JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF ELECTRICAL AND COMPUTER ENGINEERING
GRADUATE PROGRAM IN ELECTRICAL POWER ENGINEERING

EVALUATION THE IMPACT OF DISTRIBUTION NETWORK RENOVATION FOR RELIABILITY ENHANCEMENT(CASE STUDY: DILLA TOWN DISTRIBUTION NETWORK)

BY

SHIMELIS FIKIRU DUKALE

A Thesis Submitted to Jimma Institute of Technology, School of Graduate Studies, Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Electrical Power Engineering

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Approval by Board of Examiners

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Declaration

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

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Abstract

Reliable and stable electric power supply system is very important for the technological and economic growth of any society in every country. Now a days, life is directly or indirectly depends on electric power. Accordingly utility should deliver reliable power supply throughout the year. But in developing countries like Ethiopia, frequent power interruptions and instabilities occur which hamper the reliability of power supply. One possible solution which can help to restore power supply in the event of distribution system failure is network renovation. In this thesis, the network renovation on distribution system to improve reliability has been performed.

The Matlab code used for tie line and sectionalizing switch sets in order to open and close the switches using the algorithm of fast non-dominated sorting genetic algorithm(FNSGA) are used as it is written in the appendix B and C. where as Newton Raphson power flow method used to analyze the network inside Electrical Transient Analyzer Program (ETAP 19.0.1) software. The networks are radial connection in consisting of five feeder lines with two of them having 132/33kv and the remaining three of them having 132/15kv. The analysis presented both base-case and post-case for comparison on feeder line two. Based on this the pre-renovation system indices are evaluated: SAIDI (312.67) hr / customer.yr; SAIFI (497.94) f / customer.yr , CAIDI, EENS, ASAI and ASUI are recorded (0.628, 128.31, 0.9695p.u and 0.03569p.u) respectively. After renovation or post-renovation system indices evaluated: SAIDI (267.38) hr / customer.yr; SAIFI (431.12) f / customer.yr; CAIDI, EENS, ASAI and ASUI are recorded (0.620, 109.793, 0.9695 and 0.03052) respectively. This result shows as:-SAIDI, SAIFI, CAIDI, EENS, ASAI and ASUI have been improved by 14.48%, 13.41%, 1.27%, 14.43%, 0.53% and 14.48% respectively. Accordingly it can provide un-substitutable solution with regarding to enhancing reliability of the supply to meet consumer demands.

Keywords: Distribution Networks, ETAP Software, Network Renovation

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Above all I would like to thanks my almighty God that he supports me able to do this second degree education and for un-substitutable support on my thesis work. This thesis work would not be possible without the help of my main advisor Dr. Ing. Dereje Shiferaw, who has supported me by giving his invaluable guidance, encouragement, advice and suggestions throughout my M.Sc education and thesis work, Also my acknowledgment goes to my co-advisor Mr. Samuel Tesfaye for his valuable guidance's and gives me overall direction about my thesis work. My appreciation goes to Ethiopia electric utility(EEU) Hawasa district workers for providing important data and materials needed for this work and also Dilla distribution substation staffs and Dilla utility service maintenance room staffs. Specifically, I would like to acknowledge Mr. Demisie, Nasiro, Esrael, and Semere. At the last but not least my heartfelt thanks goes to my family and my friends who have supported me with material and all necessities throughout my education and my thesis work.

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List of Acronyms and Symbols

Acronyms

AAAC	All Aluminium Alloy Conductor
AAC	All Aluminium Conductor
ACSR	Aluminium Conductor Steel Reinforced
ASAI	Average Service Availability Index
ASUI	Average Service Unavailability Index
BBIM	Based on the Branch-bus Incidence Matrix
CT	CurrentTransformer
CAIDI	Customer Average Interruption Duration Index
C.B	Circuit Breaker
Ckt	Circuit
DSR	Distribution System Reconfiguration
E	East
E.C	EthiopianCalender
EENS	Expected Energy Not Supplied
EEU	EthiopiaElectricUtility
ETAP	Electrical Transient Analaysing Program
ETB	Ethiopian Birr
FNSGA	Fast Non Sorting Genetic Algorithm
GA	GeneticAlgorithm
G.C	Gregorian Calendar
IEEE	Institute of Electrical andElectronicsEngineering
JIT	Jimma Institute of Technology
LSIs	Loss Sensitivity Indices
MAIFI	Momentary Average Interruption Frequency Index
MCS	Manually Controlled Switch
MTTR	Mean Time To Repair
NERC	National Electric Reliability Council
ONAN	Oil Natural Air Nanural
PLC	Programmable Logic Circiut
RCS	Remote Controlled switch
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index

SNNPR	South Nation Nationality People Region
Trafo	Transformer

Symbols

kHz	kilohertz
KV	KiloVolt
KVA	Kilo Volt Amperes
min	minute
MHz	Mega Hert z
ms	millisecond
MVA	Mega Volt Ampere
Mw	Mega watt
N	North
ns	nano second
pu	per unit
Rs	Rupees
s	second
μ_A	Active Failure rate
μ_P	Passive Failure rate
μ_s	microsecond

CHAPTER ONE

INTRODUCTION

1.1. Background

Power system is designed to provide adequate electrical power supply to the customers in its area with an acceptable level of the supply reliability today. Utilities try to maximize system reliability, improve efficiency and reduce costs by renovating the feeder line [1]. A good and reliable distribution system is characterized by the following attributes: having the maximum reliability of the power supply; minimum operation and maintenance cost; minimum duration of interruption; voltage drop at consumers end is within 5% of nominal magnitude and efficiency is not less than 90% [2].

The historical data of reliability indices of the pre-existing network has been collected from Dilla distribution substation. The reliability parameters such as, the active failure rate μ_A, passive failure rate μ_p and MTTR input data are properly and deliberately filled on the prescribed places on reliability assessment mode [3].

The MATLAB codes are used to identify the position of Sectionalizing and tie switch which is applied after identifying the overloaded equipment's . Those switches have a vital role for uninterrupted power supply during maintenance.

Primarily Feeder line renovation can plays vital role to improvement of the system reliability. Feeder line renovation is the process of re-arranging by replacing the overloaded pre-existing feeder line electrical equipment's with high rating equipment. The overloaded equipment's are identified by simulating load flow mode that they are generated in alert case inside the ETAP software. In this case the length of the line is reduced.

The new improved reliability indices are generated inside reliability assessment mode. In generally, the impact of the distribution network renovation by restructuring feeder line in order to enhance the reliability of the distribution network by comparing the reliability of the base case with the post case are evaluated in this thesis.

Study area of this thesis is Dilla town which it is conducted on specified feeder line(feeder line two). This feeder lines expands all area of Dilla town by holding large number of loads compared to the remaining four. The reason to select this feeder line is, this feeder line encompasses all loads than the remaining feeders such as:-commercial, industrial and residential loads. In addition is is very overloaded.

1.2. Statement of the Problem

The fundamental function of the power system is to provide an adequate electrical supply to its customers as reasonable level of reliability. On the previous trend over the past many years, distribution systems have received considerably less attention devoted to reliability modeling and evaluation than the power generation and transmission systems. Because they concerned mostly on generation and transmission system. The consequence for this are, the generation stations and the transmission systems are capital intensive whereas the distribution is not. Their inadequacy can have widespread catastrophic consequences for both society and the environment. A distribution system, however, is relatively cheap as compared to the other two as its effects are localized. Therefore, less effort has been devoted to quantitative assessment of the adequacy of various alternatives and reinforcements.

Now a day's the demand of the electricity increasing day to day with introducing new technology. Depending upon the requirement of the customers, the utility have to evolve and improve the respective systems continuously. But the facts on the ground is that, the distribution system is not providing reliable supply to the customers including Dilla town. Reliability indices must lay in the prescribed limits to provide reliable power. As Dilla town this can be under quotation, because those indices are out of limits.

On the other hand, analyses of the reliability indices have a great role in evaluating the reliability of the distribution system. 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 [4].

Power interruption becomes a serious problem in Ethiopia specifically, in the case study area of this thesis work. The outage frequency is as high as 497.94 and service restoration duration is as long as 312.67 hours per year per the selected feeder. The data clearly indicates that power interruption per day is a common phenomenon in the area. Due to this problem day to day activities of the society are highly affected and hence they are strongly complaining the electric utility. Therefore, this thesis conducted to evaluate the impact of the distribution network renovation to enhance the reliability by identifying the main causes of power interruptions and uses re-structuring (re-rooting) to achieve a maximum improvement in Dilla town.

1.3. Objective of the Thesis

Power interruption in distribution system has very significant influence in the reliability of the utilities and on the power demand of the customers.

1.3.1 General Objective

The general objective of this thesis is evaluation the impact of distribution network renovation of electrical power to enhance its reliability for performance improvement .

1.3.2 Specific Objective

- To identify the position of sectionalizing switch and tie line.
- To renovate distribution network for better operation.
- To investigate the improved performance for reliability enhancement of the distribution network.
- To compare the operation of distribution networks without and with renovation and also evaluate its impact based on the finding of this thesis.
- Evaluation the cost of equipment's required for distribution renovation.

1.4. Significance of the Thesis

Network renovation have unlimited importance on reliable and efficient supply of electric power to the consumer. When network renovation is performed, the power supply reliability enhanced. Power supply reliability means: - the consumers are satisfied on the supplied power as much as possible, minimum distribution system interruption and outage and minimum frequent damage of electrical equipment's due to power interruption. If the reliability of electric increases, the demand of all loads also increase. In this thesis the main cause of interruption of the distribution power system have been identified. Among five feeder line available in Dilla town, feeder line two selected for this thesis work. Because it encompasses all type of loads such as:- commercial, residential and industrial loads. The impact can be evaluated by load flow analyzer and reliability assessment mode of ETAP software. Therefore, the reliability indices are generated with high improvement. This can have significant advantage for distribution system end user by meeting power supply demand.

1.5. Scope of the Thesis

The scope of this thesis work covers, evaluating the impact of distribution network renovation by comparing the base case reliability of feeder two only with post case depending on the output generated. The MATLAB code is used only to determine the position of sectionalizing and tie switch. This means,this thesis does not include the internal GA operators simulations on MATLAB.

1.6. Methodology

1.6.1 Data Collection

For this thesis primary data and secondary data's are used. Primary data's are obtained through questioner, direct observation and participating with the maintenance team of the Dilla utility. Secondary data are collected from monthly report of power interruption in Dilla town utility and Dilla distribution substation. Moreover the secondary input data's are collected through literature review such as books, papers, journals and Internets.

1.6.2 Data Analysis

Inside ETAP software there are three alternative methods for power flow of distribution system such as:- Adaptive Newton Raphson, Newton Raphson and Fast Decoupled. By allocating(fixing) the same precision value which is 0.0001, Adaptive Newton Raphson and Newton Raphson can converges only @ four iteration whereas, Fast Decoupled @ ten iteration. Therefore, for this thesis Newton Raphson method selected. ETAP software is applied to assess and simulate the overall behavior of the distribution system load flow, bus voltage profile and reliability indices. Whereas, Matlab software helps for write the code used for sectionalizing and tie line switch for this thesis work.

- The distribution system is represented using single line diagram
- Improved network topology renovation has been developed.
- Reliability parameters have been calculated for the existing selected feeder and the modified systems
- Based on the result of this evaluation renovated network with high rating transformer replaced. In this case the total distance of line from distribution substation reduced. The cost analyses are performed to compare the required amount during renovation.

1.7. Thesis Organization

The thesis work has been done in such a way that it gives a clear flow and understanding regarding to the thesis work. Chapter one presents introduction, objectives and problem explanation. Chapter two discusses the theoretical fundamentals of reliability and review of literature's focusing on reliability, distribution systems and related works. Chapter three presents the methodology and approaches in more detail starting from site description and data gathering; reliability and causes of interruptions has been also presented in this chapter. Simulation, result and discussion performed in Chapter four. Finally, Chapter five encompasses conclusions and recommendations of overall works of this thesis.

CHAPTER TWO

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1. Theoretical Background

Reliability is the most important terms in power system. Reliability may be defined in many ways for electric power systems. These include vulnerability of the power system, continuity of service and meeting customer demands. Most of time reliability concerns are categorized into different aspects:- adequacy (the energy to meet demand and its capacity) and security (the potential to withstand disturbances). Reliability can be discussed along with the objectives of the system. The goals of the distribution system may be identified as

(1) Aspect of adequacy which can accessing by covering the territory.

(2) Having sufficient supply capacity for peak demand (another aspect of adequacy)

(3) Being able to operate under adverse conditions (security) and

(4) Providing stable voltage (quality).

Thus, the goals of the distribution system are coherent with reliability concerns [5]. The North American Reliability Council provides a glossary of terms. Reliability and the concepts of security and adequacy are defined there as follows (NERC) glossary of terms) [6]. Reliability: - The degree of accomplishment of the elements of the bulk electric system that results in electricity being delivered to customers within accepted standards and in the amount desired. Reliability may be measured by the frequency, duration, and magnitude of adverse effects on the electric supply. Electric system reliability can be addressed by considering two fundamental and functional aspects of the electric system: adequacy and security. Adequacy: the potential of the electric system to supply the aggregated electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements. Security: the potential of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements. Distribution reliability primarily relates to equipment outages and customer interruptions. In normal operating conditions, all equipment (except stand by) is energized and all customers are energized. Scheduled and unscheduled events disrupt normal operating conditions and can lead to outages and interruptions. The unscheduled events are caused either due to human error or due to equipment failures. The scheduled events are meant for periodic maintenance of the equipment and shall be notified in advance to the customers. Several indicators are used to evaluate reliability in the transmission and distribution system. The Regulation can aim to compensate customers for very long interruptions, keep restoration times under control and create incentives to reduce the total number and duration of interruptions (disincentives to increase them).

2.1.1 Transformer Failure

Since the important components of any system quality is reliability of that system, the failure of transformers in sub-transmission systems not only reduce reliability of power system but also have significant effects on power quality. To enhance utility reliability, depending on the history of reliability indices, the active failure rate and mean time to repair are calculated, whereas the passive failure rate is taken as zero for simplicity. Transformer problems normally are caused by insulation oil degradation, overload, thermal stress, humidity in oil/paper and bushing defective and etc. From the data collection the overloaded feeder causes supply interruptions [7].

2.1.2 Distribution System Reliability

Distribution system reliability is the ability of the distribution system to perform its function under stated conditions for a stated period of time without failure. Distribution system reliability is becoming significantly important because the distribution system is the backbone of the utility to the customer. It is important to plan and maintain power systems because cost of interruptions and power outages has severe

economic impact on the utility and its customers. In addition always customers complain rises since they are not provided reliable supply. The majority of customer reliability problems stem from distribution systems. If one residential customer power is interrupted for 90 minutes per year from 70 to 80 minutes will be the problems occurring on the distribution system that it is connected [8].
This is mainly due to:

- Radial nature of most distribution systems.
- The large number of components involved(e.g many small rated trafo) and overloaded interconnection of end users.
- The scarcity of protection devices and sectionalizing switches, and
- The nearness of the distribution system to end-use customers.

In distribution systems, reliability primarily relates to equipment outages and customer interruptions. Distribution system reliability assessment methods are able to predict distribution system reliability based on system configuration, system operation, and component reliability data. Distribution system reliability is not dependent only upon component failure characteristics. It is also dependent upon how the system responds to component failures. To understand this, it is necessary to understand the sequence of events that occurs after a distribution system fault.

Table 2.1: Categories and Characteristics of Power System Electromagnetic Phenomena [9]

Categories	**Typical Spectral Content**	**Typical** Duration	**Typical Voltage Magnitude**
1.0 Transients			
1.1 Impulsive			
Nanosecond	5 ns rise	<50 ns	
Microsecond	$1\mu s$ rise	50 ns–1 ms	
Millisecond	0.1 ms rise	>1 ms	
1.2 Oscillatory			
Low frequency	<5 kHz	0.3–50 ms	0–4 pu
Medium frequency	5–500 kHz	20 μs	0–8 pu
High frequency	0.5–5 MHz	5 μs	0–4 pu
2.0 Short-duration variation			
2.1 Instantaneous		0.5–30 cycles	<0.1 pu
Interruption		0.5–30 cycles	0.1–0.9 pu
Sag (dip)		0.5–30 cycles	1.1–1.8 pu
Swell			
2.2 Momentary		30 cycles–3 s	<0.1 pu
Interruption		30 cycles–3 s	0.1–0.9 pu
Sag (dip)		30 cycles–3 s	1.1–1.4 pu
Swell			
2.3 Temporary			
Interruption		3 s–1 min	<0.1 pu
Sag (dip)		3 s–1 min	0.1–0.9 pu
Swell		3 s–1 min	1.1–1.2 pu
3.0 Long-duration variations			
3.1 Interruption, sustained		>1 min	0.0 pu
3.2 Under voltages		>1 min	0.8–0.9 pu
3.3 Over voltages		>1 min	1.1–1.2 pu
4.0 Voltage distortion		Steady state	0.5%–2%
5.0 Waveform distortion			
5.1 DC offset	Steady state	0%–0.1%	
5.2 Harmonics	0–100th harmonic	Steady state	0%–20%
5.3 Inter-harmonics	0–6 KHz	Steady state	0%–2%
5.4 Notching		Steady state	
5.5 Noise	Broadband	Steady state	0–1%
6.0 Voltage fluctuations	<25 Hz	Intermittent	0.1%–7%
7.0 Power frequency variations		<10 s	

NOTE: s second, n_s nanosecond,μ_s microsecond, m_s millisecond, kHz kilohertz, MHz

megahertz, *min* minute,*pu* per unit.

2.1.3 Reliability Indices

There are various reliability indices that can be employed in measuring reliability of a given system and or comparing the reliability of different electric utility companies. Reliability indices are statistical aggregations of reliability data for a set of loads, components or customers. The reliability of the power supply is assessed using the known reliability indices. Most reliability indices are average values of a particular reliability characteristic for an entire system, operating region, or feeder. The indices for distribution system analysis include customer oriented indices and energy-oriented indices as defined in IEEE Standard 1366™-2000 [10].

2.1.3.1 Customer Based Indices

The Utilities commonly use the following reliability indices for interruption frequency and duration of interruption to quantify the performance of their systems [11].

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

$$SAIFI = \frac{Total\ number\ of\ customer\ interruptions}{Total\ number\ of\ customer\ served} = \frac{\sum(\lambda_i \times N_i)}{N_i}.1/Year \tag{2.1}$$

Where λ_i is the failure rate and N_i is the number of customers of load point i.

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

$$SAIDI = \frac{sum\ of\ customer\ interruption\ duration}{Total\ number\ of\ customer\ served} = \frac{\sum(U_i \times N_i)}{N_i}.Hrs/Year \tag{2.2}$$

Where U_i is the annual outage time and N_i is the number of customers of load point i

(iii) Customer Average Interruption Duration Index (CAIDI):- is the average time needed to restore/repair service to the average customer per sustained interruption:

$$CAIDI = \frac{sum\ of\ customer\ interruption\ duration}{Total\ number\ of\ customer\ interruptions} = \frac{\sum(U_i \times N_i)}{\sum \lambda_i \times N_i} = \frac{SAIDI}{SAIFI}.hrs \tag{2.3}$$

Where λ_i is the failure rate, U_i is the annual outage time and N_i is the number of customers of load point i.
SAIFI indicates how often an average customer is subjected to sustained interruption over a pre-define time interval where as SAIDI indicates the total duration of interruption an average customer is subjected for a predefined time interval. CAIDI indicates the average time required to restore/repair the service.

2.1.3.2 Load and Energy Based Indices

The main and useful load and energy based indices are the following.

(i) Average Service Availability Index(ASAI)

$$ASAI = \frac{Customer\ hours\ service\ availability}{Customer\ hours\ service\ demand} = \frac{8760 - SAIDI}{8760} \times \% \tag{2.4}$$

(ii) Average service unavailability index(ASUI)

$$ASUI = \frac{Customer\ hours\ of\ unavailable\ service}{Customer\ hours\ demand} = \frac{\sum(U_i \times N_i)}{8760 * \sum N_i} \tag{2.5}$$

(iii) Expected Energy Not Supplied Index(EENS)

$$EENS = \sum L_{ai} \times U_i \tag{2.6}$$

Where N_i is the number of customers for load point i; L_{ai} the average connected load; U_i is the annual outage duration for load point i and 8760 is the number of hours in a calendar year

2.1.4 Momentary Interruption Indices

2.1.4.1 Momentary Average Interruption Frequency Index (MAIFI)

Momentary interruption is the interruption of a customer for duration of less than 5 minutes. Any interruption of duration limited to the period required to restore service by an interrupting device. This must be completed within five minutes. The formula for Momentary Average Interruption Frequency Index (MAIFI) is [3]:

$$MAIFI = \frac{Total\ number\ of\ momentary\ interruptions}{Total\ number\ of\ customers\ served} per/year \tag{2.7}$$

2.1.4.2 Mean Time to Repair (MTTR)

The average time it takes to repair a system (usually technical or mechanical). It includes both the repair time and any testing time. The clock doesn't stop on this metric until the system is fully functional again. You can calculate MTTR by adding up the total time spent on repairs during any given period and then dividing that time by the number of repairs. So, let's say we're looking at repairs over the course of a week. In that time, there were 15 outages and systems were actively being repaired for five hours. Five hours is 300 minutes. 300 divided by 15 is 20. Which means the mean time to repair in this case would be 20 minutes. MTTR is a metric support and maintenance teams use to keep repairs on track. The goal is to get this number as low as possible by increasing the efficiency of repair processes and teams.

2.1.5 IEEE Reliability Indices Standard Values

According to [12] IEEE standards, the following typical target values for these indices are shown in Table 2.2 below. These are simply design targets, and actual values can of course vary significantly from these values depending on the stage of power system development, utility policy and required reliability in the system. Elektrotek Concepts Inc.1 has reported their experience with utilities in which SAIFI is usually around 0.5 and SAIDI is between 2.0 and 3.0 h.

Table 2.2: Reliability Indices Table

S/No	Index	Target
1	SAIFI	1.0
2	SAIDI	1.0–1.5 h
3	CAIDI	1.0–1.5 h
4	ASAI	0.99983

2.1.6 Distribution System

All distributions of electrical energy are done by constant voltage system. To distribute power to consumers at constant voltage levels and with degrees of reliability that is appropriate to the various types of users distribution system is used. The distribution system needs to be planned, designed, and maintained with particular attention to prevent power interruption. According to connection scheme distribution systems are mainly three types. They are: radial, ring main and interconnected [13].

2.1.6.1 Radial Distribution Systems

A radial system is connected to only one source of supply and is exposed to many interruption possibilities. The most important of which are those due to overhead line or underground cable failures or transformer failures. Each event may be accompanied by a long interruption. Radial feeders tend to have lower reliability than feeders with alternate supply capability. Feeders and transformers have finite failure rates and interruptions are expected and statistically predictable. Feeder breaker re-closing action or temporary faults are likely to affect sensitive loads. Purely radial feeders with no alternate supply capability are usually used for small loads or rural systems. Figure 2.1 shows an example of a small radial feeder single line diagram. This is the simplest distribution circuit and has the lowest initial cost. Therefore, Dilla distribution networks are one of this example. However, it suffers from the following drawbacks.

- The end of the distributors nearest to the feeder point will be heavily loaded.
- The customers are dependent on a single feeder and single distributor. Therefore, any fault on the feeder distributor cuts off supply to the customers who are on the side of the fault away from the substation. The reliability of this system is low.

- The customers at the distant end of the distribution would be subjected to serious voltage fluctuations when the load on the distributor is changed.

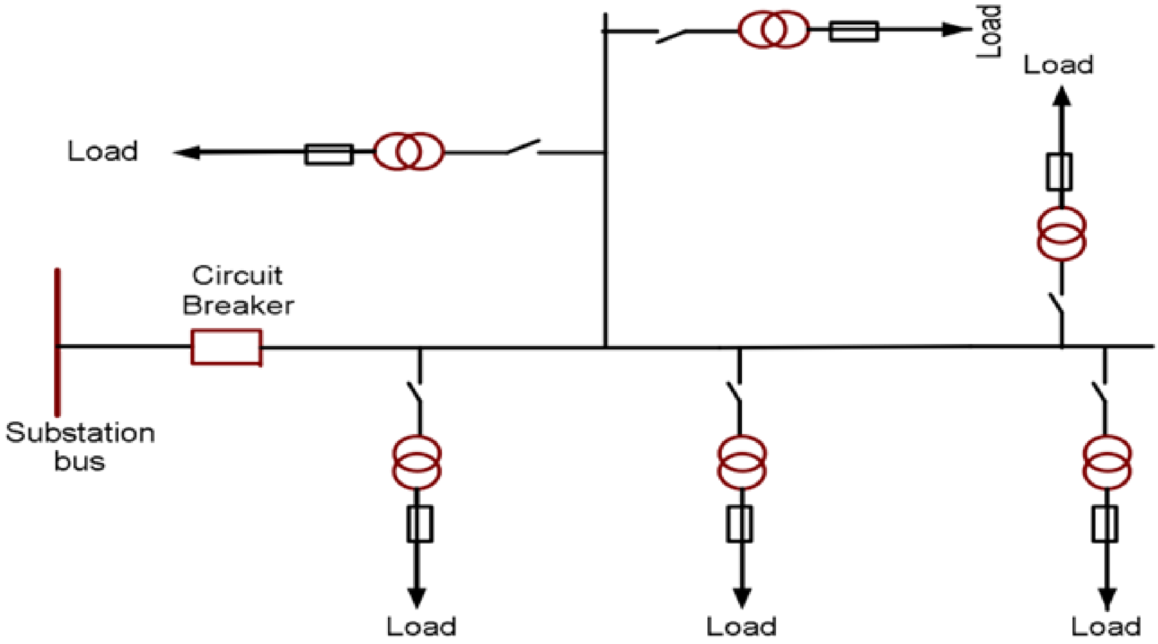


Figure 2.1: A Radial Distribution System

2.1.6.2 Ring Main Distribution System

In this system, the primaries of distribution transformers form a loop. The loop circuit starts from the substation bus-bars, makes a loop through the area to be served, and returns to the substation. Figure 2.2 shows the single line diagram of ring main system for distribution where substation supplies to the closed feeder ABCDEFGH. The distributors are tapped from different points B, D, and F of the feeder through distribution transformers. The ring main system has the following advantages:

- There are less voltage fluctuations at consumer's terminals.
- The system is very reliable as each distributor is fed via two feeders.

In the event of fault on any section of feeder, the continuity of supply is maintained. For example, suppose that fault occurs at any point F of section HAB of the feeder. Then section HAB of the feeder can be isolated for repairs and at the same time continuity of supply is maintained to all the customers via the feeder HGFEDCB.

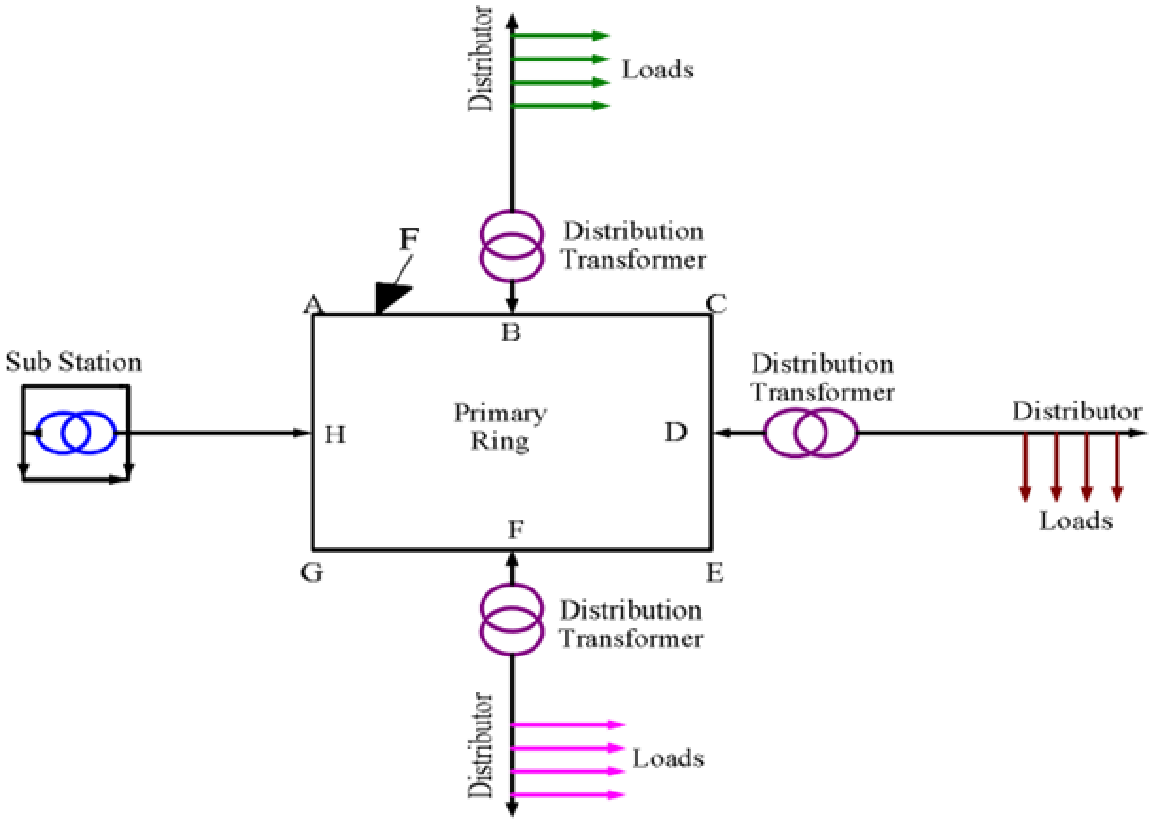


Figure 2.2: Ring Main Systems Single Line Diagram

2.1.6.3 Inter Connected Distribution System

When the feeder ring is energized by two or more than two generating stations or substations, it is called inter connected system. Figure 2.3 shows a single line diagram of inter connected system where the closed feeder ring ABCD is supplied by two substations S1 and S2 at point D and C respectively. Distributors are connected to points O, P, Q and R of the feeder ring through distribution transformers. The inter-connected system has the following advantages:

- It increases the service reliability.
- Any area fed from one substation during peak load hours can be fed from the other substation. This reduces reserve power capacity and increase efficiency of the system.

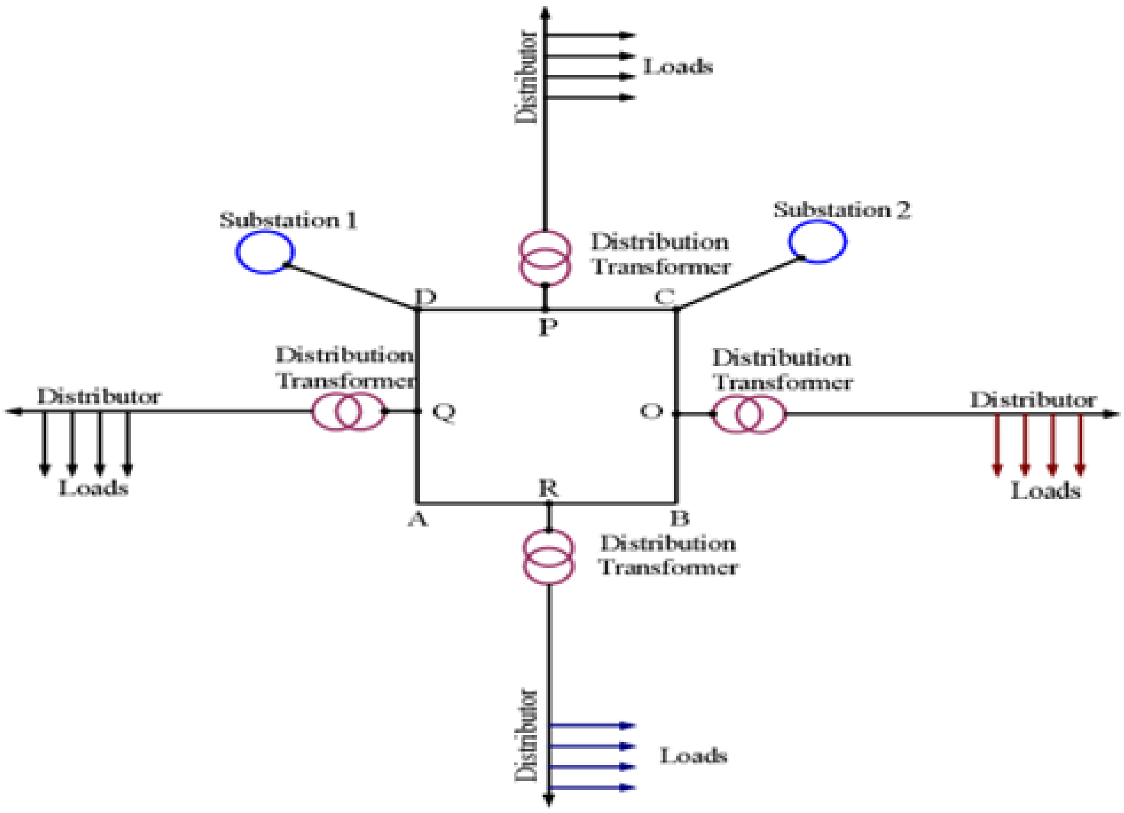


Figure 2.3: Interconnected System Single Line Diagram

2.1.7 Requirements of Distribution System

A considerable amount of effort is necessary to maintain an electric power supply within the requirements of various types of consumers. Some of the requirements of a good distribution system are: proper voltage, availability of power on demand and reliability [14].

(a) Proper voltage

One important requirement of a distribution system is that voltage variations at consumer's terminals should be as low as possible. The changes in voltage are generally caused due to the variation of load on the system. Low voltage causes loss of revenue, inefficient lighting and possible burning out of motors. High voltage causes lamps to burn out permanently and may cause failure of other appliances. Therefore, a good distribution system should ensure that the voltage variations at consumer's terminals are within permissible limits.

(b) Availability of power on demand

Power must be available to the consumers in any amount that they may require from time to time. For example, motors may be started or shut down, lights may be turned on or off, without advance warning to the electric supply company. As electrical energy cannot be stored, therefore, the distribution system must be capable of supplying load demands of the consumers. This necessitates that operating staff must continuously study load patterns to predict in advance those major load changes that follow the known schedules.

(c) Reliability

Modern industry is almost dependent on electric power for its operation. Homes and office buildings are lighted, heated, cooled and ventilated by electric power. This calls for reliable service. Unfortunately, electric power, like everything else that is man-made, can never be absolutely reliable. However, the reliability can be improved to a considerable extent by

(a) interconnected system

(b) reliable automatic control system

(c) providing additional reserve facilities.

Otherwise renovation using appropriate renovation techniques as it deliver reliable supply to distribution consumers is primary intuition.

2.1.8 Design Considerations in Distribution System

Good voltage regulation of a distribution network is probably the most important factor responsible for delivering good service to the consumers. For this purpose, design of feeders and distributors requires careful consideration.

(i) Feeders

A feeder is designed from the point of view of its current carrying capacity while the voltage drop consideration is relatively unimportant. It is because voltage drop in a feeder can be compensated by means of voltage regulating equipment at the substation.

(ii) Distributors

A distributor is designed from the point of view of the voltage drop in it. It is because a distributor supplies power to the consumers and there is a statutory limit of voltage variations at the consumer's terminals (± 6% of rated value). The size and length of the distributor should be such that voltage at the consumer's terminals is within the permissible limits.

2.2. Literature Review

Chinweike I. Amesi, Tekena K. Bala, and Anthony O. Ibe (2017) [1] they have done the paper on the title of Impact of Network Reconfiguration: A Case Study of Port-Harcourt Town 132/33kv Sub-Transmission Substation and Its 33/11kv Injection Substation in Nigeria town. They are focuses on the reconfiguration of distribution network by optimum allocation of capacitor, optimum allocation of distribution generation, tap changing transformer and restructuring of feeder line using Gauss-Seidel algorithms using ETAP12.0 software.
Those papers from (2018-2020) [11], [15], [3] are published in different time in different institutions. But they are almost the same title. In fact the titles are the reliability assessment and reliability enhancement of distribution substation of electrical energy distribution system by focusing on the reliability indices (CAIDI, SAIDI, SAIFI, and EENS). They are introduces Monte Carlo simulation systems and ETAP software used to assess and simulate the overall behavior of the distribution system reliability indices.
L.Ramesh, S.P.Chowdhury, S.Chowdhury, A.A.Natarajan, C.T.Gaunt (2009) [4] are published journal on the title of minimization of power loss in distribution networks by different techniques. Her loss minimization and reliability enhancement are performed. The re-configurations are optimal placement of capacitor, optimal placement of distribution generation and restructuring the re-existing distribution feeder line. The problem of restructuring of the distribution network under normal operation

to reduce active losses and to balance loads in the system will be considered.

Mandefro Teshome and Fsaha Mabrahtu (2020) [16] have done a paper on the title of reliability assessment and study the effect of substation feeder length on failure rate and reliability indices. In this case the effect of feeder length from distribution substation on the reliability of distribution networks are evaluated.

IEEE Std. 1366-2003, IEEE Guide for Electric Power Distribution Reliability Indices, (2004). Typical Values of Reliability Indices are listed. In this case the indices values are SAIDI is 90minutes/year; SAIFI is 11 Interruptions/year CAIDI; is 76 minutes/year and ASAI is 99.982% are archived [17].

Optimal allocation of sectionalizing switches in rural distribution system are performed in middle east university by **Mustafa Daldal** and university in Columbia by **Zhe Chen** and university of Wollongong by **Essa-J-Abdul Zehra, Mahmoud Moghavvemi, Maher M.I. Hasim and Kashem Muttaqi** [18–20] respectively.

As mentioned above, in the previous work the reliability is not enhanced in feasible percentage specially using reconfiguration by different techniques. Also sectionalizing and tie line switch is not collaboratively used with renovation for reliability enhancement. But in this thesis work the sectionalizing and tie switch is collaborated together with distribution system renovation.

CHAPTER THREE

METHODOLOGY AND SYSTEM EVALUATION

3.1. Site Description

Dilla is a market town and capital city of Gedio zone in southern Ethiopia. The administrative center of the Gede'o Zone is in the southern nations, nationalities and peoples region (SNNPR). It is located on the main road from Addis Ababa to Nairobi next to Sidama national region. The town has a longitude and latitude of $6°24'30''N$ $38°18'30''E$, respectively with an elevation of 1570 meters above sea level. It is far away 365Km from Addis Ababa. It includes a number of nation nationalities having total population 91,029 of 2015G.C census data living in Dilla town. The settlement of the people in the town is increasing and expanding from year to year. Also it is expanding in one direction especially to the southern part of the town. Due to this almost one feeder line is exposed to the expansion of electric line for those new settlement. Because they are giving supply with out plan for new settler. As a result the demand of electrical energy consumption is also increasing. The proportional increment of power supply substation capacity is also essential. There for feeder line two is one part of this problem. This increase of demand needs remedy to balance electrical energy consumption demand with proportional to urban population growth. Now days frequently, power interruption, power outage and low power supply are facing in the town. This implies that unreliable power is delivering to the customer with unimproved performance.

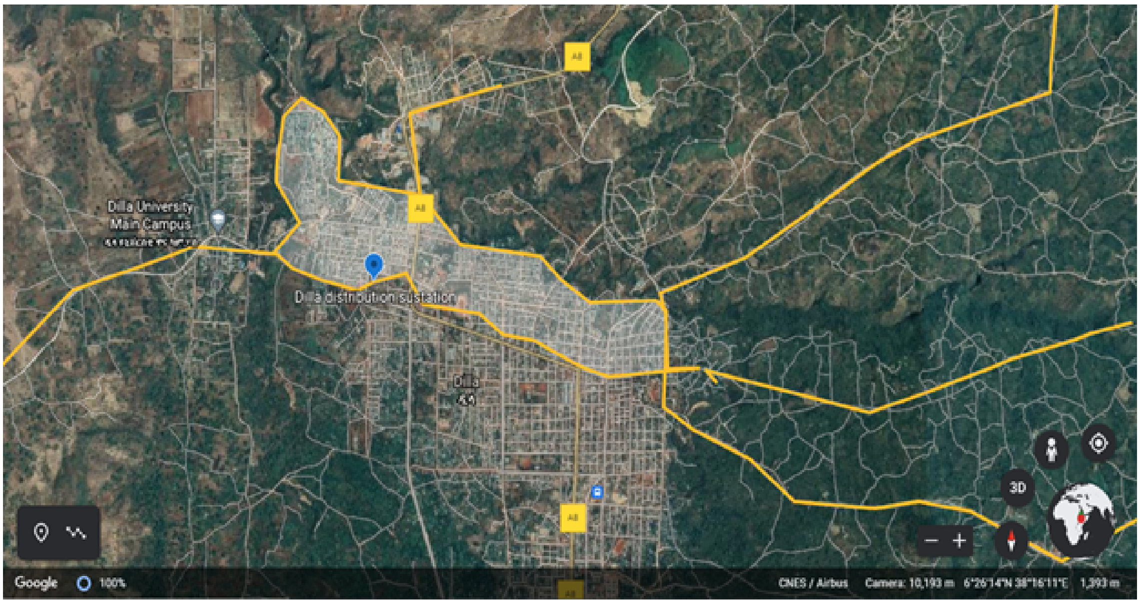


Figure 3.1: Geographical Map of Dilla Town

3.2. Dilla Distribution Network

The line 132KV coming from Hawasa to Dilla pass through Dilla substation to Hageremariam. Another side connected to three winding transformer that can provide supplies to Dilla town having three 15KV and two 33KV feeders. The following figure 3.2 shows the schematic diagram of distribution network.

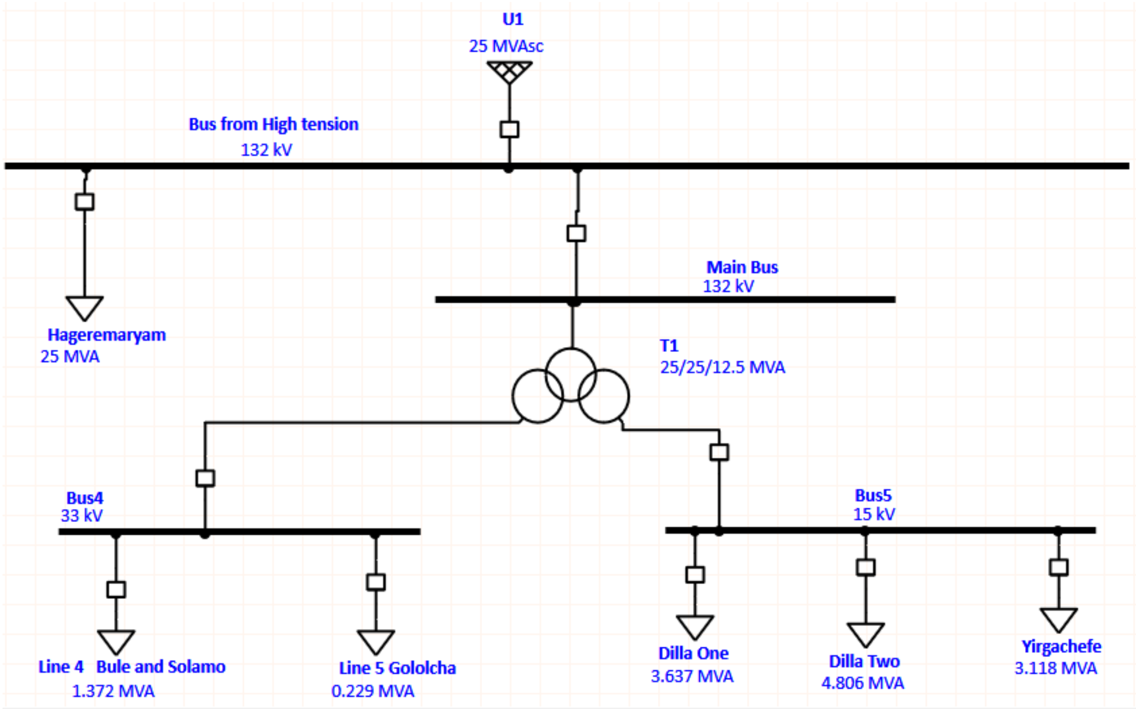


Figure 3.2: Schematic Diagram of Dilla Distribution network

3.3. Existing System (Base Case)

Dilla distribution network have five feeder lines. Three of them are 15kv line and two of them are 33kv. In existing network feeder line one and two are embraces almost all Dilla town distribution line networks. The remaining feeder line three, four and five are connected small number of loads comparatively. There is no balanced sharing of loads through all feeder line. Feeder line one and two encompasses almost all types of load such as, commercial loads industrial loads and residential loads but the remaining three feeder lines are not shares that much loads. This enforces to over flow the power in both feeder line and also decrease its reliability. Due to this, feeder line two selected for this thesis work. The figure 3.3. below shows Composite Network of the pre-existing networks of Dilla town. Since Dilla distribution networks are so bulky to put in one screen board that is why arranged in compost network.

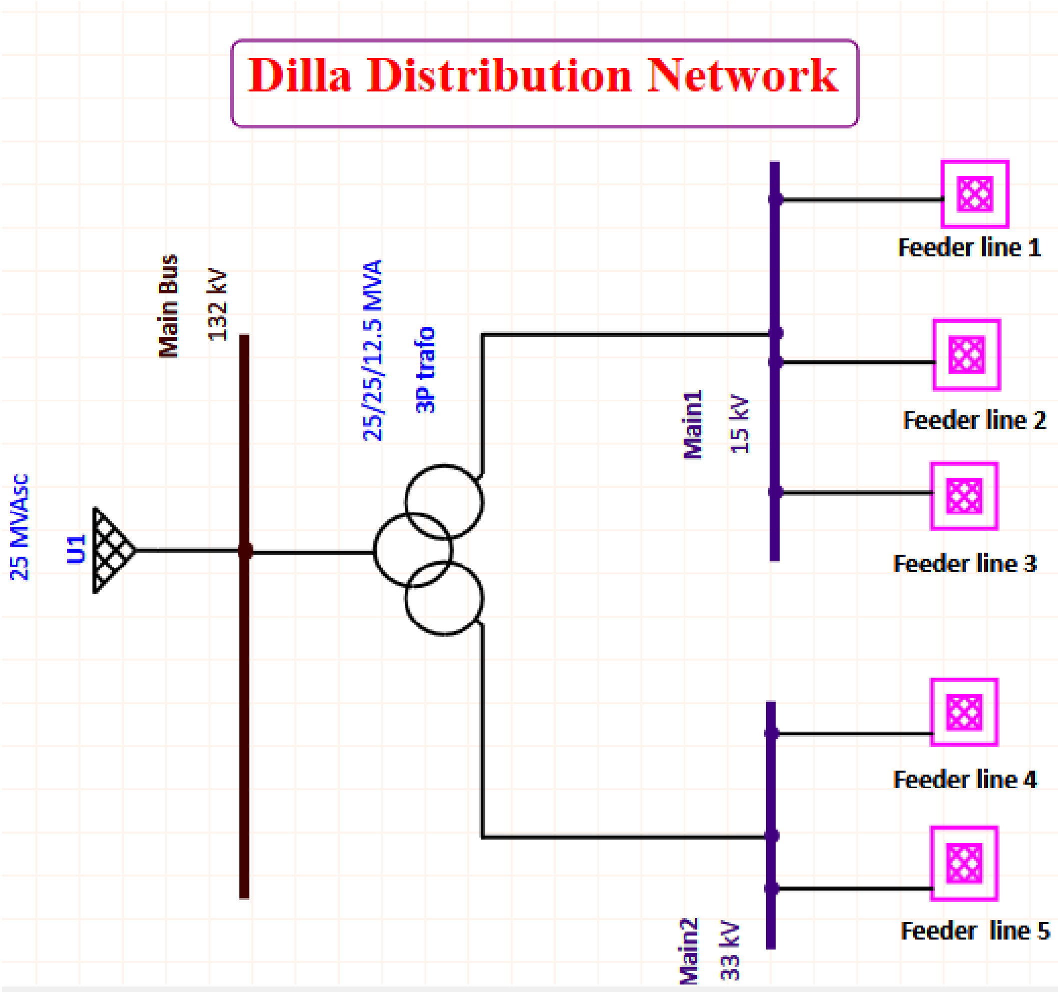


Figure 3.3: Composite Network of Dilla Pre-existing Distribution System

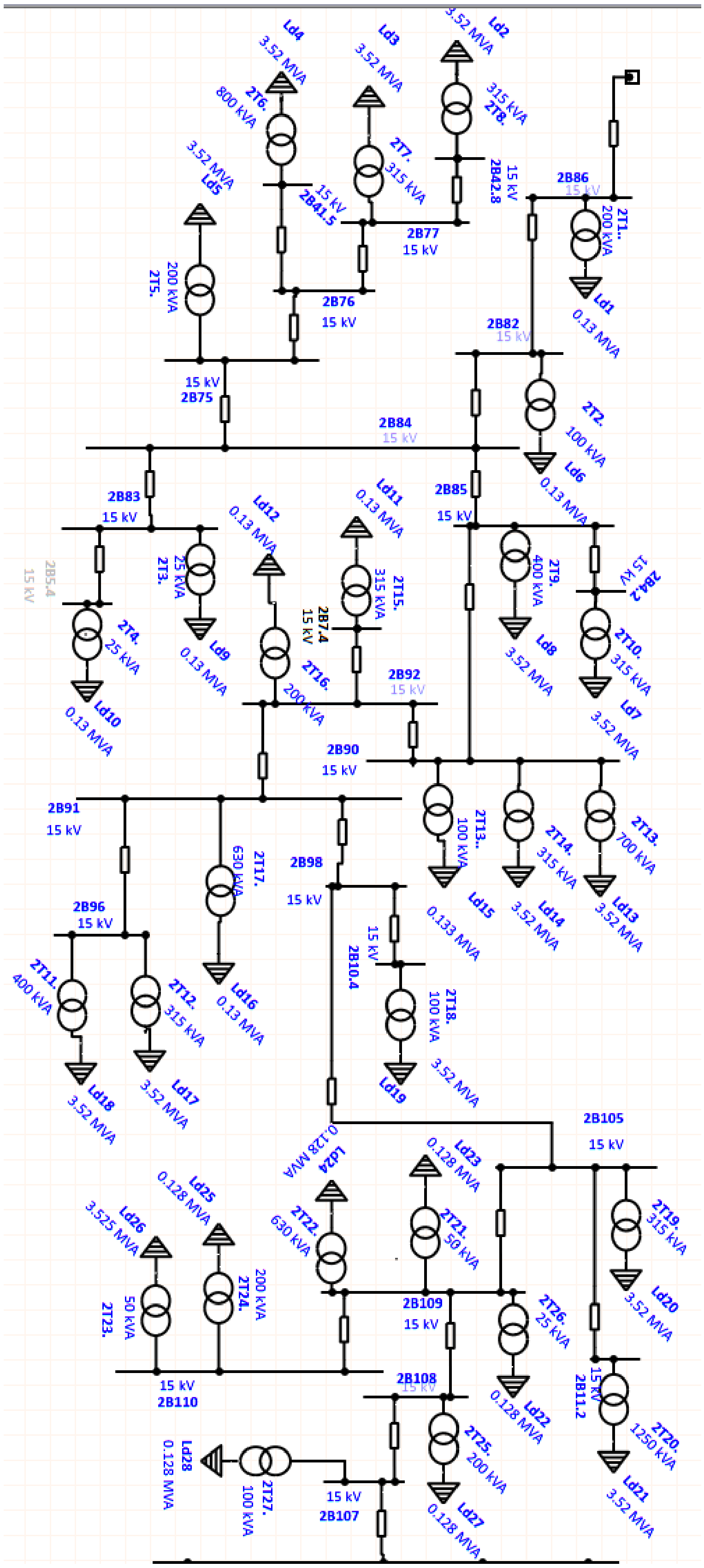


Figure 3.4: Single Line Diagram of Feeder Line Two pre-existing

3.4. Determination of Tie Line and Sectionalizing Switch

The essentiality of tie line and sectionalizing switch in this research is to open and close the line during the renovation of the line is needed. When one side of distribution network is on maintenance the remaining line must provide the supply by using those switches.
This can be determined by simulating ETAP software on power flow mode, which shows overloaded and under loaded equipment's.

(a) Tie Line

A tie line is a physical line that connects two or more feeder line of the electric distribution systems. It is normally open.

(b) Sectionalizing Switch

A sectionalizing switch is a device that isolates a faulted part from the system so that the healthy part can still be electrically supplied and the interruption duration is minimized. It is normally closed.

3.4.1 The flow Chart for FNSGA of Tie Line and Sectionalizing Switch

The flow chart for FNSGA is shown in Figure 3.5. The program written by Matlab code and data required for tie line and sectionalizing switches are shown in the Appendix B and Appendix C respectively.

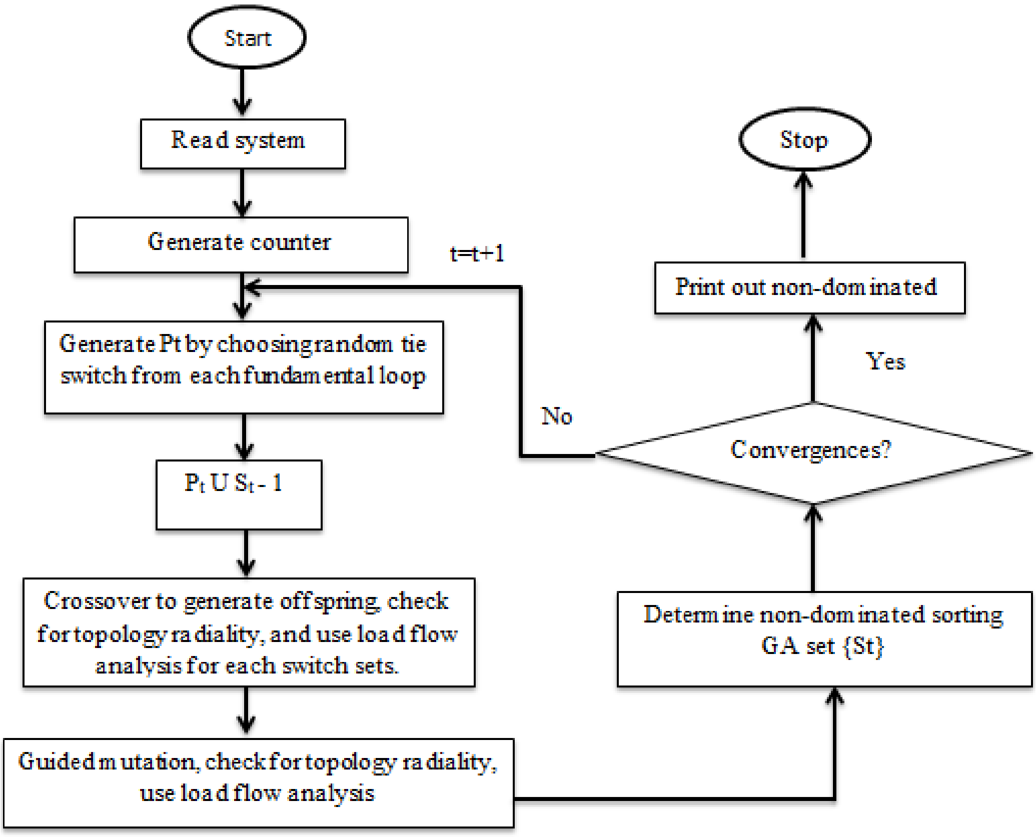


Figure 3.5: FNSGA flow diagram

3.4.2 Single Line Diagram of Distribution Network with Circuit Breaker, Tie Line and Sectionalizing Switch

The typical distribution feeder model represented in the Fig 3.6 holds the circuit breaker, tie line and sectionalizing switches for illustration. As per this figure, the first feeder section l1 is equipped with a circuit breaker at its sending end. Marked with small circles at n_k, connection points of all feeder section to the load nodes are considered candidate locations for installing disconnecting (sectionalizing)switches. At each candidate location, either remote controlled switch(RCS) or manually controlled switches (MCS) may be installed. Whereas r1 is considered as tie line.Therefore, each tie line connects the last node of a feeder to that of its adjacent feeder in order to keep the radial topology of the network. such tie lines must be kept open during normal operation. However, for post-fault network reconfiguration, these tie lines are leveraged to transfer a portion or all of the interrupted demand to its adjacent feeder. On the other hand, if both ends of the tie lines are opened, the network operators cannot monitor the availability of tie lines. In other words, if a tie line is not live, its faults cannot be detected by the protection system. Thus, in practice, each tie line is energized from one side, whereas a normally-open switch is installed at the other end. As per necessity RCS or MCS switch are applied in this research work.

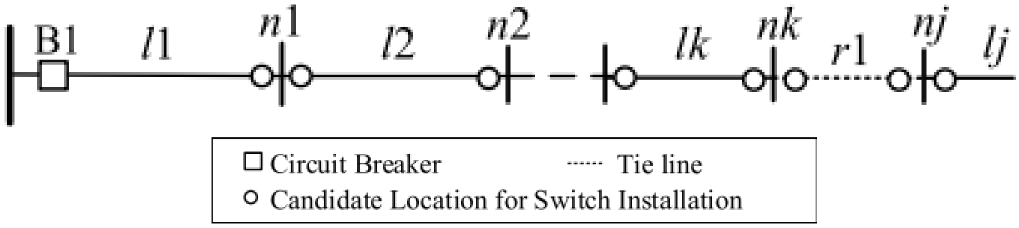


Figure 3.6: A typical distribution feeder.

3.5. Non-dominating sorting GA and Problem Formulation

According to today's demand for electric power, single objective optimization is not enough to satisfy the requirements for distribution systems. As a result, there is usually more than one objective that needs to be taken into the optimization consideration. In this thesis, instead of searching for a single solution that satisfy all the objectives, a set of non-dominated solutions is generated. The concept of non-dominated sorting was based on the non-dominated sorting genetic algorithm-II(NSGA-II)

3.6. Objectives for Optimization

The DSR problem is to determine the optimum status of all the switches in the system. As is mentioned above, the problem is formulated as a multi-objectives optimization problem to optimize system performance. These objectives are expressed as fitness functions to be implemented in the Algorithm.

3.6.1 Reliability indices

Reliability indices are important measures of the distribution system reliability, and they were first developed in 1998 by IEEE specifically for distribution system evaluation. There are many reliability indices, classified into different groups based on usage. In this thesis, only the most representative six indices were considered such as SAIFI, SAIDI, CAIDI, EENS, ASAI and ASUI.

3.6.2 Power Losses

Power losses represent the most important criterion and cannot be ignored in reconfiguration problems. In order to evaluate this criterion, it is necessary to perform the load flow analysis. Basically, power flow algorithms are iterative and are nonlinear. To calculate the losses, the current flow through all the branches of the system must be known by solving the power flow equations. The Power flow analysis, based on Newton-Raphson method, is simple and fast. Some adjustments were adopted to ensure better performance when considering more than one objectives. The expression for power loss is given in equation (3.1).

$$PL = \sum R_b * i^2 \tag{3.1}$$

3.6.3 Minimum Voltage

The purpose of voltage profile optimization is to enhance the power quality [21]. Power quality is extremely important not only for the utility companies' financial profits, but also to maintain a stable electric power supply for the customers. This can be achieved by choosing the system topology with the highest minimum voltage values. Equation (3.2) compares the voltages at all the buses in a certain topology and saves the smallest one as V_{min}. The higher the V_{min} is, the better power quality a topology has.

$$Vmin = min(V_j), j \in N \tag{3.2}$$

where V_j is voltage at bus j whereas N is bus number

3.7. Introduction to FNSGA

In this thesis, the algorithm that is introduced by the author in [21] is adopted. FNSGA is designed for both small and large distribution system optimization problems. However, in this thesis, a few changes and adjustments are made due to focusing only on the status of switches i.e, to open and close the tie line and sectionalizing switches during maintenance's are applicable. The population size of 20 for 62-bus systems are selected in this thesis work. However the crossover rate didn't show much influence on the convergence of the systems. As a result the crossover rates are set to 1 for less complexity of the calculation process. 0.5 and 1 represents on the output of Matlab codes are unavailability time and availability time respectively. For instance, if 0.5 are available on x lines it implies that the y switch what we command on that axis not available. If it is 1, it shows as availability of switch in the nearest line. Based on this result the sectionalizing switch and tie line are performed according to the point of necessity using Matlab code.

3.7.1 Coding

There is a great variety of techniques used for coding topologies (chromosomes or individuals) for GA in DSR. In this thesis, real number coding is adapted because it's not complicated or time-consuming, while most other techniques requires long strings of numbers. Real number codification is presented in [22], and it takes into account the idea of fundamental loops vectors of a network. A fundamental loop is defined as one that does not contain any other loop within itself. Also, fundamental loops are formulated starting from the source(s) side. The number of fundamental loops L of the meshed system is equal to the number of tie (open) switches, and is given by the relation:

$$L = N_b - N + 1 \tag{3.3}$$

where N_b and N are the numbers of branches and buses in the system, respectively.

3.8. Genetic Algorithm Operators

There are five basic genetic algorithms operators which are Population, Fitness function, Selection, Crossover and mutation. This thesis is also follows all of them inside of Matlab code to generate the position of sectionalizing and tie line switch.

(A) Population

The process begins with a set of individuals which is called a Population. Each individual is a solution to the problem you want to solve. An individual is characterized by a set of parameters (variables) known as Genes. Genes are joined into a string to form a Chromosome (solution). In a genetic algorithm, the set of genes of an individual is represented using a string, in terms of an alphabet. Usually, binary values are used (string of 1s and 0s). We say that we encode the genes in a chromosome, as shown in fig 3.7 The population size is one of the most important parameters that play a significant role in the performance of the genetic algorithms. The population size dictates the number of individuals in the population. Larger population sizes increase the amount of variation present in the initial population at the expense of requiring more fitness evaluations. It is found that the best population size is both applications dependent and related to the individual size (number of chromosomes within). A good population of individuals contains a diverse selection of potential building blocks resulting in better exploration. If the population loses diversity the population is said to have "premature convergence" and little exploration is being done. For larger individuals and challenging optimization problems, larger population sizes are needed to maintain diversity (higher diversity can also be achieved through higher mutation rates and uniform crossover) and hence better exploration. Many researchers suggest population sizes between 25 and 100 individual, while others suggest that it must be very much larger (1000 individual or more).

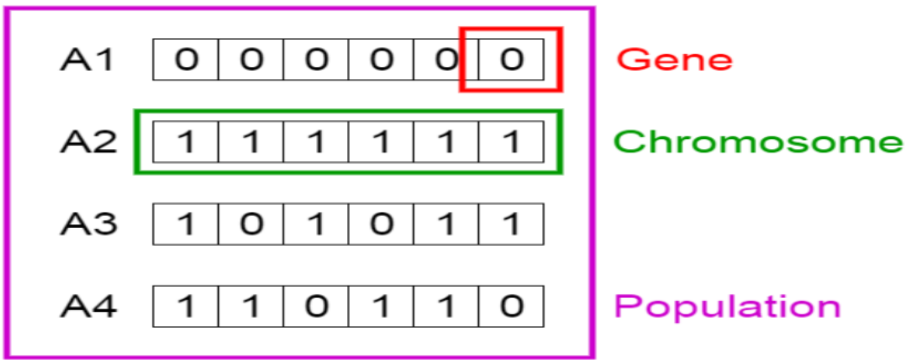


Figure 3.7: Population, Chromosomes and Genes

(B) Fitness Function

The fitness function determines how fit an individual is (the ability of an individual to compete with other individuals). It gives a fitness value to each individual. The probability that an individual will be selected for reproduction is based on its fitness value.

(C) Selection

The idea of selection phase is to select the fittest individuals and let them pass their genes to the next generation. Two pairs of individuals (parents) are selected based on their fitness values [23]. Individuals with high fitness have more chance to be selected for reproduction. Selection is the process of determining the number of times a particular individual is chosen for reproduction and, thus, the number of offspring that an individual will produce. The principle of genetic algorithms is essentially Darwinian natural selection. Selection provides the driving force in genetic algorithms. With too much force, genetic search will terminate prematurely. While with too little force, evolutionary progress will be slower than necessary. Typically, a lower selection pressure is indicated at the start of genetic search in favor of a wide exploration of the search space, while a higher selection pressure is recommended to the end to narrow the search space. In this way, the selection directs the genetic search for promising regions in the search space and that will improve the performance of genetic algorithms. Many selection methods have been proposed, examined and compared. The most common types are:

(i) Roulette wheels selection

(ii) Rank selection

(iii) Tournament selection

(iv) Steady state selection

(v) Elitism

(i) Roulette Wheel Selection

Roulette wheel selection is the commonest selection method used in genetic algorithms for selecting potentially useful individuals (solutions) for crossover and mutation. In roulette wheel selection, as in all selection methods, possible solutions are assigned fitness by the fitness function. This fitness level is used to associate a probability of selection of each individual. While candidate solutions to a higher fitness will be less likely to be eliminated, there is still a chance that they may be. With roulette wheel selection there is a chance some weaker solutions may survive the selection process; this is an advantage, as though a solution may be weak, it may include some component which could prove useful following the recombination process. The analogy between a roulette wheel can be envisaged by imagining a roulette wheel in which each candidate solution represents a pocket on the wheel; the size of the pockets is proportionate to the probability of selection of the solution. Selecting N individual from the population is equivalent to playing N games on the roulette wheel, as each candidate is drawn independently, as shown in figure 3.8

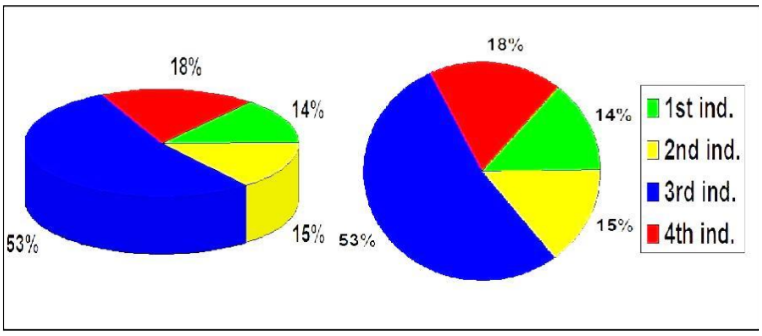
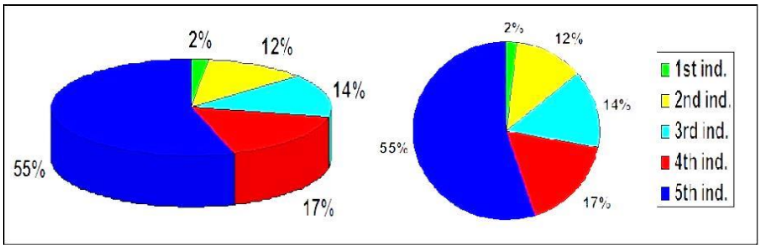


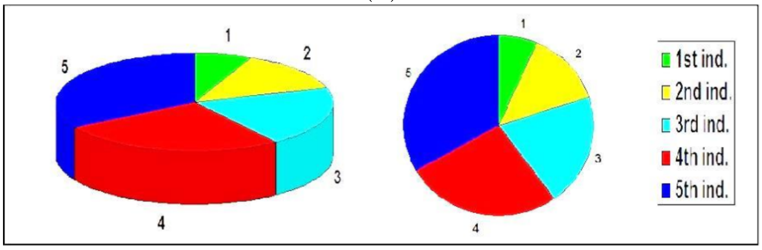
Figure 3.8: Roulette wheel selections

(ii) Rank Selection

In ranking selection, the individuals in the population are sorted through best to worst according to their fitness values. Each individual in the population is assigned a numerical rank based on fitness, and selection is based on this ranking rather than differences in fitness. The advantage of this method is that it can prevent very fit individuals from gaining dominance early at the expense of less fit ones, which would reduce the population's genetic diversity and might hinder attempts to find an acceptable solution. The disadvantage of this method is that it required sorting the entire population by rank which is a potentially time consuming procedure. Rank selection effect is shown in figure 3.9 (a and b).



(a)



(b)

Figure 3.9: Rank selection effects. (a) Before ranking. (b) After ranking

(iii) Tournament Selection

This method randomly chooses a set of individual and picks out the best individual for reproduction. The number of individual in the set is called the tournament size. A common tournament size is two, this is called binary tournament. By adjusting tournament size, the selection pressure can be made arbitrarily large or small. For example, using large Tournament size has the effect of increasing the selection pressure, since below average individuals are less likely to win a tournament while above average individuals are more likely to win it [24].

(iv) Steady State Selection

The steady state selection will eliminate the worst of individuals in each generation [25]. It works; the offspring of the individuals selected from each generation go back into the pre-existing population, replacing some of the less fit members of the previous generation.

(v) Elitism

Elitism is an addition to many selection methods that force genetic algorithms to retain some number of the best individual at each generation. It improves the selection process and save the best individuals. With elitist selection, the quality of the best solution in each generation monotonically increases from time. Without elitist selection, it is possible to lose the best individuals due to stochastic errors (due to crossover, mutation or selection pressure) [26].

(D) Crossover

Crossover is the most significant phase in a genetic algorithm. For each pair of parents to be mated, a crossover point is chosen at random from within the genes. For example, consider the crossover point to be three, as shown below in figure 3.10

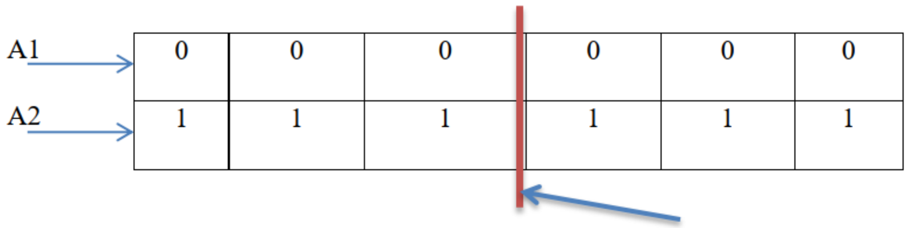


Figure 3.10: Crossover point

Offspring are created by exchanging the genes of parents among themselves until the crossover point is reached, as shown in figure 3.11. And the new offspring are added to the population, as shown in figure 3.12

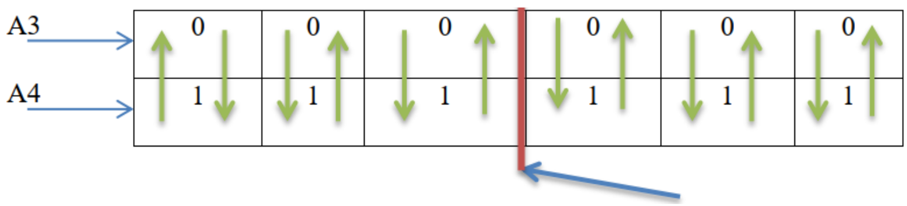


Figure 3.11: Exchanging genes among parents

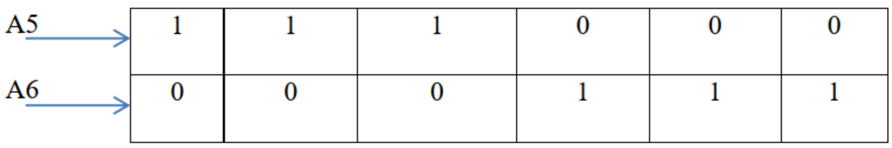


Figure 3.12: New offspring

One of the unique aspects of the work involving genetic algorithms (GAs) is the important role that Crossover (recombination) plays in the design and implementation of robust evolutionary systems. In most GAs, individuals are represented by fixed-length strings and crossover operates on pairs of individuals (parents) to produce new strings (offspring) by exchanging segments from the parents strings. Crossover rate determines the probability that crossover will occur. The crossover will generate new individuals in the population by combining parts of existing individuals. The crossover rate is usually high and application dependent. Many researchers suggest crossover rate to be between 0.6 and 0.95. [27–29]

(i) Single Point Crossover

A commonly used method of crossover is called single point crossover. In this method, a single point crossover position (called cut point) is chosen at random (e.g., between the 10th and 5th point) and the parts of two parents after the crossover position are exchanged to form two offspring, as shown in figure 3.13

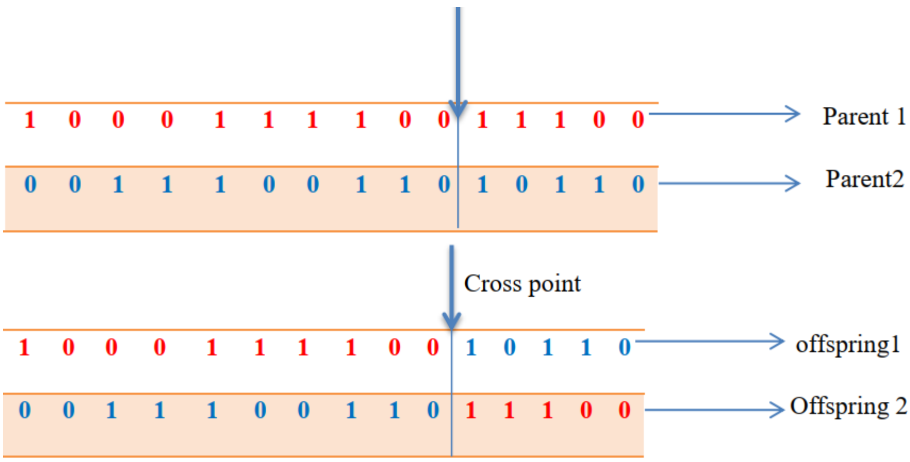


Figure 3.13: Single Point Crossover

(ii) Multi Point Crossover

Multi-point crossover is a generalization of single point crossover, introducing a higher number of cut-points. In this case multi positions are chosen at random and the segments of them are exchanged, as shown in figure 3.14

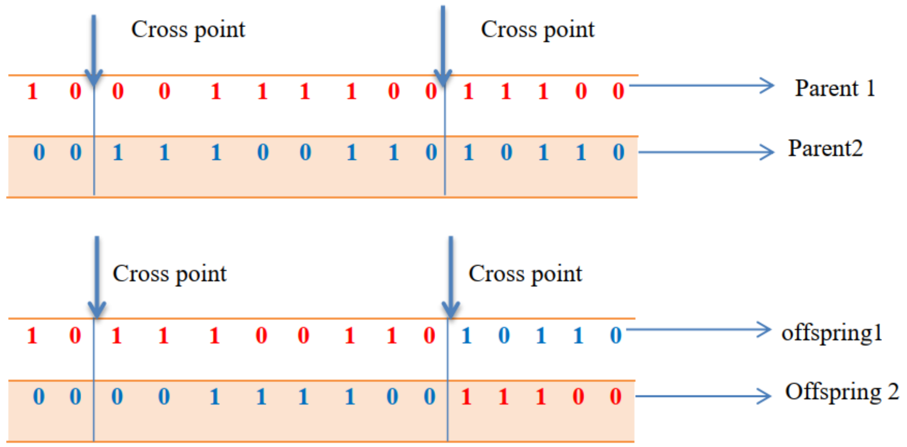


Figure 3.14: Multi point crossover

(iii) Uniform Crossover

Uniform crossover does not use cut-points, but simply uses a global parameter to indicate the likelihood that each variable should be exchanged with two parents, as shown in figure 3.15

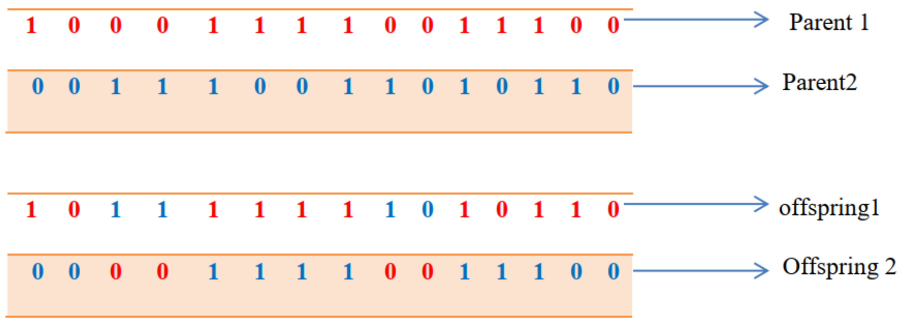


Figure 3.15: Uniform crossovers

(E) Mutation

Mutation rate determines the probability that a mutation will occur. Mutation is employed to give new information about the population (uncover new chromosomes) and also prevents the population of becoming saturated with similar chromosomes, simply said to avoid premature convergence. Large mutation rates increase the probability that good schemata will be destroyed but increase population diversity. The best mutation rate is application dependent. For most applications, mutation rate is between 0.001 and 0.1 [23]. In certain new offspring formed, some of their genes can be subjected to a mutation with a low random probability. This implies that some of the bits in the bit string can be flipped, as shown in fig 3.16

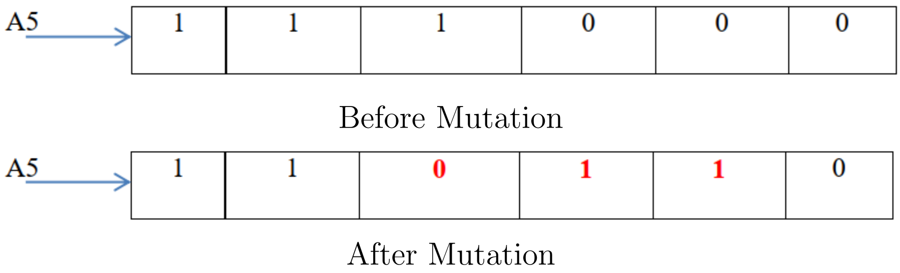


Figure 3.16: Before and After Mutation

(a) Single Point Mutation

Single gene (chromosome or even individual) is randomly selected to be mutated and its value is changed depending on the encoding type used, as shown in figure 3.17

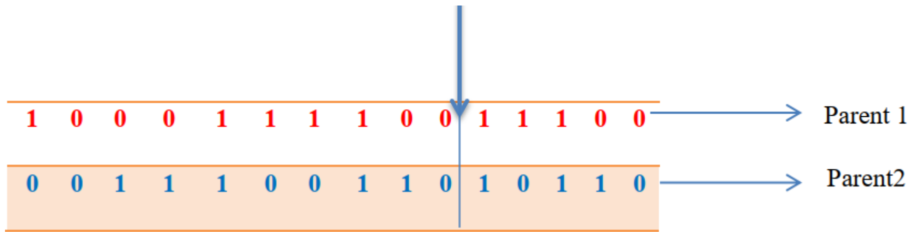


Figure 3.17: Single point mutation

(b) Multi Point Mutation

Multi genes (chromosomes or even individuals) are randomly selected to be mutated and there values are changed depending on the encoding type used, as shown in figure 3.18

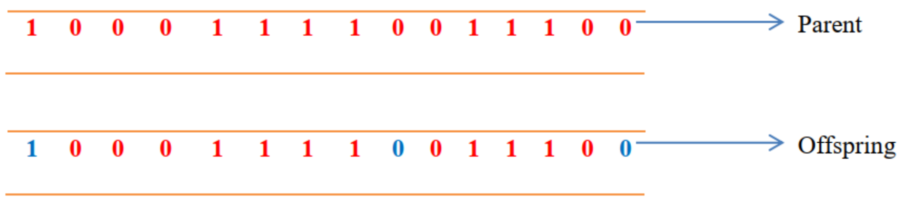


Figure 3.18: Multi point mutation

3.8.1 Radial topology

As is mentioned above, distribution systems are normally operated as radial networks for reliability and network efficiency. Moreover, Dilla distribution network is one of this kind. To create radial topologies, one should select switches from the group of fundamental loop elements that are to be disconnected (one per loop). After the switches are selected to form a chromosome, an approach based on the branch-bus incidence matrix (BBIM) was introduced to determine whether the system is radial (valid tree) [21].

3.8.2 Convergence and stopping criteria

This algorithm stops on either

(1) The number of generations reaches its limit, which is set by the operator. (Generation limit) Or

(2) No changes occur in the non-dominated solution set for four successive iterations. (Fully Convergence)

3.9. Renovating Feeder Line Two

Renovating means re-arranging distribution transformers by considering its capacity. This is performed by restructuring the pre-existing line by replacing many small rated power transformers by one high rated power transformer. The number of overhead cable and buses are reduced compared to pre-existing one. This helps to reduces equipment costs and enhance the reliability. The basic ground to identify the overloaded or under loaded transformers are by simulating load flow mode of ETAP software. Because over loaded or under loaded transformers are displayed on the alert case of the load flow mode. Depending on this ground, these thesis performs renovation as mentioned above. Due to this, there are small rated number of transformers are replaced by few high rated transformers. By this consideration complex arrangements of feeder lines are mitigated, the length of the line is reduced and also the reliability enhanced. The following table 3.1 shows that the previous and replaced equipment's with corresponding rating.

Table 3.1: The Rating of Transformers

s/no	Transformer rating old			Transformer rating new			Remarks
	Tranfo	Rating (KVA)	Individual Loads (MVA)	Tranfo.	Rating (MVA)	Total loads (MVA)	
1	2T1. 2T2.	200 100	0.13 0.13	2T1.	1	0.26	Residential loads
2	2T8.	315	3.52	2T8.	5	3.52	Industrial loads
3	2T6.	800	3.52	2T6.	5	3.5	>>
4	2T5.	200	3.52	2T5.	5	3.52	>>
5	2T10.	315	3.52	2T10	5	3.52	>>
6	2T11.	400	3.52	2T11.	5	3.52	>>
7	2T12.	315	3.52	2T12.	5	3.52	>>
8	2T18.	100	3.52	2T18.	5	3.52	>>
9	2T19.	315	3.52	2T19.	5	3.52	>>
10	2T20.	1250	3.52	2T20.	5	3.52	>>
11	2T23.	50	3.52	2T23.	5	3.52	>>
12	2T29.	1400	3.52	2T29.	5	3.52	>>
13	2T34. 2T35.	200 315	0.128 0.128	2T34	3	=0.256	Residential loads
14	2T45. 2T46.	345 100	0.128 0.128	2T45	3	=0.256	>>
15	2T38. 2T36. 2T37.	100 315 200	0.128 0.128 0.128	2T38	3	0.384	>>
16	2T41. 2T42. 2T43.	315 315 315	0.128 0.128 0.128	2T41	3	0.384	>>
17	2T51. 2T52. 2T50. 2T48.	200 100 315 50	0.128 0.128 0.128 0.128	2T51	3	0.512	>>
18	2T61.	25	0.128	2T61.	0.1	0.128	>>
Total			40.9	***		40.9	**

In order to calculate the load of each transformer we have to know the current value of each buses of distribution line. But in this thesis the only current value available are average current value for each feeder lines. Those are:- feeder line one, two, three, four and five are 140A, 185A, 120A, 24A and 0A respectively. Therefore, it is not possible to calculate each transformer loads depending on this current value.

The reason to replace the existing transformers are as shown in the figure 4.9.below with in few distance many transformers are located. This can causes many disadvantages. such as:- the problem of reliability, the cost of those materials, the complexity for maintenance etc.

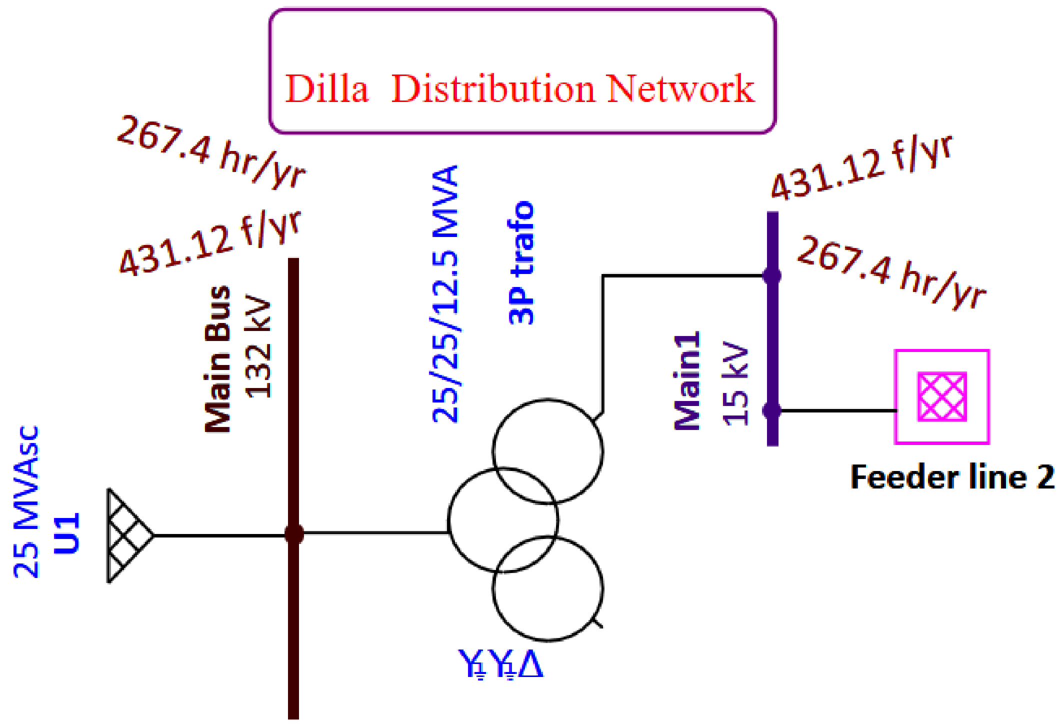


Figure 3.19: Renovated Feeder Line Two With Composite Network

The diagram below shows re-structured distribution networks

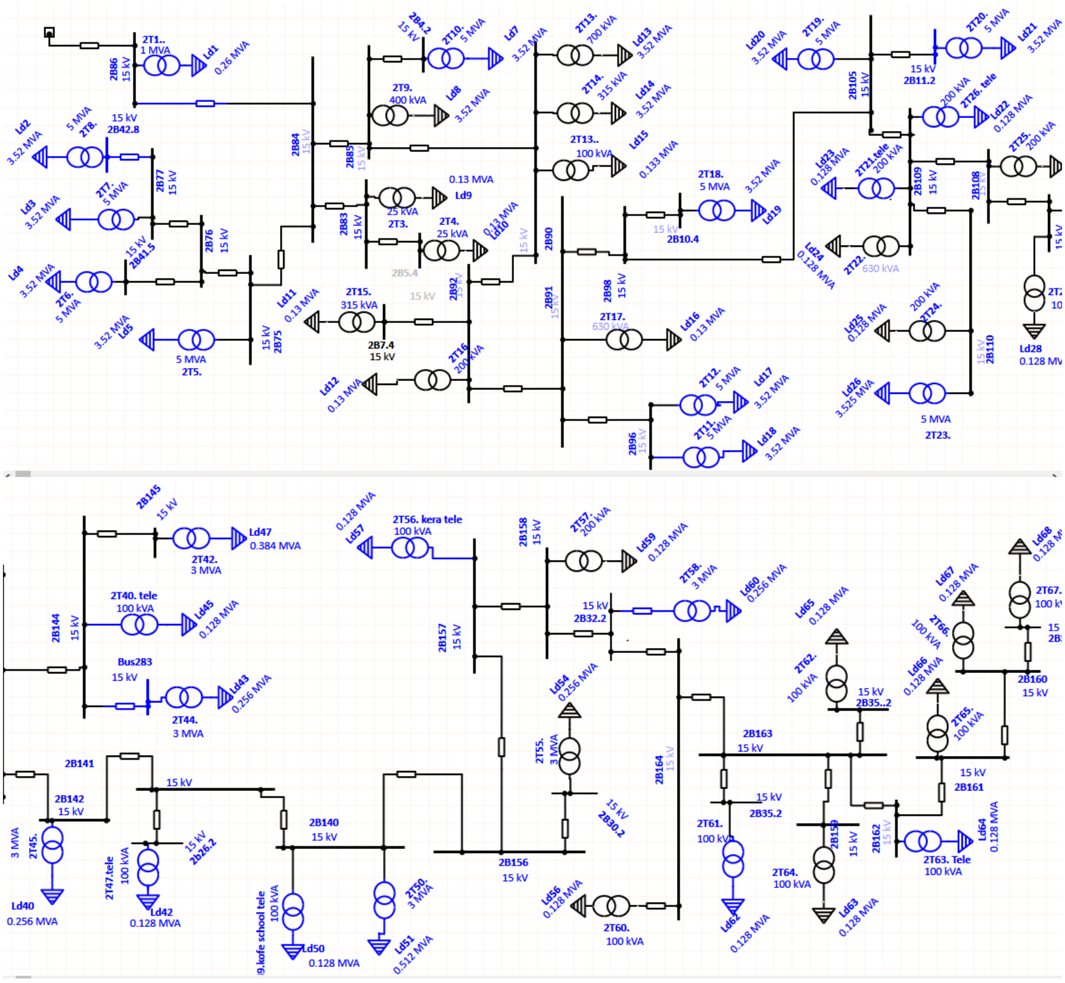


Figure 3.20: Restructured Feeder Line Two

3.10. Determination of Overloaded Transformer

Performance index of the apparent power is used to determine the percentage loading of the transformers in the network. Based on the principle of loading of distribution transformers, 85% of the design rating is considered. A transformer with loading in excess of 85% is considered as overloaded; therefore, precautions should be taken to avoid overloading of a transformer on continuous operation. The percentage loading of each distribution transformers were calculated.

$$\%Loading = \sum_{(i=1)}^{N_T} \left(\frac{S_{MVA}}{S_{MAX}}\right) \times 100 \tag{3.4}$$

Where: S_{MAX} is the MVA rating of the transformer; S_{MVA} is the operating MVA from power flow calculation, and N_T is the number of transformers. For Example, 2T7.

rated 0.315MVA, now operates at 1.093MVA. (See Figure 3.7below)

% loading of 2T8.=1.09/0.287 x 100%=379%

Before renovation Overloaded transformers simulation results are generated. In this case, its maximum rating and operating MVA clarified in the Figure 3.21

Table 3.2: Pre-renovation Simulation Results for Overloaded Transformers

Critical						
Device ID	Type	Condition	Rating/Limit	Operating	% Operating	Phase Type
2T10.	Transformer	Overload	0.315 MVA	1.124	356.9	3-Phase
2T11.	Transformer	Overload	0.4 MVA	1.277	319.2	3-Phase
2T12.	Transformer	Overload	0.315 MVA	1.066	338.3	3-Phase
2T18.	Transformer	Overload	0.1 MVA	0.271	271.3	3-Phase
2T19.	Transformer	Overload	0.315 MVA	0.991	314.5	3-Phase
2T20.	Transformer	Overload	1.25 MVA	2.055	164.4	3-Phase
2T21.	Transformer	Overload	0.05 MVA	0.071	141.7	3-Phase
2T23.	Transformer	Overload	0.05 MVA	0.085	170.6	3-Phase
2T26.	Transformer	Overload	0.025 MVA	0.056	223.3	3-Phase
2T29.	Transformer	Overload	0.4 MVA	1.131	282.6	3-Phase
2T40.	Transformer	Overload	0.025 MVA	0.034	134.6	3-Phase
2T47.	Transformer	Overload	0.025 MVA	0.036	144.7	3-Phase
2T49.	Transformer	Overload	0.025 MVA	0.036	145.6	3-Phase
2T5.	Transformer	Overload	0.2 MVA	0.727	363.6	3-Phase
2T56.	Transformer	Overload	0.025 MVA	0.036	144.4	3-Phase
2T6.	Transformer	Overload	0.8 MVA	1.988	248.5	3-Phase
2T61.	Transformer	Overload	0.025 MVA	0.033	133.8	3-Phase
2T63.	Transformer	Overload	0.025 MVA	0.033	132.8	3-Phase
2T7.	Transformer	Overload	0.315 MVA	1.093	346.8	3-Phase
2T8.	Transformer	Overload	0.287 MVA	1.09	379.3	3-Phase
3P trafo	Transformer	Overload	25 MVA	27.149	108.6	3-Phase

3.11. Determination of Bus Operating Voltage

The bus voltage performance index is used to determine the percentage bus operating voltage. To be within limit bus voltages less than 95% are considered under voltage, whereas those above 105% are considered over voltage.

$$\%operating\,voltage = \sum_{(i=1)}^{N_B} (\frac{V_i}{V_i^{sp}}) \times 100 \tag{3.5}$$

Example: % operating voltage for bus96= 8.267/11 x 100 =75.2%

Where: V_i is the bus voltage magnitude at i^{th} bus; V_i^{sp} is the specified (rated) voltage magnitude at i^{th} bus N_B is the number bus in the system. See figure 3.22 pre-upgrade voltage divided by base kV multiply by 100 is equal to the pre-upgrade % operating voltage

Table 3.3: Under Loaded Bus Voltage Profile

Critical						
Device ID	Type	Condition	Rating/Limit	Operating	% Operating	Phase Type
4b24	Bus	Under Voltage	11 kV	7.001	63.6	3-Phase
Bus104	Bus	Under Voltage	11 kV	6.217	56.5	3-Phase
Bus126	Bus	Under Voltage	11 kV	6.053	55	3-Phase
Bus127	Bus	Under Voltage	11 kV	6.625	60.2	3-Phase
Bus129	Bus	Under Voltage	11 kV	3.055	27.8	3-Phase
Bus130	Bus	Under Voltage	0.415 kV	0.369	88.9	3-Phase
Bus141	Bus	Under Voltage	11 kV	8.405	76.4	3-Phase
Bus142	Bus	Under Voltage	11 kV	5.836	53.1	3-Phase
Bus143	Bus	Under Voltage	0.415 kV	0.309	74.4	3-Phase
Bus144	Bus	Under Voltage	0.415 kV	0.347	83.6	3-Phase
Bus145	Bus	Under Voltage	0.415 kV	0.333	80.1	3-Phase
Bus146	Bus	Under Voltage	0.415 kV	0.314	75.6	3-Phase
Bus147	Bus	Under Voltage	0.415 kV	0.274	66	3-Phase
Bus149	Bus	Under Voltage	0.415 kV	0.34	81.8	3-Phase
Bus155	Bus	Under Voltage	11 kV	1.712	15.6	3-Phase
Bus160	Bus	Under Voltage	0.415 kV	0.309	74.4	3-Phase
Bus161	Bus	Under Voltage	11 kV	6.234	56.7	3-Phase
Bus162	Bus	Under Voltage	0.415 kV	0.305	73.6	3-Phase
Bus235	Bus	Under Voltage	0.415 kV	0.294	70.9	3-Phase
Bus238	Bus	Under Voltage	0.4 kV	0.296	73.9	3-Phase
Bus243	Bus	Under Voltage	0.415 kV	0.292	70.4	3-Phase
Bus246	Bus	Under Voltage	15 kV	10.883	72.6	3-Phase
Bus251	Bus	Under Voltage	0.415 kV	0.285	68.6	3-Phase
Bus253	Bus	Under Voltage	0.415 kV	0.288	69.3	3-Phase
Bus256	Bus	Under Voltage	0.415 kV	0.221	53.2	3-Phase
Bus259	Bus	Under Voltage	0.415 kV	0.274	66.1	3-Phase
Bus261	Bus	Under Voltage	0.415 kV	0.248	59.8	3-Phase
Bus263	Bus	Under Voltage	0.415 kV	0.221	53.3	3-Phase
Bus269	Bus	Under Voltage	0.415 kV	0.264	63.7	3-Phase
Bus274	Bus	Under Voltage	0.415 kV	0.278	66.9	3-Phase
Bus277	Bus	Under Voltage	0.415 kV	0.269	64.7	3-Phase
Bus279	Bus	Under Voltage	0.4 kV	0.268	67.1	3-Phase
Bus281	Bus	Under Voltage	0.4 kV	0.268	67	3-Phase
Bus283	Bus	Under Voltage	15 kV	10.332	68.9	3-Phase
Bus285	Bus	Under Voltage	0.4 kV	0.213	53.2	3-Phase
Bus286	Bus	Under Voltage	0.4 kV	0.28	70.1	3-Phase
Bus288	Bus	Under Voltage	0.4 kV	0.28	70.1	3-Phase
Bus290	Bus	Under Voltage	0.4 kV	0.28	70.1	3-Phase
Bus292	Bus	Under Voltage	0.415 kV	0.281	67.6	3-Phase
Bus313	Bus	Under Voltage	0.415 kV	0.263	63.4	3-Phase
Bus316	Bus	Under Voltage	0.415 kV	0.271	65.3	3-Phase
Bus317	Bus	Under Voltage	0.415 kV	0.263	63.3	3-Phase
Bus318	Bus	Under Voltage	0.415 kV	0.274	65.9	3-Phase
Bus321	Bus	Under Voltage	0.415 kV	0.252	60.8	3-Phase
Bus322	Bus	Under Voltage	0.415 kV	0.212	51.1	3-Phase
Bus323	Bus	Under Voltage	0.415 kV	0.249	59.9	3-Phase
Bus324	Bus	Under Voltage	0.415 kV	0.249	60	3-Phase
Bus325	Bus	Under Voltage	0.415 kV	0.211	50.9	3-Phase
Bus327	Bus	Under Voltage	15 kV	9.799	65.3	3-Phase
Bus709	Bus	Under Voltage	0.415 kV	0.278	66.9	3-Phase
Bus710	Bus	Under Voltage	11 kV	6.121	55.6	3-Phase
Bus95	Bus	Under Voltage	11 kV	5	45.5	3-Phase
Bus96	Bus	Under Voltage	11 kV	8.267	75.2	3-Phase
Bus97	Bus	Under Voltage	11 kV	6.129	55.7	3-Phase

During Re-structuring

Re-structuring is performed based on the distance between several transformers. i.e. within small gap there are many transformers with minimum rating. So, this is bankruptcy. Therefore, those transformers are collected in one central area by increasing its rating. This is the solution to improve the reliability of the system and also cost minimization which was daily, weekly, monthly and yearly consuming for maintenance of damaged networks. Over loaded transformers data are shown in the figure 3.21 and table (3.3-3.8) are listed for illustration.

3.12. Data Collection

Primary data has been collected from Dilla distribution substation and Dilla electric utility office. It was collected by the direct involvement of the researcher and workers of EEU from Dilla branch for the purpose that is intended to be done. During the site survey, the primary data necessary for this study were the length of the feeder, rating and type of each transformer, topology and layout of the system, conductor type, topography and others. The corresponding collected input data are arranged in the following consecutive tables.

One basic parameter for design of the existing system using the software (ETAP 19.0.1) is length of the line. The total length of the feeder has been segmented based on the location of tap points and transformers. The segments were represented as Ln1, Ln2, Ln3... Ln67 and it is measured by km. All successive lines are connected by nodes such as, 2B1 up to 2B39.2. The total length of the feeder line two was summed up 71.98 km before renovation.

Table 3.4: Name and Voltage Level of Dilla Substation Outgoing Feeders

Feeder Name	Voltage level in KV	C.B type	CT ratio and maximum load	Peak load in MW ,2011E.C
Dilla One=L1	15	SF6 Gas Type Circuit breaker	150-300/1 140A	3.2
Dilla Two= L2	15	SF6 Gas Type Circuit breaker	150-300/1 185A	4.2
Yirgacheffe=L3	15	SF6 Gas Type Circuit breaker	150-300/1 120A	2.8
Bule and Solamo =L4	33	SF6 Gas Type Circuit breaker	75-150/1 24A	1.2
Gololcha=L5	33	SF6 Gas Type Circuit breaker	75-150/1 4A	0.207

Table 3.5: Feeder Line One Cable Length Data

Line Name	Length of line in (km)	Line Name	Length of line in (km)
1	0.35	44	0.3
2	0.25	45	0.09
3	2	46	0.1
4	0.75	47	0.06
5	0.3	48	0.35
6	0.15	49	0.975
7	0.3	50	0.3
8	0.25	51	0.3
9	0.95	52	0.45
10	0.25	53	0.175
11	0.2	54	0.35
12	0.5	55	3
13	0.15	56	5
14	0.4	57	4.3
15	0.3	58	6
16	0.75	59	2
17	0.3	60	2
18	0.8	61	1.9
19	0.2	62	0.75
20	0.6	63	7

Line Name	Length of line in (km)	Line Name	Length of line in (km)
21	0.4	64	2.3
22	0.75	65	2
23	0.65	66	0.3
24	0.15	67	0.35
25	0.35	68	0.1
26	0.25	69	3
27	0.1	70	1
28	0.4	71	4.5
29	0.3	72	0.75
30	0.2	73	3
31	1.15	74	0.375
32	1	75	0.9
33	0.2	76	0.3
34	0.1	77	4
35	0.3	78	0.5
36	0.69	79	2
37	0.25	80	4
38	1	81	0.7
39	0.75	82	2
40	2.3	83	5
41	0.5	84	5
42	0.45	85	1.5
43	0.29	86	5
Total	**22.28**	**Total**	**83.975**
GRAND TOTAL		**106.255**	

Table 3.6: Feeder Line Two Cable Length Data

Line Name	Length of line in (km)	Line Name	Length of line in (km)
1	0.5	35	0.03
2	0.2	36	2.25
3	0.075	37	0.25
4	0.4	38	1.75
5	0.25	39	0.5
6	0.29	40	0.35
7	0.55	41	1
8	0.15	42	0.7
9	0.15	43	0.3
10	0.125	44	0.9
11	0.3	45	3.15
12	0.3	46	0.3
13	0.1	47	0.03
14	0.1	48	0.9
15	0.25	49	0.9

Line Name	Length of line in (km)	Line Name	Length of line in (km)
16	0.2	50	0.15
17	0.2	51	0.06
18	0.75	52	0.06
19	0.35	53	
20	0.09	54	1.5
21	0.75	55	2.25
22	0.75	56	0.5
23	0.5	57	0.1
24	0.2	58	5
25	0.9	59	0.9
26	0.75	60	3.4
27	1	61	4.09
28	0.7	62	4
29	0.1	63	2.09
30	0.1	64	0.58
30.	3	65	7
31	0.25	66	1
32	0.5	67	4
33	2.66		
34	4.5		
TOTAL	**21.99**	**TOTAL**	**49.99**
GRAND TOTAL		**71.98**	

Table 3.7: Feeder Line Three Cable Length Data

Line Name	Length of line in (km)	Line Name	Length of line in (km)
1	5	9	3
2	0.23	10	0.9
3	0.5	11	1.2
4	1.7	12	0.3
5	0.2	13	0.06
6	3	14	2.25
7	5	15	1.5
8	4		
TOTAL	19.63	**TOTAL**	**9.21**
GRAND TOTAL		**28.84**	

Table 3.8: Feeder Line Four Cable Length Data

Line Name	Length of line in (km)	Line Name	Length of line in (km)
1	5	8	3
2	5	9	0.9
3	5	10	3.06
4	1	11	3
5	1.5	12	4
6	6.5	13	3
7	1.5	14	5
TOTAL	**25.5**	**TOTAL**	**21.96**
GRAND TOTAL		**47.46**	

Table 3.9: Feeder Line Five Cable Length Data

Line Name	Length of line in (km)	Line Name	Length of line in (km)
1	7	6	5.2
2	2	7	10.1
3	5	8	10.75
4	5	9	5
5	12		
TOTAL	**31**	**TOTAL**	**31.05**
GRAND TOTAL		**62.05**	

Table 3.10: Renovated Feeder Line Two Cable Length Data

Line Name	Length of line in (km)	Line Name	Length of line in (km)
1	0.5	35	
2		36	1.5
3	0.075	37	
4	0.4	38	
5	0.25	39	0.555
6	0.29	40	0.35
7	0.55	41	
8	0.15	42	0.7
9	0.15	43	
10	0.125	44	0.45
11	0.3	45	1.4
12	0.3	46	
13	0.1	47	0.03
14	0.1	48	0.9

Line Name	Length of line in (km)	Line Name	Length of line in (km)
15	0.25	49	0.9
16	0.2	50	0.9
17	0.2	51	
18	0.75	52	
19	0.35	53	
20	0.09	54	
21	0.75	55	1.875
22	0.75	56	0.5
23	0.5	57	0.1
24	0.2	58	
25	0.9	59	0.45
26	0.75	60	3.4
27	1	61	4.09
28	0.7	62	4
29	0.1	63	2.09
30	0.1	64	0.58
30.	3	65	7
31	0.25	66	1
32	0.5	67	4
33	2.66		
34	4.5		
TOTAL	21.79	TOTAL	36.77
GRAND TOTAL		58.56	

Table 3.11: Transformer and Customer Data of Dilla feeder Line two

Dilla feeder line two transformer data				
S.No	Specific area/location	Transformer size in KV	#Estimated customers served	Manufactured and year
1	Donbosco	315	325	Italy 1989
2	Dilla stadium tele tower	25	1	METEC 2002
3	Dilla university water service	100	1	India 2013
4	Green park condominium	200	243	India2009
5	02 dilla water service	50	41	India2009
6	Dilla old bus station	315	278	METEC 2003
7	Dilla gibrina 04 kebele	200	223	India1974
8	Tele tower 03 kebele floor mill	315	335	METEC2007
9	Tele 03 kebele flour mill area	315	320	China 2003

10	08 kebele kocho market	25	1	METEC2004
11	Dilla technique school	315	343	Italy1998
12	Dilla TTC gibrina collage	630	450	India 2003
13	Dilla teacher union	200	287	Italy1995
14	Dilla ttc tele tower	25	1	India2009
15	DU main campus	315	320	METEC2009
16	DU main campus	630	630	India2003
17	Du main campus	315	235	China2003
18	DU tele tower	25	1	India1990
19	DU water pump	50	1	India1995
20	Dilla walame tele tower	25	1	India1993
21	Dilla waleme dombosco	100	50	India1998
22	Waleme mekelakeya (deffence)engineering	630	570	China2011
23	Odaya university customer use	50	38	METEC2006
24	Odaya university	315	310	METEC2004
25	Odaya university	630	500	China1992
26	Odaya university water treatment	315	1	METEC
27	Odaya university tele tower	25	1	India1997
28	Odaya university	800	620	China2015
29	Odaya university water service	50	1	China2004
30	Dilla saron lodge	25	1	India2000
31	Dlla EEu main office	200	255	Italy1993
32	Tele tower EEU office	25	1	India2004
33	Alli factory	200	80	China1995
34	Banko dela	100	65	ETHIOPIA2005
35	Kebado Donbosco	100	120	ETHIOPIA2002
36	Kebado hospital	315	305	WSWUGIANG 2007
37	Kebado tele office	50	1	CROTIA2000
38	Kebado floor factory	315	350	PAUWELS1988
39	Kebado safa	100	190	China2008
40	Kebado main	315	281	ZENNARO1995
Total			**7865**	

Table 3.12: Summary of Reliability Indices of Dilla Town Feeder for Years (2015-2019 G.C)

Reliability indices	Unit	2015	2016	2017	2018	2019	Average of five years	Simulated base
SAIDI	Hrs/Customer/yr	454	329	260	419	587	**409.8**	312.67
SAIFI	Int./Customer/yr	678	521	656	692	747	**658.8**	497.94
CAIDI	Hrs./Interruptions	0.67	0.63	0.39	0.605	0.78	**0.61**	0.628
EENS	MWH	647	380	502	668	860	**611.4**	128.31

The summary of interruption five years data from the 2015 to 2019G.C was selected as a base year for the system to predict its future reliability performance. Therefore, the average of five years reliability indices are taken as base year as it is listed in the table 3.12 above. As it is bulky to put the detailed interruption data with respect to the causes it happen of each year as part of this document, only interruptions data of year 2015 was selected as a sample and placed in the Appendix A for illustration. Hence,the simulated base year data used as average year data. Because the data obtained from distribution substation shows, the PLC of substation is not working properly. Due to that, average data provided for this thesis work from the PLC machine can read through out the year.

3.13. Causes of Power Interruptions

In Dilla each interruption, interruption duration and loads of each feeder per hour is recorded and also causes of interruptions are described. Such as, Single line to ground fault, double line to ground fault, Line to line fault and also total power interruptions are archived. This implies totally ten different types of faults are available. On appendix A only one year interruption data are recorded for illustration. This implies the customers in this distribution system are unsatisfied with the supplied power. Since there are different types of faults, it is difficult to put total mitigation techniques. Even the maximum percent of cause of interruption is due to feeder overloaded problems as data collected from questionnaire, this thesis developed To minimize as much as possible. To know the causes of interruptions the questioners were prepared to the employees and longtime daily workers (they are working technicians for longtime as employees of the Dilla utility). The questioner was prepared to describe the common causes of interruptions in the selected feeder line two for the last five years. After identifying the causes of interruptions, the experienced employees have been requested in order to categorize the causes according to the degree of contribution. It was very difficult to categorize the causes, at the end of the discussion respondents decided to put their agreement level. For the purpose of determining the degree of contribution of each factor the point is assigned for the agreement level from one up to five points. The allocation of the point is Five (5) for strongly agree, Four (4) for agree, Three (3) for neutral, Two (2) for disagree and One (1) for strongly disagree. Accordingly table 3.12 was prepared and 23 employees (i.e. emergency operators of distribution and substation, distribution technicians, Dilla utility customer center technicians, some distribution managers who have been worked for long time in the distribution but now working in another task of the utility) and fourteen (14) experienced daily laborers have given their response. The questioner was prepared in Amharic and the agreement levels with their translated English meaning were: 'Betam Esmamalehu' /strongly agree/, 'Esmamalehu' /Agree/, 'Enie Enja' / Neutral/, Alsmamam' /disagree/ and 'Fetsimo Alsmamam' / strongly disagree/. Based on their response as depicted in Table 3.12, feeder overloading ranked in the first place followed by tree contact, windy rain, Wear out and failure of distribution materials, Human errors, Supply errors, scheduled interruptions, Natural phenomenon, Unknown, Employees skill gaps or errors, Others, Animals and birds, and Vehicles accidents on distribution equipment's respectively as they are ranked from one up to thirteen. The factors ranked at the top have a high degree of contribution for the electric power interruptions. From the questioner and discussion with the senior technicians, substation and emergency operators, top managers and experienced laborers, the most common causes of interruptions are: trees, overload, windy rain, lightning, accidents, Animals, scheduled interruptions, human error, generation outage, equipment malfunction, unknown causes of interruptions and others [30].

(i) Feeder Over Load

Based on the questionnaire and the discussion conducted with line technicians overload is ranked first as a cause of power interruption. Transformers, lines and equipment's are overloaded above their capacity, as more and more customers are connected to existing distribution system.

(ii) Tree Contact

Per the discussion with line technicians trees are identified as cause of power interruption. Since Dilla town covered by large trees, its faults are occasionally happening problems. Tree trimming, periodically pruning vegetation adjacent to power lines to ensure safe and reliable clearances, is a critical utility activity. Many customers have extremely negative responses to tree trimming. Tree trimming should always be performed by a trained crew to ensure safety, maintain tree health and direct re-growth away from conductor location. But in Dilla area trimming is performed by the community and it is not done as per standard.

(iii) Windy Rain

Wind may cause power lines to swing together resulting in a fault or short circuit that interrupts service. Strong wind can blow tree limbs or entire trees into power lines causing them to fall to the ground. Severe winds can even break power lines and utility poles, bringing down extensive portions of the infrastructure that delivers power.

(iv) Wear out and Failure of distribution materials.

There are many distribution materials in electrical distribution system. Such as distribution transformer, distribution line (cable), circuit breaker etc. Wear Out failures is the results of material wear out. Normally, the wear out mode becomes predominant only after 20 years of operation. This normal wear out period is followed by an increasing failure rate.

(v) Human errors

Customer interruptions are often caused by Human errors which are happened by carelessness and improper works (Daily labors and junior technicians) by utility workers. The utility Workers who have informal relationship with contraband traders interrupt the line when they need. Carelessly cut down of trees and dropping heavy branch over power distribution lines causes long time power interruptions. Most of time in addition to Dilla town; also the villages located nearest to Dilla town happened these kinds of problems. Since the environment is covered by trees, it falls on the power line most of time through the year especially during summer (rainy) season. The technicians order the farmers to remove out those trees which lean on the power line. But the power line going to be damaged due to the farmers falling downs the tree on it. The technicians maintain the line badly by receiving per dime from the farmer and also it will damage after few weeks or days. Miss-connection of electric line results interruption problems.

(vi) Supply errors

Electric power distribution is the final stage in the delivery of electric power. It carries electricity from the transmission system to individual consumers. Often several customers are supplied from one transformer through secondary distribution lines. In this case several errors may occur. Such as, Individual transformer phase label error, Lateral phase label error, Three-phase customer labeled as single-phase, Single-phase customer labeled as three-phase etc.

(vii) Scheduled Interruptions

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

(viii) Natural phenomenon

Earthquakes, wildfires, floods and mudslides can wreak havoc on systems too. Less commonly, volcanic eruptions and tidal waves can also be reasons for power outages. Major events like these can knock down transmission lines, damage transformers and destroy substations.

(ix) Others

Excavation digging Sometimes, underground cables are disturbed by digging. It's important to call to authorized office before any gardening or digging project. **High Power Demand** During heat waves and other times of unusually high power demand, overburdened electric cables, transformers, and other electrical equipment can melt and fail.

(x) Small animals

Small animals can cause power outages. When animals climb on equipment, such as transformers or fuses, they can cause a short circuit interrupting the flow of power.

(xi) Vehicle Accidents

Vehicles coming into contact with utility poles are a common cause of power outages. This is occurred due to speeding automobile by illegal drivers such as informal licensed drivers, not licensed, unexperienced drivers, or drunk drivers and others accidentally striking a wooden distribution pole and usually causes the pole to lean, causing unsafe line clearances and requiring repair. These collisions may also result in a fault by causing conductors to swing together, sagging lines into the ground or damaging the pole entirely. In some places the electric lines are below the prescribed clearance limit. In this cause when the vehicles flow with loaded height above the line clearance, It may detach the line or may swing together.

Table 3.13: Summery of Questionnaires About Causes of Power Interruption

S.No.	Causes of interruptions	Contributing factor agreement levels					Total points	Rank
		Strongly Agree	Agree	Neutral	Disagree	Strongly disagree		
1	Feeder Overloaded	20	12	2	2	1	159	1
2	Tree contact	18	12	4	2	1	155	2
3	Wear out and Failure of distribution Materials	15	12	1	7	2	142	4
4	Windy rain	14	11	7	3	2	143	3
5	Vehicle accidents on distribution equipment	1	5	7	11	13	81	13
6	Scheduled Interruptions	7	9	5	6	10	108	7
7	Human errors	9	8	12	5	3	126	5
8	Supply outage	8	7	10	7	5	117	6
9	Employees skill gaps or errors	5	9	2	11	10	99	10
10	Natural phenomenon	3	10	5	12	7	101	8
11	Animals and birds	4	5	7	8	13	90	12
12	Unknown	6	7	5	8	11	100	9
13	Others	3	6	9	11	8	96	11

Furthermore, many reasons for prolongation of the outage duration were identified. Some of them are: lack of automatic fault detectors due to substation equipment (gadget) errors, shortage of maintenance tools, shortage of skilled man power, communication gap between substation operators and utility workers, unnecessary scheduled outages, over stressed utility workers (technicians) and the workers payment unsatisfaction.

The PLC machine in distribution substation of feeder line five reads approximately zero current value for all phases of relative feeders. This is happening due to PLC machine damage even there are loads available.see the table 3.13 below.

Table 3.14: Records Peak Load Data at the Injection Substations

Feeders name	Feeders rating	Feeders load Current (A)	Peak Load Feeders apparent power MVA	Feeders real power MW
Dilla one(L1)	15Kv	140	3.6	3.3
Dilla two(L2)	15KV	185	4.8	4.2
Yirgacaffe(L3)	15KV	120	3.12	2.8
Bule and solamo(L4)	33KV	24	1.4	1.2
Gololicha(L5)	33KV	0	0	0

Peak loads for the injection substations evaluated in the equation(3.6-3.17) as follows for all feeders. Each feeder load currents are average currents obtained by summing up all feeders yield to the corresponding feeder.

Peak load (A) $I_L = I_1 + I_2 + I_3 + I_4 + I_5$

Example: for Dilla one(1)

Peak load (A)I_L= $I_1 + I_2 + I_3 + I_4 + I_5 = 140$

$$Peak\ load(MVA) = \sqrt{3}V_L I_L \cos\phi \tag{3.6}$$

$$Peak\ load(MW) = MVA \cos\phi \tag{3.7}$$

$$P_1 = \sqrt{3}V_L I_L \cos\phi = \sqrt{3} * 15000 * 140 * 10^{-6} = 3.6MVA \tag{3.8}$$

$$P_1 = \sqrt{3}V_L I_L \cos\phi = \sqrt{3} * 15000 * 140 * 0.9 = 3.3MW \tag{3.9}$$

$$P_2 = \sqrt{3} * 15000 * 185 * 10^{-6} = 4.8MVA \tag{3.10}$$

$$P_2 = \sqrt{3} * 15000 * 185 * 0.9 = 4.2MW \tag{3.11}$$

$$P_3 = \sqrt{3} * 15000 * 120 * 10^{-6} = 3.12MVA \tag{3.12}$$

$$P_3 = \sqrt{3} * 15000 * 120 * 0.9 = 2.8MW \tag{3.13}$$

$$P_4 = \sqrt{3} * 33000 * 24 * 10^{-6} = 1.4MVA \tag{3.14}$$

$$P_4 = \sqrt{3} * 33000 * 24 * 0.9 = 1.2MW \tag{3.15}$$

$$P_5 = \sqrt{3} * 33000 * 0 * 10^{-6} = 0MVA \tag{3.16}$$

$$P_5 = \sqrt{3} * 33000 * 0 * 0.9 = 0MW \quad (3.17)$$

Where I_L is the total peak loads of respective outgoing feeders at the injection substation in (A); V_L is the line voltage of the feeder in (kV); $\cos\phi$ is the power factor so that the peak load is in MW

Table 3.15: The 15KV Feeder Line and Their Injection Substations

Injection Substation Name	Capacity
2T1.	200kVA(15KV/0.415KV)
2T2.	100KVA(15KV/0.415KV)
2T3.	25KVA(15KV/0.415KV)
2T4	25KVA(15KV/11KV)
2T5.	200KVA(15KV/11KV)
2T6.	800KVA(15KV/11KV)
2T7.	315KVA(15KV/11KV)
2T8.	315KVA(15KV/11KV)
2T9.	400KVA(15KV/11KV)
2T10.	315KVA(15KV/11KV)
2T11.	400KVA(15KV/11KV)
2T12.	315KVA(15KV/11KV)
2T13.	700KVA(15KV/11KV)
2T14.	315KVA(15KV/11KV)
2T15.	315KVA(15KV/11KV)
2T16.	200KVA(15KV/11KV)
2T17.	63KVA(15KV/11KV)
2T18.	100KVA(15KV/11KV)
2T19.	315KVA(15KV/11KV)
2T20.	1250KVA(15KV/11KV)
2T21.	50KVA(15KV/0.415KV)
2T22.	630KVA(15KV/11KV)
2T23.	50KVA(15KV/11KV)
2T24.	200 KVA(15KV/0.415KV)
2T25.	200 KVA(15KV/11KV)
2T26.	25 KVA(15KV/0.415KV)
2T27.	100 KVA(15KV/0.415KV)
2T28.	100 KVA(15KV/0.415KV)
2T29.	400 KVA(15KV/11KV)
2T30	200 KVA(15KV/0.415KV)
2T31	100 KVA(15KV/0.415KV)
2T32	315 KVA(15KV/0.415KV)
2T33	200 KVA(15KV/0.415KV)
2T34.	200 KVA(15KV/0.415KV)

2T35.	315 KVA(15KV/0.415KV)
2T36.	315 KVA(15KV/0.415KV)
2T37.	200 KVA(15KV/0.415KV)
2T38.	200 KVA(15KV/0.415KV)
2T39.	100 KVA(15KV/0.415KV)
2T40	25 KVA(15KV/0.415KV)
2T41.	315 KVA(15KV/0.415KV)
2T42.	315 KVA(15KV/0.415KV)
2T43.	315 KVA(15KV/0.415KV)
2T44.	200 KVA(15KV/0.415KV)
2T45.	345 KVA(15KV/0.415KV)
2T46.	100 KVA(15KV/0.415KV)
2T47.	25 KVA(15KV/0.415KV)
2T48.	50 KVA(15KV/0.415KV)
2T49.	25 KVA(15KV/0.415KV)
2T50.	315 KVA(15KV/0.415KV)
2T51.	200 KVA(15KV/0.415KV)
2T52.	100 KVA(15KV/0.415KV)
2T53.	
2T54.	315 KVA(15KV/0.415KV)
2T55.	100 KVA(15KV/0.415KV)
2T56.	25 KVA(15KV/0.415KV)
2T57.	200 KVA(15KV/0.415KV)
2T58.	200 KVA(15KV/0.415KV)
2T59.	200 KVA(15KV/0.415KV)
2T60.	100 KVA(15KV/0.415KV)
2T61.	25 KVA(15KV/0.415KV)
2T62.	100 KVA(15KV/0.415KV)
2T63	25 KVA(15KV/0.415KV)
2T64.	100 KVA(15KV/0.415KV)
2T65.	100 KVA(15KV/0.415KV)
2T66.	100 KVA(15KV/0.415KV)
2T67.	100 KVA(15KV/0.415KV)

3.14. Data Analysis

The primary as well as secondary data obtained are directly or indirectly used to design the existing system of the selected feeder in this research. All the parameters necessary for the system design are calculated and filled accordingly. As indicated in Table 3.13, the values of SAIFI are the total sum of interruptions in a desired year. SAIDI is equal to the sum of interruption duration in each year and EENS is the product of interruption duration (in hour) and the load (in MW) during that period. CAIDI is calculated by Equation 2.3. To predict the reliability indices of a distribution system, values of failure rates and mean time to repair for each component are necessary. To estimate the failure rate of the line per kilometer, the total number of outages should be divided by the feeder length (Kilo meters) as indicated in equation (3.18).The average mean time to repair of each failure is computed using equation (3.19). The calculated average failure rate of the line and repair times per km of the existing feeder are 2.08 (Interruptions/km. year) and 0.620 (Hrs. /interruption) respectively.

$$\mu_A = \frac{Total\ Number\ of\ interruptions}{(Total\ feeder\ length(km) \times (Number\ of\ years))}(Interruptions/km.year) \tag{3.18}$$

$$MTTR = \frac{Total\ Repair\ Time}{(Total\ number\ of\ interruptions)}(Hrs./interruption) \tag{3.19}$$

Where, μ_A = active failure rate of any component; $MTTR$ = Mean Time to Repair By using the above two equations the basic reliability parameters used in ETAP software for reliability analysis are calculated as follow:

For overall feeder line μ_A

$$\mu_A = \frac{Sum\ of\ all\ the\ interruptions\ of\ the\ base\ years}{(Length\ of\ the\ feeder) * 5} \tag{3.20}$$

$$\begin{aligned}\mu_A = \frac{Sum\ of\ all\ the\ interruptions\ of\ the\ base\ years}{(Length\ of\ the\ feeder) * 5} \\ = \frac{678 + 521 + 656 + 692 + 747}{(316.73x5)} = \frac{3294}{1583.65} \\ = 2.08(interruptions/km.year)\end{aligned} \tag{3.21}$$

$$\begin{aligned}MTTR = \frac{Total\ Repair\ Time}{(Total\ number\ of\ interruptions)} \\ = \frac{(454 + 329 + 260 + 419 + 587)/5)}{(678 + 521 + 656 + 692 + 747)/5)} = \frac{409.8}{658.8} \\ = 0.620(Hrs./interruption)\end{aligned} \tag{3.22}$$

To estimate the failure rate of a component ETAP 19.0.1C uses combination of active μ_A and passive μ_p failure rates together. The active failure rate μ_A is in number of failures per year per unit length. The active failure rate is associated with the component failure mode that causes the operation of the primary protection zone around the failed component and can therefore cause the removal of the other healthy components and branches from service, after the actively failed component is isolated and the protection breakers are re-closed. This leads to service being restored to some or all of the load points. It should be noted, however, that the failed component itself (and those components that are directly connected to this failed component) could be restored to service only after repair or replacement. While μ_p is the passive failure rate in number of failures per year per unit length. The passive failure rate is associated with the component failure mode that does not cause the operation of protection breakers and therefore does not have an impact on the remaining healthy components. Repairing or replacing the failed component will restore service (software library). As there is no means of isolating specific faulty areas in the system, μ_p is assumed as zero in the model. The feeder line two overhead cables have been constructed by (AAC), $50mm^2$ area and 7 stranded type, this almost matches with Pirelli Libra Code AAC $49.5mm^2$ with the temperature from 20℃to 75℃which is available in ETAP19.0.1c Library. The overhead three phase line mounted on wooden pole of height 12m, the span length 50m up to 80m according to environmental situations with triangular configuration. All the distribution transformers are pole mounted, liquid fill type and (ONAN) classes with several rating.

3.15. System Features

As explained in the software help index, Electrical Transient Analysis Program (ETAP) is a fully graphical enterprise package that runs on different Microsoft Windows operating systems. ETAP is the most comprehensive analysis tool for the design and testing of power systems available. Using its standard offline simulation modules, ETAP can utilize real-time operating data for advanced monitoring, real-time simulation, optimization, energy management systems, and high speed intelligent load shedding. ETAP allows you to easily create and edit graphical one-line diagrams, underground cable raceway systems, three-dimensional cable systems, advanced time current coordination and selectivity plots, geographic information system schematics, as well as three-dimensional ground grid systems. The program operation emulates real electrical system operation as closely as possible. ETAP incorporates innovative concepts for determining protective device coordination directly from the one-line diagram. ETAP combines the electrical, logical, mechanical, and physical attributes of system elements in the same database. ETAP is one of the foremost-integrated databases for electrical systems, allowing engineers to have multiple presentations of a system for different analysis or design purposes. The software uses to analyze different electrical analysis, like reliability, short circuit, load flow, arc flash, protection coordination and others. In this thesis ETAP 19.0.1c has been used single line diagram, simulation both load flow analysis and reliability assessment analysis tool. Load flow simulation helps to identify over loaded and under loaded electrical equipment's and reliability assessment analysis used for evaluating reliability analysis. In this case the reliability indices and required output data's are generated. Figure 3.23 shows the project editor view with the reliability page of feeder line two is open. Parameters used in designing and assessment analysis for reliability of any system are those shown on this page.

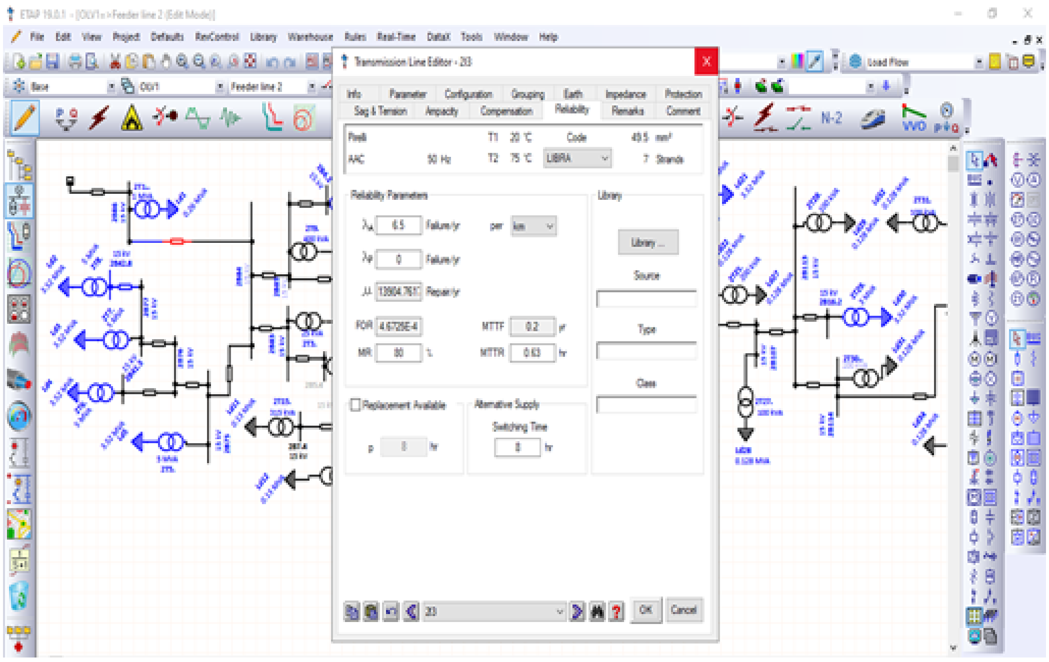


Figure 3.21: Window of ETAP19.0.1c Software as Reliability Page Opened

Single line diagram of existing feeder line two are displayed in the figure 3.23 below. Since it longer than the screen of the software, I divided it in two parts.

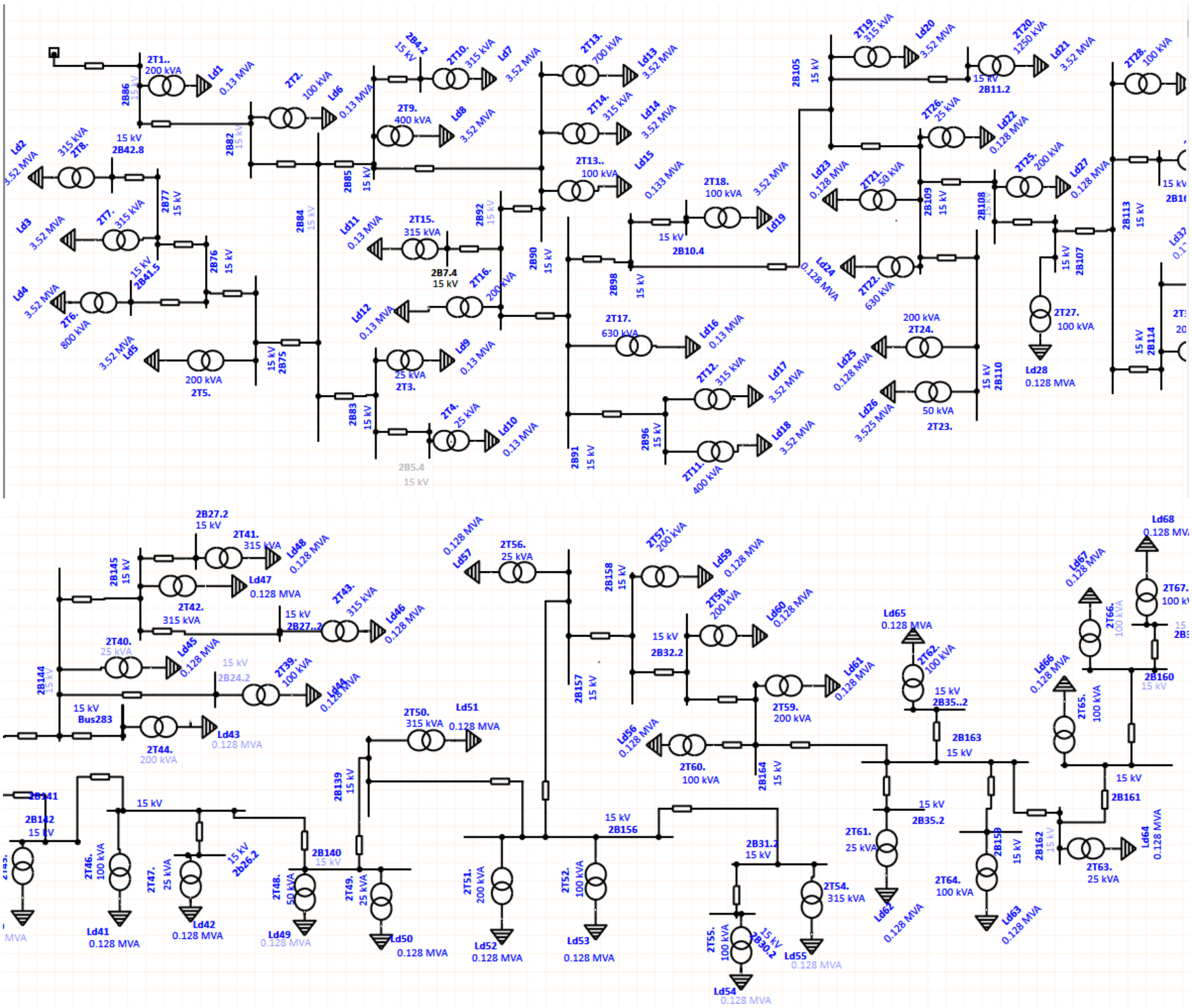


Figure 3.22: Shows the Complete Single Line Diagram of the Existing Feeder Line Two

Legends

Ld1-Ld68 = Load Points on each transformers

2Tr1-2Tr67 = Transformers

2l1-2l65 = Segmented Lines of the Feeder

CHAPTER FOUR

SIMULATION, RESULTS AND DISCUSSION

4.1. Simulation Procedure

- One line diagram of the existing system has been designed on the working plane of the software.
- Useful parameters for load flow and reliability assessment has been calculated and entered.
- Newton raphson load flow algorithm is selected inside the software among adaptive newton raphson and fast decoupled algorithm.
- Run load flow mode of ETAP software which helps to identify overloaded and under loaded electrical gadgets.
- Then simulate Matlab code to apply tie line and sectionalizing switch on pre-identified lines or equipment's.
- Then run reliability assessment mode to collect reliability indices outputs. Such as; SAIFI, SAIDI, CAIDI, EENS, ASAI and ASUI generated at the end.

The simuation is performed by

(i) Matlab software

(ii) ETAP software

(i) Matlab software:- The Matlab helps to simulate Matlab code for sectionalizing and tie line switch. Since its output varied due to inserting various buses, it is not included here.

(ii) ETAP software:- It helps to renovate and to generate the out put of reliability indices.

4.2. Simulation and Discussions of Feeder Renovation

The network analysis are categorized here base case and post case. The base case was evaluated for overall network assessment and only for feeder line two. Whereas, the post case is only for feeder line two after renovation in order to compare the generated output with base case output.

4.2.1 All Feeder Line Base Case of Distribution Substation and Distribution Network in Composite Network

The base case can be categorized in to load flow mode in order to identify overloaded equipment and reliability assessment mode to generate reliability indices.

4.2.1.1 Load Flow Mode for All Feeder Line

The flow of power from distribution substation to each consumer can be displayed by simulation of load flow mode. Three winding transformer is overloaded as shown in the figure 4.1 below.

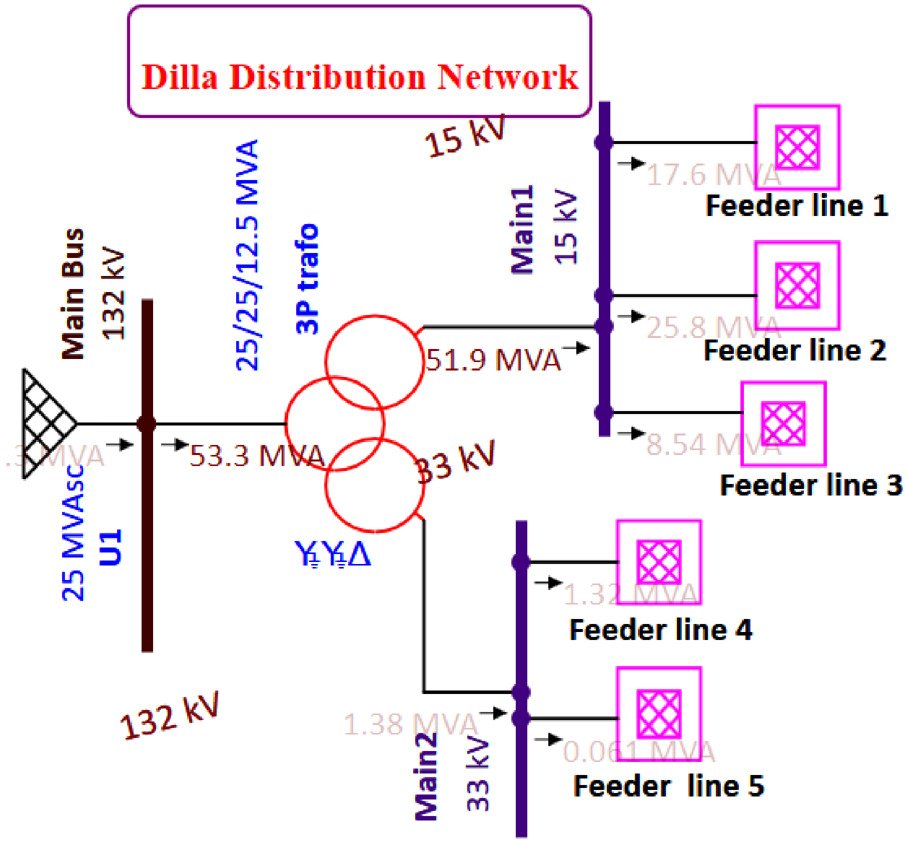


Figure 4.1: All Feeder Line Base Case Load Flow Mode

4.2.1.2 Reliability Assessment Mode for All Feeder Line

In reliability assessments mode overall SAIDI and SAIFI are displayed on all buses. Inside composite network there are also SAIDI, SAIFI, CAIDI,EENS, ASAI and ASUI for each feeder line. The figure 4.2.below shows reliability assessment for all feeders on each buses and summary of system indices.

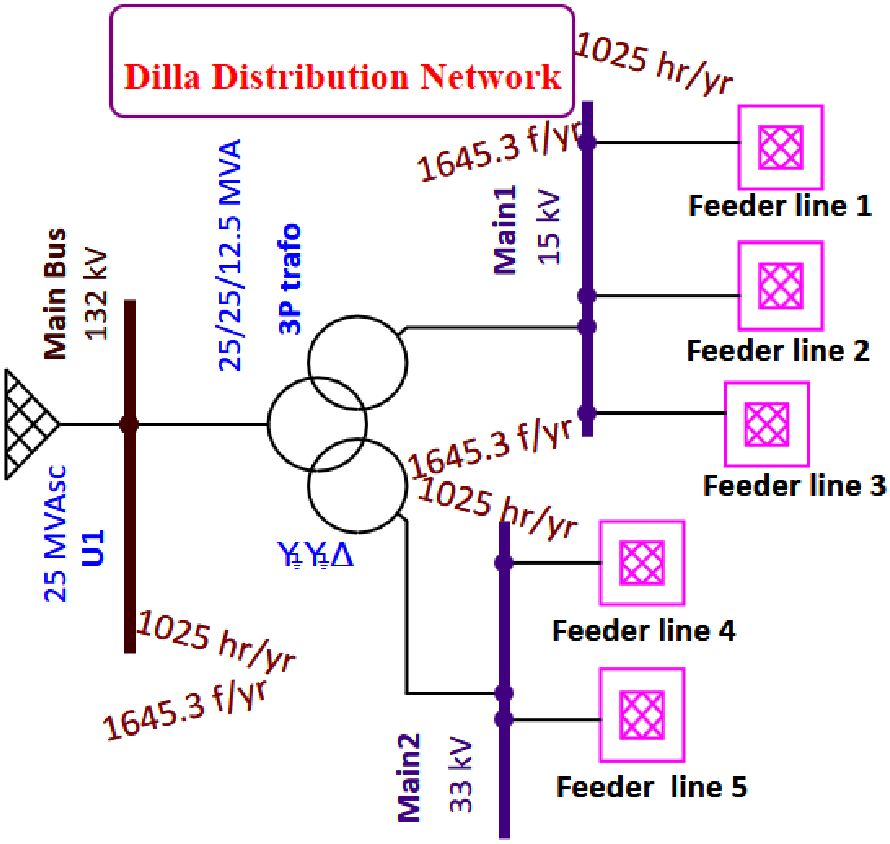


Figure 4.2: Overall Reliability Indices on Each Buses

The reliability indices of the existing system are displayed on the table 4.1 below. It encompasses all feeders.

Table 4.1: Summary of Reliability Indices

S/No	Indices	Pre-existing (all feeder)
1	SAIDI	1024.82 hr/customer.year
2	SAIFI	1645.32 f/customer.year
3	CAIDI	0.623 hr/customer interruption
4	EENS	$916.88x10^8$W hr/yr
5	ASAI	0.883 pu
6	ASUI	0.1169 pu

4.2.2 Base Case for Feeder Line Two Only

The base case of feeder line two categorized in to two such as:- Load flow mode and reliability assessment mode.

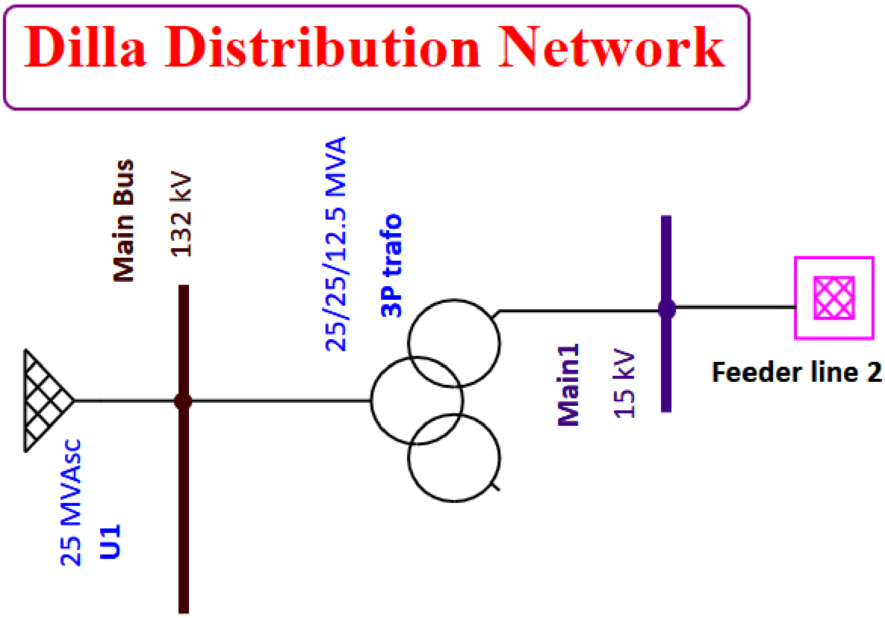


Figure 4.3: Feeder two base case

4.2.2.1 Load flow Mode of feeder line two

Several buses and transformers are in marginal and critical cases.In this case the pink color indicates that it is on critical case whereas the red color indicates marginal case. This implies many transformers are overloaded(pink) and buses are under voltage(red). This is displayed in figure 4.4 below.

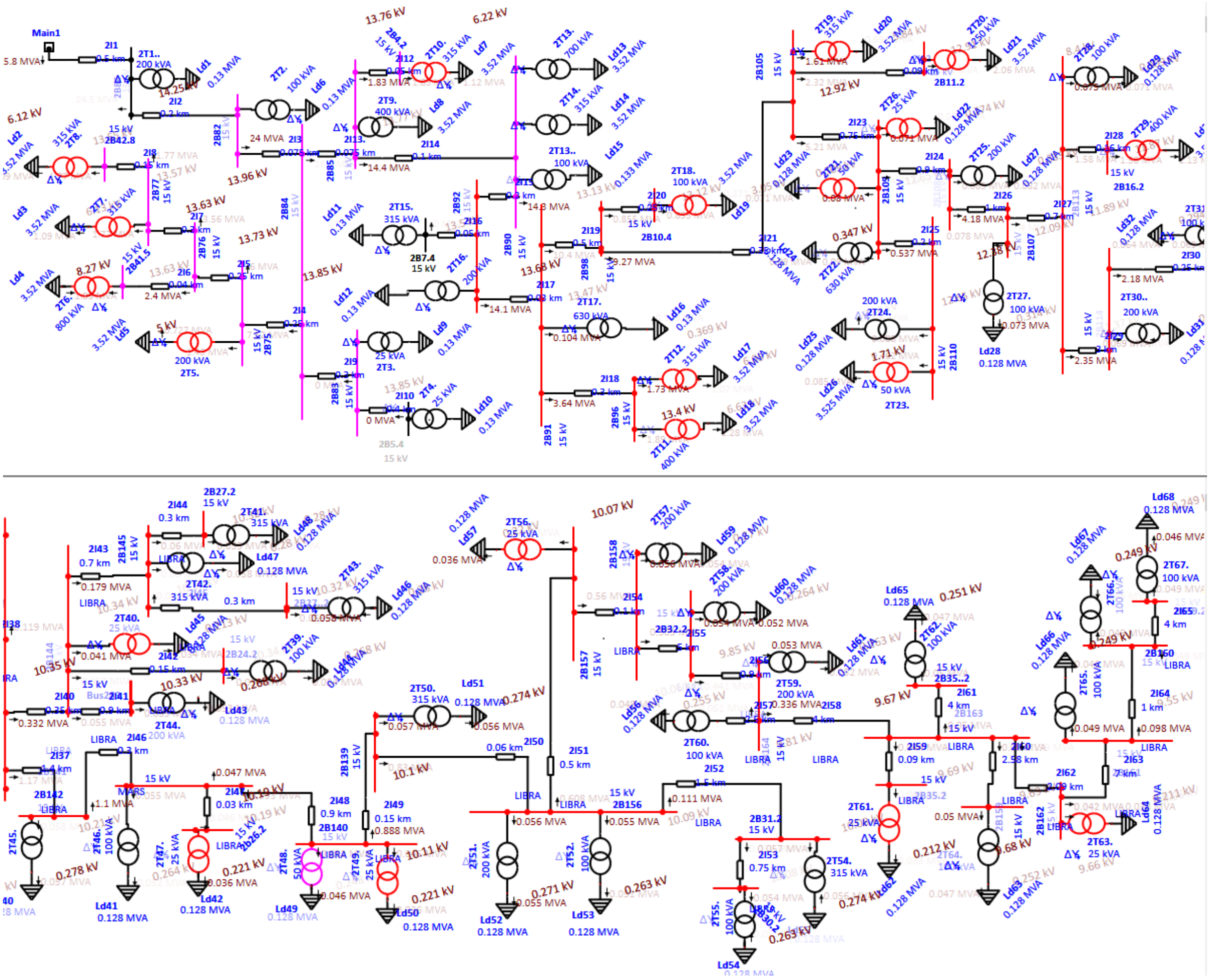


Figure 4.4: Base Case for Load Flow

4.2.2.2 Reliability Assessment Mode

Feeder line two reliability indices are generated in this mode as shown in the table 4.2 below.

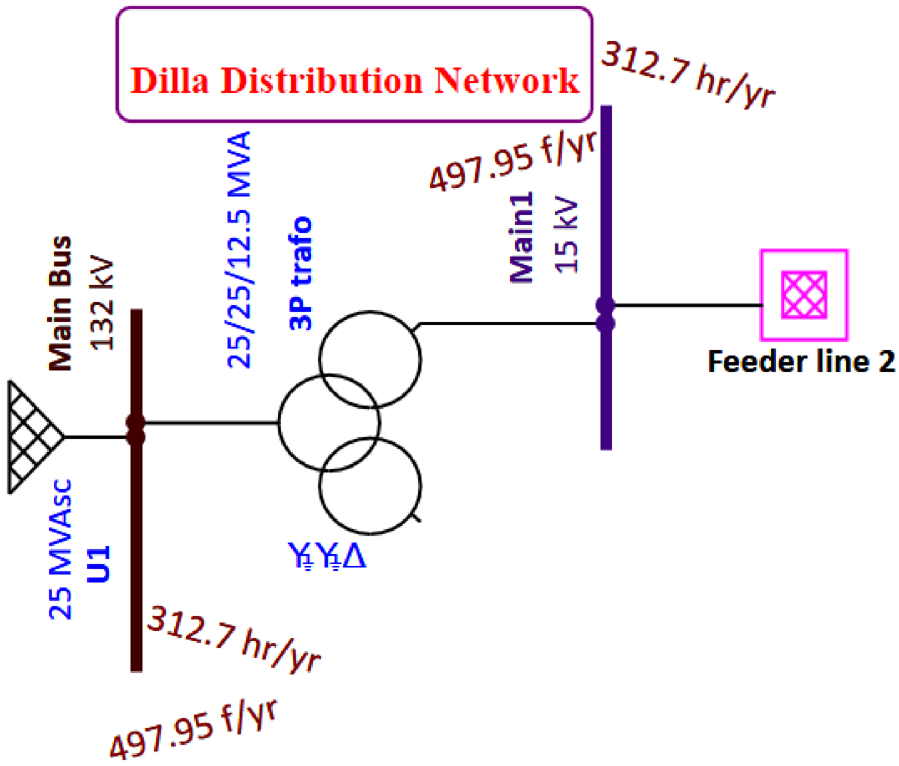


Figure 4.5: Base Case for reliability assessment mode

Table 4.2: Summary of Reliability Indices for Feeder line two base case

S/No	**Indices**	**Pre-renovation (feeder two)**
1	SAIDI	312.67 hr/customer.yr
2	SAIFI	497.94 f/customer.yr
3	CAIDI	0.628 hr/customer interruption
4	EENS	$128.31x10^8$W hr/yr
5	ASAI	0.9643 pu
6	ASUI	0.03569 pu

4.2.3 Renovated (Post Case) for Feeder Line Two Only

In this case the length of the feeder line two is decreased and many small rated transformers are replaced by high rated transformer by adding their corresponding previous loads. The blue color equipment shows the upgraded one. Whereas the black color shows us it is unchanged equipment.

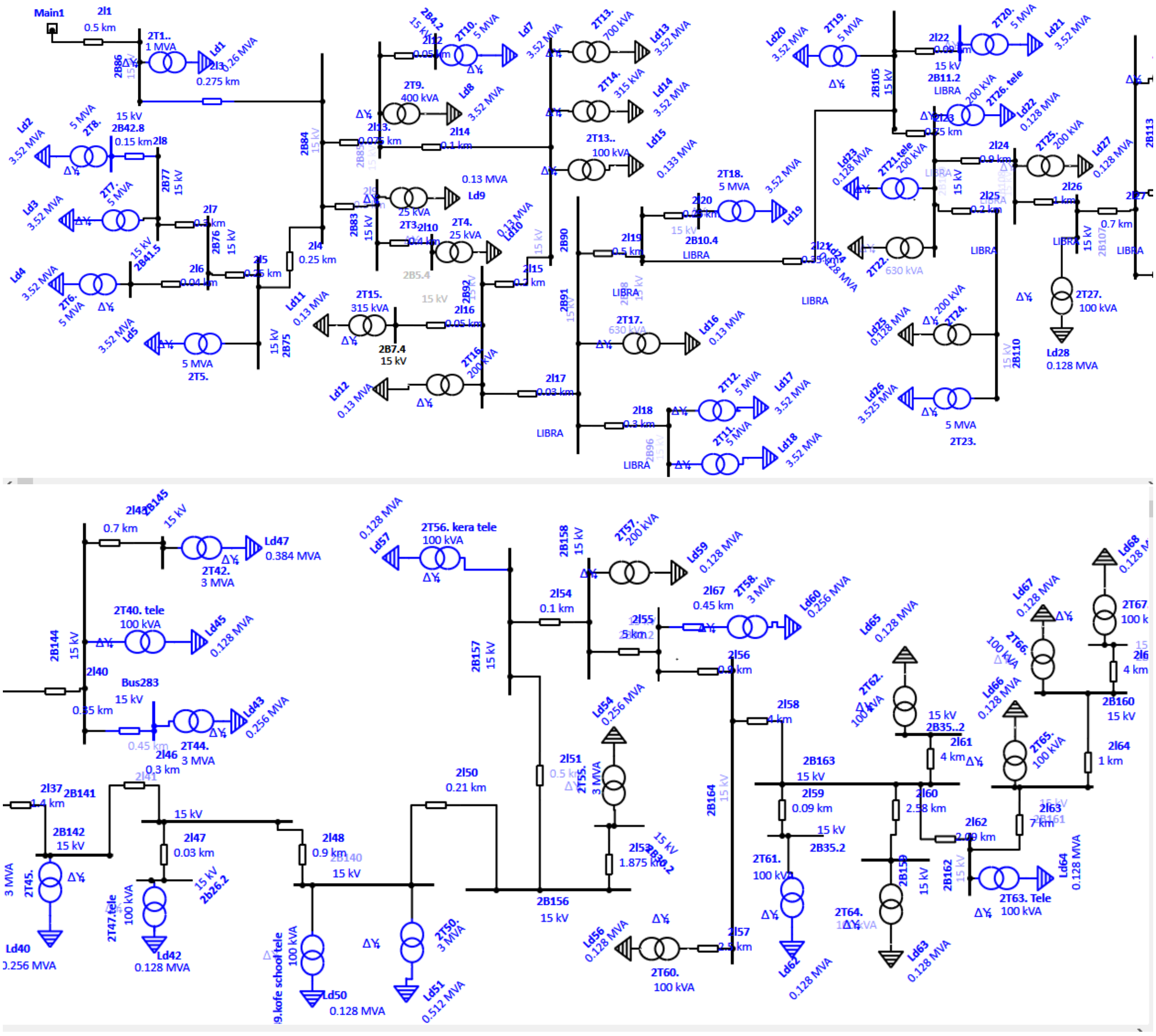


Figure 4.6: Decreased Length of Feeder Line Two

4.2.3.1 Load Flow Mode

All transformers are escaped from alert case as shown in the figure 4.7 below.

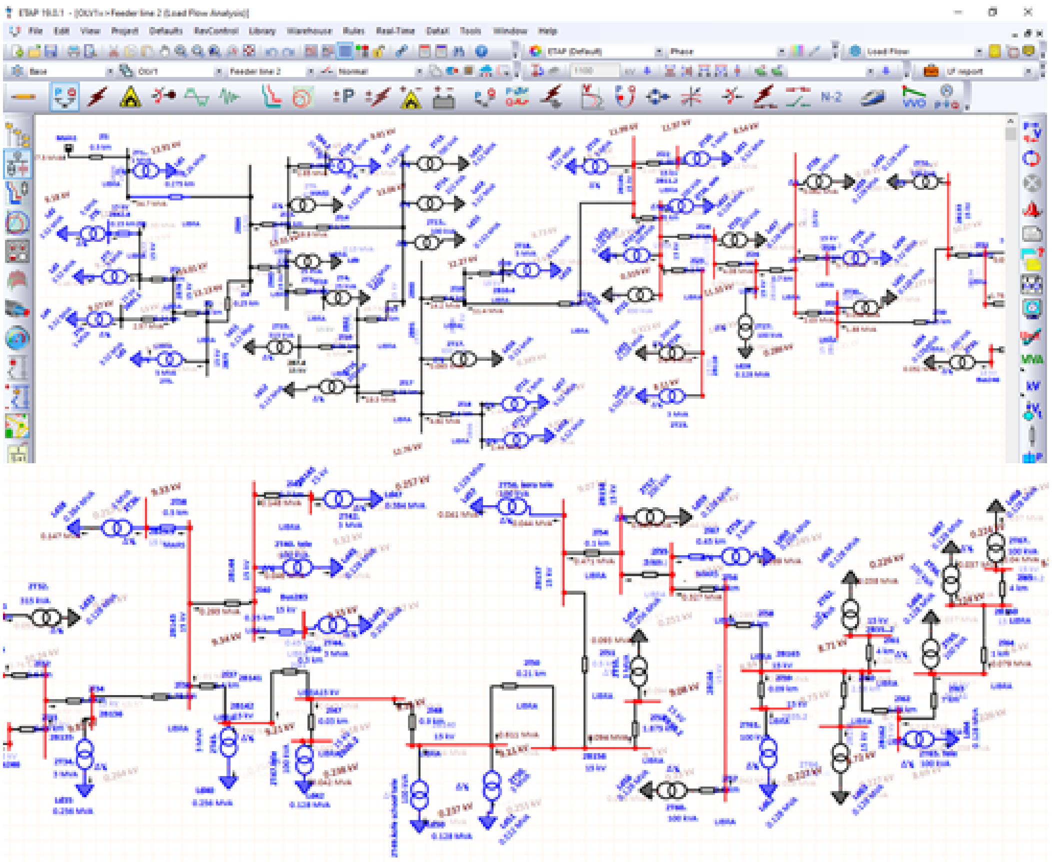


Figure 4.7: Post Case Load Flow mode of Feeder Two

4.2.3.2 Reliability Assessment Mode

Post renovation reliability assessment case for feeder line two is generated as displayed in the table 4.3 below.

Table 4.3: Summary of post-renovation Reliability Indices

S/No	Indices	Post-renovation (feeder two)
1	SAIDI	267.38 hr/customer.yr
2	SAIFI	431.12 f/customer.yr
3	CAIDI	0.620 hr/customer interruption
4	EENS	$109.793x10^8$W hr/yr
5	ASAI	0.9695 pu
6	ASUI	0.03052 pu

The reliability indices (SAIDI, SAIFI, CAIDI, EENS, ASAI and ASUI) are improved when compared the base case with post case as indicated in the table 4.4 below.

Table 4.4: Summary and Comparison of Reliability Indices Values

<table>
<tr><td colspan="2">Country</td><td>SAIFI</td><td>SAIDI</td></tr>
<tr><td colspan="2">United State</td><td>1.5</td><td>4</td></tr>
<tr><td colspan="2">Australia</td><td>0.9</td><td>1.2</td></tr>
<tr><td colspan="2">France</td><td>1</td><td>1.03</td></tr>
<tr><td colspan="2">Germany</td><td>0.5</td><td>0.383</td></tr>
<tr><td colspan="2">Italy</td><td>2.2</td><td>0.967</td></tr>
<tr><td colspan="2">Spain</td><td>2.2</td><td>1.73</td></tr>
<tr><td colspan="2">United Kingdom</td><td>0.8</td><td>1.5</td></tr>
<tr><td colspan="2">Ethiopia</td><td>20</td><td>25</td></tr>
<tr><td rowspan="3">Dilla town feeder line</td><td>Pre-existing(all feeder)</td><td>1645.32</td><td>1024.82</td></tr>
<tr><td>Feeder two base case</td><td>497.94</td><td>312.67</td></tr>
<tr><td>Feeder two post case</td><td>431.12</td><td>267.38</td></tr>
</table>

Table 4.4 shows the comparison of the most commonly used reliability indices (SAIFI and SAIDI) of Dilla town feeder with the requirements of the Ethiopian Electric Utility(EEU) and the best experienced countries.

Table 4.5: Comparison of Reliability Indices

S/No	Indices	Pre-existing (all feeder)	Base case (feeder line two)	Post case (feeder line two)	Reduction (increment) in base case with post case of feeder line two	Improvement %
1	SAIDI	1024.82	312.67	267.38	45.29	14.48
2	SAIFI	1645.32	497.94	431.12	66.82	13.41
3	CAIDI	0.623	0.628	0.620	0.008	1.27
4	EENS	916.88	128.31	109.7930	18.52	14.43
5	ASAI	0.8830	0.9643	0.9695	0.0052	0.53
6	ASUI	0.11699	0.03569	0.03052	0.00517	14.48

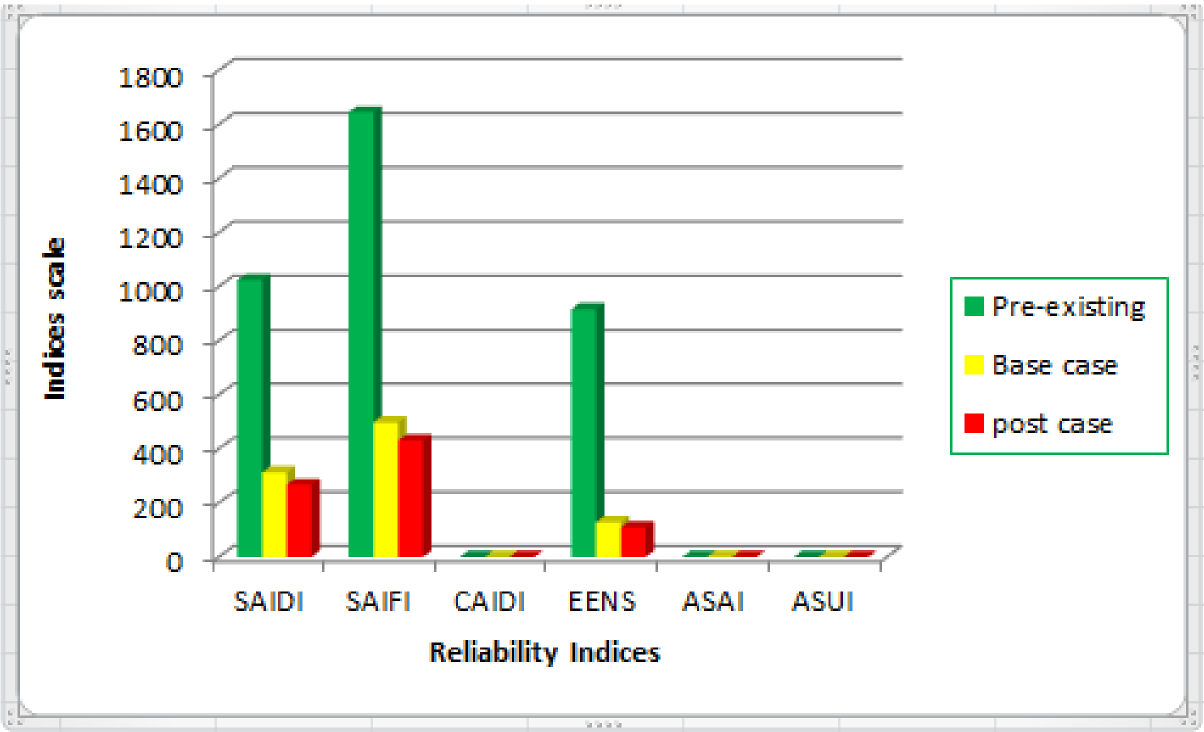


Figure 4.8: Comparison of overall indices

In this thesis the difference between base and post cases of the feeder line two of the reliability indices are evaluated. Reduction(increment) of the system evaluated by substracting base case result from post case results. The percent of improvement evaluated by dividing post case to base case. It is displayed on table 4.4 above. The figure 4.7 shows the improvement scale for each indices on column chart. Therefore,the reliability indices improved in great percentage.

4.3. Cost Analysis

Here costs analyzed are the cost of the electrical cable and power transformers only. The costs needed during re-structuring feeder lines such as, the cost of poles, manpower per Diem and the cost of another electrical devices are not included. This means it not mean that the listed cost is the only one needed for restructuring.

4.3.1 Distribution Transformer

4.3.2 Existing Trafo. in Dilla Town

The figure 4.9 below shows the installed trafo with in small distance(0.025Km) between two trafo. They are located around Mazoria Back side to Medin Building. Even though in this thesis work there are many trafo installed in this way, but some of them are not comfortable to take photo because they are concealed by some things. Therefore, this type in the figure 4.9 displayed for illustration.

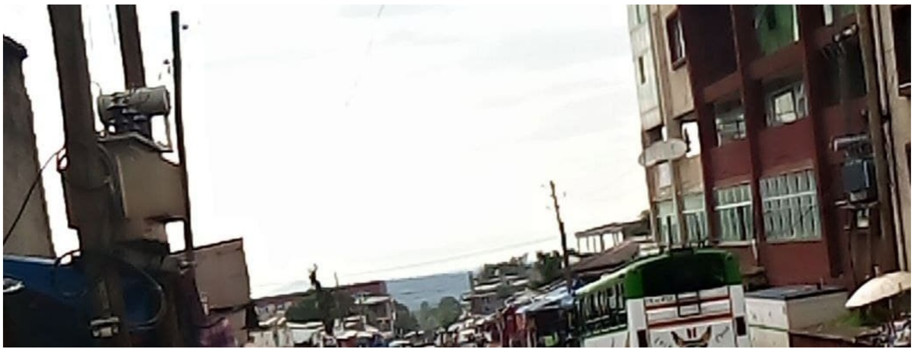


Figure 4.9: Photos for Dilla town distribution trafo.

4.3.2.1 Old power Transformer

Outdoor 3 Phase Pole Mounted 15KV and 33KV Oil Immersed power Transformer 25KVA, 50KVA 100KVA 200KVA, 300KVA, 315KVA, 345KVA, 400KVA, 630KVA, 800KVA, 1250KVA

Figure 4.10: Old Power Transformer

4.3.2.2 Replaced (New) transformer

Good Performance Outdoor 3 Phase Pole Mounted distribution transformer 15kV and 33kV Oil immersed power transformer 1MVA, 2MVA, 3MVA, 5MVA

Figure 4.11: Replaced Trafo.

4.3.3 The Price of Each Transformer With Their Rating

(1) Transformer15000/400V,25KVA=118,682.88ETB

(2) Transformer15000/400V,50KVA= 128,697.40ETB

(3) Transformer15000/400V,100KVA= 167,447.40ETB

(4) Transformer15000/400V,200KVA=317,166.25ETB

(5) Transformer15000/400V,315KVA=339,118.83ETB

(6) Transformer15000/400V,345KVA=349,386.54ETB

(7) Transformer15000/400V,400KVA=482,610.90ETB

(8) Transformer15000/400V,800KVA=731,330.00ETB

(9) Transformer15000/400V,1250KVA=862,840.00ETB

(10) Transformer15000/400V,1MVA=796,585.23ETB

(11) Transformer15000/400V,3MVA=1,425,680.62ETB

(12) Transformer15000/400V,5MVA=2,190,416.75ETB

Table 4.6: Summary of Cost Analysis of Power Transformer

S/No	Transformer with rating (old)	Quant ity of trans former	Their cost Specification (ETB)	Transformer with rating (New)	Quant ity of transf ormer	It's cost specification (ETB)
1	25KVA	7	830,780.16	0.1MVA	6	1,004,684.4
2	50KVA	3	386,092.2	0.2MVA	2	634,332.5
3	100KVA	5	837,237	1MVA	2	1,593,170.46
4	200KVA	5	1,585,831.25	3MVA	7	9,979,764.34
5	315	11	3,730,307.13	5MVA	9	19,713,744
6	345	1	345,386.54			
7	400	2	965,221.8			
8	800	1	731,330.00	Total	26	**32,925,695.7**
9	1250	1	862,840.00			
Total		36	**10,275,026.08**			

4.3.4 Overhead Distribution Line Cable Data

From feeder line two total length 13.42km are reduced. Therefore after renovation the length of feeder line two could be 58.56km.

The distribution wire used in Dilla is AAC.

Table 4.7: Distribution Line Cable Data

Application:	Overhead
Voltage:	Low and Medium Voltage Cable
Insulation Material:	Bare
Sheath Material:	None
Material Shape:	Round Wire

Figure 4.12: Overhead Distribution Line Cable Used

All aluminum conductor(AAC) 95mm^2

The price of one meter wire is 50.31ETB

50.31*13.42*1000= **675,160.2ETB**

4.3.5 SWITCH ISOLATING

Isolating switch 15KV 3X400A =**4,894.29ETB**

For removed ten trafo

10*4894.29=**48,942.9ETB**

4.3.6 Wooden pole price

IMP Wooden poles of 16MT required=**8503.26ETB**

Sixteen (16) trfo. are removed as indicated in the table 3.1. Those are 2T1.,2T2., 2T34, 2T35,2T45, 2T46, 2T36,2T37, 2T38, 2T41,2T42, 2T43, 2T48, 2T50, 2T51, 2T52 removed by replacing advanced rated trafo. The remaining trafo are upgraded to advanced rating.

Two pole per one trafo required for trafo. support tie.

2*16=32poles

32*8,503.26=**272,104.32ETB**

For those upgraded new six(6) trafo such as:-2T1, 2T34, 2T38, 2T41, 2T51, and 2T48 among the above thirty two twelve poles required.

12*8503.26=**102,039.12ETB**

4.3.7 Transformer support

Transformer support=2603.39ETB

For removed 16*2603.39=**41,654.24ETB**

For replaced 6*2603.39=**15,620.34ETB**

4.3.8 CONNECTOR

Connector 16-35MM SQ=**35ETB**

Two group of connector per trafo required

For removed trafo 10*35*2=**700ETB**

For upgraded trafo 6*35*2=**420ETB**

The remaining twelve trafo such as:- 2T8, 2T6, 2T5, 2T10, 2T11, 2T12, 2T18, 2T19, 2T20, 2T23, 2T29 and 2T61 are used the existing trafo support and poles.

By renovation the cost minimized(The cost of removed equipment's)

10,275,026.08+675,160.20+48,942.90,170,065.20+41,654.24+700.00=**11,211,548.62ETB**

The cost required for renovation

32,925,695.7+102,039.12+15,620.34+420.00=**33,043,775.16ETB**

Source:- The cost analysis data are obtained from Dilla electric utility branch which it was documented march 2020G.C.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This thesis was conducted in one of the oldest towns of Ethiopia, Dilla town, which has an old and poor electrical distribution system. The system modeling and simulation study is carried out on one of the 15kV distribution feeder to evaluate the impact of renovation to enhance the network reliability. The interruption data of years 2015 G.C has been used as a base years. Based on the interruption data of the base years and the questionnaire about the causes of interruptions, it can be seen that Dilla town feeders experienced highest number of outages. The outages are mainly due to distribution equipment failures, overload, tree, windy rain, scheduled outages and others. The single line diagram of the existing system was modeled in computer software and evaluated by load flow mode and reliability assessment mode inside of ETAP19.0.1c software. Among five feeder lines available in Dilla town, feeder line two is selected for this research. Because this feeder line encompasses all electrical loads and also it have too complicated interconnections. Renovation by restructuring of pre-existing selected feeder for this thesis work is outlined for improving the reliability of the study area. In base case, we have categorized in to two. Such as pre-existing network of all feeders and feeder line two only. The post case holds only feeder line two. During renovation, the nearest central area to put transformer for all customers is selected to minimize the line length from the distribution substation. This can minimize overhead cable length. Small rating transformers are replaced by high rating transformers. Each case includes a summary of the reliability indices reduction benefits and a cost effectiveness analysis. SAIFI, SAIDI, CAIDI, EENS, ASAI and ASUI are used as the main driver for evaluating of each case. Cost-effectiveness is considered as the main constraint of system modeling analysis in this thesis. Cost- effectiveness is defined cost of all electrical equipment which was applied on in this thesis in a base case and the cost of updated electrical equipment's. Those are the cost of transformers in different rating and the cost of the cable. In order to achieve this objective, Matlab codes are used for tie line and sectionalizing switch. In addition to that ETAP19.0.1c is also used to simulate load flow and reliability assessment, thus evaluating the impact based on reliability indices. SAIFI has been improved by 13.41 % as compared with the reliability indices value of the system in the base years. In the same case SAIDI, CAIDI, EENS, ASAI and ASUI have been improved by 14.48%, 1.27%, 14.43%, 0.53% and 14.48% respectively. In generally, renovation of the system using restructuring the feeder line should be an effective and feasible solutions for the overloading problems and temporary faults. By renovation the cost minimized 11,211,548.62ETB the cost required for renovation 33,043,775.16ETB.

5.2. Recommendations

This section brings up topics of future research works that would correlate the work presented in this thesis.

- The primary purpose of the system is to satisfy customer requirements and since the proper functioning and longevity of the system should found to be essential requisites for continued satisfaction.

- The interruption data recording have to be made systematic and rationalized meaning that all individual component failure data, localized fault data, have to be precisely recorded if future system analysis should represent true state of the system. As of now, the data have been recorded only when there is fault on the feeder. And all the hard copy data are not kept properly especially in utility.

- For utility to install new line with appropriate design from the feeder which is not overloaded. This helps to identify easily the feature demand on the feeder line where the urban settlement is expanding. Right now the problem of power is facing in Dilla town is due to over loaded connection without considering the direction at which the demands are available comparable with feeder direction.

- To reconfigure distribution network using sectionalizing switch and tie line considering optimization problems full calculation and analysis such as, Reliability indices, voltage profile and power loss minimization by collaborating with system renovation.

- As naturally Dilla is found in a thick forest zone, Scheduled tree trimming and pruning programs will have a vital role in distribution system reliability enhancement and can have profound effect on minimizing the failure rate of overhead lines. And another way to reduce number of vegetation related failure is to replace bare 15kv overhead conductor with covered conductor, which can have significant effect all on SAIFI, SAIDI, CAIDI, AENS, EENS, ASAI and ASUI.

- As this thesis is conducted on one feeder (feeder line two) only, doing renovation of networks on whole feeders are recommended.

- Practical implementation of the recommended type of renovation is also important to improve the reliability of the power distribution system.

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Appendix A

15kv out going feeder lines two daily power interruption data of year 2015G.C

Date(dd/ mm/yr)	Discon nection	Recon nection	Dur ation in time	Dura tion in hour	Interru ption Load Before in (MW)	Unsupp lied Energy in (MWh)	Causes Of Interruption
3/1/2015	15:48	16:30	0:42	0.7	1.4	0.98	L2 C.B tripped due to Line Earth Fault
6/1/2015	4:00	8:56	4:56	4.93	1.7	8.38	L2Cb tripped due to Line short ckt phase RS
	11:10	12:30	1:20	1.33	1.6	2.13	L2 C.B Opened Due To Line SOL 3 m.w
9/1/2015	10:53	12:50	1:57	1.95	1.5	1.42	L2 C.B Opened Due To Line SOL 3 m.w
14/1/2015	13:40	16:40	3:00	3.00	1.4	4.2	L2 C.B tripped due to Line Earth Fault
	17:30	17:54	0:24	0.4	1.4	0.56	L2 C.B tripped due to Line Earth Fault
15/1/2015	14:25	15:00	0:35	0.58	1.3	0.75	L2 C.B tripped due to Line short ckt phase RS
17/1/2015	17:35	18:54	1:19	1.31	1.5	1.97	L2 C.B tripped due to Line short ckt phase ST
18/1/2015	11:40	11:50	0:10	0.166	1.5	0.25	L2 C.B tripped due to Line short ckt phase ST
	18:05	19:11	1:06	1.1	1.8	1.98	L2 C.B tripped due to Line short ckt phase ST
20/1/2015	16:00	16:37	0:37	0.61	1.4	0.86	L2 C.B opened for line maintenance work
21/1/2015	15:20	15:50	0:30	0.5	1.2	0.6	L2 C.B tripped due to Line Earth Fault

22/1/2015	8:10	8:34	0:24	0.4	1.3	0.52	L2 C.B tripped due to Line short ckt phase RT
	9:45	9:55	0:10	0.166	1.4	0.23	L2 C.B opened for line maintenance work
23/1/2015	14:35	18:10	3:35	3.58	1.4	5.01	L2 C.B tripped due to Line Earth Fault
24/1/2015	13:18	15:20	2:02	2.03	1.4	2.84	L2 C.B tripped due to Line short ckt phase RS
26/1/2015	15:10	17:00	1:50	1.83	1	1.83	L2 C.B tripped due to Line short ckt phase RS
	19:50	20:20	0:30	0.5	1.7	0.85	L2 C.B opened for line maintenance work
27/1/2015	10:40	11:02	0:22	0.36	0.52	0.19	L2 C.B opened for line maintenance work
	15:25	18:25	3:00	3.00	1.2	3.6	L2 C.B tripped due to line short ckt phase RST
28/1/2015	7:14	14:44	7:30	7.5	1.2	9	Total power interruption
	7:14	21:28	14:14	14.23	1.4	19.92	L1/L2/L3/L4&L5
2/2/2015	9:37	10:01	0:24	0.4	1.7	0.68	L2 CB tripped due to Line Earth Fault
	10:19	10:38	0:19	0.31	1.7	0.53	L2 CB tripped due to Line Earth Fault
3/2/2015	9:33	10:50	1:17	1.28	1.47	1.88	L2CB opened for line maintenance work
4/2/2015	8:19	8:33	0:14	0.23	1.66	0.38	L2Cb tripped due to Line short ckt phase RS
	17:48	17:50	0:02	0.03	1.3	0.03	L2CB opened for line maintenance work
9/2/2015	3:45	0:00	20:15	20.25	1.43	28.95	L2 Cb tripped due to Line short ckt phase RT
	0:00	8:40	8:40	8.66	1.7	14.7	L2 Cb tripped due to Line short ckt phase RT
	8:40	8:55	0:15	0.25	1.7	0.425	L2 Cb tripped due to Line short ckt phase RT
	8:55	9:33	0:38	0.63	1.7	1.07	L2 Cb tripped due to Line short ckt phase RT
16/2/2015	12:45	13:20	0:35	0.58	1.4	0.81	L2Cb tripped due to Line short ckt phase RS
22/2/2015	7:50	9:15	1:25	1.41	1.7	2.39	L2 Cb tripped due to Line short ckt phase ST

24/2/2015	13:55	14:10	0:15	0.25	1.7	0.42	L2CB opened for line maintenance work
25/2/2015	3:20	7:04	3:44	3.73	1	3.73	L2 CB tripped due to Line Earth Fault
	7:04	7:22	0:18	0.3	1	0.3	L2CB opened for line maintenance work
28/2/2015	8:56	9:06	0:10	0.16	1.76	0.28	L2CB opened for line maintenance work
	10:36	11:59	1:23	1.38	1.8	2.48	L2 Cb tripped due to Line short ckt phase RT
	19:30	20:00	0:30	0.5	2.2	1.1	L2 Cb tripped due to Line short ckt phase RT
29/2/2015	17:58	18:34	0:36	0.6	2	1.2	L2 CB tripped due to Line Earth Fault
30/2/2015	7:06	8:47	1:41	1.68	1.5	2.52	L2 Cb tripped due to Line short ckt phase RT
	18:20	19:33	1:13	1.21	1.75	2.11	L2 Cb tripped due to Line short ckt phase RT
	19:34	19:38	0:04	0.06	2	0.12	L2 CB tripped due to Line Earth Fault
	10:20	10:23	0:03	0.05	2	0.1	L2CB opened for line maintenance work
4/3/2015	10:28	10:50	0:22	0.36	1.77	0.61	L2CB opened for line maintenance work
5/3/2015	0:00	8:57	8:57	8.95	1.5	13.42	L2CB opened for line maintenance work
	19:03	19:30	0:27	0.45	1.87	0.84	L2CB opened for line maintenance work
7/3/2015	2:45	8:00	5:15	5.25	1.1	5.77	L2 CB tripped due to Line Earth Fault
	12:02	13:26	1:24	1.4	1.5	2.1	L2 CB tripped due to line s/c phase RT 2.4KA
8/3/2015	16:26	16:36	0:10	0.16	1.5	0.24	L2CB opened for line maintenance work
9/3/2015	17:28	17:32	0:04	0.066	1.2	0.079	L2CB opened for line maintenance work
14/3/2015	15:04	16:52	1:48	1.8	1.7	3.06	L2 Cb tripped due to Line short ckt phase RT
	16:52	17:28	0:36	0.6	1.87	1.12	L2 Cb tripped due to Line short ckt phase RT
15/3/2015	0:28	8:28	8:00	8	1.53	12.24	L2 Cb tripped due to Line short ckt phase RT
18/3/2015	13:08	14:13	1:05	1.083	1.6	1.73	L2CB opened for line maintenance work
20/3/2015	7:05	12:46	5:41	5.68	1.86	10.56	L2CB opened for line maintenance work
23/3/2015	5:50	8:20	2:30	2.5	1.7	4.25	L2 CB tripped due to line s/c phase RST

27/3/2015	14:40	15:50	1:10	1.16	1.7	1.97	L2 CB tripped due to line s/c phase RST
29/3/2015	16:27	17:00	0:33	0.55	1.4	0.77	L2 Cb tripped due to Line short ckt phase RT
2/4/2015	16:10	16:52	0:42	0.7	1.87	1.3	L2 CB tripped due to Line Earth Fault
	16:27	17:00	0:33	0.55	1.4	0.77	L2 Cb tripped due to Line short ckt phase RT
	16:10	16:52	0:42	0.7	1.87	1.3	L2 CB tripped due to Line Earth Fault
5/4/2015	16:05	16:35	0:30	0.5	1.66	0.83	L2 CB tripped due to Line Earth Fault
9/4/2015	7:00	7:39	0:39	0.65	1.76	1.14	L2 CB tripped due to Line Earth Fault
10/4/2015	12:32	13:12	0:40	0.66	1.66	1.095	L2CB opened for line maintenance work
11/4/2015	16:58	17:12	0:14	0.23	1.7	0.39	L2 CB tripped due to Line Earth Fault
14/4/2015	19:50	20:40	0:50	0.83	2.08	1.73	L2 CB tripped due to Line Earth Fault
15/4/2015	0:00	7:46	7:46	7.76	1.45	11.25	L2 Cb tripped due to Line short ckt phase RT
	8:54	14:45	5:51	5.85	1.7	9.94	L1&L2 cb 0pened due to line sol 5mw
	9:00	9:25	0:25	0.416	1.87	0.77	TOTAL POWER INT-RUPION
	17:20	19:27	2:07	2.11	1.35	2.84	TOTAL POWER INT-RUPION
16/4/2015	0:05	7:45	7:40	7.66	1.66	12.71	L2 Cb tripped due to Line short ckt phase RS
17/4/2015	10:45	10:50	0:05	0.083	1.6	0.13	L2 Cb tripped due to Line short ckt phase RS
	14:02	14:08	0:06	0.1	1.6	0.16	L2 Cb tripped due to Line short ckt phase RS
20/4/2015	14:12	15:56	1:44	1.73	1.8	3.11	L2CB opened for line maintenance work
24/04/2015	8:42	9:00	0:18	0.3	1.66	0.498	L2CB opened for line maintenance work
25/04/2015	10:30	11:55	1:25	1.416	1.35	1.911	L2CB opened for line maintenance work
26/04/2015	6:35	7:40	1:05	1.083	1.66	1.797	L2 CB was tripped out due to earth fault
	7:40	8:12	0:32	0.533	1.66	0.88	L2CB was tripped out due to earth fault
27/04/2015	14:30	15:12	0:42	0.7	1.66	1.16	L2 Cb tripped due to Line short ckt phase RS
	15:35	15:47	0:12	0.2	1.66	0.33	L2CB opened for line maintenance work

28/4/2015	9:30	9:54	0:24	0.4	1.25	0.32	L2CB opened for line maintenance work
30/4/2015	7:10	9:34	2:24	2.4	3.29	7.89	L2 Cb tripped due to Line short ckt phase RS
3/5/2015	13:38	13:58	0:20	0.33	1.7	0.56	L2 CB tripped due to Line Earth Fault
5/5/2015	13:50	14:47	0:57	0.95	1.87	1.77	L2 CB tripped due to Line Earth Fault
	16:20	16:55	0:35	0.58	1.87	1.09	L2 CB tripped due to Line Earth Fault
7/5/2015	9:30	10:10	0:40	0.66	1.4	0.93	L2CB opened for line maintenance work
	12:40	13:55	1:15	1.25	1.6	2	L2 CB tripped due to Line Earth Fault
8/5/2015	14:56	15:59	1:03	1.05	2.15	2.25	L2 CB was tripped out due to short ckt
	16:13	16:28	0:15	0.25	1.15	0.28	L2 CB was disconected for maintenance
13/5/2015	13:40	13:56	0:16	0.266	1.87	0.48	L2 CB tripped due to Line Earth Fault
	14:30	15:00	0:30	0.5	1.78	0.89	L2 CB tripped due to Line Earth Fault
15/05/2015	15:40	16:15	0:35	0.58	1.4	0.81	L2CB opened for line maintenance work
16/05/2015	17:09	17:50	0:41	0.68	2	1.36	L2CB opened for line maintenance work
17/05/2015	0:00	7:22	7:22	7.36	1.45	10.67	L2 Cb tripped due to Line short ckt phase RS
19/05/2015	4:04	8:11	4:07	4.11	1.25	5.13	L2 CB was tripped out due to earth fault
20/05/2015	11:15	11:27	0:12	0.2	1.78	0.35	L2 CB opened for line maintenance work
21/05/2015	16:57	17:07	0:10	0.16	1.8	0.3	TOTAL POWR INTE-RRUPTION
	17:20	19:30	2:10	2.16	2	4.3	l2cB OPPENED DUE DUE SOL 1.80 MW
	18:56	19:22	0:26	0.43	2	0.86	TOTAL POWR INT-ERRUPTION
22/05/2015	8:38	8:50	0:12	0.2	0.9	0.18	L2 Cb was disconected for maintenance work
26/05/2015	14:35	15:02	0:27	0.45	0.7	0.315	L2 CB was disconected for maintenance work

28/05/2015	9:30	9:50	0:20	0.33	1.87	0.623	L2 CB opened for line maintenance work
	17:47	19:00	1:13	1.21	2	2.42	L2 Cb tripped due to Line short ckt phase ST
	17:48	18:48	1:00	1	2.2	2.2	L2 CB was tripped out due to earth fault
	16:40	17:08	0:28	0.46	1.6	0.74	L2 CB was tripped out due to earth fault
	18:45	19:20	0:35	0.58	2.2	1.28	L2 CB was tripped out due to earth fault
2/6/2015	6:52	8:10	1:18	1.3	1.3	1.69	L2 Cb tripped due to Line short ckt phase ST
	11:00	11:26	0:26	0.43	2	0.86	L2 CB opened for line maintenance work
	14:25	14:28	0:03	0.05	1.66	0.083	L2 CB opened for line maintenance work
	16:50	17:00	0:10	0.166	1.56	0.258	L2 CB opened for line maintenance work
3/6/2015	6:56	9:40	2:44	2.733	1.66	4.53	L2 Cb tripped due to Line short ckt phase ST
	13:30	14:13	0:43	0.716	1.4	1	L2 CB was tripped out due to short ckt R.S
4/6/2015	8:55	9:12	0:17	0.283	1.5	0.424	L2 CB opened for line maintenance work
5/6/2015	13:50	14:10	0:20	0.33	1.6	0.52	L2 CB opened for line maintenance work
6/6/2015	8:05	9:10	1:05	1.083	1.2	1.29	L2 Cb tripped due to Line short ckt phase ST
	14:30	15:00	0:30	0.5	1.66	0.83	L2 CB was tripped out due to short ckt R.S
8/6/2015	13:40	14:30	0:50	0.833	1.4	1.16	L2Cb tripped due to Line short ckt phase RT
10/6/2015	15:40	16:20	0:40	0.66	1.1	0.73	L2 CB opened for line maintenance work
12/6/2015	17:36	19:03	1:27	1.45	1.25	1.81	L2Cb tripped due to Line short ckt phase RT
13/6/2015	0:00	7:22	7:22	7.36	1.2	8.83	L2Cb tripped due to Line short ckt phase RT
	11:28	11:59	0:31	0.51	1.1	0.56	L2 CB opened for line maintenance work
	15:15	15:45	0:30	0.5	1.2	0.6	L2 CB opened for line maintenance work
	18:25	20:10	1:45	1.75	1.7	2.97	L2 CB opened for line maintenance work
14/6/2015	7:25	8:20	0:55	0.91	1.4	1.28	L2 CB opened for line maintenance work

15/6/2015	9:42	9:50	0:08	0.133	1.8	0.24	L2 CB opened for line maintenance work
	14:42	15:16	0:34	0.56	1.65	0.93	L2 CB opened for line maintenance work
16/6/2015	11:07	11:14	0:07	0.11	1.5	0.175	L2 CB opened for line maintenance work
19/6/2015	0:00	8:11	8:11	8.18	1.4	11.45	L2 Cb tripped due to Line short ckt phase RT
	18:34	19:38	1:04	1.066	1.8	1.91	L2 CB was tripped out due to short ckt R.S 2.04KA
25/6/2015	18:42	20:02	1:20	1.33	1.75	2.32	L2 CB tripped due to Line Earth Fault
	19:30	20:18	0:48	0.8	1.78	1.42	L2 CB was tripped out due to earth fault
27/06/2015	15:56	17:32	1:36	1.6	1.1	1.76	L2 CB was tripped out due to earth fault magn- 100 A
	17:56	18:40	0:44	0.733	1.25	0.916	L2 CB was tripped out due to short ckt
	20:35	7:58	11:23	11.38	1.6	18.2	L2 CB was tripped out due to short ckt AB magn- 1.335 KA
28/06/2015	9:34	10:20	0:46	0.766	1.45	1.11	L2 CB was tripped out due to short ckt AB magn- 1.335 KA
1/7/2015	4:04	10:22	6:18	6.3	1.1	6.93	L2 CB was tripped out due to earth fault 100 A
	10:22	10:50	0:28	0.46	1.2	0.56	L2 CB was tripped out due to earth fault 81 A
	15:10	15:38	0:28	0.46	1.2	0.56	L2 CB was opened due to line m.work nesro
	15:55	17:20	1:25	1.41	1.16	1.64	L2 CB was tripped out due to line short ckt RS 1.69 KA
2/7/2015	7:59	8:44	0:45	0.75	1.4	1.05	L2 Cb tripped due to Line short ckt phase RT 99.6A
3/7/2015	14:40	15:04	0:24	0.4	1.25	0.5	L2 CB was opened due to line m. work by nesru
4/7/2015	10:27	11:18	0:51	0.85	1.45	1.23	L2 CB opened for line maintenance work
	12:15	13:26	1:11	1.18	1.4	1.65	L2 CB opened for line maintenance work
5/7/2015	6:19	12:44	6:25	6.41	1.3	8.33	L3 CB was tripped out due to short ckt phase ST 1.38kA
	11:20	11:23	0:03	0.05	1.3	0.06	L2 CB opened for line maintenance work by Admassu
7/7/2015	18:35	20:31	1:56	1.93	1.6	3.08	L2 CB was tripped out due to line short ckt RS 1.79 KA
8/7/2015	18:10	20:13	2:03	2.05	1.4	2.87	L2 Cb tripped due to Line short ckt phaseRS 1.72KA

11/7/2015	5:20	9:02	3:42	3.7	1.45	5.36	L2 Cb tripped due to Line short ckt phaseRS 2.15KA
	17:45	18:07	0:22	0.36	1.45	0.53	L2 CB opened for line maintenance work
16/07/2015	7:18	9:40	2:22	2.36	1.4	3.304	L2 CB was tripped out due to line earth fault 73 A
	11:24	13:30	2:06	2.1	1.2	2.52	l2 CB was disconnected for maintenance for shadding(SOL
17/7/2015	10:40	11:50	1:10	1.16	1.25	1.45	L2 CB was disconnected for maintenance for shadding(SOL 2.8MW
19/7/2015	10:07	10:48	0:41	0.68	0.62	0.423	L2 CB was tripped out due to line short ckt phase RT 536A
	10:54	11:57	1:03	1.05	1.2	1.26	L2 CB was tripped out due to line earth fault 670A
	15:28	16:06	0:38	0.63	1.66	1.05	L2 CB was tripped out due to line earth fault 85A
	17:32	19:16	1:44	1.73	1.68	2.906	L2 CB was tripped out due to line earth fault 120A
20/07/2015	16:31	17:35	1:04	1.066	1.6	1.705	L2 CB was tripped out due to short ckt phase RS 1.305 KA
	17:35	18:35	1:00	1	1.6	1.6	L2 CB was tripped out due to short ckt phase RT 1.385 KA
21/07/2015	9:38	9:58	0:20	0.33	1.4	0.466	L2 CB opened for line maintenance work
	16:02	17:35	1:33	1.55	1.425	2.208	L2 CB was tripped out due to short ckt phase RT 547A
22/07/2015	7:03	8:15	1:12	1.2	1.45	1.74	L2 CB was tripped out due to short ckt phase RT 547A
	15:05	16:20	1:15	1.25	1.35	1.68	L2 CB was tripped out due to short ckt phase RT 1.385 KA
	16:30	18:55	2:25	2.416	1.36	3.28	L2 CB was tripped out due to earth fault 107 A
23/7/2015	14:23	16:58	2:35	2.583	1.39	3.586	L2 CB was tripped out due to short ckt R.S T 2.1kA
	17:49	18:08	0:19	0.316	1.36	0.430	L2 CB opened for line maintenance work
24/7/2015	7:38	8:42	1:04	1.066	1.05	1.11	L2 CB was tripped out due to earth fault 98 A
25/7/2015	10:45	10:48	0:03	0.05	1.5	0.075	L2 CB opened for line maintenance work
	14:16	19:16	5:00	5	1.38	6.9	L2 Cb tripped due to Line short ckt phaseRS 2.26kA
26/7/2015	15:21	17:00	1:39	1.65	1.66	2.73	L2 Cb tripped due to Line short ckt phaseRS 2.26kA

27/7/2015	6:58	9:42	2:44	2.733	1.43	3.908	L2 CB was tripped out due to short ckt R.S T 1.339 KA
	15:20	15:34	0:14	0.233	1.77	0.413	L2 CB opened for line maintenance work
	17:30	18:12	0:42	0.7	1.45	1.015	L2 CB was tripped out due to earth fault 86 A
28/07/2015	11:36	12:00	0:24	0.4	1.6	0.64	L2 CB was tripped out due to short ckt 524 A
29/7/2015	10:00	10:19	0:19	0.316	1.2	0.38	L2 CB opened for line maintenance work
	14:18	15:23	1:05	1.083	0.85	0.92	L2 CB was tripped out due to short ckt phase ST 1.17KA
30/7/2015	16:52	17:48	0:56	0.933	1.56	1.45	L2 CB was tripped out due to short ckt RT 668 A
	18:50	21:10	2:20	2.33	1.66	3.86	L2 cb opened due to line sol 3.2 mw
1/8/2015	8:50	10:28	1:38	1.63	0.906	1.476	L2 CB was tripped out due to short ckt RT 796 A
	12:14	14:26	2:12	2.2	2.13	4.68	L2 CB was tripped out due to earth fault 108 A
2/8/2015	17:00	17:43	0:43	0.716	1.6	1.146	L2 CB was tripped out due to short ckt RS 728A
	19:36	20:26	0:50	0.833	2.4	2	L2 CB was tripped out due to earth fault
3/8/2015	17:10	18:41	1:31	1.516	1.6	2.425	L2 CB was tripped out due to earth fault
	18:44	19:13	0:29	0.483	2	0.966	L2 CB was tripped out due to short ckt RS 728A
4/8/2015	18:59	19:59	1:00	1	2	2	L2 CB was tripped out due to earth fault
5/8/2015	13:20	13:54	0:34	0.566	1.6	0.906	L2 CB was tripped out due to earth fault 86 A
6/8/2015	10:10	10:30	0:20	0.33	1.6	0.533	L2 CB opened for line maintenance work
	12:32	13:59	1:27	1.45	1.6	2.32	L2 CB was tripped out due to earth fault 69.6A
	14:52	17:38	2:46	2.76	1.38	3.808	L2 CB was tripped out due to earth fault 82.8A
7/8/2015	9:53	10:15	0:22	0.366	1.5	0.55	L2 CB opened for line maintenance work
8/8/2015	9:35	10:00	0:25	0.416	1.25	0.520	L2 CB opened for line maintenance work
	17:20	18:30	1:10	1.16	1.66	1.92	L2 CB opened for line maintenance work
	17:49	19:50	2:01	2.016	1.13	2.27	L2 CB was tripped out due to short ckt phase ST 1.17KA
10/8/2015	10:14	11:03	0:49	0.816	1.4	1.143	L2 CB was tripped out due to earth fault 69.6A

12/8/2015	6:34	8:45	2:11	2.183	1.35	2.947	L2 CB was tripped out due to earth fault 69.6A
14/8/2015	0:00	8:47	8:47	8.78	1.3	11.41	L2 CB was tripped out due to short ckt RT 1.513KA
	10:24	10:52	0:28	0.466	1.6	0.746	L2 CB was tripped out due to short ckt RT 1.513KA
15/8/2015	9:34	9:41	0:07	0.116	1.4	0.163	L2 CB opened for line maintenance work
	13:40	14:35	0:55	0.916	0.725	0.664	L2 CB was tripped out due to earth fault 360 A
16/8/2015	3:35	9:35	6:00	6	1.35	8.1	L2 CB was tripped out due to short ckt RT 1.513KA
17/8/2015	8:10	9:44	1:34	1.56	1.25	1.95	L2 CB was tripped out due to short ckt RT 1.99KA
18/8/2015	0:30	9:41	9:11	9.183	1.36	12.48	L2 CB was tripped out due to short ckt phase ST 1.02KA
	15:25	16:20	0:55	0.916	0.7	0.641	L2 CB was tripped out due to short ckt RT 1.99KA
	16:20	18:00	1:40	1.66	1.35	2.24	L2 CB was tripped out due to short ckt phase ST 447 A
19/8/2015	7:45	8:33	0:48	0.8	1.55	1.24	L2 CB opened for line maintenance work
20/8/2015	16:40	17:45	1:05	1.083	0.5	0.541	L2 CB was tripped out due to short ckt phase ST 1.02KA
21/8/2015	14:30	15:31	1:01	1.016	0.75	0.762	L2 CB was tripped out due to short ckt RT 578A
22/8/2015	18:48	19:42	0:54	0.9	2	1.8	L2 CB opened for line maintenance work
24/8/2015	12:41	15:06	2:25	2.416	1.6	3.86	L2 CB was tripped out due to short ckt phase RS 1.66 A
25/8/2015	10:08	10:18	0:10	0.166	1.45	0.241	L2 CB opened for line maintenance work
26/8/2015	10:22	11:56	1:34	1.56	1.45	2.26	L2 CB was tripped out due to short ckt phase RS 11.47 A
	15:25	16:14	0:49	0.816	0.5	0.408	L2 CB was tripped out due to short ckt phase RS 518.4 A
28/8/2015	18:59	20:00	1:01	1.016	1.36	1.38	L2 CB was tripped out due to earth fault 81A
29/8/2015	10:59	12:00	1:01	1.016	1.56	1.38	L2 CB was tripped out due to earth fault 102A
3/9/2014	14:32	14:48	0:16	0.266	1.4	0.37	L2 CB opened for line maintenance work
	17:36	18:46	1:10	1.166	1.4	1.63	L2 CB was tripped out due to earth fault 94A

4/9/2015	11:00	11:30	0:30	0.5	1.36	0.68	L2 CB opened for line maintenance work
	11:32	11:50	0:18	0.3	1.36	0.408	L2 CB was tripped out due to short ckt phase st 1.2KA
5/9/2015	9:43	9:50	0:07	0.11	1.25	0.145	L2 CB opened for line maintenance work
7/9/2015	14:08	15:29	1:21	1.35	1.22	1.64	L2 CB was tripped out due to earth fault 97A
8/9/2015	14:30	15:27	0:57	0.95	1.1	1.045	L2 CB was tripped out due to earth faul 90A
	10:31	17:46	7:15	7.25	1.1	7.97	L2 CB was tripped out due to earth faul 97A
11/9/2015	9:32	11:36	2:04	2.066	0.33	0.681	L2 CB was dis connected due to line mentenance work
	15:45	17:32	1:47	1.783	0.73	1.301	L2 CB was dis connected due to line SOL 2.7 MW
	19:14	19:46	0:32	0.533	1.6	0.853	L2 CB WAS tripped due to line earth fault 92 A
12/9/2015	14:27	15:10	0:43	0.716	1.7	1.218	L2 CB WAS tripped due to line earth fault 84 A
	10:50	11:26	0:36	0.6	1.65	0.99	L2 CB opened for line maintenance work
17/09/2015	7:04	8:29	1:25	1.416	0.575	0.814	L2 CB WAS tripped due to line earth fault 92 A
	11:47	13:00	1:13	1.216	1.25	1.52	L2CB opened for line maintenance work
	19:46	20:46	1:00	1	1.36	1.36	L2CB was tripped out due to earth faul 625A
21/09/2015	14:30	15:52	1:22	1.36	0.6	0.816	L2 CB was tripped out due to earth fault mgn 91 A
	15:17	16:39	1:22	0.366	1.5	0.55	L2 CB was tripped out due to earth fault mgn 91 A
23/9/2015	16:01	16:45	0:44	0.733	0.9	0.66	L2 CB was trippe due to line earth fault 104A
24/9/2015	17:18	17:47	0:29	0.483	1.7	0.821	L2 CB was trippe due to line earth fault 99A
25/09/2015	11:00	13:27	2:27	2.45	1.2	2.94	L2 CB was dis connected due to line SOL 2.7 MW
	17:27	18:04	0:37	0.616	1	0.616	L2 CB was tripped due to line earth fault
26/09/2015	7:28	8:23	0:55	0.916	1.25	1.145	L2 CB was tripped out due to earth fault mgn 91 A
	16:32	16:40	0:08	0.133	1.6	0.213	L2 CB was tripped out due to earth fault mgn 91 A
	18:34	20:09	1:35	1.583	1.8	2.849	L2 CB was tripped due to line s/c phase RT 2.9KA

27/9/2015	8:45	9:07	0:22	0.366	1.55	0.568	L2 CB was tripped due to line earh fault 102A
	10:35	11:25	0:50	0.833	1.45	1.208	L2 CB was tripped due to line earh fault 99A
30/9/2015	12:00	13:05	1:05	1.08	1.6	1.728	L2 CB was tripped due to line earh fault 99A
	8:49	10:10	1:21	1.35	1.76	2.376	L2 CB was disconnected due to line maintainance work
1/10/2015	12:50	14:01	1:11	1.183	1.5	1.774	L2 CB was tripped due to line earth fault 101A
2/10/2015	15:11	15:47	0:36	0.6	0.9	0.54	L2 CB was disconnected due to line maintanance work
6/10/2015	13:40	14:27	0:47	0.783	0.4	0.313	L2CB was tripped due to line earth fault 94A
	18:27	19:23	0:56	0.933	1.8	1.68	L2CB was tripped due to line s/c phase ST21.05kA
9/10/2015	12:43	13:55	1:12	1.2	1.1	1.32	L2 CB was tripped due to line earth fault 90A
	13:56	14:34	0:38	0.633	1.1	0.696	L2 CB was tripped due to line earth fault 95A
10/10/2015	14:15	15:24	1:09	1.15	0.25	0.287	L2 CB was tripped due to line earth fault 2.46KA
13/10/2015	2:44	8:40	5:56	5.933	1.1	6.526	L2 CB was tripped due to line earth fault
16/10/2015	6:34	8:37	2:03	2.05	0.92	1.886	L2 CB was tripped due to line s/c phase ST 2.2KA
	15:01	15:38	0:37	0.616	1.3	0.801	L2 CB was tripped due to line s/c 484A
17/10/2015	6:45	7:31	0:46	0.766	1.4	1.07	L2 CB was tripped due to line earth fault 97A
21/10/2015	17:59	18:13	0:14	0.233	1.7	0.396	L2 CB was disconnected due to line maintanance work
25/10/2015	9:50	12:03	2:13	2.216	1.67	3.700	L2 CB was tripped due to line s/c phase RS 982A
26/10/2015	9:18	9:26	0:08	0.133	1.6	0.213	L2 CB was disconnected due to line maintainance work
28/10/2015	7:14	8:33	1:19	1.316	1.4	1.842	L2 CB was tripped due to line earth fault 81A
29/10/2015	10:15	10:42	0:27	0.45	1.66	0.747	L2 CB was disconnected due to line maintanance work
30/10/2015	7:56	9:29	1:33	1.55	0.916	1.419	L2 CB was tripped due to line s/c phase RT 1.1KA
2/11/2015	9:42	10:11	0:29	0.483	1.45	0.7008	L2 CB was tripped due to line s/c phase RS 681A
3/11/2015	5:16	9:21	4:05	4.083	1.04	4.246	L2 CB was tripped due to line s/c phase RT 3KA
6/11/2015	13:10	13:20	0:10	0.166	1.87	0.311	L2 CB was tripped due to line earth fault

7/11/2015	9:50	10:33	0:43	0.716	1.17	0.838	L2 CB was tripped due to line earth fault
9/11/2015	10:23	14:36	4:13	4.216	1.63	6.872	L2 CB was disconnected for maintenance for shadding (SOL 2.8MW
1/12/2015	14:35	15:10	0:35	0.58	1.7	0.99	L2 Cb tripped due to Line short ckt phase RS
2/12/2015	9:15	9:44	0:29	0.48	1.87	0.89	L2 Cb tripped due to Line short ckt phase ST
	10:01	10:23	0:22	0.36	1.87	0.67	L2 Cb tripped due to Line short ckt phase RT
	11:43	12:14	0:31	0.516	1.66	0.85	L2 CB opened for line maintenance work
3/12/2015	9:55	10:16	0:21	0.35	1.6	0.56	L2 CB tripped due to Line short ckt phase RS
	13:37	13:43	0:06	0.1	1.6	0.16	L2 CB opened for line maintenance work
5/12/2015	7:45	7:48	0:03	0.05	1.87	0.093	L2 CB opened for line maintenance work
	16:05	16:35	0:30	0.5	1.66	0.83	L2 CB tripped due to Line Earth Fault
7/12/2015	16:21	16:50	0:29	0.48	1.45	0.69	L2 CB tripped due to Line Earth Fault
	18:45	19:03	0:18	0.3	1.7	0.51	L2 CB tripped due to Line Earth Fault
8/12/2015	9:00	9:35	0:35	0.58	1.36	0.79	L2 CB tripped due to Line Earth Fault
	10:43	10:53	0:10	0.166	1.36	0.226	L2 CB opened for line maintenance work
	14:55	15:22	0:27	0.45	1.45	0.65	L2 CB tripped due to Line Earth Fault
9/12/2015	13:45	13:48	0:03	0.05	1.87	0.093	L2 CB opened for line maintenance work
	13:45	14:10	0:25	0.416	1.87	0.779	L2 CB tripped due to Line Earth Fault
10/12/2015	12:32	13:12	0:40	0.66	1.66	1.095	L2CB opened for line maintenance work
11/12/2015	16:58	17:12	0:14	0.23	1.7	0.39	L2 CB tripped due to Line Earth Fault
	19:15	20:20	1:05	1.08	2.2	2.37	L2 CB tripped due to Line short ckt phase RT
13/12/2015	4:30	7:30	3:00	3	1.2	3.6	L2 CB tripped due to Line Earth Fault
14/12/2015	18:55	19:18	0:23	0.38	2.08	0.79	L12 CB tripped due to Line short ckt phase RS
	19:50	20:40	0:50	0.83	2.08	1.73	L2 CB tripped due to Line Earth Fault

15/12/2015	15:45	19:30	3:45	3.75	1.5	5.62	L2 CB opened for line maintenance work
	17:20	19:27	2:07	2.11	1.35	2.84	Total power interruption
28/12/2015	8:58	9:40	0:42	0.7	1.3	0.91	L2 CB tripped due to Line Earth Fault
	9:30	9:54	0:24	0.4	1.25	0.32	L2CB opened for line maintenance work
	17:35	17:54	0:19	0.316	1.45	0.459	L2 CB tripped due to Line Earth Fault
	17:35	17:49	0:14	0.233	1.25	0.291	L2 CB tripped due to Line Earth Fault
29/12/2015	9:45	10:00	0:15	0.25	0.62	0.155	L2 CB tripped due to Line Earth Fault
30/12/2015	11:40	11:54	0:14	0.23	1.45	0.338	L2 CB tripped due to Line Earth Fault
Total				**454.44**	**433.12**	**647.45**	**********

Appendix B

Program code for feeder two 62 bus System sectionalizing and tie line switch analysis

```
clc;clear all;
bus63data;
%obtain the modified topology:
disp('choose three different lines to break following the instruction:')
i1 =input('line to break from FL1(choose from 1.........62) = '); % line1
T(line(i1,2),line(i1,3))=0;
T(line(i1,3),line(i1,2))=0;
if i1  = 62 % debugging for two adjunct tie switches(line 5)
if i1 == 61 % if l4 is cut off, the route should be able to pass from
T(61,62)=1; % node 5 to 6, but not 6 to 5, otherwise vice versa.
else T(62,61)=1;
end
end
%————main program——————
for k=1:62 % find f of node5 to node17
%————–find path1—————-
i=2; h=2; g=2;fp=k; % "g"- count for third route
pr = 0; sr = 0; tr = 0; % "i"- count for primary route;
pr(1)= fp; lp = fp; % "h"- count for secondary route;
times= 0; %"times"- the times that count==2;
path1out = false; % "fp"- former point;% "lp"- current load point;
while path1out == false % "pr"- primary route;
count = 0; % "sr"- secondary route;
for j =1:62 % "tr"- third route
if T(lp, j)>0 and j  = fp
count=count+1; % count the number of paths
end
```

```
end
if count ==1 % if path number = 1
flag = 0;
for j =1:62
if T(lp, j)>0 and j =fp
flag =1; fp=lp; lp=j;
pr(i)=lp; i=i+1;
end
if flag==1
break
end
end
end
if count ==2 % if path number = 2
times= times+1;
flag1 = 0;
for j =1:62
if T(lp, j)>0 and j =fp
flag1= flag1+1;
if flag1==1 % select first available point into path1 pr(i)=j;i=i+1;
end
if flag1==2 and times ==1
sr(1)=lp;sr(h)=j; % select second available point into path2,
h=h+1;
fp=lp; lp=pr(i-1); % and store as the beginning of branch
end
if flag1==2 and times ==2
tr(1)=lp;tr(g)=j;% select second available point into path3,
g=g+1;
fp=lp; lp=pr(i-1); % and store as the beginning of branch
end
end
```

```
if flag1==2
break
end
end
end
if count ==3
flag1_2 =0;
for j =1:62
if T(lp, j)>0 and j =fp
flag1_2= flag1_2+1;
if flag1_2==1 % select first available point into path1
pr(i)=j;i=i+1;
end
if flag1_2==2
sr(1)=lp;sr(h)=j; % select second available point into path2,
h=h+1; % and store as the beginning of branch
end
if flag1_2==3
tr(1)=lp;tr(g)=j;
g=g+1; % select third available point into path3,
fp=lp;lp=pr(i-1);% and store as the beginning of branch
end
end
if flag1_2==3
break
end
end
end
if count ==0
path1out = true;
end
end
```

```
%————–find path2—————-
if sr =0
fp2 = sr(1);lp2 = sr(2);%”fp2”- former point;
path2out=false; %”lp2”- current load point;
while path2out ==false
count2 = 0;flag2 = 0;
for j =1:62
if T(lp2, j)>0 and j =fp2
count2 =count2+1; % count the number of paths,
flag2 =1; fp2=lp2; lp2=j; % as in 16bus system there won’t
sr(h)=lp2; h=h+1; % be two branches in path2,so
end % count2 can only be 1 or 0
if flag2==1
break
end
end
if count2==0
path2out=true;
end
end
end
%————–find path3—————-
if tr =0
fp3 = tr(1);lp3 = tr(2); %”fp3”- former point;
path3out=false; %”lp3”- current load point;
while path3out ==false
count3 = 0;flag3 = 0;
for j =1:62
if T(lp3, j)>0 and j =fp3
count3 =count3+1; % count the number of paths,
flag3 =1; fp3=lp3; lp3=j; % as in 16bus system there won’t
tr(g)=lp3; g=g+1; % be two branches in path3,so
```

```
end % count2 can only be 1 or 0
if flag3==1
break
end
end
if count3==0
path3out=true;
end
end
end
lpr= length(pr); lsr= length(sr);ltr= length(tr);% length of each path62
%———-unavailability matrix———-
% unavailable time matrix
UT=zeros(62,62); %ri matrix
%————for primary route————
check=0; % determine where is the nearest sectionalizer;
for n=1:lpr-1 % check = 1 - the nearest sectionalizer funded;
if check==0 % check = 0 - not yet;
if n == 1
if T(pr(n),pr(n+1))==2 % 2 - sectionalizer, 0.5h, otherwise 1h;
UT(pr(n),pr(n+1))=0.5; % analyze unavailable time for the
else UT(pr(n),pr(n+1))=1; % nearest line;
end
else if T(pr(n),pr(n+1))==2 —— T(pr(n),pr(n-1))==2
UT(pr(n),pr(n+1))=0.5; % analyze unavailable time for other
else UT(pr(n),pr(n+1))=1; % lines;
end
end
if UT(pr(n),pr(n+1))== 0.5
check =1;
end
end
```

```
if check==1
UT(pr(n),pr(n+1))=0.5;
end
end
%———-for secondary route————
if sr =0
% step1 find the complete secondary route
sro=0;check2=0; % sro= routes before the path2;
for n = 1:lpr
if pr(n) = sr(1)
sro(n) = pr(n);
else check2=1;
end
if check2 == 1
break
end
end
if sro =0
src=[sro,sr];
else src=sr;
end
lsrc=length(src); % src- complete secondary route;
% step2 analyze unavailable time for secondary route
check2_ 2=0; % determine where is the nearest sectionalizer;
for n=1:lsrc-1 %check = 1 - the nearest sectionalizer funded;
if check2_ 2==0 %chech = 0 - not yet;
if n == 1
if T(src(n),src(n+1))==2
UT(src(n),src(n+1))=0.5; %analyze unavailable time for the
else UT(src(n),src(n+1))=1; %nearest line
end
else if T(src(n),src(n+1))==2 —— T(src(n),src(n-1))==2
```

```
UT(src(n),src(n+1))=0.5; %analyze unavailable time for other
else UT(src(n),src(n+1))=1;
end
end
if UT(src(n),src(n+1))== 0.5
check2_2 =1;
end
end
if check2_2==1
UT(src(n),src(n+1))=0.5;
end
end
end
%———for third route————
if tr =0 %step1 find the complete third route
tro=0;check3=0; %tro= routes before the path3;
for n = 1:ltr
if pr(n) = tr(1)
tro(n) = pr(n);
else check3=1;
end
if check3 == 1
break
end
end
if tro =0
trc=[tro,tr];
else trc=tr;
end
ltrc=length(trc); %trc- complete third route;
%step2 analyze unavailable time for third route
check3_2=0; %determine where is the nearest sectionalizer;
```

```
for n=1:ltrc-1 %check = 1 - the nearest sectionalizer funded;
if check3_2==0 %check = 0 - not yet;
if n == 1
if T(trc(n),trc(n+1))==2
UT(trc(n),trc(n+1))=0.5; %analyze unavailable time for the
else UT(trc(n),trc(n+1))=1; %nearest line
end
else if T(trc(n),trc(n+1))==2 —— T(trc(n),trc(n-1))==2
UT(trc(n),trc(n+1))=0.5; %analyze unavailable time for other
else UT(trc(n),trc(n+1))=1;
end
end
if UT(trc(n),trc(n+1))== 0.5
check3_2 =1;
end
end
if check3_2==1
UT(trc(n),trc(n+1))=0.5;
end
end
end
disp(UT);
% ————calculate f_rate———
D=zeros(62,62); % initialize for position counting
lpr= length(pr); lsr= length(sr);
ltr= length(tr); % length of each path
for n=1:lpr-1;
D(pr(n),pr(n+1))=1;
end % marking related position
for n=1:lsr-1;
D(sr(n),sr(n+1))=1;
end
```

```
for n=1:ltr-1;
D(tr(n),tr(n+1))=1;
end
D = D.*f; % modified failure rate matrix
fr=sum(D);
fr=sum(fr);
F(k)=fr;
% ————unavailability————-
UT=UT.*D;
un=sum(UT);
un=sum(un);
UN(k)=un;
end
SAIFI = F*ApparentPower'/total;
disp('SAIFI');disp(SAIFI);
disp('unavailability');disp(UN);
SAIDI = sum(UN*ApparentPower')/total;
disp('SAIDI');disp(SAIDI);
CAIDI = SAIDI/SAIFI;
disp('CAIDI');disp(CAIDI);
ENS = sum(UN*MW');
disp('ENS');disp(ENS);
data = [SAIFI, SAIDI, CAIDI, ENS];
```

APPENDIX C

Data for feeder two 62 bus System sectionalizing and tie line switch analysis

%——————62 bus data———————

line=[1 1 0 6.5;

2 2 1 9.15; % line info

3 3 2 9.15; % column 1: line number;

4 4 3 9.15; % column 2: start bus;

5 4 5 9.15; % column 3: end bus

6 5 7 9.15; % column 4: Active failure rate

7 5 6 9.15;

8 6 8 9.15;

9 9 3 9.15;

10 11 12 9.15;

11 11 3 9.15;

12 11 15 9.15;

13 14 15 9.15;

14 14 16 9.15;

15 16 19 9.15;

16 16 17 9.15;

17 17 18 9.15;

18 17 20 9.15;

19 20 21 9.15;

20 20 22 9.15;

21 22 23 9.15;

22 22 24 9.15;

23 23 25 9.15;

24 25 26 9.15;

25 26 27 9.15;

26 26 28 9.15;

27 28 29 9.15;

28 31 32 9.15;

29 32 33 9.15;

30 33 34 9.15;

31 34 37 9.15;

32 37 38 9.15;

33 37 36 9.15;

34 36 35 9.15;

35 37 39 9.15;

36 39 40 9.15;

37 39 41 9.15;

38 39 42 9.15;

39 42 43 9.15;

40 42 44 9.15;

41 38 45 9.15;

42 45 46 9.15;

43 45 47 9.15;

44 48 47 9.15;

45 48 49 9.15;

46 50 49 9.15;

47 49 51 9.15;

48 51 52 9.15;

49 50 53 9.15;

50 53 54 9.15;

51 54 55 9.15;

52 327 55 9.15;

53 55 57 9.15;

54 57 58 9.15;

55 57 59 9.15;

56 56 57 9.15;

57 57 60 9.15;

58 61 60 9.15;

59 62 61 9.15;

60 63 62 9.15;

61 210 9 9.15;

62 216 14 9.15];

% complete topology:1 - line; 2 - sectionalizer; -1 - tie switch(fuse);

% n 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17..................62

T =[0,2,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %1

1,0,0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %2

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %3

0,0,0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,2,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 2, 0, 0, 0, 0; %4

0,0,0, 0, 2, -1, -1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %5

0,0,0, 0, 0, 2, -1, -1, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %6

0,0,0, 0, 0, 0, 2, -1, -1, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %7

0,0,0, 0, 0, 0, 0, 2, -1, -1, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %8

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 2, 0, 0, 0; %9

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %10

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %11

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %12

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,-1, 0, 0, 0, 0, 0, 0, 0, 0; %13

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,-1, 0, 0, 0, 0, 0, 0, 0, 0; %14

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0,0,0,-1, 0, 0, 0, 0, 0, 0, 0, 0; %15

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 2, 0, 0; %16

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,1,0, 0, 0, 0, 0, 0, 0, 0, 0; %17

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,2,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %18

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,2,-1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %19

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %20

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,2,0, -1, -1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %21

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,1, 0, 0, 0, 0, 0, 0, 0, 0; %22

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 2, -1, -1, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %23

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,2, 0, 0, 0, 0, 0, 0, 0, 0; %24

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,1,0, 0, 0, 0, 0, 0, 0, 0, 0; %25

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %26

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %27

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %28

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %29

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %30

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %31

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %32

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %33

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %34

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %35

0,0,0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %36

0,0,0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %37

0,0,0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %38 0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %39

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 2, -1, -1, -1, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %40

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %41

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %42

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %43

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %44

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %45

0,0,0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0,0,0,-1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %46

0,0 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0,-1,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %47

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2,1, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %48

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 1, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %49

0,0,0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %50

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2,0,0,-1, 0, 0, 0, 0, 0, 0, 0, 0; %51

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %52

0,0,0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %53

0,0,0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %54

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %55

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %56

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,-1,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %57

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 2, 0, 0, 0, 0; %58

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %59

0,-1,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0; %60

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 2, -1; %61

0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0]; %62

% **falure rate matrix**

f = [9.15, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 1,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0,0;
0, 0, 0,9.15, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,9.15, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,9.15, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0,0;
0, 0, 0, 0, 0, 0, 0,9.15, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,9.15, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,9.15, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0,0;
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,9.15, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,9.15, 0, 0, 0,0,0,0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0.5, 0, 0, 0,0,0,0;
9.15, 0, 0, 0,9.15,9.15, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,9.15, 0, 0, 0,9.15,9.15, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3.5,0,0,0,0,3.5, 0, 0, 0,9.15,9.15, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0,0;
0, 0, 0,9.15, 0, 0, 0, 0, 0, 0,9.15, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,3.0, 0, 0, 0, 0, 0, 0,4.0, 0, 0, 0, 0, 0,3.5,0,0,0, 0, 0, 0,3.0, 0, 0, 0, 0, 0, 0,4.0, 0, 0, 0, 0, 0,0,0,0,0,0,0,0;
0, 0, 0,1.5, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,1.5, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,3.5,0,0,0, 0, 0, 0,1.5, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0,0;
0, 0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,0,0,0,0, 0, 0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,0,0,0,0, 0, 0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,0,0,0,0,0,0,0;
0,1.1, 0, 0, 0, 0, 0, 0,2.8,1.1, 0, 0, 0, 0, 0, 0,0,0,0,0, 0,1.1, 0, 0, 0, 0, 0, 0,2.8,1.1, 0, 0, 0, 0, 0, 0,0,0,0,0, 0,1.1, 0, 0, 0, 0, 0, 0,2.8,1.1, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0,0;
0, 0, 0, 0, 0, 0, 0,2.8, 0, 0,0.8,2.0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,2.8, 0, 0,0.8,2.0, 0, 0, 0, 0,3.5,0,0,0, 0, 0, 0, 0, 0, 0, 0,2.8, 0, 0,0.8,2.0, 0, 0, 0, 0,0,0,0,0,0,0,0;
0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0,5.0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0,5.0, 0, 0,0,3.5,0,0, 0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0,5.0, 0, 0,0,0,0,0,0,0,0;
0, 0, 0, 0,4.0, 0, 0, 0,0.8, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0,4.0, 0, 0, 0,0.8, 0, 0, 0, 0, 0, 0, 0,0,3.5,0,0, 0, 0, 0, 0,4.0, 0, 0, 0,0.8, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0,0;
0, 0, 0, 0, 0, 0, 0, 0,2.0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0,2.0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0,2.0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0,0;
0, 0,0.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,1.5, 0,0,0,0,0, 0, 0,0.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0,1.0,1.5, 0,0,0,0,0, 0, 0,0.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,1.5, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0,0;

0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0.5, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0.5, 0, 0, 0,0,0,0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0.5, 0, 0, 0,0,0,0;

3.5, 0, 0, 0,3.0,1.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,3.5, 0, 0, 0,3.0,1.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,3.5, 0, 0, 0,3.0,1.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0,3.0, 0, 0, 0, 0, 0, 0,4.0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,3.0, 0, 0, 0, 0, 0, 0,4.0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,3.0, 0, 0, 0, 0, 0, 0,4.0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0,1.5, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,1.5, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,1.5, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0,1.0,0,0,0,0, 0, 0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,0,0,0,0, 0, 0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,0,0,0,0,0,0;

0,1.1, 0, 0, 0, 0, 0, 0,2.8,1.1, 0, 0, 0, 0, 0, 0,0,0,0,0, 0,1.1, 0, 0, 0, 0, 0, 0,2.8,1.1, 0, 0, 0, 0, 0, 0,0,0,0,0, 0,1.1, 0, 0, 0, 0, 0, 0,2.8,1.1, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0,2.8, 0, 0,0.8,2.0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,2.8, 0, 0,0.8,2.0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,2.8, 0, 0,0.8,2.0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0,5.0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0,5.0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0,5.0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0,4.0, 0, 0, 0,0.8, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0,4.0, 0, 0, 0,0.8, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0,4.0, 0, 0, 0,0.8, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0,2.0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0,2.0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0,2.0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0,0.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,1.5, 0,0,0,0,0, 0, 0,0.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,1.5, 0,0,0,0,0, 0, 0,0.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,1.5, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0, 0, 0,0;

0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0.5, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0.5, 0, 0, 0,0,0,0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0.5, 0, 0, 0,0,0,0;

3.5, 0, 0, 0,3.0,1.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,3.5, 0, 0, 0,3.0,1.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,3.5, 0, 0, 0,3.0,1.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0,3.0, 0, 0, 0, 0, 0, 0,4.0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,3.0, 0, 0, 0, 0, 0, 0,4.0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,3.0, 0, 0, 0, 0, 0, 0,4.0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0,1.5, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,1.5, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0,1.5, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,0,0,0,0, 0, 0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,0,0,0,0, 0, 0, 0, 0, 0,3.5, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,0,0,0,0,0,0;

0,1.1, 0, 0, 0, 0, 0, 0,2.8,1.1, 0, 0, 0, 0, 0, 0,0,0,0,0, 0,1.1, 0, 0, 0, 0, 0, 0,2.8,1.1, 0, 0, 0, 0, 0, 0,0,0,0,0, 0,1.1, 0, 0, 0, 0, 0, 0,2.8,1.1, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0,2.8, 0, 0,0.8,2.0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,2.8, 0, 0,0.8,2.0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,2.8, 0, 0,0.8,2.0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0,5.0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0,5.0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0,1.1, 0, 0, 0, 0, 0,5.0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0,4.0, 0, 0, 0,0.8, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0,4.0, 0, 0, 0,0.8, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0,4.0, 0, 0, 0,0.8, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0,2.0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0,2.0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0,2.0, 0, 0, 0, 0, 0, 0, 0,0,0,0,0,0,0;

0, 0,0.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,1.5, 0,0,0,0,0, 0, 0,0.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,1.5, 0,0,0,0,0, 0, 0,0.5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.0,1.5, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0, 0, 0, 0, 0, 0, 0,1.0, 0, 0, 0, 0, 0, 0, 0,4.4, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,5.0, 0, 0,1.0, 0, 0, 0,0,0,0,0,0,0;

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,1.5, 0, 0,4.4,0,0,0,0,0,0];

%%**Power Matrix**

MW =[-17.452 -17.037 -16.882 -5.054 4.180 1.788 2.359 1.172 0 1.207 -11.703 10.496 -10.264 10.265 2.469 7.680 0.464 7.008 1.801 4.020 3.430 0.297 3.280 3.131 0.976 2.035 1.890 1.823 1.759 -0.059 1.643 1.547 1.492 1.012 0.102 0.052 0.292 0.049 0.050 0.159 0.053 0.053 00.948 0.037 0.860 -0.773 0.722 -0.525 0.098 0.047 0.488 0.439 0.382 0.045 0.289 0.033 0.044 -0.044 0.164 -0.128 -0.085 -0.043];

ApparentPower =[-17.209, -16.904, -16.789, -5.477,1.608, 2.670, 1.329, 0.00,1.370, -11.221, 9.851,-9.682,9.682,2.676,2.247,6.942,0.719,6.071,1.456, 3.318, 2.683, 0.448, 2.589, 2.492, 1.244, 1.173, 1.080, 1.042,1.008, -0.030, 0.935,0.877,0.849,0.586,0.056,0.027,0.157, 0.025,0.028, 0.081, 0.027, 0.027, 0.551, 0.027, 0.495, -0.435, 0.409, -0.304,0.052, 0.026, 0.276,0.250,0.220,0.025,0.170,0.026,0.023,-0.024,0.095,-0.071,-0.047,-0.024];

total= sum(ApparentPower);

F=zeros(1,62); %failure rate for each node