INVESTIGATION OF DISTRIBUTED GENERATION IN IMPROVING POWER SYSTEM RELIABILITY

(Power Distribution System of Adama Town)

By: Mr. Hayder Mohammed Hassen

A Thesis Submitted to

The Department of Electrical Power and Control Engineering

School of Electrical Engineering & Computing

Presented in Partial Fulfillment of the Requirement for the Degree of

Masters of Science in Electrical Power Engineering

Office of Post Graduate Studies

Adama Science and Technology University

Feb. 2022 G.C

Adama, Ethiopia

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Declaration

I hereby declare that this Master Thesis entitled “INVESTIGATION OF DISTRIBUTED GENERATION IN IMPROVING POWER SYSTEM RELIABILITY” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Mr. Hayder Mohammed

________________ _____________

Name Signature

Recommendation

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “INVESTIGATION OF DISTRIBUTED GENERATION IN IMPROVING POWER SYSTEM RELIABILITY” prepared under my guidance by Hayder Mohammed Hassen. Submitted in partial fulfillment of the requirements for the degree of Master’s of science in Electrical Power Engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dr. Molla Biweta

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Major Advisor Signature

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Approval

I, the advisor of the thesis entitled "INVESTIGATION OF DISTRIBUTED GENERATION IN IMPROVING POWER SYSTEM RELIABILITY" developed by Hayder Mohammed Hassen, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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Major Advisor Signature

We, the undersigned, members of the Board of Examiners of the thesis by Hayder Mohammed Hassen have read and evaluated the thesis entitled "INVESTIGATION OF DISTRIBUTED GENERATION IN IMPROVING POWER SYSTEM RELIABILITY" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Electrical Power Engineering.

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Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the office of postgraduate studies (OPGS) through the department Graduate Council (DGC) and School Graduate Committee (SGC).

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Acronyms

A	Ampere
AAC	All Aluminum Conductor
AC	Alternating Current
CT	Current Transformer
DLOL	Distribution Line over Load
DPEF	Distribution Permanent Earth Fault
DPSC	Distribution Permanent Short Circuit
DTEF	Distribution Temporary Earth Fault
DTSC	Distribution Temporary Short Circuit
DUR	Duration
EC	Ethiopian Calendar
EEU	Ethiopia Electric Utility
FRQ	Frequency
GUP	Generation Unit Problem
HV	High Voltage
IC	Interconnected system
IEEE	Institute of Electrical and Electronics Engineer
Km	Kilometer
KV	Kilo Volt
KVA	Kilo Volt Ampere
KVARH	Kilo Volt Amps Reactive Hour
KWh	Kilo Watt Hour
L	Line
LV	Low Voltage
M	Mobile
MV	Mega Volt
MVA	Mega Volt Ampere
MW	Mega Watt

NK	Not Known
O&M	Operation and Maintenance
OP	Operation Problem
PTOL	Power Transformer over Load
R	Remote
SA	Strongly Agree
SCADA	Supervisory Control and Data Acquisition
SD	Strongly Disagree
SF6	Sulfur Hexafluoride
SOL	System over Load
SS	Sub-Station
TLP	Transmission Line Problem
V	Voltage
VT	Voltage Transformer

ABSTRACT

This thesis work is the study of Distribution Generation (DG) in improving power system reliability, of Adama distribution substation. The first task of the study was to analyses the main failure factors and to evaluate the reliability of the existing distribution system by collecting and analyzing data from Adama substations and calculating the most powerful reliability indices, then to improve the reliability of the system by using DGs.

The present Adama substation has encountered frequent power interruptions and power quality problems. 50% of the total interruption duration, and 44% of the total interruption frequency is mainly caused by planned (operational) problems, and 36% of the total duration and 32% of the total frequency of interruption is due to permanent short circuit.

The substations system average interruptions frequency index (SAIFI) and system average interruption duration index (SAIDI) are 156.23 and 148.248 respectively. This reliability indices are then far from the EEPCO's standard which set (SAIFI= 20 and SAIDI= 25) and the standard of other countries. To alleviate this problem, integrating distributed generation to the existed system is analyzed in this thesis. Distributed generation is a generation of an electric power close to the load. The resources are wind generators and Photovoltaic PV solar arrays, fuel cells and so on. Since Adama is rich in wind and solar energies, such renewable energies should be explored for system reliability improvement. The study utilized different meteorological and statistical data and like MS-Excel, Digsilent powerfactory software. The simulation is used to evaluate the power distribution substation to ascertain that, it produces the desired reliability improvements. The result of the simulation shows that the integration of DGs can advance the reliability indices values. Assuming that all DGs and protective devices are fully reliable and DGs are engaged at all feeder lines the overall reliability of the system can be improved up to the standard set by EEPCO and even more. "This means that the average service availability index (ASAI) become 1". And the others zero. But locating DGs to all feeders requires high investment cost.

Key words: Power System Reliability, Distributed Generation, DG technology.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Power systems are one of the most complex infrastructures found worldwide and they are expected to operate with high quality and reliability. The fundamental purpose of power systems is to provide an economic and reliable channel for electrical energy to transfer from points of generation to customer locations. The economic and reliability constraints can be mutually competitive, making planning and operation of power systems a complex problem [1]. The distribution system reliability evaluation considers the ability of the distribution system to transfer energy from bulk supply points such as typical transmission system end-stations, and from local generation points, to customer loads.

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

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

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

Electric utilities are responsible for maintaining the safety of their systems and planning for the future power needs of their customers. Initially, the electric power industry developed voluntary standards to ensure coordination of linked interruption operations. Today, mandatory reliability standards for planning and operating power systems and for addressing security concerns at critical electrical infrastructure are in place.

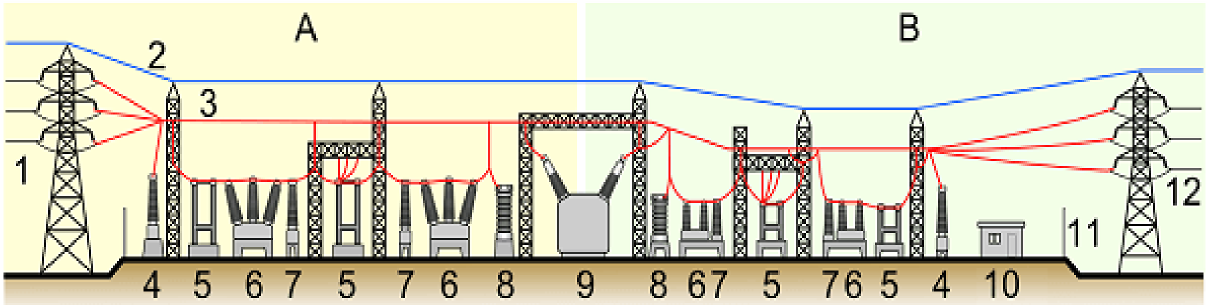

Figure 1.1: Elements of a power system: generation power plant: transmission lines: and distribution lines.[24]

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

Reliability: - measures the power system's ability to supplying electricity to its customers within accepted standards and in the magnitude desired, for the period of time intended, under the operating conditions required.

In this thesis a reliable electrical system is one that works as designed without fail, and it does with ideally 100% reliability. Now the question become is this even possible? If it is, is it affordable? In both cases, the answer is yes. Especially using DGs as back up sources.

Distributed Generation (DG): With recent advances in technology, use of distributed generation (DG) in the power distribution system is increasing. Though integrating DG into the power system is associated with many challenges in terms of interconnection, protection, coordination and voltage regulation, increased reliability and reduced cost are the primary incentives of adding DG to a power network.

Distributed generation is small modular generation of an electric power close to the load. With advances in fuel cells and renewable energy sources, increase of DG is projected. DG may be connected at the generation substation, at any point in a distribution feeder or at customer load points. Renewable energy sources include mini hydro, wind powered and photovoltaic generation. Other Distributed Energy resources (DER) include fuel cells and micro turbines. DG may be synchronous or induction generator.

Distributed generation is mainly used in standby or backup mode when the grid experiences power interruption. Some of the other DG applications encompass, peak shaving, independent generation, net metering, voltage support, combined heat and power etc. In the backup mode, the DG improves the system adequacy index while in the peak shaving way, DG enhances the system reliability by serving some of loads and decreasing energy costs in high demand periods.

1.2 Statement of the Problem

The issue of reliability is of great concern in our daily life. Since Adama is a preferred location for most of the industries, considerable share of the electric power supply is directed towards the city. Due to this fact, Adama is one of the load centers of Ethiopian electric power system. The substation faces distribution inefficiency, repetitive and infrequent power interruptions.

The people in Adama town are facing problems because it is associated with their livelihood. All residential, commercial and industrial customers are victims of the problem. It is really challenging to tolerate power interruption since it causes much revenue loss within hours of interruption. So the root cause of this problem should first be identified and the possible solutions should be investigated.

1.3 Objectives

1.3.1 General Objective

The main objective of this thesis is to study the main fault factors and power system reliability problems in Adama substation and mitigation techniques.

1.3.2 Specific Objectives

- To investigate the main causes of fault factors to power interruptions
- To evaluate the reliability of the present Adama substation.
- To identify possible solutions for those reliability problems/ improvement.
- To compare the available types of Distributed Generators
- Draw relevant conclusions and recommendations from the result of the investigation.

1.4 Significance of the Study

The economic and social effects of loss of proper electric service have significant impacts on both the utility and the end users of electric device. Study shows that the impact even a small power cut can be catastrophic. Analyses from the power interruption events in some countries show that a 30 minute power cut results in an average loss of around four hundred thousand birr for medium and large industrial clients [4].

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

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

1.5 Scope and Limitations of the Thesis

This thesis will cover, studying the current power system reliability problems of the substation, their causes, percentage of improvements gained by penetrating distributed generators to the then time of Adama substation and even to, if the reliability level reaches 100% .

The resources of DG will be shown using Excel and the reliability models have been developed using digital simulation, DigSilent software.

1.6 Outline of the thesis

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

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

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

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

Chapter four presents a detailed description of existing study area geographically. Analysis of fault factors and power interruption data's together with reliability indices.

Chapter five presents' detailed basic and failure data's for Digsilent simulation process.

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

CHAPTER TWO

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Electrical Power Reliability

Power reliability can be defined as the ability of a power system to deliver electricity to its consumers within accepted standards, and in the amount desired and in the time needed. The degree of reliability may be measured by the frequency, duration, and magnitude of adverse effects on the electric supply.

The reliability analysis of distribution system has connected network by switching which results of consider connect switching. Reliability indices from calculate are composed SAIFI, SAIDI and CAIDI. Including analysis, cost of network system as such: outage cost, investment cost and total cost.

Reliability analysis involves determining, generally using statistical methods, the total electric interruptions for loads within a power system. The interruptions are described by several indices that consider aspects such as:

- The number of customers;
- The connected load;
- The duration of the interruptions;
- The amount of power interrupted; and
- The frequency of interruptions.

The outage events in the distribution system are caused mainly by the equipment, animal, tree, traffic accident and natural disaster. Accordingly, to reduce for causing that should be modified and improved, using adding equipment prevents and maintenance of the distribution system. Analyses reliability indices of these databases are the basic data of particular elements may be determined for improvement of reliability which adding equipment prevents and maintenance of the distribution. There are many indices for measuring reliability. The three most common are referred to as SAIFI, SAIDI, and CAIDI, defined in IEEE standard 1366.

- SAIFI, or system average interruption frequency index, is the average frequency of sustained interruptions per customer over a redefined area. It is the total number of customer interruptions divided by the total number of customers served.

- SAIDI, or system average interruption duration index, is commonly to as customer minutes of interruption or customer hours, and is designed to provide information as to average time the customers are interrupted. It is the sum of the restoration time for each interruption event times the number of interrupted customers for each interruption event divided by the total number of customers.

- CAIDI, or customer average interruption duration index, is the average time needed to restore service to the average customer per sustained interruption. It is the sum of customer interruption duration divided by the total number of customer interruptions.

2.2. Distributed Generation

2.2.1. Definition of Distributed Generation

Distributed generation, for the moment loosely defined as small-scale electricity generation, is a fairly new concept in the economics literature about electricity markets, but the idea behind it is not new at all. In the early days of electricity generation, distributed generation was the rule, not the exception. The first power plants only supplied electricity to customers in the close neighborhood of the generation plant. The first grids were direct current (DC) based, and therefore, the supply voltage was limited, as was the distance that could be used between generator and consumer Balancing demand and supply was partially done using local storage, i.e. batteries, which could be directly coupled to the DC grid. Along with distributed generation, local storage is also returning to the scene. All this resulted in increased convenience and lower per unit costs and massive electricity systems were constructed, consisting of huge transmission and distribution grids and large generation plants. Balancing demand and supply was done by the averaging effect of the combination of large amounts of instantaneously various loads. Security of supply was increased as the failure of one power plant was compensated by the other power plants in the interconnected system. In fact this interconnected high voltage system made the economy of scale in generation possible. In the last decade, technological innovations and a changing economic and regulatory environment have resulted in a renewed interest for distributed generation. This is confirmed by the international energy agency (IEA) (2002), who lists five major factors that contribute to this evolution, i.e. developments in distributed generation technologies, constraints on the construction of new transmission lines, increased customer demand for highly reliable electricity, the electricity market liberalization and concerns about climate change.

DG is one of the new trends in power systems used to support the increased energy-demand, peak shaving and to use as a backup generator. There is no commonly accepted definition of DG as the concept involves many technologies and applications. Different countries use different notations like "embedded generation", "dispersed generation" or "decentralized generation." [5]

2.2.2 Why Distributed Generation?

In the introduction, it was mentioned that the IEA identifies 5 major factors that contribute to the renewed interest in distributed generation. We feel that these five factors can be further reduced to two major driving forces, i.e. electricity market liberalization and environmental concerns. The developments in distribution technologies have been around for a long time, but were as such not capable of pushing the "economy as scale" out of the system. We doubt that distributed generation is capable of postponing, and certainly not of avoiding, the development of new transmission lines: at the minimum the grid has to be available as backup supply. The third element, being reliability, is at this moment not an issue in the interconnected European high voltage system, although this may change rapidly in the following years. This section discusses these major driving forces.

There is the increased interest by electricity suppliers in distributed generation because they see it as a tool that can help them to fill in niches in a liberalized market. In such a market, customers will look for the electricity service best suited for them. Different customers attach different weights to features of electricity supply, and distributed generation technologies can help electricity suppliers to supply to the electricity customers the type of electricity service they prefer. In short, distributed generation allows players in the electricity sector to respond in a flexible way to changing market conditions. Some major examples are discussed below.

In liberalized markets, it is important to adapt to the changing economic environment in the most flexible way. Distributed generation technologies generally provide this flexibility because of their small sizes and the short construction lead times compared to most types of larger central power plants. According to the IEA (2002), the value of their flexibility is probably understated when economic assessments of distributed generation are made3. It should be stated that the lead time reduction is not always that evident. Public resistance to for instance wind energy and use of landfill gasses may be very high.

Standby capacity or peak use capacity (peak shaving) many distributed generation technologies are indeed flexible in several respects: operation, size and expandability. For example, making use of distributed generation allows reacting in a flexible way to electricity price evolutions. Distributed generation then serves as a hedge against these price fluctuations.

Apparently, the US demand for distributed generation is mainly driven by price volatility, i.e. using distributed generation for continuous use or for peaking use (peak shaving). In Europe, market demand for distributed generation is, for the moment, driven by heat applications, introduction of renewables and by potential efficiency improvements. Reliability and Power Quality The second major driver of US demand for distributed generation is quality of supply considerations. Reliability problems refer to sustained interruptions, which are voltage drops to near zero (usually called outages), in electricity supply. The liberalization of energy markets makes customers more aware of the value of reliable electricity supply. In many European countries, the reliability level has been very high, mainly because of high engineering standards. Customers do not really care about supply interruptions because they do not feel it as a great risk. This can change in liberalized markets, because a high reliability level implies high investment and maintenance costs for the network and generation infrastructure. Because of the incentives for cost-effectiveness that come from the introduction of competition in generation and from the re-regulation of the network companies, it might be that reliability levels will decrease. However, having a reliable power supply is very important for industry (chemicals, petroleum, refining, paper, metal, and telecommunication). Firms in these industries may find the reliability of the grid supplied electricity too low and they will decide to invest in distributed generation units in order to return their overall reliability of supply to present, pre-liberalized standards.[5]

2.2.3. Types of Distributed Generation Technologies

There are different types of distributed generation. Some of them are photovoltaic system (PV), wind turbines, fuel cells, micro turbines, and gas turbines.

A photovoltaic system (PV), converts the light energy received from the sun radiation to electric energy. Semi conducting materials are used to construct solar cells which are capable of transforming self-contained energy of photons into electricity when they are exposed to solar radiation. The cells are placed in an array that is either fixed or moving to keep tracking the sun to generate the maximum power.[6] PV systems are comfortable to environment since they are not associated with emissions, easy to use, are simple in designs and it does not need any other fuel than solar light. Their disadvantage is that they need large spaces and the initial cost is decreasing to $0.55 per watt [16].

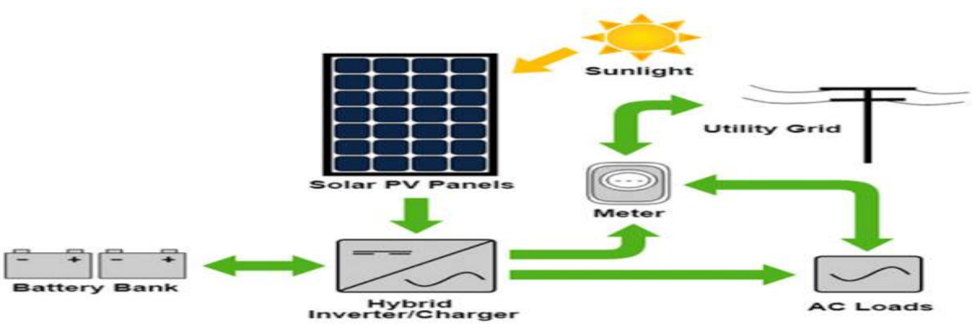

Figure 2.1: A photovoltaic system [6]

The system generates DC voltage then transferred to AC with the aid of inverters. The design of such systems can be with and without battery storages.

B. Wind turbines

Wind turbines are capable of converting wind energy into electricity. The wind has high stochastic nature, which cannot be stored, thus, it must be handled according to this characteristic. A general scheme of a wind turbine is shown in Figure 2.2, where its main components are shown. [6][16]

There are two conversion steps in wind turbines. First, the rotor takes the kinetic energy of the wind; convert it into mechanical torque in the shaft; and then the generator system converts this mechanical torque into electricity. Mostly, the generator system gives an AC output voltage which is dependent on the wind speed. As wind speed is not constant, the voltage generated must be transferred to DC and back again to AC with the aid of inverters. However, turbines with fixed wind speed can directly be connected to grid.

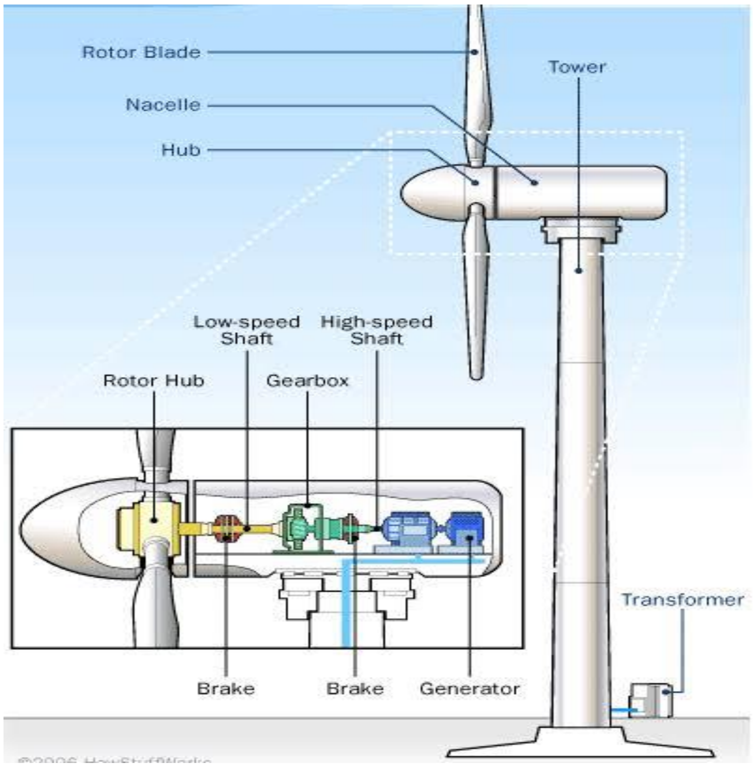

Figure 2.2: Parts wind turbine

C. Fuel cells

Fuel cells generate electricity through an electrochemical reaction that combines hydrogen and oxygen to form water vapor, heat and electricity. Its principle of operation resembles a battery that is continuously charged with a fuel gas with high hydrogen content; this is the charge of the fuel cell together with air, which supplies the required oxygen for the chemical reaction. [6] The fuel produces an induced DC voltage by using a reaction of hydrogen and oxygen with the aid of an ion conducting electrolyte. [16]

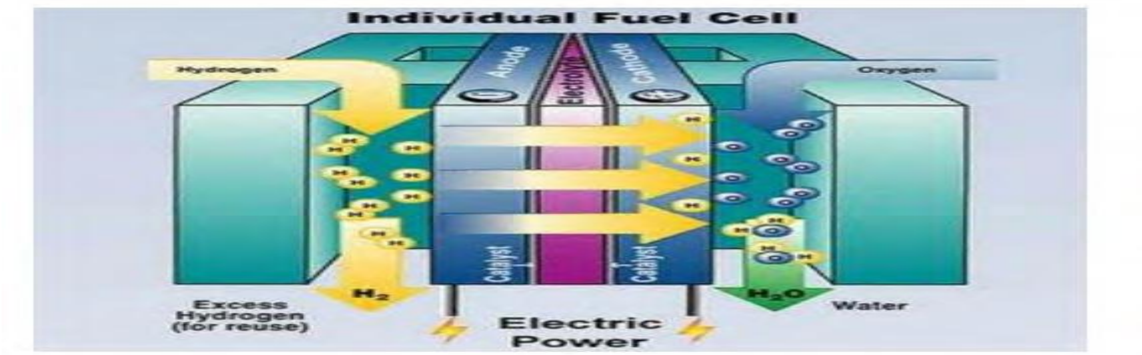

Figure 2.3: Fuel cell, [6]

By using inverters, this DC voltage is converted to AC and then is supplies to the grid. The main advantage of fuel cell is the absence of moving parts, which increase the reliability of this technology and no noise is generated while the disadvantage is high running cost.

- **Types of Fuel Cells**

Fuel cells are classified according to the type of electrolyte used. There are various fuel cell types at different stages of development. The various types of fuel cells in the increasing order of their operating temperature are: [6]

- Proton exchange membrane fuel cell (PEMFC-175 F^o)
- Phosphoric acid fuel cell (PAFC-400 ^{o}F)
- Molten carbonate fuel cell (MCFC-1250 ^{o}F)
- Solid oxide fuel cell (SOFC-1800 ^{o}F).

D. Micro-turbine

Micro-turbines, as the name implies, are small combustion turbines that burn gaseous or liquid fuels to drive an electrical generator, and have been commercially available for more than a decade. A micro-turbine is a mechanism that uses the flow of a gas, to convert thermal energy into mechanical energy. The combustible (usually gas) is mixed with air in the combustor chamber, which is pumped by the compressor. This product makes the turbine to rotate, which at the same time, impulses the generator and the compressor. In the most commonly used designs, the compressor and turbine are mounted above the same shaft as the electric generator. To have similar nominal voltage and frequency, the output voltage of micro-turbines should be converted to DC and then back to AC before connecting it to the grid. The main advantage of micro-turbines is the clean operation with low emissions and good efficiency. Its disadvantages are the high maintenance cost and the lack of experience in this field. Very little micro-turbines have been operated for enough time periods to establish a reliable field database. [6][16]

- **Major features of Micro- Turbines**

Some of the advantages of the newly developed micro turbines are listed as follows. [7]

- They can easily be installed and simple infrastructure requirements (install the units almost anywhere- on a pole, platform, in a substation, roof, vault or pad).
- They have low maintenance cost - less than $0.005/kWh.
- The fuel requirement is flexible (diesel, gasoline, ethanol, propane).
- Their simplicity in structure made them reliable and durable
- Environmental superiority of MTs on natural gas.
- They have high electrical efficiency, with fuel energy-to- electricity conversion reaching 25-30%.
- Possibility of cogeneration by using the waste heat recovery, which increases the overall energy efficiency, levels reaching 75%.

- **Application of Micro-Turbines**

Some of the applications of low cost and high efficiency micro turbines are:

- They serve as firm power for isolated communities, small commercial buildings and light industry.
- During overloading, they serve for peak shaving to the utility systems in order to decrease the required incremental cost.
- To maintain reliable operation of the utility and with important loads, micro turbines used as standby and emergency power.
- Provide Uninterruptible power supply (UPS) since they provide low initial cost, low maintenance requirements and high reliability.

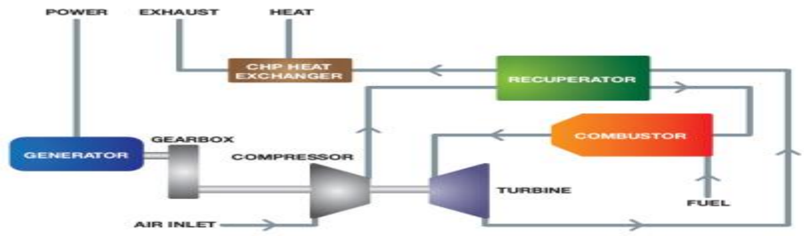

Figure2.4: Parts of micro turbine [8][16]

Table 2.1: Attributes of micro turbine [8]

Electrical Output	Available from 33 to 500 kW with integrated modular packages up to 1,000 kW.
Thermal Output	Exhaust temperatures in the range of 500 to 600 °F, suitable for supplying a variety of site thermal needs, including hot water, steam, and chilled water
Fuel flexibility	Can utilize a number of different fuels, including natural gas, sour gas (high sulfur, low Btu content), and liquid fuels (e.g., gasoline, kerosene, diesel fuel, and heating oil.
Reliability and life	Design life is estimated to be 40,000 to 80,000 hours with overhaul.
Emissions	Low NOx combustion when operating on natural gas; capable of meeting stringent California standards with carbon monoxide/volatile organic compound (CO/VOC) oxidation catalyst.
Modularity	Units may be connected in parallel to serve larger loads and to provide power reliability.
Part-load Operation	Units can be operated to follow load with some efficiency penalties.
Dimensions	Compact and light weight, 2.3-2.7 cubic feet (cf) and 40-50 pounds per kW.

2.2 Benefits of DG

Connection of Distributed Generation can provide several advantages: [9]

- Increases power supply reliability and reduces transmission and distribution systems losses.
- Can improve voltage profile; enhance power quality and supports voltage stability, so that the system can withstand higher loading situations.
- Many countries are subsidizing the development of renewable energy projects through a portfolio obligation and green power certificates. This incentives investment in small generation plants.
- Some DG technologies have low pollution and good overall efficiencies like combined heat and power (CHP) and micro-turbines.
- Renewable energy based DG like PV and wind turbines play great role in the reduction of greenhouse gases.

2.3 Drawback of DG

Injection of a DG has not only advantages, but also its own challenges to the existing distribution system. [9]

- Power converters are needed to connect DG with the grid we need, which are capable of injecting harmonics into the system.
- The connection of DG might cause over-voltage, fluctuation and unbalance of the system voltage if coordination with the utility supply is not properly achieved.
- Depending on the network configuration, the penetration level and the nature of the DG technology, the power injection of DG may increase the power losses in the distribution system.
- Short circuit levels are changed when a DG is connected to the network. Therefore, relay settings should be changed and if there is a disconnection of DG, relay should be changed back to its previous state.

2.4 Review of Other Related works

An electric power system consists of three hierarchical levels (HLs) namely: the generation (HL1), transmission (HL2) and distribution (known as hierarchical level 3, HL3).The reliability analysis of each hierarchy level can be done in the following ways.

1. Generating capacity reliability – related with generation adequacy.

2. Composite system reliability- considers both generation and transmission lines.

3. Distribution system reliability – considers local network connected to end-users

Conducting the overall power systems reliability is complicated due to variety and enormity of problems. But independent reliability analyses of the generating facilities,of composite generation and transmission systems, and of distribution system are conducted.

Power system reliability is concerned with total electric power interruptions which results in a total loss of voltage, but not just deformations of the electric sine wave. So, reliability does not cover sags, swells, impulses or harmonics. Power reliability can be defined as the ability of a power system to deliver electricity to its consumers within accepted standards, and in the amount desired and in the time needed. The degree of reliability may be measured by the frequency, duration, and magnitude of adverse effects on the electric supply.

The reliability of the system is examined with and without disconnects, by applying DG at selected locations. The presence of disconnects to the main line plays great role in the improvement of reliability. Connection of DG alone cannot improve reliability unless there are disconnectors to the main line. This is because DGs can supply the loads isolated by disconnectors from the substation in the occurrence of section or distributor lateral failures. So DG should be placed at a point where there are most load and most customers. [10]

Tabu search technique is used for optimal placement and sizing of DG in distribution systems. Connection of a DG in a distribution system results in several benefits such as increased overall system efficiency. The effectiveness of the proposed method was demonstrated by a case study of a distribution network of RBTS bus 2. It was seen that distributed generation can reduce the customer interruption cost and therefore improve the reliability of the system. [11]

Power system analysis was made without and with DGs in terms of total power loss and voltage profile of all the buses. The total power loss in with DG was reduced to 37% of total power losses in the system and the voltage profile of all the buses remained stable within the tolerable limits. The reliability indices EENS and ECOST are also reduced by about 29 %. [12]

This paper analyzed the system with and without DG for different case studies and the following result was obtained for the corresponding SAIDI and CAIDI. SAIDI with DG was reduced by 50% and CAIDI BY 42%. [13]

Reliability worth assessment is undertaken in [14]. The installations of DG at supply point will barley improve system reliability. DG at further point will increase their role of improvement. As far the location is from the substation, the reliability system indices increase. The best location for the placement of the DG is at the end of the line where much improvement is achieved.

It is found out that reliability indices (ENS, SAIDI and CAIDI) got improved as the DG is installed away from the substation, as the size of DG increased and the best location of DG is at the end of the line. [15]

2.4.1 Reliability Analysis Methods

Reliability analysis of electrical distribution system is considered as a tool for the planning engineer to ensure a reasonable quality of service and to choose between different system expansions plans that cost wise were comparable considering system investment and cost of losses.

There are two main approaches applied for reliability evaluation of distribution system, namely Simulation (Monte Carlo) method and analytical methods. The simulation (Monte Carlo) method is based on drawings from statistical distributions (Monte Carlo) and that of Analytical methods is based on solutions of mathematical models. The requirement of large number of drawings to obtain accurate results made this approach to be time consuming. The analytical approach is relies on the solutions of mathematical models on assumption of statistical distributions of failure rates and repair times.

Reliability indices are usually evaluated by analytical approach based on failure mode assessment and the use of equations for series and parallel networks.

There are three common reliability indices used in this method of reliability evaluation. These are: expected failure rate (λ), the average outage time(r), and the expected annual outage time (U), which are enough for the simple radial system. In distribution system whether the networks are radial or meshed, they are mostly operated radially and, this makes the assessment simple. The evaluation process becomes more sophisticated for parallel or meshed networks. [16]

2.4.2 Analytical Method

As described above, the majority of techniques have been analytically based and simulation techniques have taken lesser role in specialized applications [16].

2.4.3 Reliability Evaluation of Power System using Markov Models

A Markov model is the most commonly used method in the quantitative reliability analysis, and that is comfortable to provide required concept about principle of reliability analysis. In this method, a simple mathematical formula can be used to determine radial system reliability. [20] This method is known as duration-frequency technique, and the beginning point is the failure of the individual component. In a stationary Markov process, it basically operates with two central concepts:

- Failure frequency (λ) and
- Repair time (r).

It is assumed for example that a component-wise reliability can only be in one of the following conditions

1: Component is in operating or working state (in);

2: Component is out of service or it is in repair state (out).

This is shown in two state model diagram in Figure 2.5, where (0 represents a component in down state and 1 refers component is in an operating state).

λ=1/m

μ=1/r

Figure 2.5: Transition diagram of component states. [16]

Where λ fault frequency,

M mean time to failure (MTTF),

μ repair frequency and

r mean time to repair (MTTR)

Where, $\lambda = \frac{Number\ of\ outages\ on\ a\ component\ in\ a\ given\ period}{Total\ time\ the\ component\ is\ in\ opration}$

The markov model is capable of giving a simple description of a component, which can be handled well with mathematical methods. This means that the system must be represented as a system which lacks memory of previous states with identifiable system states. Figure 2.6shows, expected operational or working and failure time for a component which is known as state cycle. [14, 16]

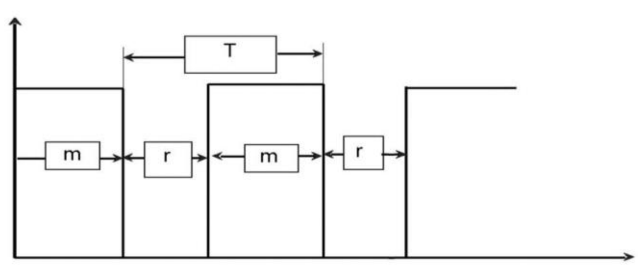

Figure 2.6: Average state cycle [17][19]

Where, average function time m is given by, $m = \frac{1}{\lambda}$

m=MTTF= mean time to failure

r=MTTR=mean time to repair, is given by, r=1/μ

m + r =MTBR, mean time between failures, T=1/f

f=cycle frequency, f= 1/T

The following equations (2.1) and (2.2) show that the relationship of repair rate μ and the outage-time r and the corresponding probabilities of a component to be in working (Up) or in down state (P_1, P_0)

2.4.3.1 Series System

In system where there is unidirectional power flow or radial system, components such as; circuit breakers, lines, switches, transformers and at the end a "Customers" are connected in series pattern. In the series structure both components must be operating state for the whole system to be in upstate, that means if there is a failed device anywhere in the network, the whole system enters to a state of failure. This is shown in figure 2.7 and equations 2.4 to 2.7 give the basic indices of failure and repair times.

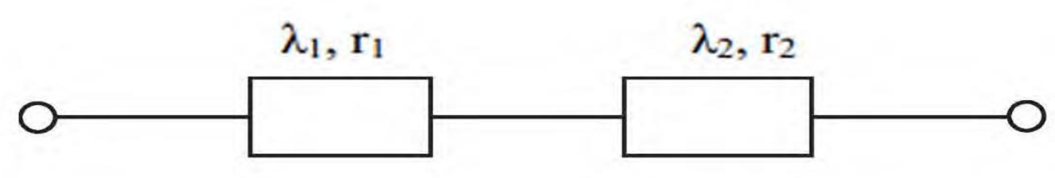

Figure 2.7: Series system (structure) [17][19]

2.4.3.2 Parallel Structure

In the parallel structure, there is an alternative path of power flow for the consumers i.e. to interrupt a load point; two or more equipment need to fail at the same time. “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.” [16]

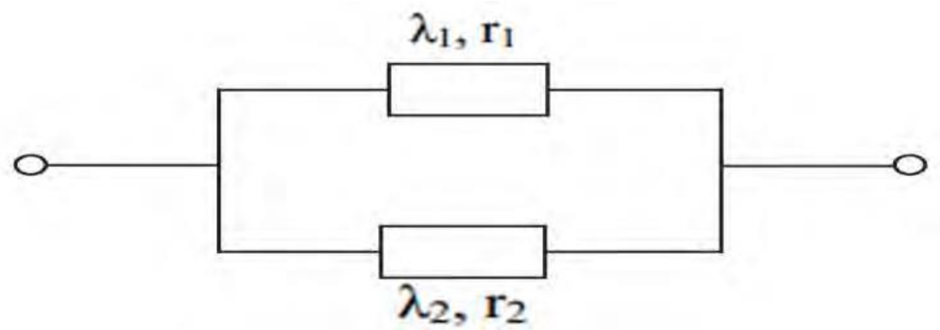

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Figure 2.8: Parallel system [19]

2.5 Numerical or Monte Carlo Simulation Methods

Monte Carlo simulation method is the most commonly utilized numerical method. In this method, simulation of physical relationship is used to analyze the random behavior of the system. The possible outcomes of this technique are not only average values like that of analytical methods, but also the expected probability distributions of reliability indices. The method provides the possibility to be applied to a more complicated component models, e.g. including effects of component aging. But this has its own side effect .i.e. increased computation time which makes the Markov models to be utilized much more often.

In addition to the analytical techniques, the simulation methods may also be used to estimate the output power and evaluate the reliability of a renewable generation system. Monte Carlo simulation consists of randomly sampling system states, testing them for acceptability and aggregating the contribution of loss of load states to the reliability till the coefficients of variation of these indices drop below pre-specified tolerances. There are two approaches of MCS, sequential and random approaches. If the approach is applied for each hour in of a year chronologically, the approach is called chronological approach while if the hours of study time taken at random, the approach tends to be random approach. Load flows, dispatch algorithms are the tools used for the simulation of randomly selected systems. The results of these simulations are current flows, voltage levels and energy curtailment which are required for determination of necessary indices of power system reliability. [16, 17]

As previously pointed out, the major demerits of MCS are the requirement of several experiments to obtain accurate results. This makes the method to take large computational time.

"To reduce this large computational burden, several variance reduction techniques such as control variants, importance sampling, stratified sampling and antithetic variants, have been developed". [18]

2.6 PowerFactory

PowerFactory is one of power system analysis software, which is designed by the software developer DigSilent. It models different aspects concerning the planning and operation of a power system. The well-known advantages of this software are its overall functional integration, for modeling of generation, transmission-, distribution- and industrial networks and its comprehensive user interface. Power Factory is also an important tool for studying the grid connection of new generation-technologies. Power generation at distribution system has challenges to the existing grid network due to bi-directional power flows, drop in voltage and huge difference in equipment loadings. Different types of generation technologies are possible, such as synchronous and asynchronous cogeneration units, PV-cells, wind turbines, fuel cells and micro-turbines and other renewable energy technologies. Typical studies include steady-state and dynamic analyses, taking into consideration time-varying correlated or un-correlated energy sources.

Power Factory is capable of analyzing the impact of distributed generation integration to the current grid network. It provides a combined classical distribution system analysis functions such as unbalanced network, voltage drop calculation, load and generation modeling, selectivity analysis, etc. with the power of a highly modern analysis tool featuring dynamic simulation functions and reliability analysis. [18]

2.6.1 Reliability Assessment under PowerFactory

The assessment of reliability indices for the whole network or for the parts of it is associated to the capability of that network to supply the electricity demand of its customers in adequate availability. The Power Factory's reliability assessment module provides two distinct calculation functions for the analysis of network reliability under probabilistic conditions: known as network reliability assessment and voltage sag assessment.

Network reliability assessment: the probabilistic assessment of interruptions during an operating period of the power system. Network reliability assessment is used to determine expected interruption frequencies and annual interruptions costs, or to compare alternative network designs.

Voltage sag assessment: The probabilistic assessment of the frequency and severity of voltage sags during an operating period. It is used to determine the expected number of equipment trips due to deep sags.

The reliability assessments indices consist of the following reliability modules. These are: Failure modeling, Load modeling, System state production, Failure Effect Analysis (FEA), Statistical analysis and Reporting. [18]

The basic reliability analysis calculation flow diagram is shown below in Figure 2.9. The failure models generally shows failure of components, that describe the way of component failures, frequency of failures and the time needed to repair them.

The load models may include only a few possible load demands, or may be based on precise load forecast and growth conditions. .System State is combination of one or more simultaneous faults and a specific load condition. The system state production module will use the failure models and load models to build a list of relevant system states.

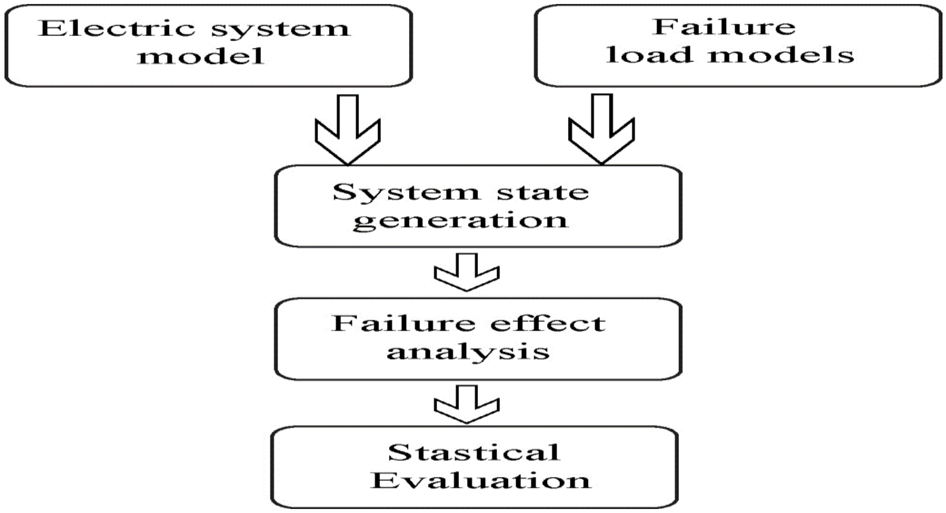

Figure 2.9: Reliability analyses under power factory [17]

Each of these system states may have one or more faults. Then, the failure effect analysis module, FEA analyzes the faulted system states by imitating the system reactions to these faults, given the current load demands. The FEA undertake the power system through different operational states which may include: [18]

- The faults will be cleared by tripping protection breakers;
- The fault will be isolated by opening separating switches;
- Restoration of Power by closing normally open switches;
- Alleviation of overload by load transfer and load shedding.

The major role of the FEA functions is to search whether the faults occurred will result in to load interruptions and if so, which loads will be interrupted and for how long.

To update the reliability statistics, the outcomes of the FEA are combined with the data which describe the expected frequency of occurrence of the system state and its expected duration that is provided by the system state production module. A system state with a single feeder on outage (i.e. due to a short circuit), will have a duration equal to the time needed to repair that feeder. This is no more a problem in the case of a double feeder where no loads may suffer any interruption. In the case that loads are interrupted by the outage, the power may be restored by network reconfiguration (i.e. by fault separation and closing a back-stop switch). The interruption duration will then equal the restoration time, and not the repair duration (system state duration). The availability gives the fraction of time during which the component is in service; the unavailability gives the fraction of time during which it is in repair; and P+Q = 1.0.

2.6.2Network Reliability Assessment

“Reliability analysis is an automation and probabilistic extension of contingency evaluation. The planner is not required to pre-define outage events, but can optionally select that all possible outages are considered for analysis. The relevance of each outage is considered using statistical data about the expected frequency and duration of outages according to component type. The effect of each outage is analyzed in an automated way, meaning that the software simulates the protection system and the network operator's actions to re-supply interrupted customers. As statistical data regarding the frequency of each event is available, the results can be formulated in probabilistic terms.”

An analytical assessment of the network reliability indices (transmission, sub-transmission or distribution level) is initiated by the following actions within PowerFactory:

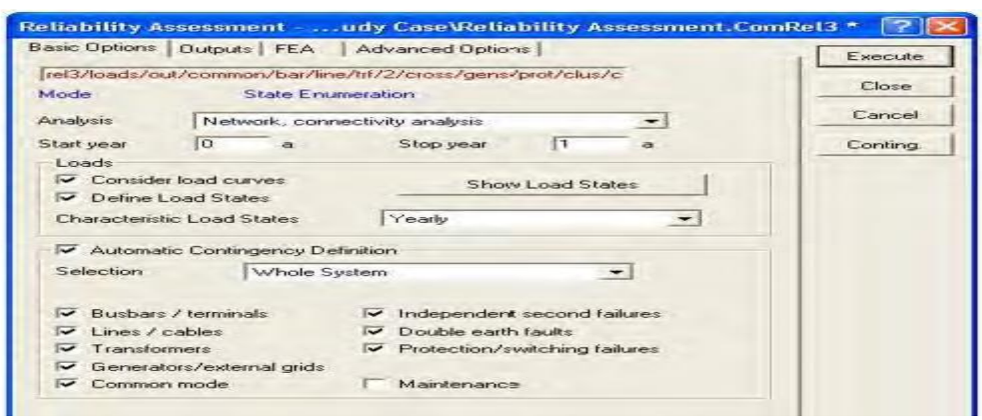

Figure 2.10: Reliability analysis interface

A reliability assessment will be started when the Execute button is pressed.

2.6.3 Outputs

The output option interface of PowerFactory is shown in figure below.

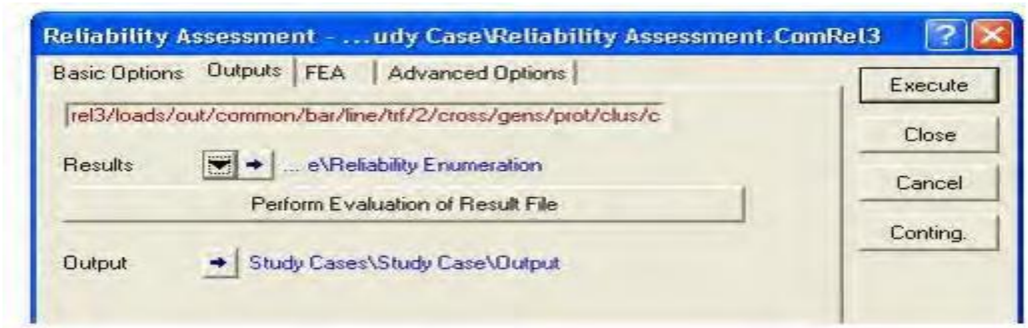

Figure 2.11: Output tab of reliability assessment dialogue

2.7 Results

The result options in PowerFactory allow the choice of the result element (ElmRes) where the results of the reliability analysis will get stored.

These results include all the indices of power system reliability indices such as SAIDI, SAIFI, and ASAI, ENS and so on. If load flow analysis option is executed, the result box shows the voltage profile, the active and reactive powers, total generation from the external grid and from our DG and also the losses due reliability problems. [PowerFactory45].

2.8 Reliability Indices

Power system reliability indices are used as a means of measuring the reliability of the individual as well as the overall system. Reliability indices typically consider such aspects as:

- The number of customers;
- The connected load;
- The duration of the interruption measured in seconds, minutes, hours, or days;
- The amount of power (kVA) interrupted; and
- The frequency of interruptions.

A. Customer-Oriented Indices

These indices are directly related to customers. Some of these indices are listed below. They are defined in IEEE Standard 1366. [16][17][19]

1. System Average Interruption Frequency Index (SAIFI):

It is the average frequency of sustained interruptions per customer over a predefined area. It is the total number of customers interruptions divided by the total number of customers served.

$$SAIFI = \frac{Total\ number\ of\ customer\ interruptions}{Total\ number\ of\ customers\ served} = \frac{\sum i\lambda iNi}{\sum iNi} \quad (2.1)$$

Where is the failure rate at load point I, and Ni is the number of customers found at load point i.

2. Customer Average Interruption Frequency Index (CAIFI):

This index gives the average frequency of sustained interruptions for those customers experiencing sustained interruptions. The customer is counted once regardless of the number of times interrupted for this calculation.

$$CAIFI = \frac{Total\ number\ of\ customer\ interruptions}{Total\ number\ of\ customers\ affected} = \frac{\sum Ni}{\sum N0} \quad (2.2)$$

Where No is total number of customer interruptions and Ni is the number of customers found at load point i.

3. 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 as to the average time the customers are interrupted. It is the sum of the restoration time for each interruption event times the number of interrupted customers for each interruption event divided by the total number of customers

$$SAIDI = \frac{Total\ number\ of\ customer\ interruption\ durations}{Total\ number\ of\ customers\ served} = \frac{\sum iUiNi}{\sum \lambda iNi}. \quad (2.3)$$

Where Ui is the annual outage time at load point i and Ni is the number of customers at load point i.

4. Customer Average Interruption Duration Index (CAIDI)

It is the average time needed to restore service to the average customer per sustained interruption. It is the sum of customer interruption durations divided by the total number of customer interruptions.

$$\text{CAIDI}= \frac{Sum\ of\ customer\ interruption\ durations}{Total\ number\ of\ customers\ interruptions} = \frac{\sum iUiNi}{\sum i\lambda iNi} \qquad (2.4)$$

Where λi is the failure rate at load point i, Ui is the annual outage time at load point i and Ni is the number of customers at load point i.

5. Average Service Availability Index (ASAI):

This index represents the fraction of time (Often in percentage) that a customer has power provided during one year or the defined reporting period.

$$\text{ASAI} = \frac{Customer\ hours\ of\ available\ service}{Customer\ hours\ demanded} = \frac{\sum NiX8760-\sum UiNi}{\sum NiX8760} \qquad (2.5)$$

6. Average Service Unavailability Index (ASUI): This index is the complementary value to the average service availability index (ASAI).

$$\text{ASUI} = 1\text{- ASAI} = \frac{Customer\ hours\ of\ unavailable\ service}{Customer\ hours\ demanded} = \frac{\sum iUiNi}{\sum NiXi8760} \qquad (2.6)$$

B. Load or Energy-Oriented Indices

1. Energy Not Supplied Index (ENS): This index represents the total energy not supplied by the system. And it is given by

$$\text{ENS} = \sum Ls(i)U \qquad (2.7)$$

Where Ls (i) is the average load given by

$$\text{Ls(i)} = \text{Lp(i)*Lp(i)} =\frac{\text{Ed(i)}}{t} \qquad (2.8)$$

LP is peak load demand, LF is the load factor, and Ed is the total energy demanded in the period of interest t.

1. **Average Energy Not Supplied Index (AENS):** This index represents the average energy not supplied by the system.

   $$\text{AENS} = \frac{\text{Total energy not supplied}}{\text{Total number of customers served}} = \frac{\sum \text{La(i)U}}{\sum \text{N}} \tag{2.9}$$

2. **Average Customer Curtailment Index (ACCI):** This index represents the total energy not supplied per affected customer by the system.

   $$\text{ACCI} = \frac{Total\ energy\ not\ supplied}{total\ number\ of\ customers\ served} = \frac{\sum iLaUi}{\sum iNo} \tag{2.10}$$

Where: La (i) is the average load, No. is the number of customers affected.

In this thesis, SAIDI, SAIFI and ENS are taken for comparison of reliability indices after connecting DG.

The major demerits of reliability indices is that the presence of debate about comparing these indices from one geographic area to another and exactly how the input data is to be applied in making the calculations. Many state public utility commissions require utilities to compute and track certain reliability indices, but comparing them from region to region and utility to utility has been problematic due to differences in how the data is applied, system designs, weather differences, and even differences in vegetation growth. Because of this, the indices are limited in their usefulness. If the calculation method is kept the same, they are useful within a specific geographic area in evaluating changes in reliability over time, perhaps as a measurement of the effectiveness of maintenance practices.

2.9 Costs-Benefit Analysis

When a power is interrupted, both the utility and customers face interruption costs. When a customer faces such interruption, there is an amount of money that the customer is willing to pay to evade the interruption and this amount is referred to as the customer cost of reliability. Such costs are of tangible and intangible types and also there is an opportunity cost. But assessing the interruption cost from the customer side is difficult.

So to maximize the reliability, utility should balance their reinforcement cost for reliability improvement and the customer cost for poor reliability.

Therefore, the optimal level of reliability is said to be achieved when the sum of utility cost and the customer cost are minimum. [20]

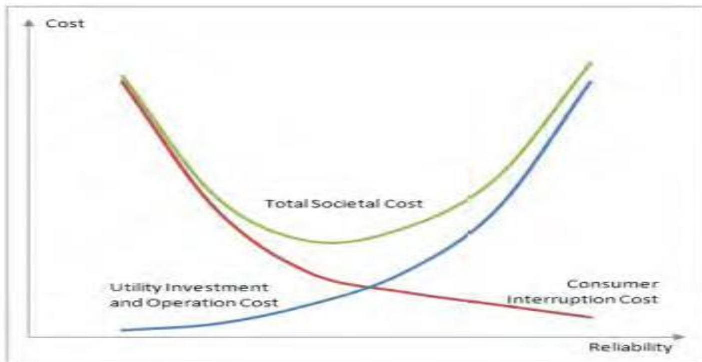

Figure 2.12: Reliability worth and reliability cost [5]

The above graph shows the cost of both customer and utility and it tell us that high reliability achieved by investing high cost.

CHAPTER THREE

METHDOLOGY OF THE STUDY

3.1 Research Approaches

In this study, quantitative methods from the primary data collection methods was used for researching the DGs marketing values and descriptive approach, from secondary data collection methods was also used to investigate, show, and summarize interruption data statistically, together with their main sources of cause of interruptions.

3.1.1 Quantitative approach in this process, Distributed Generators (DGs) marketing values was collected from online sources. Specifications and other detailed data objectively collected and analyzed. Numerical data to describe, predict, or control variables of the study. The goal of quantitative research is to test casual relationships between variables, make predictions, and generalize results to wider populations.

3.1.2 Descriptive approach in this research interview methods were used to describe the characteristics of the variables under study. This methodology focuses on answering questions relating to "what" than the "why" of the sources of power interruption causes. The primary focus of descriptive research is simply describing the nature of the demographics under study instead of focusing on "why".

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

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

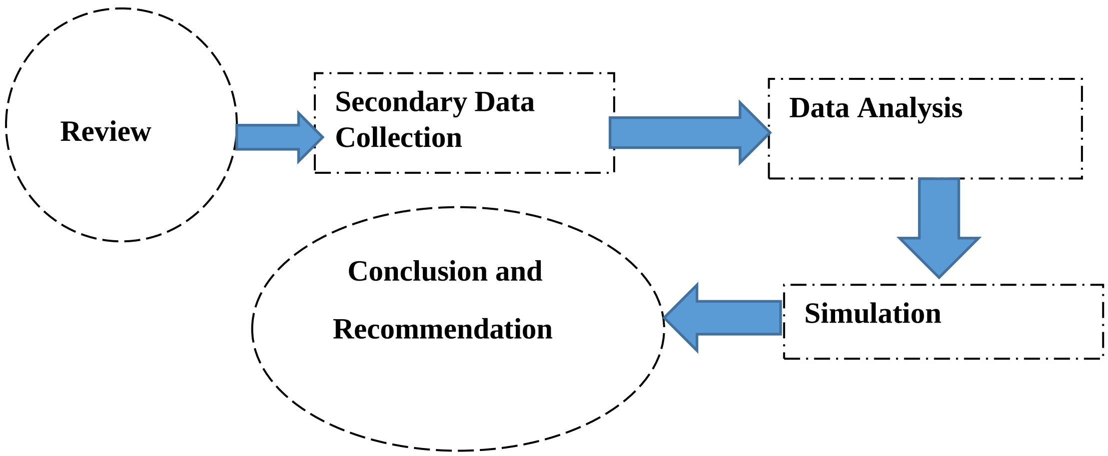

Figure 3.1 General Methodologies Outline

- **Review: -** “Nazareth town distribution network development plan”, Books, annual reports, journals, thesis reports, research and information provided on other websites.
- **Secondary data: -**Important data from other research, journals and government records. i.e. data primarily used for other purposes.
- **Data analysis:** - evaluating types of interruption data using statistical data analysis, calculating the reliability indices of the distribution substation, calculating the additional optimum power and costs required.
- **Simulation: -**the research main target is the improvement of the distribution power system reliability using Distributed generations (DGs), thus to show its improvement and execute other important data simulation software will be utilized.
- **Conclusion: -**are important in the research processes. It interprets the finding of the research. It answers the statement of the problem and the significance of the findings of a research project. If possible concluding with a quotation from or reference to a primary or secondary source, one that amplifies the main perspective.
- **Recommendation:** - drawing the recommendation from the conclusions, these opinions are supported by the research findings.

3.2 Data Sources and collection methods

Data is a collection of facts, figures, objects, symbols, and events gathered from different sources. The collect data help to make better decisions. Without data, it would be difficult for making appropriate conclusions and decisions, and so data is collected at various points in time from different audiences. The primary data necessary for this study were the feeder information, protection system information, rating and type of each transformer, topology and layout of the system, conductor type, and topography and others. The secondary data especially the frequency and duration of power interruption, which was very necessary data for this study collected, mainly since from 2009 E.C up to 2011 E.C was manually recorded monthly, and since from 2012E.C up to now the SCADA system record data automatically report in the station. Usually in Adama distribution system data on sustained and temporary interruptions was reported to the regulatory authority.

In Adama substation each interruption duration and frequency (number of interruption) of each feeder per hour is recorded together with the causes of interruptions are described and identified well. But to put an appropriate mitigation technique for the power interruption problem in the case

Important data were collected from three sources of data and analyzed at different stages of the study.

- **Surveys: -** online surveys were used to collect marketing values of the different types of DGs. Once the data was collected, surveys software
- **Interviews: -** in this study face to face and telephone interview method was used. A series of inquiries will be raised to interviewee; the data from the interviews were summarized. All the interviewees had sufficient experience, during and even before the construction of the rehabilitation of the Adama distribution substation.

3.2.1 Data collection:

- Four years and Nine months (2009-2013) (EC) interruption data has been collected from Adama SS.
- All feeder information, type of faults, number and ratings of transformers information has been collected from the existing system.

- Interview and questioner was prepared to identify the main root causes of fault factors and discussions with concerned workers regarding the system setting and configuration, and reliability status.
- All specifications of data of wind turbines/ generators and photo voltaic/ solar power system.

3.3.2 Sampling designs

Engineers', distribution technician and supervisors or team leader, Operation & Maintenance technicians, and experienced daily laborers of EEU of Adama district station were involved during the interview data collection.

3.3.3 Data Analysis

The quantitative and descriptive data were collected and analyzed using Excel, Homer and Digsilent software.

The following simple steps were identified and sorted out for analysis.

- Data requirement specification- describes short and straight forward questions, the answers to which finally helpful to make a decision.
- Data collection- gathering power interruption data and DGs marketing values based on measurement parameters and collect data from databases, websites, and many other sources.
- Data processing- organize data, cross-check data with reliable sources.
- Data Analysis- using Excel, Homer and Digsilent software, sorting, plotting, and identifying correlations will be involved during analysis.
- Interpret results- Based on the result of this analysis and assessments, recommend solutions that have been evaluated for potential reliability improvement on power interruption.

CHAPTER FOUR
EVALUATION OF RELIABILITY

4.1 Reliability Analysis and Description of Existing Substation

Power reliability can be defined as the degree to which the performance of the elements in a bulk system results in electricity being delivered to customers within accepted standards and in the amount desired. Thus, under this chapter the collected interruption data and other relevant data which are important for reliability analysis are included. These data are analyzed to identify the main sources of interruption and the reliability status of Adama substation since 2009 up to 2013(E.C).

4.2 Adama distribution substation

The data from Adama substation has been collected and analyzed for about five years, from 2009 to 2013 E.C. The substation had only 50MVA capacity before end of Nehase 2009E.C, starting from Meskerem 2010 E.C where upgrading made, the substation has got a total capacity of 100MVA, of which 50MVA is from newly installed mobile station. By now the station has three incoming feeders. From Adama wind farm, Koka, and Awash Melkasa. However these days, the substation is feed only from Koka hydropower generation and Adama wind farm and converts it from 132KV to 15 kV by using three parallel connected transformers(25MVA, 25MVA & 50MVA), and then 758 distribution transformers are used to further step-down the voltages to customer-level voltage of 400/230 volts at the load points.

The distribution feeder system for the city had a primary voltage of 15 kV, and supplies approximately 70,000 customers including residential, commercial and industrial customers.

Currently, the substation feeds Adama city with 11 medium voltage outgoing feeder, 6 feeders are from two 25MVA (i.e. 50MVA) and the remaining 5 feeders from mobile substation (i.e. 50MVA).

Fig 4.1 a, overview of Adama distribution Substation [GOOGLE IMAGE]

Fig 4.1 b overview of Adama distribution Substation [GOOGLE IMAGE]

Fig 4.2 overview of the wind farm at Adama city [GOOGLE MAP]

4.3 Site Description of Adama substation

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 [21]. Based on Ethiopia Administrative Regions Cities and Population, the city has an estimated population of about 355,475 people and an annual population growth rate of about 4.3% [21, 22]. The households are estimated at about 60 thousand and the housing units at about 400 less than the households. The city is believed to be fully electrified with a total number of customers at about 35.7 thousand leading to the conclusion that one customer of EEU may provide electricity on average to about 1.7 households (i.e. for every 3 consumers just over 5 households are electrified) [22].

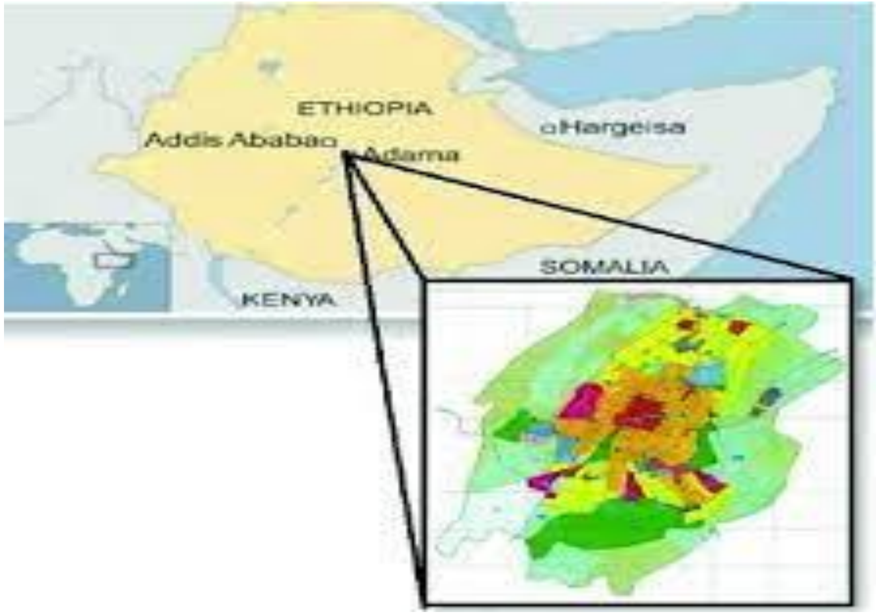

Figure 4.3: Geographical map of Adama City [Google Map]

4.4 Major Interruption Causes of Adama Substation

In Adama substation, major faults occurring frequently are short circuit, earth fault, blackout, overload, under frequency. And there are planned outages for operational and maintenance purpose. The major faults occurring can either be of temporary and permanent type. Permanent or Sustained interruptions are long-duration interruptions which last longer than 5 minutes whereas interruptions with duration of less than 5 minutes are termed momentary interruptions [22]. Usually, only data on sustained interruptions is reported to the regulatory authority. Many of the distribution problems are temporary and mainly caused by tree, animal contact, and whether condition. They can easily be solved with little or no intervention from the system. Then by simply reclosing, the system will be re-energized. But permanent faults can't be restored by simple re-energizing. Permanent faults can be caused by Equipment malfunction, cable failure, down line or persistent tree contact. [16]

Permanent (Sustained) interruptions can be classified as Planned and Unplanned Interruptions [14]. Planned interruptions (operational outages) occur mainly for the purpose of construction, preventative maintenance or repair. A planned interruption occurs at a selected time less inconvenient for the customers and the customers have been notified beforehand of the interruption. On the other hand, if the occurrence time of the interruption has not been selected, then the interruption is unplanned. Unplanned interruption occurs, for example, due to fault clearing, unwanted operation of the protection system or due to inadvertent initiation of opening operation of a switching device by a human.

Non-momentary interruption: are the results of the following faults

Distribution Short Circuit (DSC)

Short circuit is the most commonly used term to describe the cause of a power failure. It occurs when an electric current travels along a path that is different from the intended one in an electrical circuit. When this happens, there is an excessive electric current which can lead to circuit damage, fire, and explosion. In fact, short circuits are one of the primary causes of electrical fires throughout the world [15]. It also occurs when the insulation of the wiring used breaks down. It can also occur due to the presence of an external conducting material (such as water) that is introduced accidently into the circuit. Electrical batteries can explode if they are subjected to a large current. Short circuits can even occur when electric motors are forced to operate when the moving parts are jammed. This can result in abnormal buildup of current, ultimately leading to a short circuit.

Water can lead to short circuits and power failure. Because water is conductive so the current easily flows through it. Current will always take the easiest path. Since there is little resistance in water, the current will flow from positive to negative (or vice-versa) through the water causing the short circuit. The damage caused due to water in electrical circuits can be very expensive so it makes sense to ensure that you are well protected from it. Electrical switchboards, wires, and circuits should be protected from exposure to water. Dust can also wreak havoc with electrical systems and lead to short circuits and power failures

Distribution Earth (ground) fault (DEF)

This fault occurs when there is a conducting connection between any electric conductor and any conducting material that is grounded or that may become grounded. Electricity always wants to find a path to the ground. In a ground fault, electricity has found a path to ground, but it is a path the electricity was never intended to be on, such as through a person’s body [23]. The earth fault, caused by an insulation loss between a live conductor and an exposed conductive part, represents a plant engineering problem which may cause damage to the electrical installations and above all may jeopardize people; as a matter of fact, people could get in touch with an exposed-conductive-part not normally live but which, due to the fault, might have a dangerous potential to ground.

Power Transformer Overload

Overloaded transformers are found in industry as a result of a combination of factors. Often times rapid plant expansion without adequate capacity planning can lead to overloaded transformers. This combined with the poor power factor and high harmonic currents generated by inductive loads, can cause a transformer to become heavily loaded

Distribution Line Overload:

Increasing demands for electric power have caused existing power grids to become overloaded. Overloading is a common cause of line voltage fluctuations. Inadequate power generation and

Inadequate distribution systems are also causes of line voltage problems. Improper or poorly designed power regulating devices may create voltage fluctuations. Loose or corroded connections at the electric service user end can create voltage irregularities. The same conditions on the distribution power lines may also affect voltage. Many voltage fluctuation problems can be traced back to inadequate infrastructure.

Blackout

Blackout is a total loss of the electric service in one area. It can be caused by catastrophic equipment failure or severe weather. It can also be caused by the utility itself for peak shaving purpose

Table 4.2: Summary of Adama substation fault factor indices

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

4.5. 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 behavior in response to operator actions and events while proactively recommends / implements decisions to improve operations. In Adama SCADA substation integrated with 55 distribution transformers and 8 switching station switching station but R7 and R8 not finished so far.

The substation is managed and controlled by SCADA Power Grid Distribution Management System. There are 13 feeders and out of these feeders only 11 feeders are actively give a service to the Town. From the 11 feeders only 8 feeders are remotely managed and controlled by SCADA Power Grid Distribution Management System through Remote Terminal Unit (which is abbreviated by R) connection to substation. Currently the substation only made a Remote Terminal Unit connection (R-connection) at switching station to feeder lines L1, L3, L4, L7, M1, M3, M5, and M6. The R-connection for those feeder lines are L1-R5, L3-R6, L4-R3, L7-R1, M1-R2, M3-R7, M6-R4 and M5-R8. Currently from those R-connections only 6 feeder lines are properly controlled and managed from the substation using Power Grid Distribution Management System. L1-R5 and M3-R7 are out of the remote connection and needs maintenance. Figure 4.17 shows home page snap shoot of remote monitoring system using SCADA Power Grid Distribution Management System in this substation. [22]

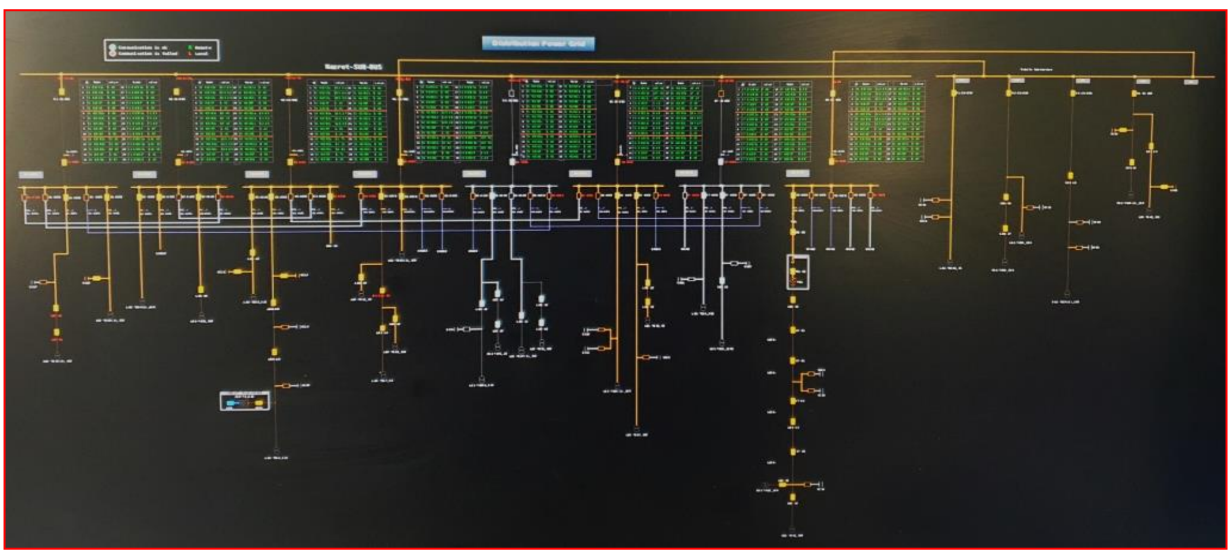

Figure 4.4: Single line diagram of Adama city distribution line [Snap shoot from SCADA Management system]

4.6 Reliability Related data of Adama Distribution Substation

This section contains the compiled reliability related secondary data that are collected from Adama city distribution substation. The collected data from 2009 to 2013(E.C) are manually recorded by supervisors that include only type of faults, frequency and duration of interruption of 11 medium voltage (15kV) outgoing feeder lines of the distribution system.

The reliability of the power supply is assessed using the known reliability indices. The indices for the distribution system analysis include customer oriented indices and load or energy oriented indices as defined be IEEE standard. This thesis mainly focused on customer oriented indices, thus important inputs to calculate the indices are the number of interruptions and duration of interruptions. The interruptions are categorized according to their fault factors.

1.1.1 Basic data of Adama Distribution Substation

1.1.2 The data collected include;

❖ **Pre-rehabilitation data and analysis**

- Reliability related data and analysis of Adama during 2009 (E.C)
- Electricity tariff Ethiopian Electric Utility(EEU) since July 8, 2007

❖ **Post-rehabilitated data and analysis**

- Single line diagram of Adama Substation.
- 132kv/15kv transformers data at substation
- 15kv/380v transformers data in the city
- Electricity tariff Ethiopian Electric Utility(EEU) since
- Reliability analysis from 2009 to 2013 (E.C)

Table 4.2: all fault factors, interruption duration and frequency of 2009 E.C.

LINES	DPEF DUR.	DPEF FRQ.	DPSC DUR.	DPSC FRQ.	DTEF DUR.	DTEF FRQ.	DTSC DUR.	DTSC FRQ.	OP DUR.	OP FRQ.
L1	72.51	31	124.7	43	63.76	24	54.49	30	191.5	121
L3	21.43	10	18.2	13	18.96	37	8.32	10	164.1	100
L4	104.1	53	189.7	47	117.8	48	83.21	41	138.0	130
L5	210.8	108	144.9	97	107.7	63	94.25	43	126.1	61
L6	128.8	107	240.4	144	142.5	88	126.2	62	292.9	139
L7	138.9	80	213	102	124.4	77	132.0	67	473.3	102
TOTAL	676.74	389	931.14	446	575.32	337	498.58	253	1386.2	653

Observation on Pre-rehabilitation working status during 2009(E.C)

As can be seen from table 4.2 during 2009 E.C, total of 1,967 numbers of interruptions, for duration of 2,481.27 hours, service were not delivered to customers.

- In general, based on the data collected and the analysis of its results, the following major points can be drawn:

- There was high unavailability of electric power in the network, and
- There was also much loss of unsupplied energy due to sustained interruptions in the present power grid of Adama city
- The reliability of the power supply in Adama did not meet the requirements set by the regulatory body that is Ethiopian Electric Agency (EEA),
- The reliability of Adama city power supply was not good enough as compared to the international reliability indices of best experienced countries such as USA, Europe, Germany…etc.,

1. Interruption data after rehabilitation from 2010 to 2013(E.C)

- Total Duration of Interruption

Table 4.3 Total Duration of Interruption from Line one, 2010 to 2013E.C

Year	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	14.99	6.5	1	5.94	0	0	0	0	20
2012	101.38	0	1	2.742	0	0	0	0	5.86
2011	65.51	0	11.49	18.68	0	0	0	0	47.58
2010	95.92	0	18,71	3.19	0	24.2	16	0	113.84
Total	277.804	6.5	32.2	30.552	0	24.4	16	0	187.28

Table 4.4 Total Duration of Interruption from Line three, 2010 to 2013E.C

Year	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	99.88	0.73	1.27	1.27	0	0	23.33	0	53.15
2012	211.29	4.2	0.18	0.18	0	0	27.99	0	28.365
2011	112.19	0	14.09	10.87	0	0	0	0	423.55
2010	30	0	3.22	1.99	0	0	15.18	0	212.91
Total	454.24	4.95	18.76	14.31	0	0	66.5	0	717.975

Table 4.5 Total Duration of Interruption from Line four, 2010 to 2013E.C

Year	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	181.69	30.07	0.58	7.42	0	0	21.42	0	266.29
2012	129.49	0.4	0	4.149	0	0	59.25	0	146.4
2011	127.68	0	9.51	8.47	0	0	0	0	372.12
2010	132.97	0	4.85	1.68	0	0	7.18	0	126.85
Total	571.83	30.47	14.94	21.719	0	0	87.85	0	911.66

Table 4.6 Total Duration of Interruption from Line five, 2010 to 2013E.C

Year	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	0	0	1.68	0	0	0	21.83	0	9
2012	67.58	0	6.25	7.17	0	0	7.27	0	29.66
2011	30.88	0	11.96	2.24	0	0	0	0	149
2010	13.07	0	3.12	0.14	0	0	1.12	0	44.28
Total	111.53	0	23.01	9.55	0	0	30.22	0	231.94

Table 4.7 Total Duration of Interruption from Line six, 2010 to 2013E.C

Year	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	0	0	1.68	0	0	0	21.83	0	9
2012	67.58	0	6.25	7.17	0	0	7.27	0	29.66
2011	12.03	0	2.26	1.06	0	0	0	0	281
2010	191.77	0	2.8	1.6	0	0	1.12	0	87.05
Total	271.38	0	12.99	9.83	0	0	30.22	0	406.71

Table 4.8 Total Duration of Interruption from Line seven, 2010 to 2013E.C

Year	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	166.84	21.36	0.58	13.87	0	0	19	0	42.53
2012	259.34	0	0	7.8	0	0	52.67	0	24.16
2011	109.45	0	16.41	11.92	0	0	0	0	390
2010	116.98	0	6.7	2.83	0	0	16.06	0	94.9
Total	652.61	21.36	23.69	36.42	0	0	87.73	0	551.59

Table 4.9 Total Duration of Interruption from Line 1 to 7, all fault factors (2010 to 2013E.C)

Feeder	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
L1	305.346	6.5	55.12	23.536	0	0	91.16	0	209.927
L3	155.82	4.95	22.41	15.36	0	0	66.5	0	673.29
L4	368.23	30.47	17.45	20.492	0	0	87.85	0	535.38
L5	111.53	0	23.01	9.55	0	0	30.22	0	231.94
L6	271.38	0	12.99	9.83	0	0	30.22	0	406.71
L7	652.62	21.36	27.04	18.517	0	0	87.73	0	560.76
TOTAL	1864.916	63.28	158.02	97.285	0	0	393.68	0	2618.007

Table 4.10 Summary of total duration of interruptions as per the fault factors

Faults	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
Dur.(hr.)	1864.92	63.28	158.02	97.285	0	0	393.68	0	2618.01

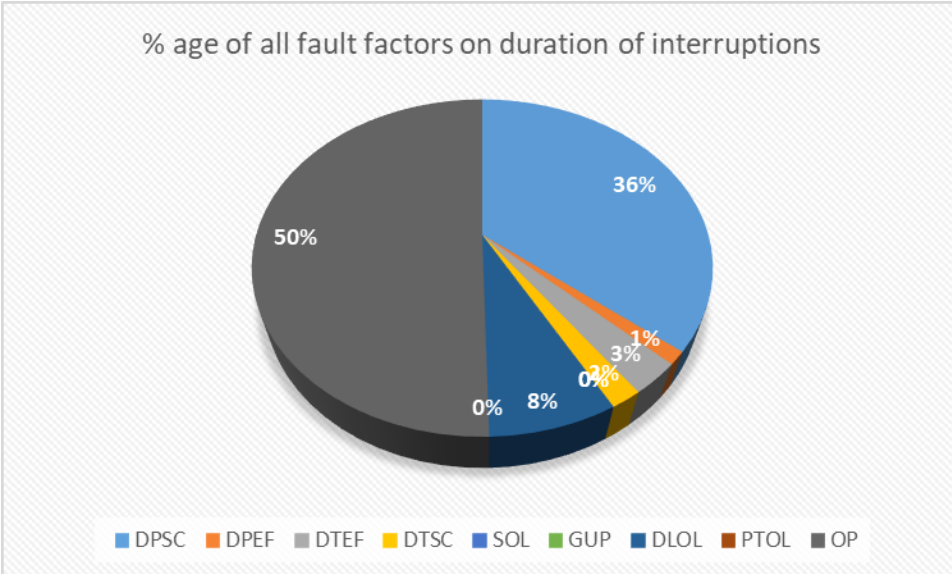

Figure 4.5 Percentage of all fault factors on duration of interruption

4.7 Observation on Post Rehabilitation, Duration of Interruption Data (2010- 2013 E.C)

- As can be seen from fig. 4.5, 50% of the interruption duration is due to operation and maintenance problem, 36% is due to permanent short circuit, 8% is due to line over load, 3% is due to temporary earth fault, 3% is due to temporary short circuit and the remaining faults recorded 0% on distribution L1 to L7.
- After rehabilitation, starting from hidar 2010 to megabit 2013 E.C, The existed feeder lines (L1 to L7) have been interrupted for 5,219.386 hours. That is about 217.5 days.
- L7 with 1368.017hr has highest fault duration. L4, L3 and L1 have the next ranks.

Frequency of interruption 2010 to 2013 E.C

Existed feeder lines, from L1 to L7

Table 4.11 Number of interruption (Frequency) on line one, 2010 -2013E.C

LINE1									
YEAR	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	12	4	6	32	0	0	0	0	17
2012	49	0	0.7	31	0	0	0	0	29
2011	27	0	35	22	0	0	0	0	128
2010	64	0	13	7	0	0	16	0	192
TOTAL	152	4	54.7	92	0	0	16	0	366

Table 4.12 Number of interruption on line three, 2010- 2013E.C

LINE3									
YEAR	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	95	2	9	56	0	0	0	0	45
2012	116	1	1	23	0	0	0	0	28
2011	27	0	35	22	0	0		0	128
2010	64	0	13	7	0	0	15	0	192
TOTAL	302	3	58	108	0	0	15	0	393

Table 4.13 Number of interruption on line four, 2010- 2013E.C

LINE4									
YEAR	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	20	0	8	17	0	0	0	0	9
2012	28	0	9	7	0	0	0	0	28
2011	44	0	26	20	0	0	0	0	124
2010	54	0	48	9	0	0	4	0	118
TOTAL	146	0	91	53	0	0	4	0	279

Table 4.14 Number of interruption on line five, 2010- 2013E.C

LINE5									
YEAR	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	20	0	8	17	0	0	14	0	9
2012	24	0	38	7	0	0	0	0	28
2011	9	0	39	6	0	0	0	0	51
2010	8	0	30	2	0	0	1	0	37
TOTAL	61	0	115	32	0	0	15	0	125

Table 4.15 Number of interruption on line six, 2010- 2013E.C

LINE6									
YEAR	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0
2011	6	0	5	1	0	0	0	0	7
2010	46	0	25	7	0			0	135
TOTAL	52	0	30	8	0	0	0	0	142

Table 4.16 Number of interruption on line seven, 2010- 2013E.C

LINE7									
YEAR	DPSC	DPEF	DTEF	DTSC	SOL	GUP	DLOL	PTOL	OP
2013	109	0	5	86	0	0	0	0	50
2012	114	0	0	52	0	0	0	0	40
2011	44	0	46	24	0	0	0	0	142
2010	73	0	40	11	0	0	8	0	146
TOTAL	340	0	91	173	0	0	8	0	378

Table 4.17 Total Number of interruption from L1 to L7 from 2010- 2013E.C

Feeder	DPSC	DPEF	DTEF	DTSC	TLP	GUP	DLOL	PTOL	OP
L1	152	4	54.7	35	0	0	55	0	373
L3	302	2	58	30	0	0	36	0	350
L4	146	0	91	53	0	0	4	0	279
L5	61	0	115	32	0	0	15	0	125
L6	52	0	30	8	0	0	0	0	142
L7	340	0	91	47	0	0	31	0	146
TOTAL	1053	6	439.7	205	0	0	141	0	1415

Table 4.18 total frequency of interruption during 2010- 2013E.C

DPSC	DPEF	DTEF	DTSC	TLP	GUP	DLOL	PTOL	OP
1053	6	439.7	205	0	0	141	0	1415

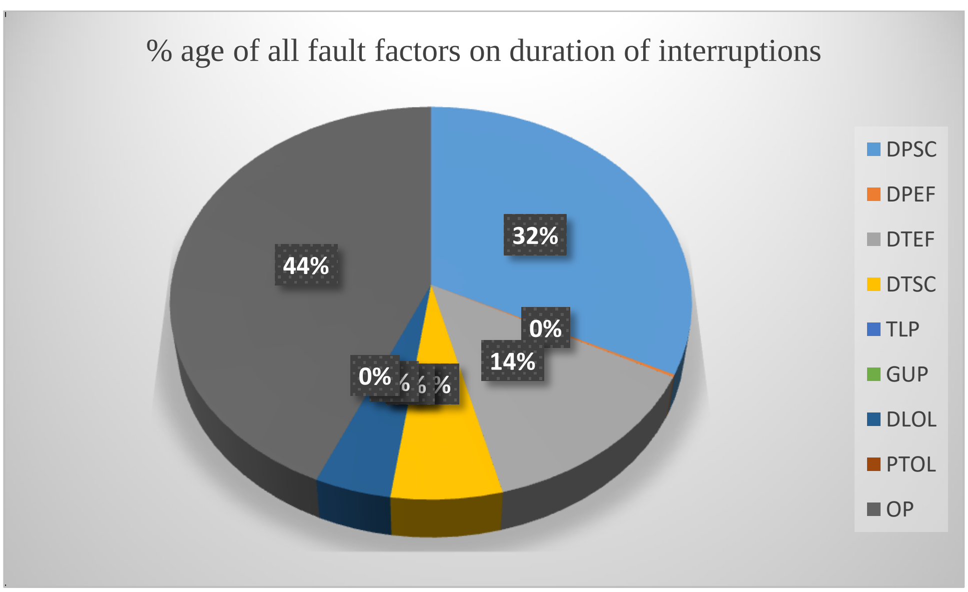

Figure 4.6 percentages of all fault factors on duration of interruptions

4.8 Observation on Post Rehabilitation Data 2010- 2013E.C

Frequency of interruption, L1 to L7

As can be seen from the tables 4.18, total number of interruption occurred was 3,259.7, 44% of the total interruptions was due to Operational interruption (i.e. 1415times), 32% was due to permanent earth fault (i.e. 2nd highest with 1053 number of interruption), 14% was due to temporary earth fault (439.7times), .L3 is ranked 1st, due to total number of interruption with 778times. L1 is 2nd (673.7), L7is ranked 3rd (655) and L4 is 4th (573times).

Mobile substation interruption data duration (hr.) from 2010E.C to 2013E.C

Table 4.19 Total duration of interruption of M1 from 2010 to 2013E.C

YEAR	DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
2013	80.467	10.33	9.283	0.12	0	19.001	0	29.873
2012	104.99	79.75	12.17	3.17	0	56.17	0	60.33
2011	74.68	211.12	13.67	15.64	0	0	0	478.94
2010	138.11	185.3	75.32	1.33	0	0	0	68.35
TOTAL	398.247	486.5	110.443	20.26	0	75.171	0	637.49

Table4.20 Total duration of interruption of M2 from 2010 to 2013E.C

YEAR	DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
2013	40.303	65.681	4.047	0.42	0	20.751	0	16.167
2012	110.33	179.83	7.016	10.91	0	44.999	0	60.33
2011	62.59	222.93	6.02	12.48	0	0	0	478.94
2010	87.3	137.22	0.24	0.06	0	1	0	68.35
TOTAL	300.523	605.66	17.323	23.87	0	66.75	0	623.79

Table 4.21 Total duration of interruption of M3 from 2010 to 2013E.C

YEAR	DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
2013	0	37.66	0	3.29	0	0	0	12.06
2012	7.852	37.55	0	3.96	0	0	0	33.09
2011	73.53	195.22	5.91	9	0	0	0	430.9
2010	84.67	169	169	2.61	0	1	0	44.61
TOTAL	166.052	439.43	174.91	18.86	0	1	0	520.66

Table 4.22 Total duration of interruption of M5 from 2010 to 2013E.C

YEAR	DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
2013	1.03	239.8	2.28	3.29	0	0	0	12.06
2012	9.31	283.72	0.93	3.96	0	0	0	33.09
2011	129.83	131.66	7.72	9.43	0	0	0	432.75
2010	218.68	219.06	17.92	0.85	0	1	0	89.01
TOTAL	358.85	874.24	28.85	17.53	0	1	0	566.91

Table 4.23 Total duration of interruption of M6 from 2010 to 2013E.C

YEAR	DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
2013	6.09	305.77	0.39	4.76	0	0	0	11.87
2012	1.47	366.14	0	7.45	0	0	0	33.09
2011	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0
TOTAL	7.56	671.91	0.39	12.21	0	0	0	44.96

Table 4.24 total duration of interruption M1 to M6 from 2010 E.C to 2013E.C

Feeder	DPEF	DPSC	DTEF	DTSC	GUP	GUP	DLOL	PTOL	OP
M1	88	566.15	41	162	0	0	0	0	331
M2	57	92	25	11	0	0	0	0	167
M3	97	209	61	42	0	0	0	0	205
M5	55	257	77	205	0	0	0	0	176
M6	76	267	34	106	0	0	0	0	223
TOTAL	373	1391.15	238	526	0	0	0	0	1102

Table 4.25 Summary of total duration of interruption M1 to M6 from 2010 E.C to 2013E.C

DPEF	DPSC	DTEF	DTSC	GUP	GUP	DLOL	PTOL	OP
373	1391.15	238	526	0	0	0	0	1102

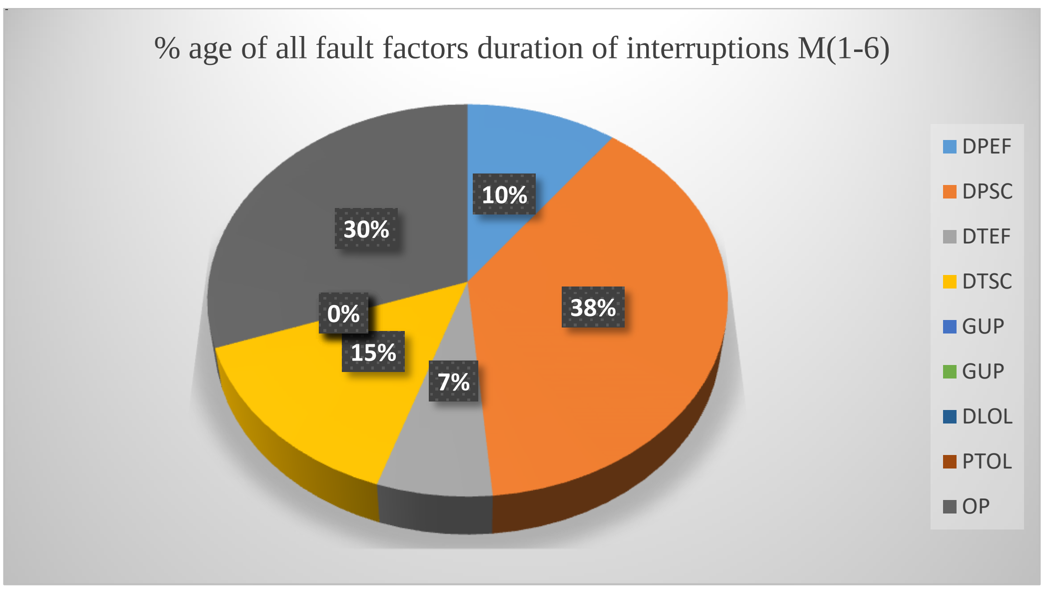

Figure 4.6 Percentage of all fault factors duration M1 to M6 (2010E.C to 2013E.C)

- ❖ As can be seen from the pie chart, 38% of the interruption duration is due to permanent short circuit, 30% is due to operation and maintenance problem, 15% is due to temporary short circuit, 10% is due to permanent earth fault, 7% is due to temporary earth fault, the remaining faults recorded 0% on distribution M1 to M6.

Table 4.26 Frequency of Interruption M1, 2010 to 2013 E.C

Year (E.C.)	DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
2013	0	183	0	71	0	0	0	69
2012	5	158.15	1	62	0	0	0	58
2011	22	66	31	25	0	0	0	141
2010	61	59	9	4	0	0	0	63
Total	88	566.15	41	162	0	0	0	331

Table 4.27 Frequency of Interruption M2, 2010 to 2013 E.C

Year (E.C.)	DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
2013	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0
2011	18	55	18	10	0	0	0	106
2010	39	37	7	1	0	0	0	61
Total	57	92	25	11	0	0	0	167

Table 4.28 Frequency of Interruption M3, 2010 to 2013 E.C

Year (E.C.)	DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
2013	0	35	0	18	0	0	0	29
2012	5	44	0	24	0	0	0	20
2011	27	65	13	0	0	0	0	133
2010	65	65	48	0	0	0	0	43
Total	97	209	61	42	0	0	0	205

Table 4.29 Frequency of Interruption M5, 2010 to 2013 E.C

Year (E.C.)	DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
2013	5	120	6	109	0	0	0	51
2012	5	120	2	88	0	0	0	40
2011	10	9	30	6	0	0	0	51
2010	35	8	39	2	0	0	0	34
Total	55	257	77	205	0	0	0	176

Table 4.30 Frequency of Interruption M6, 2010 to 2013 E.C

Year (E.C.)	DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
2013	6	93	4	38	0	0	0	43
2012	3	122	0	60	0	0	0	38
2011	6	6	5	1	0	0	0	7
2010	61	46	25	7	0	0	0	135
Total	76	267	34	106	0	0	0	223

Table 4.31 Total frequency of interruption from M1 to M6, from 2010 E.C to 2013E.C

Year (E.C.)	DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
M1	398.247	486.5	110.443	20.26	0	75.171	0	637.49
M2	300.523	605.66	17.323	23.87	0	66.75	0	623.79
M3	166,052	439.43	174.91	18.86	0	1	0	520.66
M5	358.85	874.24	28.85	17.53	0	1	0	566.91
M6	7.56	671.91	0.39	12.21	0	0	0	44.96
Total	1,231.232	3077.74	331.916	92.73	0	143.92	0	2393.81

Table 4.32 Summary of total frequency of interruption from M1 to M6, from 2010 to 2013E.C

DPEF	DPSC	DTEF	DTSC	GUP	DLOL	PTOL	OP
1238.792	3749.65	332.306	104.94	0	143.921	0	2438.77

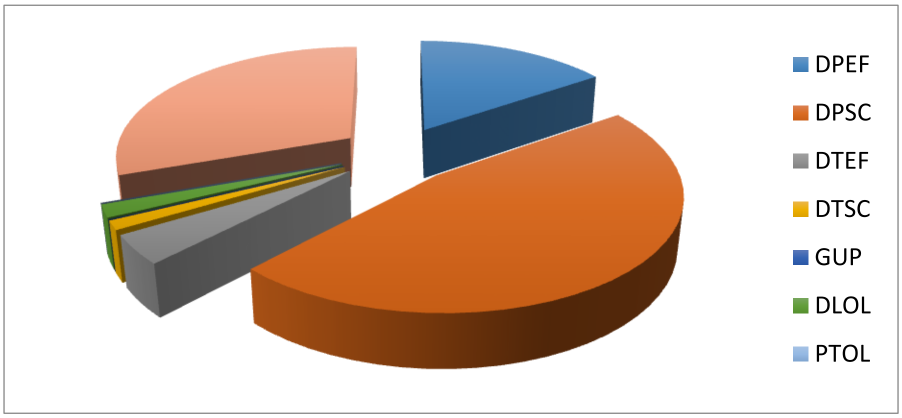

Figure 4.7 Percentage of all fault factors duration M1 to M6 (2010E.C to 2013E.C)

As can be seen from the pie chart, permanent short circuit is the leading fault factors for mobile station, temporary earth fault and permanent earth fault factors followed 2nd and 3rd.

Table 4.33 total interruption duration & frequency during (2010-2013) E.C

LINE	M1	M2	M3	M5	M6
Dur(hr.)	1728	1637	1320	1847	737
Freq.	1188	252	614	770	706

Frequency of interruption, M1 to M6 from 2010 to 2013 (E.C)

As can be seen from the tables 4.31 total number of interruption occurred 3530times.

M1 is ranked 1st, due to total number of interruption with 1188

M5 is 2nd (770), M6 is ranked 3rd (706).

Duration of interruption, M1 to M6, from 2010 to 2013 (E.C)

As can be seen from the tables 4.31

Total duration of interruption occurred 3,259.7 times.

M5 is ranked 1st, due to total the duration of interruption with 1847times. M1 is 2nd (1728), M2 is ranked 3rd (1637).

Table 4.34 calculated SAIFI values for each feeders and system, 2009 -2013 E.C

LINE	2009(pre)	2010(post)	2011	2012	2013
L1	**106**	**292**	212	110	71
L3	**58**	**291**	212	169	207
L4	**221**	**233**	214	72	54
L5	**311**	**78**	105	97	68
L6	**405**	**213**	19		
L7	**336**	**278**	256	206	250
M1				408	321
M2		**145**	207		
M3		**221**	238	102	73
M5		**118**	106	255	291
M6		**274**	25	223	184
Average	**239.5**	**214.3**	159.4	182.444	168.778
rank	1st	2nd	5th	3rd	4th

As can be seen from table 4.34, SAIFI in 2009E.C (pre rehabilitation) was so high, that means there were high number of interruptions. In 2011E.C the least SAIFI or numbers of interruptions were recorded, average number of interruptions decreased significantly from 239.5(2009E.C) to 159.4(2011E.C). However the number of interruption doesn’t constantly decreasing, rehabilitation works on the distribution system brought significant improvement. And again still it’s far away from the standards of EEPCO ≤ 20. Therefore penetration of DGs is mandatory to sustainably improve the reliability of the city.

Table 4.35 calculated SAIDI values for each feeders and system, 2009 -2013 E.C

LINE	2009	2010	2011	2012	2013
L1	**191.8**	271.9	143.3	110.99	48.4
L3	**58.6**	264	560.7	272.2	179.6
L4	**482.6**	273	518	340	507
L5	**557.8**	62	194		
L6	**638**	284	296	118	33
L7	**553**	237	528	344	264
M1		468	794	317	149
M2		294	783	413	147
M3		470.9	714	82.5	53
M5					
M6		546.5	711.4	331	258.5
Average	**413.633**	317.13	524.24	258.743	182.167
rank	2nd	3rd	1st	4th	5th

As can be seen from table 4.35 SAIDI during 2009E.C (pre rehabilitations) was 2nd highest to SAIDI of 2011E.C, this shows that in spite of the fact that rehabilitation works improved the reliability of the system significantly, penetration of DGs near to the customer load would enable to ensure the reliability of the system to the required limit i.e. SAIDI $\leq$ 25

Table 4.36 calculated CAIDI values for each feeders and system, 2009 -2013 E.C

Feeder	**2009 (pre)**	**2010 (post)**	**2011**	**2012**	**2013**
L1	1.809	0.93	0.68	1	0.68
L3	1.01	0.91	2.645	1.61	0.87
L4	2.18	1.17	2.42	4.7	9.39
L5	1.79	0.79	1.85	---	---
L6	1.575	1.33	15.58	---	---
L7	1.65	0.85	2.06	1.67	1.06
M1	----	---	---	0.78	0.46
M2	----	2.02	3.84	---	---
M3	----	2.13	3.29	0.81	0.73
M4	----	----	---	---	---
M5	----	4.63	6.71	1.3	0.89

Table 4.37 calculated ASAI values for each feeders and system, 2009 -2013 E.C

Feeder	2009 (pre)	2010 (post)	2011 E.C	2012 E.C	2013 E.C
L1	0.98	0.969	0.98	0.987	0.9925
L3	0.99	0.969	0.94	0.968	0.972
L4	0.945	0.97	0.94	0.961	0.921
L5	0.945	0.99	0.98	---	0.996
L6	0.927	0.967	0.97	0.986	0.9949
L7	0.937	0.97	0.939	0.96	0.959
M1	----	0.947	0.909	0.0.964	0.977
M2	----	0.966	0.91	0.952	---
M3	----	0.946	0.918	0.99	0.977
M4	----	---	---	---	0.99
M5	----	0.937	0.92	0.962	0.96

Table 4.38 calculated ASUI values for each feeders and system, ASUI (2009 -2013) E.C

Feeder	2009 (pre)	2010 (post)	2011 E.C	2012 E.C	2013 E.C
L1	0.02	0.031	0.02	0.013	0.0075
L3	0.01	0.031	0.06	0.032	0.028
L4	0.055	0.03	0.06	0.039	0.079
L5	0.055	0.01	0.02	---	0.004
L6	0.073	0.033	0.03	0.014	0.0051
L7	0.937	0.03	0.061	0.04	0.023
M1	----	0.061	0.019	0.036	0.023
M2	----	0.091	0.09	0.048	---
M3	----	0.054	0.081	0.01	0.023
M5	----	0.063	0.08	0.012	0.04

Table 4.39 Annual average energy and power consumption of each feeder bus bar

Feeder Name	Average MVA	Average Active power (MW)	Average Reactive power (MVAr)	Average Active Energy(KWH)	Average Reactive Energy (KVArH)
Line1	3,342	3,03	1,41	26,555,550.00	12,373,391.67
Line2	2,5	2,21	1,17	19,374,187.50	10,252,179.17
Line3	3,98	3,57	1,76	31,305,012.50	15,431,933.33
Line4	3,488	3,19	1,41	27,908,837.50	12,369,458.33
Line5	1,431	1,38	0,38	12,085,92.83	3,293,016.67
Line6	2,406	2,14	1,1	18,775,387.50	9,594,225.00
Line7	0.872	0,77	0,41	6,742,687.50	3,600,675.00
TOTAL	**18,019**	**16.29**	**7.64**	**142,747,583.33**	**66,914,879.07**

Based on Table 4.39, the power factor (pf) for the system can be calculated as:

Pf =cos (tan−1 (Q/P));

$= \cos(\tan^{-1}(66{,}914{,}879.07/142{,}747{,}583.33))$;

$=\cos(\tan^{-1}(.469)) = 0.905$ …………………. (4.1)

Where

Pf = power factor

P= active power in (MW) =

Q= reactive power in (MVAr)

Hence, the power factor of the overall system is 0.905 and it is a good value. If power factor is lower than 0.9, it reduces electrical system's distribution capacity by increasing current flow and causing voltage drops.

Table 4.40 Average Hourly Load (MW) of Each Feeder of Adama Substation

	Hourly loads of each feeders of Adama substation											
Feeder Line	6-7Am	8-9Am	10-11Am	12-1Pm	2-3Pm	4-5Pm	6-7Pm	8-9Pm	10-11Pm	12-1Am	2-3Am	4-5Am
L1	2.1	2	1.8	2.1	2.4	4.3	6.2	6.8	4	2.8	2.3	2.2
L3	2.3	2.2	2	2.5	3	4	8	9.3	5	2.9	2.5	2.3
L4	2.1	2	1.9	2	3.1	3.3	7.5	8.5	4.2	2.5	2.3	2.1
L5	0.9	1.2	1.08	1.02	1.8	2.5	8	9.2	2.5	1	0.8	0.9
L6	1.4	1.1	1.05	1.15	1.8	2.1	5	9.5	1.9	1.6	1.5	1.4
L7	0.9	0.9	0.8	0.8	1	1.2	2	8	1.1	1.1	0.9	0.9
M1	2	1.8	1.8	2	2.3	4.1	6.1	6.8	4	2.5	2.3	2.2
M2	2.2	1.9	1.8	1.9	2.1	4.5	6.5	6.7	4	2.3	2.1	2.2
M3	1.8	1.7	1.7	1.8	2.1	3.5	5.9	9	3	2.1	1.8	1.8
M4	1.9	1.9	1.8	2.1	2.8	4	6	9	4	2	1.9	1.9
M5	1.7	1.65	1.6	1.8	2.1	3	5	9	3	2	1.9	1.8

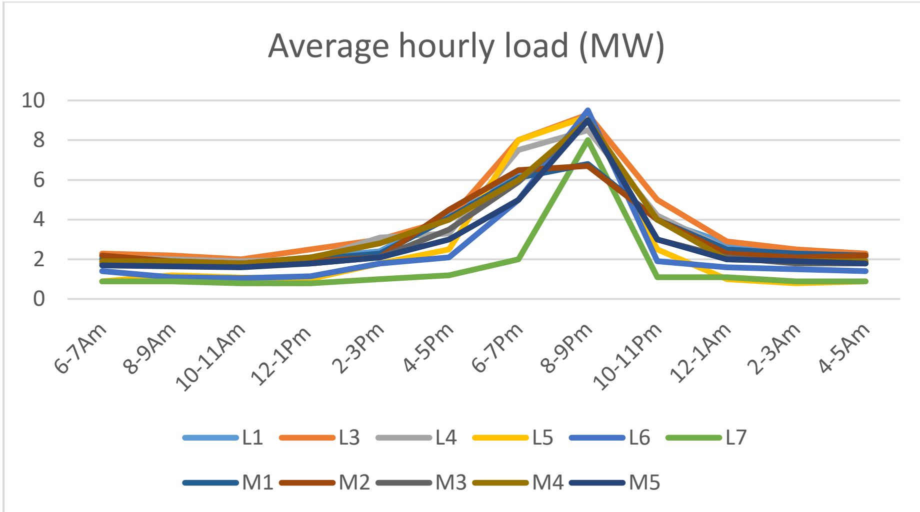

Figure 4.7Average Hourly Load (MW) of Each Feeder lines of Adama Substation

The following conclusions can be made:

(1) The maximum load of the residential load of the system occurs from 19:00 to 22:00; that is, from 12:00 to 4:00 o'clock local time.

(2) From all the residential feeders, the minimum load is 0.49MW while the maximum load is 6.28MW.

(3) For the residential load of the system the minimum load is 10.66MW while the maximum load is 25.27MW.

4.9 Estimation of Future load

Table 4.41 10 years peak demand forecasting of Adama Substation with 6% growth rate.

Year (E.C)	2012	2013	2014	2015	2016	2016	2017	2018	2019	2020
MW	83.5	88.51	93.82	104.4	110.7	117.35	124.39	131.8	139.7	148.14

Table 4.42 transformer data at the Adama distribution substation

LINE			No. of Trafo.	Voltage (kv)	Trafo. Capacity (MVA)	Total capacity
HV	MV	LV				
3	0	7	2	132/15	25	50
3	0	6	1	132/15	50	50

4.10 Economic Aspects of the Designed System

Using the energy not supplied index (ENS) we can see how much Birr will be lost in the existing and the new substations. And we can compare the savings from these systems. Since the minimum value of the tariff is 0.273 Birr/kWh and the maximum value is 0.6943 Birr/kWh then we can take the mean value of this to perform this analysis which is equal to 0.4835 Birr/kWh.

Table 4.43 Tariff

No.	Tariff Category and Block Identification	Monthly Conception (kw)	Birr / (kwh)
1	Domestic	0 – 50	0.273
2	Domestic	51 – 100	0.3564
3	Domestic	101-200	0.4993
4	Domestic	201 – 300	0.55
5	Domestic	301 – 400	0.566
6	Domestic	401 – 500	0.588
7	Domestic	Above 500	0.6943
1	Commercials	0 – 50	0.6088
2	Commercials	Above 50	0.6943
1	Industrial	>50	

4.11 Interruption Costs to Customers

Access to electricity supplies at reasonable cost and quality levels has become a basic condition for development, economic growth and welfare. The more developed societies are, the more vulnerable they are to electricity supply interruptions. This dependence on reliable electricity supplies implies that costs are associated with electricity supply interruptions.

The size of the economic losses due to interruptions depends largely on the composition of the customers that experience interruptions. Customers at Adama city are roughly divided into three categories: residential, commercial, and industrial customers.

For industries, electricity supply interruption costs are strongly related to production losses and to costs involved in restoring production. In addition, interruptions also cause property damages and revenue loses for industries, commercial customers and for private individuals.

Wide-spread long-lasting blackouts put the vulnerable society to the test and involve extra expenses required to maintain tolerable living conditions. It is difficult to estimate the exact value interruption costs and economical loses, since the properties of each customer are different.

CHAPTER FIVE

SIMULATION AND RELIABILITY IMPROVMENT

5.1 Introduction

Power system reliability improvement is the essence of any power sector. This chapter mainly focuses on the selection criteria and sizing of the proper DG technology, the cost, and reliability analysis using Digsilent Powerfacory software. Equipment used in this analysis from the PowerFactory are, lines, breakers, transformers, loads, DG, external grid, bus bars and so on.

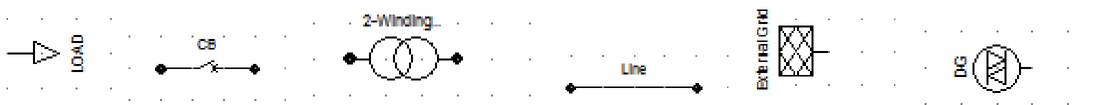

Figure 4.1: Equipment used in reliability analysis of PowerFactory

The electrical and failure inputs given to each equipment. Every equipment has electrical and failure inputs.

- External Grid
- Bus Bar
- Transformer
- Circuit Breaker
- Feeder Lines
- General Load

5.2 Important Electrical inputs given to equipment

Table 5.1 Rating of Bus Bars within the guide of ANSI/ IEEE

Description	132KV	15KV
Types of bus bar	Copper	Copper
Rated current	1.25KA	11KA
Rated insulation voltage	3MV	0.454MV
Rated short time withstand current	65KA	320KA
Conductors • Bus bar dimension 90*6mm2=540	90mm*6mm2=540mm2	2*440mm*6mm=5,280mm2
Resistance	0.036m*ohm/m	0.0041m*ohm/m
Reactance	0.01m*ohm/m	0.0011m*ohm/m
Impedance	0.038m*m*ohm/m	0.0043m*0hm/m
Voltage drop(L to L) at power factor 0.91	0.08v/m	0.08v/m

Table 5.2 Technical Specification of Selected Power Transformer

Technical Specification of Selected Power Transformer		
MVA	50	25
KV Ratio	132/ 15KV	15/0.4 KV
Cooling	ONAN/ONAF	ONAN/ONAF
Impedance	8% at25.2MVA	8%at 12.5MVA
Winding Resistance	10% 25.2MVA	10%at12.5MVA
Tapping mode	OLTC	OLTC
Tapping range	+/-10%at 1.25%(16steps)	+/-10%at 1.25%(16steps)
Temp. rise(oil/ water)	50/55 ^{0}c	50/55 ^{0}c
Phases	3	3
Frequency	50HZ	50HZ

Table 5.3 Basic data for reliability analysis

Feeder	No. customers	Frq. /year λ	Hours r	Average active power (P)	Average Reactive Power (Q)	Conductor size (mm^2)
1	5633	185	1005.17	4.56	1.9	185
3	4906	306	1472.1	5.37	2.36	185
4	5448	348	1708.5	4.53	1.9	185
5	3047	247	818.99	2.07	0.54	185
6	4063	357	1657.33	3.035	1.5	185
7	7295	417	2094.60	0.7	0.55	185
M1	9234	226	1498.20	10	3.9	300
M2	5263	169	1229.80	5	2.3	300
M3	6556	192	1245.77	9	3.8	300
M4	4617	177	1244.45	9	3.8	300
M5	6800	197	1392.72	5	2.3	300
M6	----	---	----	---	---	

5.3 Stochastic Failure Models

This section describes the stochastic failure models of different substation components using this stochastic failure model the two substations are evaluated in the Dig silent software. Stochastic Failure models define the probability that a component will fail and when it does fail, the mean time to repair the component. A stochastic reliability model is a statistical representation of the failure rate and repair duration time for a power system component. For example, a line might suffer an outage due to a short circuit. After the outage, repair will begin and the line will be put into service again after a successful repair.

Bus Bar/Terminal Stochastic Model

The probability of the bus bar failure is the sum of the failure data for the bus bar and the failure data per connection. For example a bus bar with 3 connections, a failure frequency for the bus bar of 0.002 and a failure frequency of 0.005 per connection will have a total probability of failure of 0.002 + 3 * 0.005 = 0.017.

Table 5.5: Bus Bar/Terminal Stochastic Model

Bus bar	Failure frequency (1/a)	Additional failure per connection (1/a)	Repair duration (hr)
1	4	8	12
2	3	8	15
3	7	6	10

Line/Cable Stochastic Model

The probability of the line failure is determined using the Sustained failure frequency and the length of the line. For example, a 10 km line with a Sustained failure frequency of 0.022

(1/ (a*km)) will have a failure probability of 10 * 0.022 = 0.0022 (1/ (a*km)).

Table5.6: Line/Cable Stochastic Model

Lines	Failurefrequency (1/km*a)	Repair duration (hr.)	Fault frequency (1/a*km)
L1	18	0.8	4
L3	14	3	6
L4	16	22	3
L5	4	18	2
L6	10	14	4
L7	8	20	3
M1	3	8	10
M2	4	12	8
M3	5	24	6
M4	6	32	10
M5	7	18	3

Transformer Stochastic failure Model

The probability of the transformers is also includes the failure frequency (1/a) and the repair durations (h). The failure data for the transformer is given in table.

Table 5.7: Transformer Stochastic Model

Transformer no.	Failure frequency(1/a)	Repair duration(hr.)
1	0.015	200
2	0.015	200
3	0.012	200

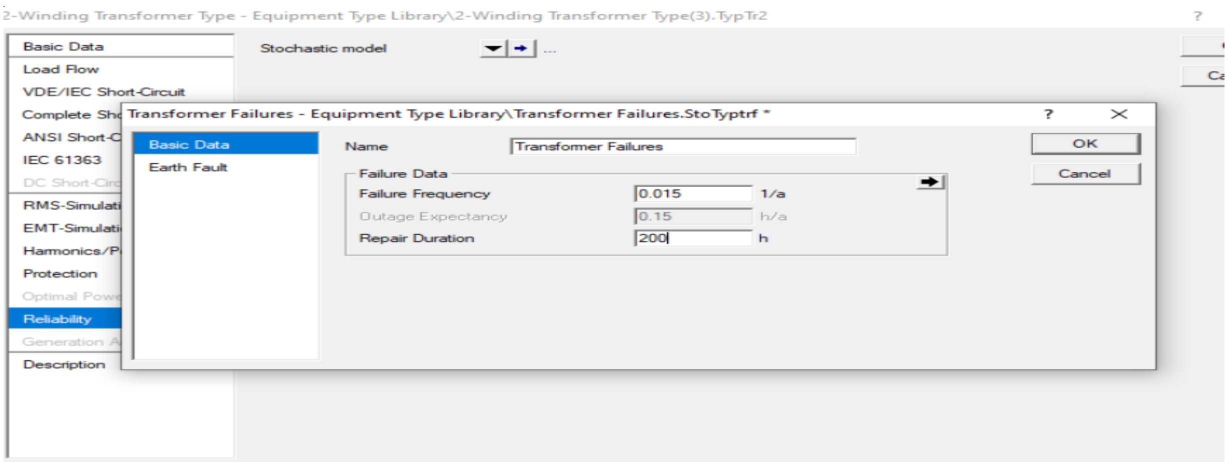

Figure 5.2 transformer failure , powerfacotry data input

5.4 Simulation Result of the Existing Substation

The result of reliability analysis is obtained by performing the following procedures in the Dig Silent power factory software

- Draw the one line diagram on the working plane of the software
- Specify the voltage and power levels for each component
- Enter the created stochastic models in each component
- Specify the type and operation characteristics of switching and protection devices
- Run the reliability assessment

The following figure illustrates the existing substation of Adama town. In this figure, it is shown that the existing system is a single bus bar arrangement and there is no any radial feeder.

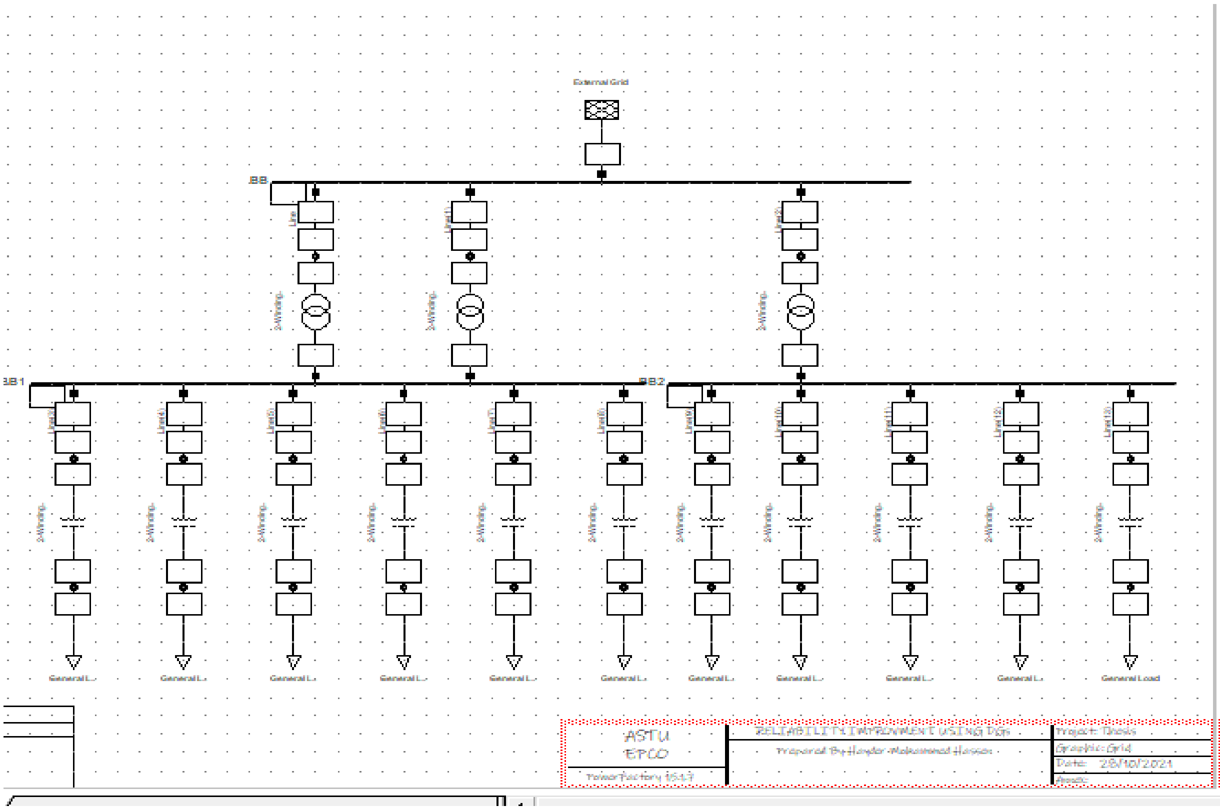

Figure 5.1: One line diagram Adama substation

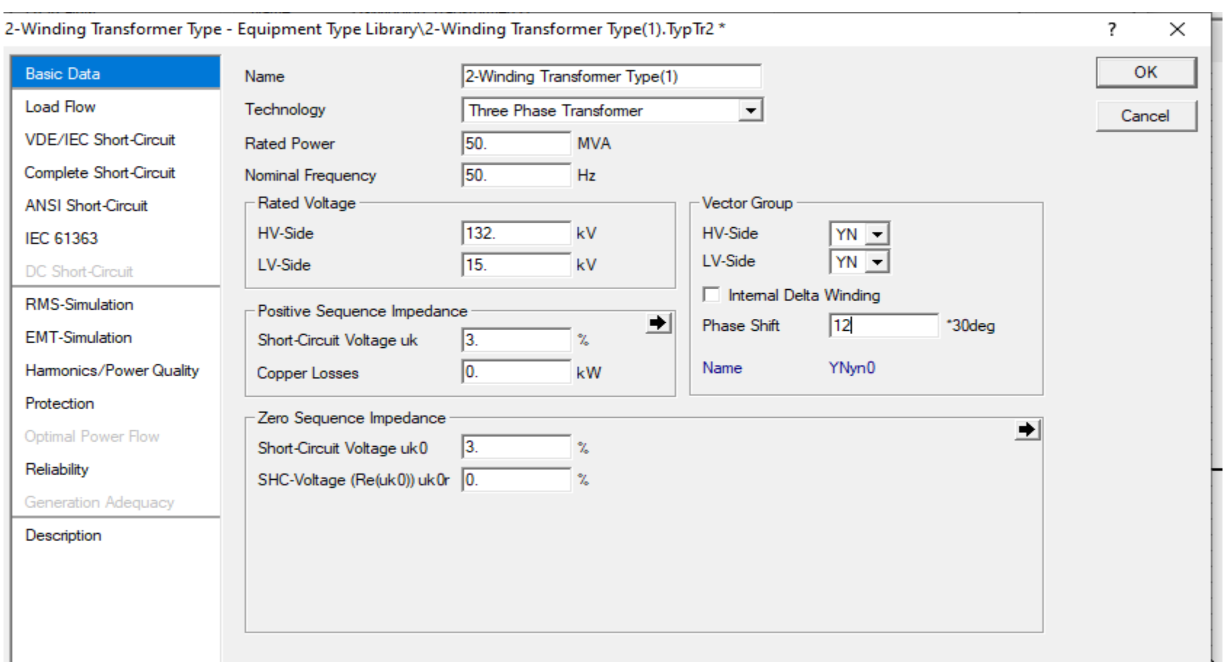

Figure 5.3 basic data of 2 winding transformer , powerfacotry data input

Table 5.8 .Output of system reliability indices for the existing Adama power system 2013E.C

```
---------------------------------------------------------------+----------------------------
| System Summary
--------------------------------------------------------------------------------------------
| System Average Interruption Frequency Index       :  SAIFI: =  156.230926 1/Ca
| Customer Average Interruption Frequency Index     :  CAIFI: =  157.347627 1/Ca
| System Average Interruption Duration Index        :  SAIDI: =  148.248327 h/Ca
| Customer Average Interruption Duration Index      :  CAIDI: =    0.948    h
| Average Service Availability Index                :  ASAI:  =    0.9830766750
| Average Service Unavailability Index              :  ASUI:  =    0.0169233250
| Energy Not Supplied                               :  ENS:   =3816.206    MWh/a
| Average Energy Not Supplied                       :  AENS:  =    0.039    MWh/Ca
| Average Customer Curtailment Index                :  ACCI:  =    0.000    MWh/Ca
| Expected Interruption Cost                        :  EIC:   =    0.000    M$/a
| Interrupted Energy Assessment Rate                :  IEAR:  =    0.000    $/kWh
| System energy shed                                :  SES:   =    0.000    MWh/a
--------------------------------------------------------------------------------------------
```

5.5 Selection of DG technology

Distributed Generation (DG) of electricity is expected to become more important in the future electricity Generation system. .Different geographical areas have different resources, both renewable and non-renewables. Therefore, among the different DG technologies the wind turbine has been selected mainly due to, the low operational, maintenance cost and suitability to the environment (i.e. in and around Adama town.)

Table 5.9 summaries the different DG technologies and their suitability

No.	Technology	Strength	Main drawbacks	Available capacity
1	Fuel cell	Low emission, quit and high efficiency	Expensive, pre-commercial and need high quality fuel.	20kw-2mw
2	Micro- turbine	Compact size, light weight, and low emission	Relatively high capital cost and requires. Reliable and affordable fuel supply.	35kw-1mw
3	Solar photo voltaic	Low O&M cost and low emission	High capital cost and highly intermittent production.	20w-100kw
4	Wind turbine	Low O&M cost and low emission	High capital cost and highly intermittent production.	200w-3mw
5	Combustion turbine	Very mature technology	High emission, noisy and requires fossil fuel.	1kw-250mw

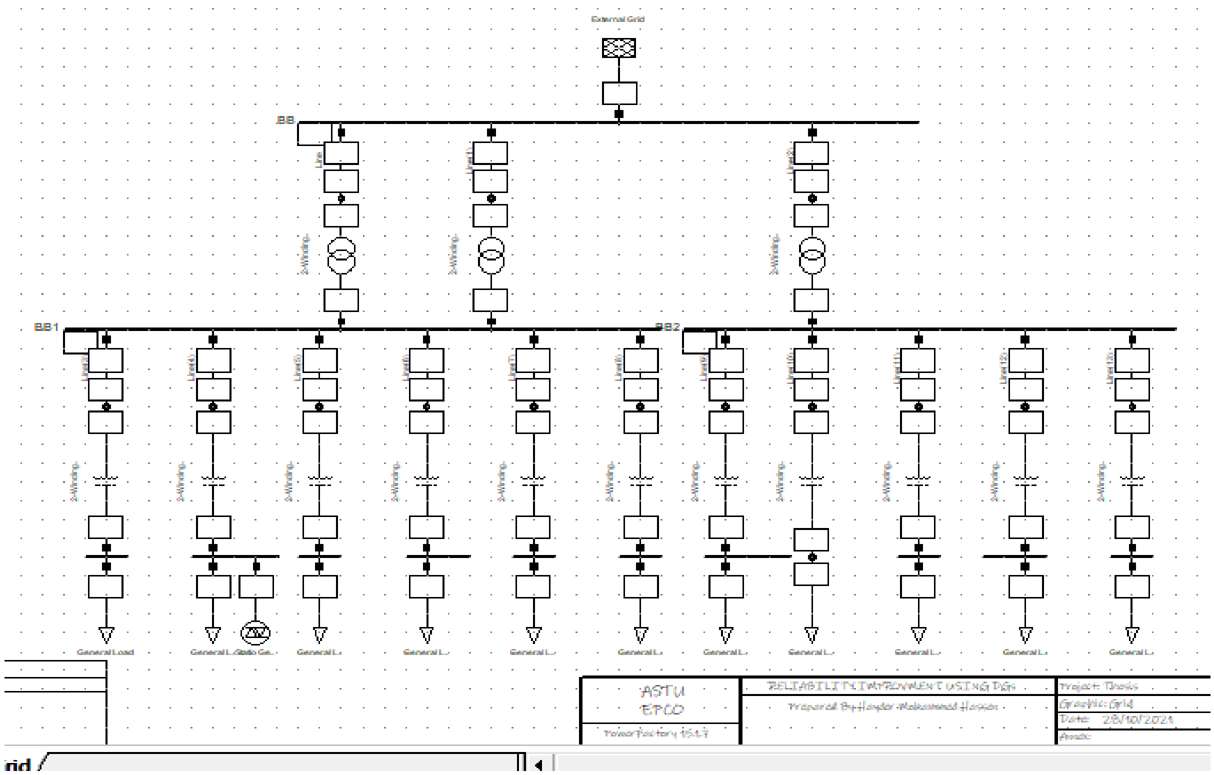

Figure 5.4: single line diagram with DGs connected on L3

Table 5.10 reliability indices improvement by connecting DG at L3

System Summary				
System Average Interruption Frequency Index	:	SAIFI: =	124.457709	1/Ca
Customer Average Interruption Frequency Index	:	CAIFI: =	140.807645	1/Ca
System Average Interruption Duration Index	:	SAIDI: =	134.574	h/Ca
Customer Average Interruption Duration Index	:	CAIDI: =	1.081	h
Average Service Availability Index	:	ASAI: =	0.9846376380	
Average Service Unavailability Index	:	ASUI: =	0.0153623620	
Energy Not Supplied	:	ENS: =	4396.216	MWh/a
Average Energy Not Supplied	:	AENS: =	0.044	MWh/Ca
Average Customer Curtailment Index	:	ACCI: =	0.000	MWh/Ca
Expected Interruption Cost	:	EIC: =	0.000	M$/a
Interrupted Energy Assessment Rate	:	IEAR: =	0.000	$/kWh
System energy shed	:	SES: =	0.000	MWh/a

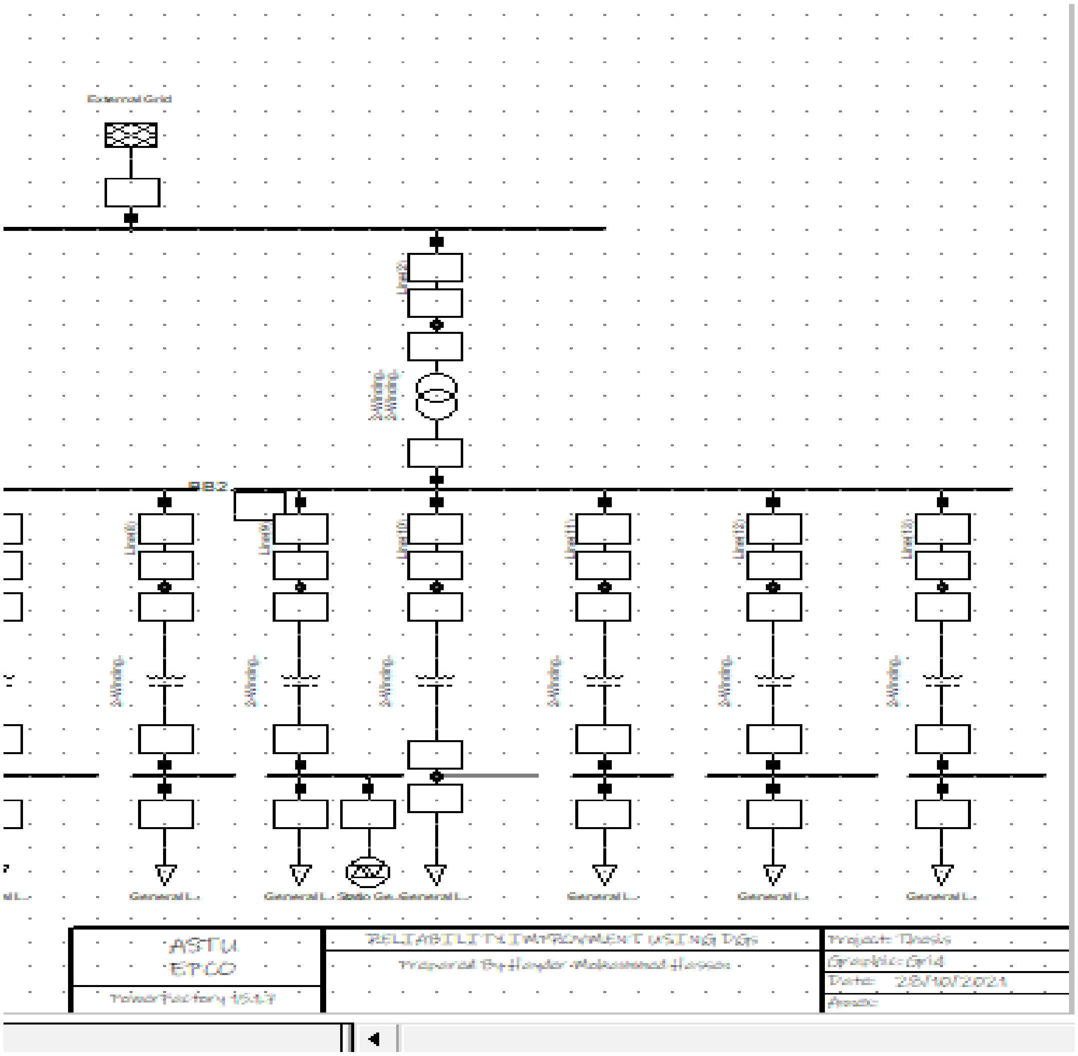

Figure 5.5: single line diagram with DGs connected on M1

Table 5.11reliability indices improvement by connecting DG at M1

System Summary			
System Average Interruption Frequency Index	SAIFI:	= 118.336589	1/Ca
Customer Average Interruption Frequency Index	CAIFI:	= 138.337612	1/Ca
System Average Interruption Duration Index	SAIDI:	= 122.279	h/Ca
Customer Average Interruption Duration Index	CAIDI:	= 1.033	h
Average Service Availability Index	ASAI:	= 0.9860412252	
Average Service Unavailability Index	ASUI:	= 0.0139587748	
Energy Not Supplied	ENS:	=3456.788	MWh/a
Average Energy Not Supplied	AENS:	= 0.036	MWh/Ca
Average Customer Curtailment Index	ACCI:	= 0.000	MWh/Ca
Expected Interruption Cost	EIC:	= 0.000	M$/a
Interrupted Energy Assessment Rate	IEAR:	= 0.000	$/kWh
System energy shed	SES:	= 0.000	MWh/a

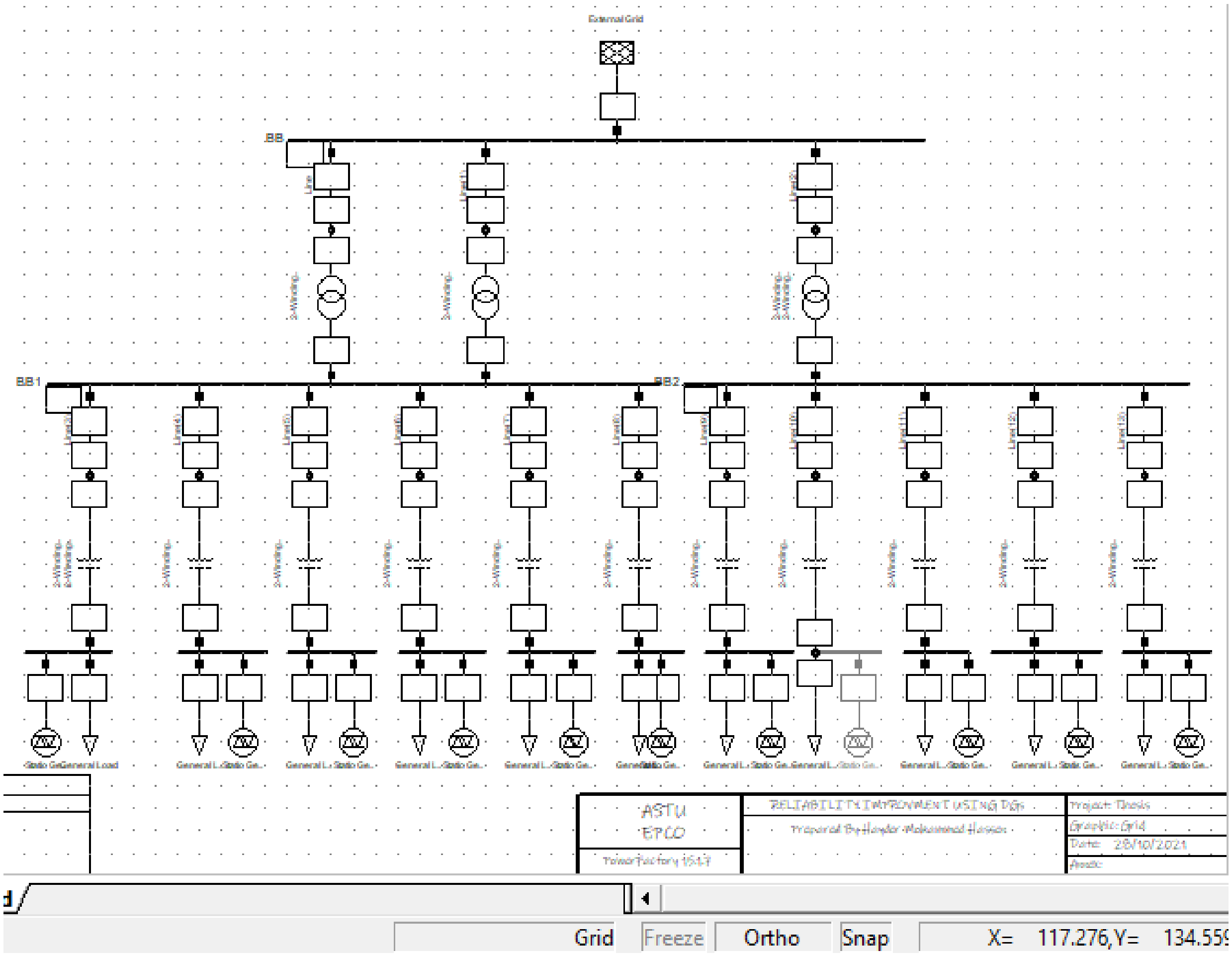

Figure 5.6: single line diagram with DGs connected on all feeder lines

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

This thesis work was conducted in Adama distribution system, in which the study was carried out on eleven 15KV distribution feeder lines. This study mainly focus were on identification of the main fault factors, evaluation of the reliability of the distribution system, and improving the reliability of the system by using DGs.

The average frequency of interruption and average duration of the city grid have been estimated to be 156.23 interruptions per customer per year and 148.24 hours per customer per year respectively. This indicates the reliability of Adama distribution substation is far from international standard and even from Ethiopian Electric Power Corporation (EEPCO). After the rehabilitation (i.e. hidar,2010E.C to megabit,2013E.C) the existed feeder lines have totally interrupted for 5,219.386 hours, it means 217.5 days of a feeder line were shaded. 50% the total interruptions were caused by planned (operational) interruptions, this shows the distribution technician take more time to locate a fault occurred during maintenance, since as there is no automatic fault locating mechanisms. Among the fault factors operational interruption was the highest number of fault factor (44% and 1415 times) and permanent and temporary earth fault were 2nd (32% and 1053times) and 3rd (14% and 439.7 times) respectively in percentage and numbers.

DGs were engaged to feeder lines L3 and M1, in which reliability affected highly. As a result of these DGs, the overall system's reliability improved significantly.

Assuming connection of reliable DGs and automated system using smart recloses, the system reliability improved to the limit required.

6.2 RECOMMENDATION

In order to upgrade the reliability of the distribution substation the following recommendations are drawn.

- Nowadays automatic fault locating or detectors mechanism are widely used in distribution system for their positive impact on system reliability and power system loss reduction. So, to minimize long time taken by distribution technicians to detect and locate faults in distribution system during maintenance and operational tasks in the system, better to install an automatic fault detecting and locating mechanism in distribution system.
- Fault factors, component failure data, interruption data, number of customers served and customers interrupted, number of transformers and detailed documents, lines, buses, feeders, circuit breakers and disconnectors and evaluated reliability analysis should be documented by research institution together with EEPCO.
- Since Adama is rich in wind and solar energy. So renewable energy based DGs should be explored for system reliability improvement.
- The trainings of the maintenance personnel should be high priority so that maintenance works of the distribution system is conducted with good skill at required quality on regular basis.
- Continuous research and development should be conducted on the impact of DGs on

6.3 FUTURE WORK

- Designing of distribution substations with options to accommodate distributed generations, which ensure system reliability improvement.
- Different distributed generation options other than wind turbine and PV technologies can be studied for Adama substation's reliability improvement.
- Limitations of DG should be studied for the actual implementation of system reliability improvement.

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APPENDIX A. from 2009E.C. up to 2011E.C. [22]

/No.	Feeder _Line	Month	Year	DPEF _DUR	DPEF _FRQ	DPSC _DUR	DPSC _FRQ	DTEF _DUR	DTEF _FRQ	DTSC _DUR	DTSC _FRQ	OP_DUR	OP_ FRQ
1	L1	1	2009	3.2	2	4.2	2	5.17	2	2.18	1	12.28	5
2	L1	2	2009	7.28	4	17.04	4	4.49	2	3.32	3	15.36	6
3	L1	3	2009	4.11	2	11.15	3	8.34	3	4.4	3	11.29	4
4	L1	4	2009	0	0	2.3	1	6.05	2	5.11	2	4.54	3
5	L1	5	2009	3.3	3	1.5	1	2.33	1	3.56	1	6.33	3
6	L1	6	2009	5.58	3	1.5	1	6.15	2	5.05	1	4.32	5
7	L1	7	2009	3.23	2	12.05	4	3.42	1	4.22	3	11.42	6
8	L1	8	2009	20.31	6	25.01	7	4.52	1	6.29	4	10.16	9
9	L1	9	2009	11.03	2	15.35	4	3.23	2	4.07	3	40.28	32
10	L1	10	2009	7.03	3	6.12	3	2.01	1	5.28	3	21.02	30
11	L1	11	2009	4.42	1	20.36	9	8.03	3	3.54	2	37.33	10
12	L1	12	2009	3.02	3	8.2	4	10.02	4	7.47	4	17.22	8
13	L1	1	2010	3.56	5	12.11	8	0.01	1	0	0	3.91	12
14	L1	2	2010	3.56	4	12.11	7	0.01	1	0	0	3.91	12
15	L1	3	2010	3.5	5	11.23	8	0.5	2	0	0	3.45	13
16	L1	4	2010	2.76	4	1.31	2	0.06	1	0.03	1	7.35	16
17	L1	5	2010	10.3	7	2.05	3	0	0	0.03	1	13.41	27
18	L1	6	2010	6.41	5	0.17	1	0	0	0	0	17.08	25
19	L1	7	2010	5	1	4.68	4	0	0	0.13	1	36.08	31
20	L1	8	2010	0.05	4	14.15	5	13.73	1	0	0	5.63	7
21	L1	9	2010	31.18	16	4.25	3	0.2	2	0	0	12	12
22	L1	10	2010	3.5	5	11.23	8	0.5	2	0	0	3.45	13
23	L1	11	2010	4.05	4	11.4	7	3.2	1	2.5	2	4.12	11
24	L1	12	2010	3.5	5	11.23	8	0.5	2	0.5	2	3.45	13
25	L1	1	2011	0	0	2.2	2	0.18	1	0.17	1	2.28	3
26	L1	2	2011	20.04	2	6.28	3	1.32	4	0.49	2	11.36	5
27	L1	3	2011	1.15	1	5.11	3	1.4	4	1.34	2	1.29	4
28	L1	4	2011	0	0	0	0	0.11	1	0	0	4.54	6
29	L1	5	2011	0.01	1	4.3	3	0.56	3	0.33	1	2.33	3
30	L1	6	2011	1.1	1	2.58	2	0.05	1	0.15	1	4.32	5

31	L1	7	2011	11.42	3	2.23	1	1.22	4	2.42	6	13.42	13
32	L1	8	2011	30.01	5	19.31	5	0.29	1	0.52	1	41.16	18
33	L1	9	2011	13.35	3	10.03	2	2.07	4	1.23	2	55.28	28
34	L1	10	2011	4.12	3	8.03	2	1.28	2	0	0	213.02	29
35	L1	11	2011	25.36	7	3.42	1	0.54	3	1.03	2	67.33	11
36	L1	12	2011	6.2	3	2.02	3	2.47	7	11	4	7.22	3
37	L3	1	2009	6.25	3	1.06	1	3.4	4	2.36	2	11.2	6
38	L3	2	2009	1.4	1	1.04	1	2.08	1	2.03	1	11.04	8
39	L3	3	2009	3.46	1	2.03	2	4.09	3	1.05	1	11.3	6
40	L3	4	2009	0	0	1.83	1	1.45	2	0.32	1	10.02	5
41	L3	5	2009	0	0	1	1	0	0	0	0	10.23	6
42	L3	6	2009	2	1	0	0	0.54	2	1	1	9.01	7
43	L3	7	2009	0	0	0.28	1	1.01	2	0	0	17.26	10
44	L3	8	2009	0	0	5.73	3	1.46	6	1	1	12.45	9
45	L3	9	2009	1.03	1	0	0	0	0	0	0	40.13	26
46	L3	10	2009	0	0	0	0	1.23	3	0.31	1	15.4	8
47	L3	11	2009	0	0	5.23	3	1.32	6	0.07	1	16.1	9
48	L3	12	2009	7.29	3	0	0	2.38	8	0.18	1	0	0
49	L3	1	2010	19.53	8	4.05	2	0.21	3	0	0	13.35	15
50	L3	2	2010	19.53	8	0	0	0.21	3	0	0	13.35	15
51	L3	3	2010	19.23	7	0	0	0.34	5	0.13	1	13.45	16
52	L3	4	2010	12.73	10	0	0	0.03	1	0	0	0	0
53	L3	5	2010	12.3	4	0	0	0.2	2	0	0	24.43	23
54	L3	6	2010	9.06	9	2.5	2	0	0	0.1	1	17.48	28
55	L3	7	2010	5.9	4	1	1	0.08	1	0	0	44.09	29
56	L3	8	2010	19.85	9	0	0	0	0	0	0	41.9	9
57	L3	9	2010	9.81	6	0	0	0.13	1	0	0	7.73	12
58	L3	10	2010	19.23	7	1.26	1	0.34	5	0.13	1	13.45	16
59	L3	11	2010	15.23	5	19.06	2	1.34	3	1.5	1	10.23	14
60	L3	12	2010	19.23	7	3.01	1	0.34	5	0.13	1	13.45	16
61	L3	1	2011	1.4	1	17.07	6	2.11	3	4	3.29	6.11	10
62	L3	2	2011	5.54	3	16.56	8	0.4	3	0	0	24	10
63	L3	3	2011	0.07	1	9.06	5	2.03	6	0.53	2	2.34	5

64	L3	4	2011	1.43	2	3.35	2	0.44	3	0.13	1	2	4
65	L3	5	2011	5.32	4	10.21	4	0.5	4	0	0	0.22	2
66	L3	6	2011	0	0	3.45	3	0	0	0	0	6.02	9
67	L3	7	2011	4.48	10	17.5	7	7.24	3	0.42	2	12.06	6
68	L3	8	2011	18.43	6	23.17	4	0.58	2	0	0	28.15	11
69	L3	9	2011	12.55	2	5.39	4	0.29	2	3.14	4	53.11	27
70	L3	10	2011	9.16	3	3.24	2	0.15	1	0	0	212.22	28
71	L3	11	2011	3.16	1	2.17	6	0.15	2	2.02	5	68.4	14
72	L3	12	2011	11.17	2	1.02	1	0.2	1	0.63	1	1.55	3
73	L4	1	2009	6.2	6	13.51	6	12.36	6	10.03	4	17.86	10
74	L4	2	2009	5.3	5	22.51	5	10.36	5	20.03	8	27.86	18
75	L4	3	2009	8.1	7	11.4	4	14.34	5	14.03	6	16.32	11
76	L4	4	2009	1.04	1	11.58	2	11.04	6	10.04	4	10.04	6
77	L4	5	2009	0	0	6.36	1	0	0	11.04	7	9.09	10
78	L4	6	2009	9.49	2	20.38	2	9.08	4	5.09	3	7.4	7
79	L4	7	2009	8.73	5	8.46	5	8.04	0	10.4	5	18.43	9
80	L4	8	2009	32.73	4	27.16	7	0	0	1.04	1	4.23	5
81	L4	9	2009	10.11	4	7.56	4	10.23	4	0	0	6.9	8
82	L4	10	2009	7.2	7	21.4	4	14.34	5	0.03	1	6.32	16
83	L4	11	2009	8.03	5	18.05	3	14.75	6	1.45	1	7.32	14
84	L4	12	2009	7.2	7	21.4	4	13.34	7	0.03	1	6.32	16
85	L4	1	2010	7.76	12	15.61	3	0.43	7	0.11	1	11.26	11
86	L4	2	2010	7.76	11	15.61	4	0.43	7	0.11	1	11.26	11
87	L4	3	2010	6.54	12	15.63	3	0.34	6	0.11	1	11.12	11.12
88	L4	4	2010	2.78	5	3.98	5	0.08	1	0	0	0	0
89	L4	5	2010	4.43	10	3.04	4	0.1	1	0	0	15.29	20
90	L4	6	2010	13.25	5	1.43	2	0.21	4	0	0	17.3	12
91	L4	7	2010	1.98	3	5.65	4	0	0	0.08	1	14.46	9
92	L4	8	2010	36.5	12	22.31	11	0.1	2	0	0	2.9	4
93	L4	9	2010	17.96	12	7	6	0.18	3	0.16	1	9.9	5
94	L4	10	2010	6.54	12	15.63	3	0.34	6	0.11	1	11.12	12
95	L4	11	2010	5.01	10	11.45	6	2.3	5	0.89	2	11.12	11

96	L4	12	2010	6.54	12	15.63	3	0.34	6	0.11	1	11.12	12
97	L4	1	2011	4.35	3	26.4	5	3.13	7	0.17	1	2.1	6
98	L4	2	2011	1.1	1	4.44	4	0.34	2	0	0	9.23	4
99	L4	3	2011	0	0	3.32	2	0.35	3	1.31	2	3.34	6
100	L4	4	2011	0	0	4.14	4	0	0	0.41	3	3.16	6
101	L4	5	2011	1.34	1	19.37	4	0	0	0.48	1	1.21	1
102	L4	6	2011	0	0	1.4	1	0	0	0.2	2	6.27	6
103	L4	7	2011	10.54	2	12.54	2	1.33	4	1.07	3	8.54	6
104	L4	8	2011	11.46	3	27	7	1.55	2	3.11	3	25.1	13
105	L4	9	2011	0	0	5.17	3	0.41	3	0.4	1	61.39	26
106	L4	10	2011	4.59	3	10.36	5	0.35	1	0.3	1	223.25	30
107	L4	11	2011	7.26	3	2.41	2	1.01	2	0.57	2	70.54	15
108	L4	12	2011	1.17	1	11.13	5	1.04	2	0.45	1	3.51	5
109	L5	1	2009	13.55	12	17.26	9	9.56	6	10.15	5	11.2	4
110	L5	2	2009	14.55	11	7.26	5	10.56	7	10.15	5	12.04	5
111	L5	3	2009	103.44	12	10.13	7	8.45	4	12.03	6	10.3	4
112	L5	4	2009	15.05	8	12.9	10	10.15	7	8.04	4	5.04	3
113	L5	5	2009	11.32	8	8.34	7	10.13	8	1.14	2	6.23	2
114	L5	6	2009	10.12	9	14.54	10	8.24	8	5.07	2	0	0
115	L5	7	2009	11.71	7	9.46	6	9.03	8	5.08	2	17.26	10
116	L5	8	2009	14.53	8	15.31	9	7.23	2	8.09	3	12.45	5
117	L5	9	2009	5.16	6	24.48	12	0	0	10.05	6	40.13	24
118	L5	10	2009	3.44	10	8.13	8	10.45	5	12.3	6	5.4	2
119	L5	11	2009	4.55	9	9.04	9	13.45	3	2.03	1	6.1	2
120	L5	12	2009	3.44	8	8.13	5	10.45	5	10.12	1	0	0
121	L5	1	2010	1.28	2	0	0	0.2	2	0	0	0	0
122	L5	2	2010	1.28	2	0	0	0.2	2	0	0	0	0
123	L5	3	2010	1.28	3	0	0	0.2	3	0	0	0	0
124	L5	4	2010	0.86	3	1.83	1	0.88	1	0	0	0	0
125	L5	5	2010	0.39	2	0	0	0	0	0	0	7.52	8
126	L5	6	2010	0.11	1	0	0	0.01	1	0	0	7.58	9
127	L5	7	2010	1	1	0.28	1	0.05	2	0	0	17.88	12

128	L5	8	2010	23.37	7	5.73	3	0.63	6	0.11	1	1.16	1
129	L5	9	2010	2.95	4	0	0	0.35	4	0	0	4.01	3
130	L5	10	2010	1.28	3	0	0	0.2	3	0	0	0	0
131	L5	11	2010	2.03	4	5.23	3	0.2	3	0.03	1	6.13	4
132	L5	12	2010	1.28	3	0	0	0.2	3	0	0	0	0
133	L5	1	2011	5.25	3	4.05	2	2.4	4	1.36	2	1.2	4
134	L5	2	2011	0.4	1	0	0	0.08	2	0	0	1.04	2
135	L5	3	2011	1.46	1	0	0	1.09	4	0	0	1.3	1
136	L5	4	2011	0	0	0	0	0.45	2	0.32	1	0	0
137	L5	5	2011	0	0	0	0	0	0	0	0	0.23	1
138	L5	6	2011	2	1	2.5	2	0.54	2	0	0	0	0
139	L5	7	2011	0	0	1	1	1.01	2	0	0	17.26	10
140	L5	8	2011	0	0	0	0	1.46	6	0	0	12.45	5
141	L5	9	2011	1.03	1	0	0	0	0	0	0	40.13	24
142	L5	10	2011	0	0	1.26	1	1.23	3	0.31	1	5.4	2
143	L5	11	2011	0	0	19.06	2	1.32	6	0.07	1	6.1	2
144	L5	12	2011	7.29	3	3.01	1	2.38	8	0.18	1	0	0
145	L6	1	2009	13.55	10	10.04	5	11.11	7	10.03	4	12.81	5
146	L6	2	2009	13.55	12	12.04	6	10.52	5	12.03	4	17.02	7
147	L6	3	2009	23.44	14	10.01	5	10.3	8	20.03	8	11.54	5
148	L6	4	2009	14.05	8	13.02	7	11.2	8	11.05	6	15.33	5
149	L6	5	2009	11.32	12	13.51	5	12.33	9	12.08	5	11.56	4
150	L6	6	2009	10.12	11	13.55	5	10.07	8	14.3	5	10.5	5
151	L6	7	2009	11.71	12	21.61	10	10.45	7	8.09	6	13.31	5
152	L6	8	2009	14.53	5	32.61	18	10.15	6	5.06	4	33.02	14
153	L6	9	2009	5.16	4	15.15	19	18.09	11	2.08	1	72.07	28
154	L6	10	2009	3.44	8	32.61	21	10.7	5	10.03	5	27.26	31
155	L6	11	2009	4.55	6	33.65	28	12.4	6	11.45	8	56.33	21
156	L6	12	2009	3.44	5	32.61	15	15.21	8	10.03	6	12.21	9
157	L6	1	2010	7.2	7	20.51	5	0.36	4	0.03	1	7.86	17
158	L6	2	2010	7.2	7	20.51	5	0.36	4	0.03	1	7.86	17
159	L6	3	2010	7.2	7	21.4	4	0.34	3	0.03	1	6.32	16
160	L6	4	2010	0	0	4.58	2	0	0	0	0	0	0

161	L6	5	2010	0	0	0.36	1	0	0	0	0	9.09	10
162	L6	6	2010	9.49	3	20.38	2	0.08	3	0	0	7.4	7
163	L6	7	2010	8.73	6	8.46	5	0	0	0	0	18.43	9
164	L6	8	2010	32.73	8	27.16	7	0	0	0	0	4.23	5
165	L6	9	2010	10.11	4	7.56	4	0.23	1	0	0	5.9	8
166	L6	10	2010	7.2	7	21.4	4	0.34	3	0.03	1	6.32	16
167	L6	11	2010	8.03	5	18.05	3	0.75	4	1.45	2	7.32	14
168	L6	12	2010	7.2	7	21.4	4	0.34	3	0.03	1	6.32	16
169	L6	1	2011	0	0	2.47	2	0	0	1.06	1	0.17	1
170	L6	2	2011	9.54	6	9.56	4	2.26	5	0	0	1.56	6
171	L6	3	2011	0	0	0	0	0	0	0	0	0	0
172	L6	4	2011	0	0	0	0	0	0	0	0	0	0
173	L6	5	2011	0	0	0	0	0	0	0	0	0	0
174	L6	6	2011	0	0	0	0	0	0	0	0	0	0
175	L6	7	2011	0	0	0	0	0	0	0	0	0	0
176	L6	8	2011	0	0	0	0	0	0	0	0	0	0
177	L6	9	2011	0	0	0	0	0	0	0	0	0	0
178	L6	10	2011	0	0	0	0	0	0	0	0	0	0
179	L6	11	2011	0	0	0	0	0	0	0	0	0	0
180	L6	12	2011	0	0	0	0	0	0	0	0	0	0
181	L7	1	2009	13.28	8	32.02	8	11.52	7	11.44	4	12.54	4
182	L7	2	2009	10.04	6	15.2	10	10.07	8	10.58	5	13.29	5
183	L7	3	2009	5.41	2	10.07	7	10.2	9	11.47	7	13.01	6
184	L7	4	2009	8.09	4	12.07	6	10.48	9	11.27	6	13.41	4
185	L7	5	2009	10.07	5	14.17	6	10.11	1	12.01	8	12.18	5
186	L7	6	2009	11.48	7	17.18	7	10.3	4	10.23	6	6.42	4
187	L7	7	2009	10.07	6	13.3	8	11.25	4	11.25	5	9.2	5
188	L7	8	2009	11.5	5	1.01	1	10.11	7	11.31	5	16.09	8
189	L7	9	2009	8.09	4	19.48	10	10.22	8	10.07	4	22.01	19
190	L7	10	2009	12.23	8	11.2	8	12.16	9	11.19	4	231.51	21
191	L7	11	2009	22.17	13	32.06	15	0	0	10.88	6	62.22	11
192	L7	12	2009	16.52	12	35.24	16	18.07	11	10.35	7	61.43	10
193	L7	1	2010	3.55	11	7.26	6	0.56	6	0.15	2	4.98	13

194	L7	2	2010	3.55	11	7.26	6	0.56	6	0.15	2	4.98	13
195	L7	3	2010	3.44	11	8.13	5	0.45	5	0.12	1	5.12	12
196	L7	4	2010	3.05	4	2.9	3	0.15	1	0	0	0	0
197	L7	5	2010	1.32	2	3.34	7	0.13	2	0.14	2	11.35	20
198	L7	6	2010	0.12	1	15.54	9	0.24	4	0	0	24.14	23
199	L7	7	2010	1.71	3	7.46	6	0.03	1	0	0	23.1	23
200	L7	8	2010	14.53	5	15.31	5	0.23	2	0	0	3.7	3
201	L7	9	2010	5.16	9	24.48	10	0	0	0	0	2.15	5
202	L7	10	2010	3.44	11	8.13	5	0.45	5	0.12	1	5.12	12
203	L7	11	2010	4.55	14	9.04	6	3.45	3	2.03	2	5.14	10
204	L7	12	2010	3.44	11	8.13	5	0.45	5	0.12	1	5.12	12
205	L7	1	2011	0	0	22.05	7	0.33	2	0.5	1	2.56	5
206	L7	2	2011	1.11	1	2.17	2	1.03	4	1.11	3	8.15	5
207	L7	3	2011	0	0	2.19	2	0.2	1	0.34	1	3.21	6
208	L7	4	2011	0	0	3.21	2	0.51	4	0.47	1	9.02	13
209	L7	5	2011	1.2	1	3.32	2	1.11	4	0	0	3.39	4
210	L7	6	2011	2.49	1	7.01	5	1.28	6	0	0	3.23	7
211	L7	7	2011	1.33	1	16.15	5	2.27	7	2.22	4	17.26	10
212	L7	8	2011	14.33	4	25.02	6	1.41	3	2.42	4	25.47	17
213	L7	9	2011	1.14	1	1.3	1	1.16	6	1.12	2	68.18	28
214	L7	10	2011	0	0	11.56	6	2.22	4	1.09	3	236.53	32
215	L7	11	2011	9.24	4	11.14	4	4.4	2	1.3	3	71.18	12
216	L7	12	2011	3.35	3	4.33	2	0.49	3	1.35	2	1.2	3
217	M1	1	2009	0	0	0	0	0	0	0	0	0	0
218	M1	2	2009	0	0	0	0	0	0	0	0	0	0
219	M1	3	2009	0	0	0	0	0	0	0	0	0	0
220	M1	4	2009	0	0	0	0	0	0	0	0	0	0
221	M1	5	2009	0	0	0	0	0	0	0	0	0	0
222	M1	6	2009	0	0	0	0	0	0	0	0	0	0
223	M1	7	2009	0	0	0	0	0	0	0	0	0	0
224	M1	8	2009	0	0	0	0	0	0	0	0	0	0
225	M1	9	2009	0	0	0	0	0	0	0	0	0	0
226	M1	10	2009	0	0	0	0	0	0	0	0	0	0

227	M1	11	2009	0	0	0	0	0	0	0	0	0	0
228	M1	12	2009	0	0	0	0	0	0	0	0	0	0
229	M1	1	2010	0	0	0	0	0	0	0	0	0	0
230	M1	2	2010	0	0	0	0	0	0	0	0	0	0
231	M1	3	2010	0	0	0	0	0	0	0	0	0	0
232	M1	4	2010	0	0	0	0	0	0	0	0	0	0
233	M1	5	2010	9.09	8	3.51	4	0.14	2	0	0	12.01	7
234	M1	6	2010	5.08	7	13.55	5	0	1	0	0	5.36	12
235	M1	7	2010	6.35	7	21.61	10	0	0	0	0	15.93	8
236	M1	8	2010	22.38	7	32.61	8	0.05	1	0	0	6.28	7
237	M1	9	2010	30.33	12	15.15	9	0.03	1	0.28	3	12.18	9
238	M1	10	2010	22.38	7	32.61	8	0.05	1	0	0	6.28	7
239	M1	11	2010	20.12	6	33.65	7	75	2	1.05	1	4.03	6
240	M1	12	2010	22.38	7	32.61	8	0.05	1	0	0	6.28	7
241	M1	1	2011	12.43	4	14.17	6	1.11	3	3.55	4	2.81	3
242	M1	2	2011	1.1	1	23.15	6	0.52	1	1.18	3	7.02	7
243	M1	3	2011	19.21	3	21.4	7	0.3	2	2.89	3	1.54	5
244	M1	4	2011	0.56	1	7.2	1	1.2	2	0	0	5.33	4
245	M1	5	2011	1.36	1	6.03	3	2.33	5	0.3	1	1.56	4
246	M1	6	2011	8.08	2	8.33	3	0	0	0.35	1	0.5	3
247	M1	7	2011	1.55	1	28.53	9	0.45	3	1.1	2	13.31	12
248	M1	8	2011	6.16	3	24.3	4	0.15	1	2.22	4	33	14
249	M1	9	2011	3.45	1	2.58	2	0	0	1.31	2	72.07	28
250	M1	10	2011	1.25	1	3.01	2	0	0	0.5	1	273.26	31
251	M1	11	2011	17.03	3	37.35	13	2.4	5	1.11	2	56.33	21
252	M1	12	2011	2.5	1	35.07	10	5.21	9	1.13	2	12.21	9
253	M2	1	2009	0	0	0	0	0	0	0	0	0	0
254	M2	2	2009	0	0	0	0	0	0	0	0	0	0
255	M2	3	2009	0	0	0	0	0	0	0	0	0	0
256	M2	4	2009	0	0	0	0	0	0	0	0	0	0
257	M2	5	2009	0	0	0	0	0	0	0	0	0	0
258	M2	6	2009	0	0	0	0	0	0	0	0	0	0
259	M2	7	2009	0	0	0	0	0	0	0	0	0	0

260	M2	8	2009	0	0	0	0	0	0	0	0	0	0
261	M2	9	2009	0	0	0	0	0	0	0	0	0	0
262	M2	10	2009	0	0	0	0	0	0	0	0	0	0
263	M2	11	2009	0	0	0	0	0	0	0	0	0	0
264	M2	12	2009	0	0	0	0	0	0	0	0	0	0
265	M2	1	2010	0	0	0	0	0	0	0	0	0	0
266	M2	2	2010	0	0	0	0	0	0	0	0	0	0
267	M2	3	2010	0	0	0	0	0	0	0	0	0	0
268	M2	4	2010	0	0	0	0	0	0	0	0	0	0
269	M2	5	2010	6.32	4	2.43	1	0.05	1	0	0	8.55	8
270	M2	6	2010	12.31	8	6.38	2	0.05	1	0	0	3	6
271	M2	7	2010	12.05	6	13.86	6	0	0	0.06	1	19.15	10
272	M2	8	2010	13.71	5	23.98	5	0.03	1	0	0	8.95	8
273	M2	9	2010	3.03	2	18.63	8	0	0	0	0	4.68	6
274	M2	10	2010	13.71	5	23.98	5	0.03	1	0	0	8.95	8
275	M2	11	2010	12.46	4	23.98	5	0.05	2	0	0	7.16	7
276	M2	12	2010	13.71	5	23.98	5	0.03	1	0	0	8.95	8
277	M2	1	2011	3.28	2	42.02	8	1.52	4	0.15	1	2.54	4
278	M2	2	2011	0	0	15.2	10	0	0	0	0	3.29	3
279	M2	3	2011	5.41	3	0	0	0.2	1	8.49	2	3	5
280	M2	4	2011	0	0	2.07	1	0.48	1	0	0	3.41	4
281	M2	5	2011	0	0	14.17	6	0.11	1	1.55	2	2.18	5
282	M2	6	2011	11.48	3	17.18	7	0.3	4	0	0	6.42	7
283	M2	7	2011	0	0	13.3	1	1.25	4	2.05	4	9.2	5
284	M2	8	2011	11.5	5	41.01	8	0	0	0	0	26.09	15
285	M2	9	2011	0	0	9.48	4	0	0	0.24	1	42.01	19
286	M2	10	2011	2.23	1	1.2	1	2.16	3	0	0	231.51	21
287	M2	11	2011	22.17	2	32.06	3	0	0	0	0	60.22	11
288	M2	12	2011	6.52	2	35.24	6	0	0	0	0	6.43	7
289	M3	1	2009	0	0	0	0	0	0	0	0	0	0
290	M3	2	2009	0	0	0	0	0	0	0	0	0	0
291	M3	3	2009	0	0	0	0	0	0	0	0	0	0
292	M3	4	2009	0	0	0	0	0	0	0	0	0	0

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

326	M4	2	2009	0	0	0	0	0	0	0	0	0	0
327	M4	3	2009	0	0	0	0	0	0	0	0	0	0
328	M4	4	2009	0	0	0	0	0	0	0	0	0	0
329	M4	5	2009	0	0	0	0	0	0	0	0	0	0
330	M4	6	2009	0	0	0	0	0	0	0	0	0	0
331	M4	7	2009	0	0	0	0	0	0	0	0	0	0
332	M4	8	2009	0	0	0	0	0	0	0	0	0	0
333	M4	9	2009	0	0	0	0	0	0	0	0	0	0
334	M4	10	2009	0	0	0	0	0	0	0	0	0	0
335	M4	11	2009	0	0	0	0	0	0	0	0	0	0
336	M4	12	2009	0	0	0	0	0	0	0	0	0	0
337	M4	1	2010	0	0	0	0	0	0	0	0	0	0
338	M4	2	2010	0	0	0	0	0	0	0	0	0	0
339	M4	3	2010	0	0	0	0	0	0	0	0	0	0
340	M4	4	2010	0	0	0	0	0	0	0	0	0	0
341	M4	5	2010	3.55	2	0	0	0	0	0	0	5.28	7
342	M4	6	2010	1.59	2	13.46	6	0.05	1	0	0	10.01	9
343	M4	7	2010	2.46	2	13.11	5	0.1	1	0	0	23.85	8
344	M4	8	2010	30.05	6	7.83	3	0	0	0	0	1.08	1
345	M4	9	2010	14.88	7	26.18	10	0	0	0.25	3	6.88	10
346	M4	10	2010	30.05	6	7.83	3	0	0	0	0	1.08	1
347	M4	11	2010	31.05	7	8.56	4	0	0	0	0	1.08	1
348	M4	12	2010	30.05	6	7.83	3	0	0	0	0	1.08	1
349	M4	1	2011	13.5	4	30.04	8	1.05	1	0.55	1	2.25	4
350	M4	2	2011	8.52	4	27.33	8	0.06	1	0.55	1	6.18	3
351	M4	3	2011	14.43	6	7.02	4	1.29	3	0	0	2.29	7
352	M4	4	2011	0	0	4.22	3	0.35	2	0	0	1.14	2
353	M4	5	2011	5.25	3	12.52	6	1.09	3	0.47	1	0.3	1
354	M4	6	2011	1.05	1	3.13	2	0.2	1	0.58	1	4.58	2
355	M4	7	2011	8.25	2	19.24	6	1.03	2	0	0	12.59	4
356	M4	8	2011	8.37	3	13.06	3	0	0	0	0	62.35	19
357	M4	9	2011	4.3	2	9.56	5	0	0	0	0	70.39	28
358	M4	10	2011	1.4	1	13.1	4	1.28	2	1	1	240.4	30

359	M4	11	2011	9.25	4	17.42	2	1.02	2	0	0	83	14
360	M4	12	2011	12.01	4	7.28	2	1.05	3	0.2	1	16.15	10
361	M5	1	2009	0	0	0	0	0	0	0	0	0	0
362	M5	2	2009	0	0	0	0	0	0	0	0	0	0
363	M5	3	2009	0	0	0	0	0	0	0	0	0	0
364	M5	4	2009	0	0	0	0	0	0	0	0	0	0
365	M5	5	2009	0	0	0	0	0	0	0	0	0	0
366	M5	6	2009	0	0	0	0	0	0	0	0	0	0
367	M5	7	2009	0	0	0	0	0	0	0	0	0	0
368	M5	8	2009	0	0	0	0	0	0	0	0	0	0
369	M5	9	2009	0	0	0	0	0	0	0	0	0	0
370	M5	10	2009	0	0	0	0	0	0	0	0	0	0
371	M5	11	2009	0	0	0	0	0	0	0	0	0	0
372	M5	12	2009	0	0	0	0	0	0	0	0	0	0
373	M5	1	2010	0	0	0	0	0	0	0	0	0	0
374	M5	2	2010	0	0	0	0	0	0	0	0	0	0
375	M5	3	2010	0	0	0	0	0	0	0	0	0	0
376	M5	4	2010	0	0	0	0	0	0	0	0	0	0
377	M5	5	2010	8.09	4	8.47	6	0.17	3	0	0	3.54	7
378	M5	6	2010	24.24	4	24.42	10	0.1	1	0	0	12.5	11
379	M5	7	2010	7.15	2	0.06	1	0	0	0.33	1	28.7	14
380	M5	8	2010	53.2	11	39.41	8	0	0	0.08	0	6.18	6
381	M5	9	2010	0.08	7	35.05	12	17.65	1	0.08	1	18.08	16
382	M5	10	2010	51.4	10	38.21	9	0	0	0.09	1	6.18	6
383	M5	11	2010	51.28	11	35.23	10	0	0	0.18	1	7.65	8
384	M5	12	2010	51.4	10	38.21	9	0	0	0.09	1	6.18	6
385	M5	1	2011	15.02	4	17.52	5	0	0	0	0	2.05	9
386	M5	2	2011	4.42	2	20.09	7	0	0	0.58	1	13.09	15
387	M5	3	2011	13.03	6	4.34	1	0.17	1	1.47	2	1.31	3
388	M5	4	2011	7.2	5	11.57	6	0.34	3	1.27	2	3.38	8
389	M5	5	2011	6.05	3	10.01	5	0	0	2.01	2	2.55	6
390	M5	6	2011	5.37	4	5.01	3	1.24	5	0	0	1.23	9
391	M5	7	2011	18.27	6	15.24	7	0.35	2	1.25	2	7.07	5

392	M5	8	2011	29.25	5	19.39	11	1.15	3	1.31	3	29.27	13
393	M5	9	2011	0	0	4.58	3	0.46	3	0	0	49.46	23
394	M5	10	2011	2.39	2	12.38	2	3.25	2	1.19	4	212.53	29
395	M5	11	2011	26.27	5	9.31	3	1	1	0	0	84.56	18
396	M5	12	2011	2.56	2	2.22	1	0	0	0.35	1	26.25	10

APPENDIX B. from 2012E.C.upto 2013E.C.

Date:-01/11/2011 to 30/11/2011

District Name...Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remark
1	Adama Substation		R1-03															
3		R1/ L-07	R1-05							1	0:12					1	0:12	
4			R2-02															
5			R2-03															
7		R2/ M-01	R2-05															
8			R3-02							1	0:14			1	0:05	2	0:19	
9		R3/ L-04	R3-03															
10			R4-02			6	46:22:00			1	0:19			2	0:39	9	47:20:00	
11		R4/ M-06	R4-03															
12			R5-02			4	17:00			1	0:10			1	0:03	6	17:13	
13		R5/ L-01	R5-03			2	1:28			1	0:08			2	0:12	5	1:48	
14			R6-04			3	14:41									3	14:41	
15		R6/ L-03	R6-05			1	0:50			1	0:18	2	10:50	1	0:17	5	12:15	

Date- 01/12/2011 to 30/12/2011

ict Name...Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

Substation Name	Feeder Name	Out -going Switching Station	Distribution DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Rer
Adama Substation		R1-03			1	3:25			3	40'			5	3:15	9	7:20	
	R1/ L-07	R1-05			4	18:30			5	1:00			4	1:05	13	20:35	
		R2-02															
		R2-03	1	2:15	2:15	11:30			4	55'			2	1:55	7.09375	16:35	
	R2/ M-01	R2-05							1	10'			1	35'	2	45'	
		R3-02	1	45'	6	8:20		R7-02	1	15'			2	27'	10	9:47	
	R3/ L-04	R3-03			2	7:25							1	25'	3	7:50	
		R4-02	2	1:04	6	16:30:00			2	30'			4	2:20	14	20:24:00	
	R4/ M-06	R4-03			1	3:20									1	3:20	
		R5-02			2	3:00							1	1:20	3	4:20	
	R5/ L-01	R5-03			5	5:25			3	30'			3	1:02	11	6:57	
		R6-04	1	4:20	7	22:08			3	34'					11	27:02:00	
	R6/ L-03	R6-05			6	11:45							3	2:25	9	14:10	
		R7-02	1	1:15											1	1:15	
	R7/ M-03	R7-03	3	6:30	2	1:35							1	5'	6	8:10	
		R8-02	3	2:25	13	45'			8	1:00			2	20'	26	4:30	
	R8/ M-05	R8-05															
		AT	1	10:10									1	1:00	2	11:10:00	
		SUM	13	28:44:00	55.09375	113:38:00			30	5:34			30	16:14	128.09375	164:10:00	
														SAIFI	8		

Date- 01/01/2012 to 30/01/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution												Frequency Of inturuption	Duration Of inturuption	Remark
				DPEF		DPSC		DTEF		DTSC		LDC		OP				
				F	D(Hr)	F	D(Hr)	F	D(Hr)	F	D(Hr)	F	D(Hr)	F	D(Hr)			
1	Adama Substation		R1-03			2	3:04			2	19'			1	1:17	5	4:40	
3		R1/ L-07	R1-05							3	24'			2	2:09	5	2:33	
4			R2-02															
5			R2-03			10	8:33			9	53'			1	1:03	20	10:29	
7		R2/ M-01	R2-05															
8			R3-02			6	9:58			1	12'			3	21'	10	10:31	
9		R3/ L-04	R3-03			3	6:32			1	17'					4	6:49	
10			R4-02			6	10:12:00			3	32'			2	15'	11	10:59:00	
11		R4/ M-06	R4-03			1	5'							1	6'	2	11'	
12			R5-02			4	6:35			1	8'			1	2:00	6	8:43	
13		R5/ L-01	R5-03			2	1:35	1	7'	5	44'			2	26'	10	2:52	
14			R6-04											1	2:48	1	2:48	
15		R6/ L-03	R6-05			5	3:09	1	8'	1	4'			5	3:30	12	6:51	

Date- 01/02/2012 to 30/02/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution												Frequency Of inturuption	Duration Of inturuption
				DPEF		DPSC		DTEF		DTSC		LDC		OP			
				F	D(Hr)	F	D(Hr)	F	D(Hr)	F	D(Hr)	F	D(Hr)	F	D(Hr)		
1	Adama Substation		R1-03			2	43'			1	9'			5	2:13	8	3:05
3		R1/ L-07	R1-05			1	3:22			3	43'			16	10:17	20	14:22
4			R2-02														
5			R2-03			14	16:00			3	21'			1	1'	18	16:22
7		R2/ M-01	R2-05			2	2:13			1	18'			1	36'	4	3:07
8			R3-02			6	7:58			3	40'			2	46'	11	9:24
9		R3/ L-04	R3-03			4	3:26							1	1'	5	3:27
10			R4-02	1	43'	14	33:06:00			5	1:09			2	1:01	22	35:59:00
11		R4/ M-06	R4-03							1	13'			1	10'	2	23'
12			R5-02							2	22'			2	21'	4	43'
13		R5/ L-01	R5-03	2	3:40	8	7:46			5	40'			8	2:26	23	14:32
14			R6-04							1	7'					1	7'
15		R6/ L-03	R6-05			11	27:07:00			1	4'			1	26'	13	27:37:00

Date- 01/03/2012 to 30/03/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution												Frequency Of inturuption	Duration Of inturuption	Remark
				DPEF		DPSC		DTEF		DTSC		LDC		OP				
				F	D(Hr)	F	D(Hr)	F	D(Hr)	F	D(Hr)	F	D(Hr)	F	D(Hr)			
1	Adama Substation		R1-03			5	3:03			2	28'			7	2:22	14	5:53	
3		R1/ L-07	R1-05			3	2:20							7	4:07	10	6:27	
4			R2-02															
5			R2-03	1	55	11	11:38			5	1:02			6	2:27	23	16:02	
7		R2/ M-01	R2-05															
8			R3-02			3	2:19			1	11'			5	1:21	9	3:51	
9		R3/ L-04	R3-03			2	1:30			1	9'			1	7'	4	1:46	
10			R4-02			4	3:46:00			4	40'			2	37'	10	5:03:00	
11		R4/ M-06	R4-03															
12			R5-02			1	36'							4	2:06	5	2:42	
13		R5/ L-01	R5-03			2	20'							4	1:08	6	1:28	
14			R6-04			1	1:05									1	1:05	
15		R6/ L-03	R6-05			7	8:24			6	1:02			4	1:18	17	10:44	

N-Megabit | Hamle | Nehassie | Meskerem1 | Nehassei | Meskerem | Tikimt | Hidar | Tah …

Date- 01/04/2012 to 30/04/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remark
1	Adama Substation		R1-03			3	3:32			2	18'					5	3:50	
3		R1/ L-07	R1-05			3	3:40			3	46'			2	52'	8	5:18	
4			R2-02															
5			R2-03			7	7:09	1	2'	5	40'			5	2:32	18	10:23	
7		R2/ M-01	R2-05							3	20'					3	20'	
8			R3-02			1	32'							7	1:54	8	2:26	
9		R3/ L-04	R3-03			1	1:19							1	38'	2	1:57	
10			R4-02			4	4:48:00			4	47'			6	42'	14	6:17:00	
11		R4/ M-06	R4-03			1	45'							1	6'	2	51'	
12			R5-02			1	1:25			1	8'					2	1:33	
13		R5/ L-01	R5-03							2	13'			1	23'	3	36'	
14			R6-04							1	30'					1	30'	
15		R6/ L-03	R6-05															

Hamle | Nehassie | Meskerem1 | Nehassei | Meskerem | Tikimt | Hidar | Tahissas | Tir

Date- 01/05/2012 to 30/05/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remark
1	Adama Substation		R1-03			3	1:19			4	36'					7	1:55	
3		R1/ L-07	R1-05			2	1:40			2	17'			1	18'	5	2:15	
4			R2-02															
5			R2-03			10	13:06			1	5'			4	3:34	15	16:45	
7		R2/ M-01	R2-05			2	1:17			1	1'			2	15'	5	1:33	
8			R3-02			3	2:35			3	35'			1	14'	7	3:24	
9		R3/ L-04	R3-03			3	8:01									3	8:01	
10			R4-02			9	9:30:00			8	1:10			6	1:39	23	12:19:00	
11		R4/ M-06	R4-03			1	49'									1	49'	
12			R5-02															
13		R5/ L-01	R5-03							6	55'			2	25'	8	1:20	
14			R6-04															
15		R6/ L-03	R6-05			3	3:20			2	10'			2	30'	7	4:00	

Hamle | Nehassie | Meskerem1 | Nehassei | Meskerem | Tikimt | Hidar | Tahissas | Tir

Date- 01/05/2012 to 30/05/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remark
1	Adama Substation		R1-03			3	1:19			4	36'					7	1:55	
3		R1/ L-07	R1-05			2	1:40			2	17'			1	18'	5	2:15	
4			R2-02															
5			R2-03			10	13:06			1	5'			4	3:34	15	16:45	
7		R2/ M-01	R2-05			2	1:17			1	1'			2	15'	5	1:33	
8			R3-02			3	2:35			3	35'			1	14'	7	3:24	
9		R3/ L-04	R3-03			3	8:01									3	8:01	
10			R4-02			9	9:30:00			8	1:10			6	1:39	23	12:19:00	
11		R4/ M-06	R4-03			1	49'									1	49'	
12			R5-02															
13		R5/ L-01	R5-03							6	55'			2	25'	8	1:20	
14			R6-04															
15		R6/ L-03	R6-05			3	3:20			2	10'			2	30'	7	4:00	

Tir | Yekatit | Megabit | Miazia | Ginbot | Sene | Hamlie | Nehassie-2012 | Meskerem-201…

Date- 01/06/2012 to 30/06/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Rema
1	Adama Substation		R1-03			6	12:19			3	40'			2	27'	11	13:26	
3		R1/ L-07	R1-05			11	20:14			3	26'			6	4:22	20	25:02:00	
4			R2-02			1	5:05							1	2'	2	5:07	
5			R2-03			10	8:59			3	21'			2	55'	15	10:15	
7		R2/ M-01	R2-05															
8			R3-02			1	25'			6	1:08			1	23'	8	1:56	
9		R3/ L-04	R3-03			2	3:10			1	17'					3	3:27	
10			R4-02			5	2:59:00			5	35'					10	3:34:00	
11		R4/ M-06	R4-03							1	6'					1	6'	
12			R5-02			1	5:05							1	2'	2	5:07	
13		R5/ L-01	R5-03			2	1:38			2	25'			3	30'	7	2:33	
14			R6-04							1	12'					1	12'	
15		R6/ L-03	R6-05			3	2:13			1	6'					4	2:19	
16			R7-02															
17		R7/ M-03	R7-03															
18			R8-02			6	10:46			4	28'			5	2:16	15	13:30	

Date- 01/07/2012 to 30/07/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remark
1	Adama Substation		R1-03			12	48:49:00			3	42'			1	1'	16	49:32:00	
3		R1/ L-07	R1-05			7	23:38			1	6'			1	44'	9	24:28:00	
4			R2-02			5	19:19			3	13'					8	19:32	
5			R2-03			21	28:17:00			1	18'					22	28:35:00	
7		R2/ M-01	R2-05															
8			R3-02			16	26:54:00			6	48'					22	27:42:00	
9		R3/ L-04	R3-03			7	14:10			7	1:13			1	1:15	15	16:38	
10			R4-02			14	97:27:00			11	1:40					25	99:07:00	
11		R4/ M-06	R4-03			6	48:49:00			3	10'					9	48:59:00	
12			R5-02			1	40'			3	23'					4	1:03	
13		R5/ L-01	R5-03			4	25:14:00			2	14"			1	6'	7	25:34:00	
14			R6-04			2	2:28			1	7'					3	2:35	
15		R6/ L-03	R6-05			10	15:29			1	4'					11	15:33	
16			R7-02															
17		R7/ M-03	R7-03															
18			R8-02			15	60:31:00			14	2:10:00					29	62:41:00	
19		R8/ M-05	R8-05															
20			AT	1	1:01	5	29:22:00	1	13'							7	30:36:00	
			SUM	1	1:01	125	441:07:00	1	13'	56	8:08			4	1:66'	**187**	**452:35:00**	
															SAIFI	**13**		

Tir | Yekatit | **Megabit** | Miazia | Ginbot | Sene | Hamlie | Nehassie-2012 | Meskerem-201…

Date- 01/08/2012 to 30/08/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remar
1	Adama Substation		R1-03			4	8:10:00			2	23'			3	1:24	9	9:57:00	
3		R1/ L-07	R1-05			6	18:22			1	5'			1	4'	8	18:31:00	
4			R2-02	1	1:53					3	25'			3	3:50	7	6:08	
5			R2-03	1	26'	5	5:04			2	2'			2	8'	10	5:40	
7		R2/ M-01	R2-05			7	25:01:00			2	6'			1	6'	10	25:13:00	
8			R3-02			3	3:50			2	17'			1	33'	6	4:40	
9		R3/ L-04	R3-03			1	50'			2	8'					3	58'	
10			R4-02			9	20:18:00			3	21'			2	1:55	14	22:34:00	
11		R4/ M-06	R4-03															
12			R5-02															
13		R5/ L-01	R5-03															
14			R6-04			1	29'			1	16'			1	1:46	3	2:31	

Date- 01/09/2012 to 30/09/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution: DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remark
1	Adama Substation		R1-03			15	39:11:00			12	2:00			8	7:39	35	48:50:00	
3		R1/ L-07	R1-05			7	9:18			4	23'					11	9:41:00	
4			R2-02			4	3:20			2	16'			6	15:26	12	19:02	
5			R2-03			4	1:34			2	12'			5	11:27	11	13:13	
7		R2/ M-01	R2-05			11	6:36:00			3	25'			9	11:20	23	18:21:00	
8			R3-02			8	11:41			4	48'			1	46'	13	13:15	
9		R3/ L-04	R3-03			3	12:01			2	11'			1	34'	6	12:46	
10			R4-02			9	32:52:00			7	1:18			3	3:06	19	37:16:00	
11		R4/ M-06	R4-03			2	1:51:00			1	6'			3	2:48	6	4:45:00	
12			R5-02			1	13:54									1	13:54	
13		R5/ L-01	R5-03															
14			R6-04			2	14:12							2	4:08	4	18:20	

Tir | Yekatit | Megabit | Miazia | **Ginbot** | Sene | Hamlie | Nehassie-2012 | Meskerem-2013

Date- 01/10/2012 to 30/10/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution: DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remark
1	Adama Substation		R1-03			10	23:55:00			3	27'			1	1:23	14	25:45:00	
3		R1/ L-07	R1-05			8	25:31:00			4	44'					12	26:15:00	
4			R2-02			5	5:08							1	1:10	6	6:18	
5			R2-03			5	20:40			3	39'			1	2:06	9	23:25	
7		R2/ M-01	R2-05			18	23:38:00			3	12'			3	2:58	24	26:48:00	
8			R3-02			9	13:37			2	20'			2	6:30	13	20:27	
9		R3/ L-04	R3-03			1	22'							2	28'	3	50'	
10			R4-02			21	52:29:00			4	30'					25	52:59:00	
11		R4/ M-06	R4-03			2	2:34:00							1	18'	3	2:52:00	
12			R5-02			1	1:01							1	6'	2	1:07	
13		R5/ L-01	R5-03															
14			R6-04			2	1:43			2	19'			2	41'	6	2:43	

Tir | Yekatit | Megabit | Miazia | Ginbot | **Sene** | Hamlie | Nehassie-2012 | Meskerem-2013

Date- 01/11/2012 to 30/11/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution: DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remark
1	Adama Substation		R1-03			12	16:07:00			6	1:09					18	17:16:00	
3		R1/ L-07	R1-05			12	17:50:00			4	57'			2	2:36	18	21:23:00	
4			R2-02			4	20:16			2	17'			3	4:28	9	25:01:00	
5			R2-03			10	14:40			1	5'			1	20'	12	15:05	
7		R2/ M-01	R2-05			12	14:47:00			1	18'			7	8:53	20	23:58:00	
8			R3-02			13	20:00			4	46'			2	5:31	19	26:17:00	
9		R3/ L-04	R3-03			3	12:09							4	5:42	7	17:51	
10			R4-02			10	20:42:00							3	3:14	13	23:56:00	
11		R4/ M-06	R4-03							4	46'			3	1:09	7	1:55:00	
12			R5-02															
13		R5/ L-01	R5-03															
14			R6-04			2	1:15			2	18'			4	8:02	8	9:35	

Tir | Yekatit | Megabit | Miazia | Ginbot | Sene | **Hamlie** | Nehassie-2012 | Meskerem-2013

Date- 01/11/2012 to 30/11/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution: DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Rema
1	Adama Substation		R1-03			12	16:07:00			6	1:09					18	17:16:00	
3		R1/ L-07	R1-05			12	17:50:00			4	57'			2	2:36	18	21:23:00	
4			R2-02			4	20:16			2	17'			3	4:28	9	25:01:00	
5			R2-03			10	14:40			1	5'			1	20'	12	15:05	
7		R2/ M-01	R2-05			12	14:47:00			1	18'			7	8:53	20	23:58:00	
8			R3-02			13	20:00			4	46'			2	5:31	19	26:17:00	
9		R3/ L-04	R3-03			3	12:09							4	5:42	7	17:51	
10			R4-02			10	20:42:00							3	3:14	13	23:56:00	
11		R4/ M-06	R4-03							4	46'			3	1:09	7	1:55:00	
12			R5-02															
13		R5/ L-01	R5-03															
14			R6-04			2	1:15			2	18'			4	8:02	8	9:35	

Tir | Yekatit | Megabit | Miazia | Ginbot | Sene | **Hamlie** | Nehassie-2012 | Meskerem-201…

Date- 01/12/2012 to 05/13/2012

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution: DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remar
1	Adama Substation		R1-03			9	14:09:00			2	30'			4	1:45	15	16:24:00	
3		R1/ L-07	R1-05			12	20:34:00			3	38'			3	45'	18	21:57:00	
4			R2-02			14	28:59:00			2	24'	1	1:58	3	1:33	20	32:54:00	
5			R2-03			10	60:27:00			1	11'	1	1:58	3	2:02	15	64:38:00	
7		R2/ M-01	R2-05			17	23:42:00			2	21'	2	10:00	2	45'	23	34:48:00	
8			R3-02			12	22:36			5	1:02			5	10:41	22	34:19:00	
9		R3/ L-04	R3-03			7	15:09			2	21'			3	4:42	12	20:12	
10			R4-02			19	36:27:00			4	48'			3	1:54	26	39:09:00	
11		R4/ M-06	R4-03			3	8:00:00			5	45'			1	9'	9	8:54:00	
12			R5-02															
13		R5/ L-01	R5-03															
14			R6-04			1	4:41			1	12'			5	5:16	7	10:09	

… | Tir | Yekatit | Megabit | Miazia | Ginbot | Sene | Hamlie | **Nehassie-2012** | Meskerem-201… …

Date- 01/01/2013 to 30/01/2013

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	Distribution: DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Rer
1	Adama Substation		R1-03			1	21:37:00			3	33'					4	22:10:00	
3		R1/ L-07	R1-05			4	3:46:00			5	37'			1	34'	10	4:57:00	
4			R2-02			2	13:04:00			3	15'			1	2:14	6	15:33:00	
5			R2-03			11	25:03:00			2	37'			1	2:07	14	27:47:00	
7		R2/ M-01	R2-05			12	10:26:00			9	1:58			3	2:43	24	15:07:00	
8			R3-02			8	10:09			8	1:03					16	11:12:00	
9		R3/ L-04	R3-03			3	4:48							1	19'	4	5:07	
10			R4-02			11	29:35:00			5	36'			1	20'	17	30:31:00	
11		R4/ M-06	R4-03			1	34'									1	34'	
12			R5-02															
13		R5/ L-01	R5-03															
14			R6-04			1	4:48									1	4:48	

… | Yekatit | Megabit | Miazia | Ginbot | Sene | Hamlie | Nehassie-2012 | **Meskerem-2013** | Ti …

Date- 01/02/2013 to 30/02/2013

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remark
1	Adama Substation		R1-03			10	12:10:00			8	1:34			2	5:12	20	18:56:00	
3		R1/ L-07	R1-05			9	15:28:00			7	1:12					16	16:40:00	
4			R2-02			6	17:02:00			4	1:00			2	9:12	12	27:14:00	
5			R2-03			7	8:37:00			2	27'			1	15'	10	9:19:00	
7		R2/ M-01	R2-05			16	21:35:00			10	2:09			1	8'	27	23:52:00	
8			R3-02			9	18:00			8	1:30			1	56'	18	20:26:00	
9		R3/ L-04	R3-03			2	5:24			2	24'			1	15'	5	6:03	
10			R4-02			6	110:15:00			1	20'					7	110:35:00	
11		R4/ M-06	R4-03															
12			R5-02															
13		R5/ L-01	R5-03															
14			R6-04							3	32'					3	32'	

Date- 01/03/2013 to 30/03/2013

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption	Remark
1	Adama Substation		R1-03	1	6:34	5	3:18:00			9	1:37			1	42'	16	12:11:00	
3		R1/ L-07	R1-05	2	9:11	2	2:18:00			4	46'			2	2:23	10	14:38:00	
4			R2-02											1	3:23	1	3:23:00	
5			R2-03			1	7:24:00			1	11'			1	3:17	3	10:52:00	
7		R2/ M-01	R2-05			6	3:40:00			2	23'			2	3:32	10	7:35:00	
8			R3-02	1	24'	6	5:04	2	18'	7	47'			1	19'	17	6:52:00	
9		R3/ L-04	R3-03	1	30'	6	18:53			1	8'					8	19:31	
10			R4-02			3	9:48:00	2	11'	1	10'			3	1:37	9	11:46:00	
11		R4/ M-06	R4-03											1	1:09	1	1:09:00	
12			R5-02															
13		R5/ L-01	R5-03															
14			R6-04			1	1:17							1	1:01	2	2:18	

Date- 01/04/2013 to 30/04/2013

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption
1	Adama Substation		R1-03	1	21'	10	9:09:00	2	21'	8	1:05			3	2:11	24	13:07:0
3		R1/ L-07	R1-05	2	5:29	2	1:20:00			3	30'			6	4:00	13	11:19:0
4			R2-02			2	2:44:00			1	15'			1	2:35	4	5:34:0
5			R2-03			2	6:33:00			3	43'			1	2:36	6	9:52:0
7		R2/ M-01	R2-05	1	53'	11	15:07:00			5	56'			2	28'	19	17:24:0
8			R3-02	1	1:40	8	10:16	1	7'	4	34'			4	6:58	18	19:35:0
9		R3/ L-04	R3-03	1	23'	5	15:13	1	12'	1	19'					8	16:0
10			R4-02	2	1:07	7	11:05:00	2	28'	3	30'			8	12:11	22	25:21:0
11		R4/ M-06	R4-03			2	26:32:00							2	1:08	4	27:40:0
12			R5-02			2	1:43			1	20'			2	3:51	5	5:5
13		R5/ L-01	R5-03											4	6:12	4	6:1
14			R6-04							1	8'			4	20:53	5	21:0

Date- 01/05/2013 to 30/05/2013

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	Out -going Switching Station	DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	Frequency Of inturuption	Duration Of inturuption
1	Adama Substation		R1-03			4	4:55:00			8	1:23			2	1:11	14	7:29:00
3		R1/ L-07	R1-05			4	2:53:00			8	1:29			3	4:28	15	8:50:00
4			R2-02			1	1:27:00							4	2:14	5	3:41:00
5			R2-03			4	2:45:00							2	2:31	6	5:16:00
7		R2/ M-01	R2-05			3	1:53:00			6	1:16			3	2:13	12	5:22:00
8			R3-02			6	9:52			4	1:16			1	2:40	11	13:48:00
9		R3/ L-04	R3-03							1	19'			1	13'	2	32'
10			R4-02			4	5:42:00			2	30'			1	54'	7	7:06:00
11		R4/ M-06	R4-03														
12			R5-02			2	1:05			1	9'					3	1:14
13		R5/ L-01	R5-03							10	1:51			1	3'	11	1:54
14			R6-04											4	5:58	4	5:58

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

Substation Name	Feeder Name	going Switching Station	DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	y O inturu n
Adama Substation		R1-03			7	22:12:00			3	21'			5	3:10	
	R1/ L-07	R1-05			1	58'							4	1:46	
		R2-02											7	7:49'	
		R2-03			5	2:45:00			4	33'			4	21:38	
	R2/ M-01	R2-05			6	17:04:00			2	12'			6	6:11	
		R3-02			3	4:16	1	4'	3	43'			4	51'	
	R3/ L-04	R3-03			1	23'							3	6:24	
		R4-02			11	19:30:00			5	52'			5	16:06	
	R4/ M-06	R4-03			1	8:43:00			2	20'			2	27'	
		R5-02			1	8:02'			3	1:16'			3	28'	
	R5/ L-01	R5-03							8	1:16'			3	5:11'	
		R6-04			4	1:23			1	10'			8	13:13'	
	R6/ L-03	R6-05			6	14:26'			6	54'			1	1:23	
		R7-02			3	3:17'			1	20'			1	46'	
	R7/ M-03	R7-03			1	42'			1	10'			1	54'	
		R8-02			7	4:29'			4	50'			7	2:04'	
	R8/ M-05	R8-05			5	6:22'	3	1:26					4	8:59'	
		AT			4	2:44'				2:13'			4	21'	
		SUM													
														SAIFI	

Date- 01/06/2013 to 30/06/2013

District Name…Adama

MV INTURUPTION SUMMARY REPORT /SCADA OFFICE/

No.	Substation Name	Feeder Name	going Switching Station	DPEF F	DPEF D(Hr)	DPSC F	DPSC D(Hr)	DTEF F	DTEF D(Hr)	DTSC F	DTSC D(Hr)	LDC F	LDC D(Hr)	OP F	OP D(Hr)	y Of inturuption	Of inturuption	Remark
1	Adama Substation		R1-03			2	4:29:00			7	1:02			8	10:07			
3		R1/ L-07	R1-05	1	41'	3	1:43:00	3	37	1	14'			4	3:23			
4			R2-02			1	21'			1	20'			1	17'			
5			R2-03			14	18:44:00			5	43'			4	21:38			
7		R2/ M-01	R2-05			6	4:52:00			2	23'			2	0:00			
8			R3-02			18	7:56	1	3'	1	19'			2	1:01			
9		R3/ L-04	R3-03	1	27	2	3:19	1	7	1	11'			3	1:41			
10			R4-02	3	3:52	14	19:40:00			6	59'			6	5:35			
11		R4/ M-06	R4-03	1	1:10	1	1:04:00							3	2:18			
12			R5-02	3	5:39	5	3:42	5	59	1	6'			1	2:38			
13		R5/ L-01	R5-03	1	1:11	2	1:07	1	1'	8	1:36			3	1:49			
14			R6-02	1	54'	1	1:14	2	22					1	1:27			
15			R6-04			2	4:19			3	27'			1	3:01			
16		R6/ L-03	R6-05	1	43'	2	52'	1	7'	1	13'			1	37'			
17			R7-02	1	1:12	8	7:52			13	1:57			2	1:16			
18			R7-03			3	2:57			3	46'			2	1:06			
		R7/ M-03	R7-05			3	2:00											
19			R8-02	3		9	8:47:00			12	3:06:00			3	7:24			
20		R8/ M-05	R8-05	1	1:46	2	1:48	2	12'	4	33'			2	29'			
21			AT	1	45'	1	45'	1	12'	1	16'			3	7:49			