00	710.00
KVA of Transformer		17680.00	24070.00	15600.00	10560.00	15040.00	23615.00	16490.00	20280.00	9090.00	8480.00	16290.00	177195.00
Number of Transformer		85.00	101.00	59.00	16.00	40.00	108.00	98.00	70.00	49.00	41.00	98.00	765.00
Transformer Hour		85439.83	148682.34	100801.21	13103.89	66301.22	226217.08	146824.07	86085.65	61042.58	51008.69	59887.02	1045393.58
Transformer Minute		5126389.95	8920940.54	6048072.30	786233.21	3978072.96	13573024.85	8809444.22	5165139.29	3662554.98	3060521.42	3593220.95	62723614.69
Transformer Interupted		43350.00	84941.00	56463.00	10864.00	39280.00	123768.00	60858.00	32480.00	25921.00	19926.00	23263.00	521114.00
SAIDI (minute)		3056.19	4018.29	3849.87	437.33	3231.09	6868.77	6305.45	4136.64	2794.04	2102.19	2985.36	39785.23
SAIFI		20.23	31.58	29.75	6.67	25.07	68.30	37.27	20.70	17.67	12.53	14.90	284.67
CAIDI		151.05	127.24	129.41	65.56	128.88	100.57	169.19	199.80	158.14	167.76	200.38	1597.99
CTAIDI							0.07						
CAIFI							0.00						
ASAI							-3.20						
CEMIn							0.94						
CELID-s													
CELID-t							0.94						
ASIFI							266.46						
ASIDI							589.63						
MAIFI							134.80						
MAIFIe							134.80						
CEMSMIn							0.94						
Unsold Electricity		12062094.00	17665228.80	20501940.00	9827915.16	19890364.80	25135231.20	22473072.00	9223463.03	16817854.50	16795544.40	10445409.75	180838117.64
Total Interruption Frequency							7756.00						
Total Interruption Duration							15367.50						
Average Ineterruption Frequency per line							775.60						
Average Ineterruption Duration per line							1536.75						
Average Ineterruption Frequency per day							258.53						
Average Ineterruption Duration per day							512.25						
Average Ineterruption Frequency per day per line							25.85						
Average Ineterruption Duration per day per line							51.23						
Total mw		8	8	8	8	8	8	10	5	9	9	5	
CT		300/1	300/1	300/1	300/1	300/1	300/1	300/1	800/1	800/1	800/1	800/1	