THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION

INSTITUTE OF SCIENCE AND TECHNOLOGY

ENHANCEMENT OF RELIABILITY INDICES IN RADIAL DISTRIBUTION POWER NETWORKS WHERE 3-PHASE TRIPPING RECLOSERS ARE USED INSTEAD OF MAIN CIRCUIT BREAKERS

MASTER THESIS

QASIM MOHAMMED ARJANE

THE DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

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QASIM MOHAMMED ARJANE, having student number 1406030011 and enrolled in the Master Program at the Institute of Science and Technology at the University of Turkish Aeronautical Association, after meeting all of the required conditions contained in the related regulations, has successfully accomplished, in front of the jury, the presentation of the thesis prepared with the title of: "ENHANCEMENT OF RELIABILITY INDICES IN RADIAL DISTRIBUTION POWER NETWORKS WHERE 3-PHASE TRIPPING RECLOSERS ARE USED INSTEAD OF MAIN CIRCUIT BREAKERS"

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Thesis Defense Date: 17.07.2017

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I hereby declare that all the information in this study I presented as my Master's Thesis, called: ENHANCEMENT OF RELIABILITY INDICES IN RADIAL DISTRIBUTION POWER NETWORKS WHERE 3-PHASE TRIPPING RECLOSERS ARE USED INSTEAD OF MAIN CIRCUIT BREAKERS, has been presented in accordance with the academic rules and ethical conduct. I also declare and certify with my honor that I have fully cited and referenced all the sources I made use of in this present study.

17.07.2017

QASIM MOHAMMED ARJANE

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In the name of ALLAH, the Most Gracious and the Most Merciful. Moreover, I send more blessings and peace be up on our prophet Mohammed who saves us from the depths of darkness and leads us forth into science light, and guidance.

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July 2017 **QASIM MOHAMMED ARJANE**

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LIST OF ABBRIVIATION

2-Bus	Network Term Consists of Two Bus
AENS	Average Energy Not Supplied Index
ASAI	Average Service Availability Index
Bus 2	Bus Number two or (11) Kilo Volt Side
C.B.	Three Phase Circuit Breaker
CAIDI	Customer Average Interruption Duration Index
DS	Deferential Search
ENS	Energy Not Supplied Index
FMEA	Failure Mode and Effect Analysis Technique
GA	Genetic Algorithm
MAIFI	Momentary Average Interruption Frequency Index
MAIFIe	Momentary Average Interruption Events Frequency Index
PSO	Particle Swarm Optimization
r series	Failure Duration Rate for series components of radial system
r	Failure Duration Rate
R	Three Phase Tripping Recloser
RBTS	Roy Billinton Test System
RCS	Remote Control Switch
rp	Permanent Failure Duration Rate
rt	Temporary Failure Duration Rate

SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition System
SF6	Sulfur Hexafluoride Gas
sw	Switching or Restoration Time
U series	Annual average outage for series components of radial system
U	Annual average of unavailability or outage
XLPE	Dielectric Cross-Linked Polyethylene
λ series	Failure Frequency Rate for series components of radial system
λ	Failure Frequency Rate
λp	Permanent Failure Frequency Rate
λt	Temporary Failure Frequency Rate

ABSTRACT

ENHANCEMENT OF RELIABILITY INDICES IN RADIAL DISTRIBUTION POWER NETWORKS WHERE 3-PHASE TRIPPING RECLOSERS ARE USED INSTEAD OF MAIN CIRCUIT BREAKERS

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Service reliability has become one of the most important necessities for customer satisfaction in modern society. But, large areas of the common radial distribution power networks have been suffered from power outages. In this work, we have studied the enhancement of reliability indices in radial distribution power networks where 3-phase tripping reclosers are used instead of main circuit breakers. This recloser is removing for the effect of temporary interruptions automatically hence getting more continuity of service.

Finally, for explaining that; a radial distribution power network for (Bus 2) of RBTS is used for analytical purposes and the work simulations are done by Failure Mode and Effect Analysis technique in MATLAB environment. In conclusion, we have investigated successful reliability indices results while lowering the investment requirements.

Keywords: 3-Phase tripping Recloser, Radial distribution power network, Momentary outages, Reliability indices of SAIDI, SAIFI, MAIFI, AENS, and ASAI.

ÖZET

ANA DEVRE KESİCİLER YERİNE 3-FAZLI OTOMATİK AÇ-KAPA ŞALTERLERİNİN KULLANILDIĞI RADYAL DAĞITIM GÜÇ ŞEBEKELERİNDE GÜVENİLİRLİK ENDEKSLERİNİN İYİLEŞMESİ

ARJANE, Qasim

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Tez Danışmanı: Prof. Dr. Doğan ÇALIKOĞLU

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Genelde, belli bir yerden enerji dağıtan sistemler geniş alanlarda oluyor, güvenilir olması için gelişmiş ve ekonomik olması beklenir. Yani çözümler gelişmiş olması gerekir, düşük bir yatırımla işin içinden çıkılması gerekir. Birde bu iş sürekli olması lazım. Çok kesintiler, çalıştırmada, çevresel faktörlerden kaynaklanır. Bu çalışmada ağın gücünü radial dağıtımdaki güvenirlik indeksini iyileştirip ve gerekli araştırmalar yapıldı ve 3 fazlı tekrar kapananlar breaker devrenin yerine kullandık. Bu tekrar kapayıcı, geçici kesintilerin etkisiyle otomatik olarak kaldırılıyor ve böylece daha fazla hizmet sürekliliği sağlıyor.

Sonuç olarak, bu iş gelişmiş teknolojiyi müşteriye güvenirlik sağlamak içindir, 3ph- gezgin ile otomatik kontrol yapmayı rahatlandırılacaktır. Birde, 3ph-gezgini noktasal enerji dağıtıcısının tabanı ile oluşmaktadır. Yani, tek bir noktadan dağıtmak yerine olaya daha yakından dahil oluyor. Sonuç olarak, standart RBTS (Bus 2), noktasal güç dağıtım sistemi daha analitik işler FMEA için MATLAB ortamında kullanılır.

Anahtar Kelimeler: 3Ph- gezgini Rikloser, Yakınsayan, Noktasal güç dağıtım ağı, Anlık depolama, SAIDI'in Güvenilirlik indeksi, SAIFI, MAIFI, AENS ve ASAI.

CHAPTER ONE

INTRODUCTION

1.1 Presentation

Reliability indices have been exploited in earlier studies [1]. In this work, the usage of 3-phase tripping recloser instead of the main circuit breaker is investigated in order to enhance and improve reliability indices in the performance of radial distribution power network. In this venture, lowering the investment requirements is also considered. For this, the failure mode and effect analysis (FMEA) technique [2] is used and simulations are done in MATLAB programming environment. Finally, for analytical computations we used the reliability test system for educational purposes as described in [3].

Currently, the reliability in supplying power is one of the important issues for customers. Large areas of the radial distribution power networks suffer from power outages. Most of the outages in overhead distribution power networks are momentary type in nature [4], [5] and [6].

Recently, many studies and researches have been focused on the distribution power reliability topics for securing the power supply continuity. This eventually results in increasing the reliability service and obtaining customer satisfaction.

Therefore, in this work we have aimed at enhancing the reliability indices by utilizing a three phase tripping recloser instead of each main circuit breaker in radial distribution power feeders [7], [8]. This has resulted in getting good reliability indices for the radial distribution networks while lowering the investment requirements.

1.2 Three Phase Tripping Recloser

A three-phase tripping recloser is a circuit breaker assembled with controllers and mechanism apparatuses. In addition, this 3-phase tripping recloser (auto recloser) can automatically reclose after its breaker has been opened as a result of a fault occurrence [6], [9].

Reclosers are used for the power system protection and reliability, to detect and remove the momentary faults. In return, many short-circuits faults on overhead lines are cleared spontaneously [4]. However, the recloser enhances or improves service reliability by its super speed restoration. Also, it is regarded to be a common eliminator for transient or momentary events. It should be noted that, it has a super speed reclosing trip which is de-energizing the fault current [6], [10].

The control system for the 3ph-tripping recloser allows a selected number of attempts to restore service after adjustable time delays. For instance, a 3ph-tripping recloser may have 1 or 2 or 3 "fast" reclose operations with a few seconds delay followed by a longer delay and one reclose. If the last attempt is not successful, the recloser will lock out and the requirement of human intervention to reset is then needed [11]. However, if the outage is a permanent fault type then the recloser will finish its repeated programming attempts in order to re-energize the line and it still remains tripped off until manually commanded to return on again [10].

The general operation sequence of a recloser is illustrated below in Figure (1.1). Where, the reaction time for each trip is represented by t1, t3 or t5 while the waiting time for each trip is represented by t2, t4 or t6 respectively. The recloser in reaction time senses the fault and it has disconnected for a waiting period and it is called the waiting time. Both of reaction and waiting periods are representing the reclosing trip time and the total trips time represents the max duration of temporary fault.

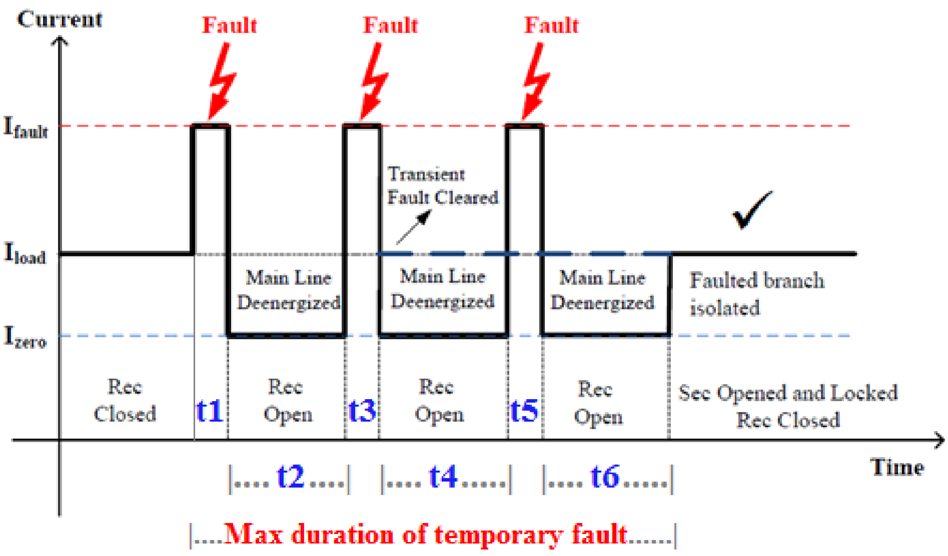

Figure 1.1 3Ph-tripping operation sequence

1.2.1 Importance and applications

The reclosers are having many features as modern devices in the electrical networks. Whereas, the reclosers protect the electric networks and improve its reliability indices by reducing number of outage durations. Moreover, they clear the momentary faults which represent 70% of total faults [4], [5], and [6]. So, they perform a better service reliability of the networks for less energy not supplied.

The applications of reclosers exist up on overhead distribution and transmission power lines as outdoor automatic three phase power switches. Also, some of them may be used inside the substation instead of main substation's breakers as indoor 1ph-tripping power switches [10], [12].

1.2.2 Types and Properties

Generally, the reclosers are designed in single-phase tripping and three-phase tripping devices. However, these types use of oil, vacuum, or SF6 interrupters [6]. Additionally, the controls for the recloser ranges are starting from the original electromechanical apparatuses to the digital electronics with metering apparatuses or the automated (SCADA) programming system. The ratings of recloser working voltage is ranging of (2.4–38) kV for load currents from (10 –1200) A, and fault currents from (1–16) kA. Also, for power quality the super speed reclosing trip of modern reclosers have waiting time reaches (100) milliseconds for giving the customer apparatuses such as the microwaves and the clocks to be not influenced by the momentary faults [10], [11].

1.3 The Contributions in This Area

Electrical power system over all its levels need for enhancements reliability. These levels represent the generation, transmission, and distribution power systems. However, the third level has been suffered of power outages more than others due to the various connected loads and its natures [5]. Recently, many researches and studies addressed distribution power networks reliability. Also, they enhance or improve reliability indices by several techniques and modes. By considering the fact that they took the less investment requirements of the equipment is used for improving the reliability indices [7].

In recent studies, they focused on reliability indices improvement in distribution power networks by different modes. For instance, E. Vidyasagar and others in 2011 had presented ‘‘Reliability Improvement of a Radial Feeder Using Multiple Fault Passage Indicators’’. Moreover, they offered the fault passage indicator device which set up on three phase overhead lines. However, these indicators help the utility to restore power by decreasing the time that an operating crew needs to seek a fault. Eventually, this process reduced the repair time and led to enhance the reliability indices for the radial distribution power network [13].

In 2013, Hamid SHARIFIAN and others had offered smart switches of VIT in “THE STUDY OF THE RELIABILITY INDICES OF DISTRIBUTION NETWORKS WITH VIT SWITCHES ON THE MV FEEDERS AUTOMATION”. Moreover, these switches converted the distribution network into automation mode and the last are useful in determining a fault. Finally, the reliability indices were computed by using Failure Mode and Effect Analysis FMEA technique [14].

In 2014, both Ashish Ranjan and J N Rai had presented “Optimal Switch Placement in Radial Distribution System Using GA and PSO”. Moreover, they used two types of artificial intelligence algorithms in order to improve reliability indices for 13-Bus standard network of Roy Billinton test system (RBTS). These algorithms are genetic algorithm, and particle swarm algorithm to determine the better location for each switch. Finally, the previous two approaches give a close result, and they recommended for using of two switches for each specified location in order to increase the improvement [15].

In 2015, Umesh Agarwal and Monika Vardia had produced “Reliability Enhancement of Radial Distribution System Using Network Reconfiguration”. Moreover, they used a technique of Network Reconfiguration to enhance the radial distribution network reliability indices. Also, they used RBTS 6-Bus, (Bus 2) radial distribution network for analytical purposes. In addition, this technique is based on (open/close) principle for specific switches that are existed in the radial network. Finally, reliability indices enhancement depends on the specific changes of the radial network structure [16].

In 2016, Saheli Ray and others had presented another optimized algorithm in “Optimal Allocation of Remote Control Switches in Radial Distribution Network for Reliability Improvement”. Moreover, their Differential Search (DS) algorithm had got reliability indices improvement results of expected energy not supplied index (ENS), better than of (PSO) algorithm. Finally, by their optimized (DS) algorithm they got better solution for remote control switches (RCS) arrangement by using of 8-Bus and 33-Bus RBTS radial test networks [17].

1.4 The Main Aspects of the Work and Its Importance

For this work, we utilized of the 3-phase tripping recloser which removes the momentary outage events continuously. Also, we took the standard radial distribution power network (Bus 2) with 4-feeders of Roy Billinton Test System RBTS 2-Bus [3]; Figure (1.2).

Then, we installed this recloser as a main power switch instead of the main circuit breaker (C.B.), [8]. As a result, we have got better reliability indices enhancement for each radial distribution power feeder as well as we did also for the overall radial distribution power network.

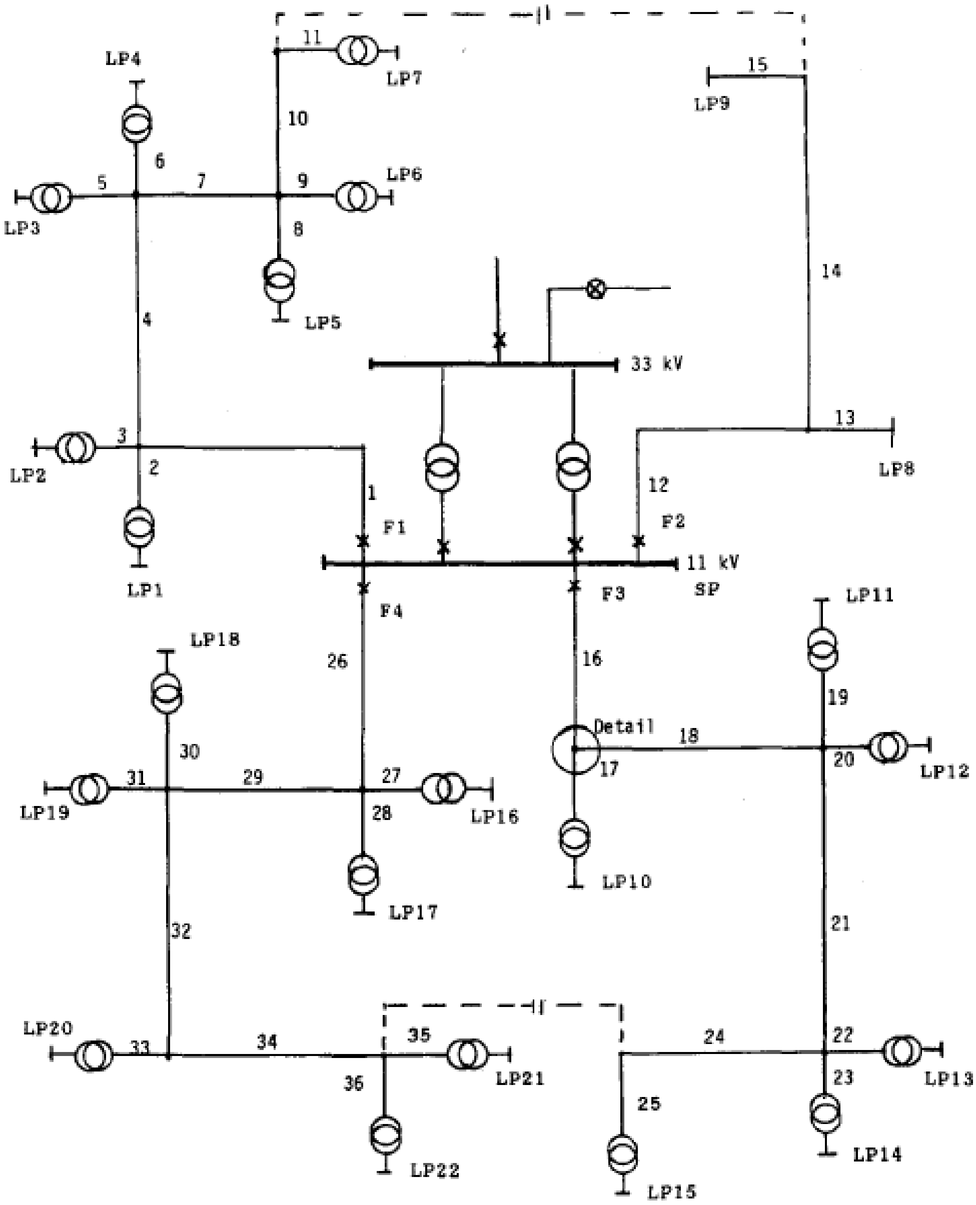

Figure 1.2 Radial distribution power network RBTS Bus 2, 4-Feeder

Consequently, we could utilize of the operational location for the main circuit breaker (C.B.) as a main operation point upon radial feeder head. In addition, the super speed reclosing trip of the recloser plays a key role against momentary outages that represent 70% of overall outages [5], [4] and [6].

Finally, we used just one recloser for each radial distribution power feeder. And that had been getting to less number of invested developed 3-phase tripping recloser eventually.

During last few years, a considerable number of contributions had been published about the distribution power reliability assessment to enhance its indices. In general, these studies are classified into three directions in development researches. The first effort includes enhancements or improvements for the distribution power reliability by experimenting modern switch technique or apparatus. While, the second effort used to rearrange the network itself with or without restrictions by Network Reconfiguration technique. In the third effort, that developed the programming methods for analyzing. This was by optimizing the algorithms to analyze the distribution networks and to determine the optimal locations for their switches in order to enhance the reliability indices.

For instance, E. Vidyasagar and others in 2011, had presented ‘‘Reliability Improvement of a Radial Feeder Using Multiple Fault Passage Indicators’’. Moreover, they offered the fault passage indicator device which set up on three phase overhead lines [13]. However, they reduced the repair or maintenance time but the number of outages still constant, and they have been investing more of these indicators.

Moreover, in 2013 Hamid SHARIFIAN and others had offered smart switches of VIT in “THE STUDY OF THE RELIABILITY INDICES OF DISTRIBUTION NETWORKS WITH VIT SWITCHES ON THE MV FEEDERS AUTOMATION”. However, they converted the distribution power network into automation mode by this type of automatic switches [14]. But, this way is not feasible with respect to large areas of distribution power system due to the high cost of large investment.

Additionally, in 2014, both Ashish Ranjan and J N Rai had produced “Optimal Switch Placement in Radial Distribution System Using GA and PSO”. Moreover, they rearranged the switches’ locations for optimal position by GA and PSO algorithms in the distribution network [15]. However, they did not consider the important effect of momentary interruptions events.

Also, in 2015 Umesh Agarwal and Monika Vardia had presented “Reliability Enhancement of Radial Distribution System Using Network Reconfiguration”. Moreover, they rearranged the radial distribution power feeder via adding and subtracting some components by specific switches, through (open/close) characteristic [16]. However, if the tow situations (before and after) have the different load balancing; it is not getting more improvement.

Finally, in 2016 Saheli Ray and others had offered another optimized algorithm in “Optimal Allocation of Remote Control Switches in Radial Distribution Network for Reliability Improvement”. Moreover, their optimized Differential Search (DS) algorithm had got faster mathematical analysis with respect to (PSO) algorithm [17]. However, the remote control switches (RCS) are a costly investment over all the radial distribution power networks.

From the contributions of previous studies in the recent years, we note that there are techniques, modes, and programming algorithms for processing the distribution network. Where, they addressed the distribution power reliability assessment in order to enhance or improve reliability indices. However, they are wonderful and fantastic, but there are also large areas of common radial distribution power networks require to solve for reliability improvement. Therefore, we have to consider the lowering the investment requirements, to get a better reliability improvement economically.

Conclusively, we introduce this work to be one of the reliability feasible solutions in considering the investment aspect by using one modern power switch technique for every radial distribution feeder. All in all, processing for any radial feeder reflects on its radial distribution power network totally.

In the remaining parts of the thesis, the second chapter addresses the theoretical ground for our thesis topic. Then, in the third chapter illustration for the basic structure with methodology formulation of our work is given. The fourth chapter explains the reliability indices results for each radial distribution power feeder discretely. The fifth chapter explains the reliability indices results for the overall radial distribution power network, and its improvement results. Finally, in the sixth chapter the evaluation of this thesis work with the discussions about the achievements that are obtained during this work are presented, also additional suggested works that can be carried out in the future.

CHAPTER TWO

DISTRIBUTION SYSTEM RELIABILITY ASSESSMENT

Reliability assessment is a common factor in designing and planning for distribution power system to operate it in an economic way and with minimum interruptions for customer loads. In the previous years, the distribution power system had not received a good attention of reliability modeling and evaluating with respect to generating system. Although, the distribution power system has the most of the power outages that have been happening in the power system [5]. But, the main cause is the generating system has big capital costs and the generation efficiency has a great impact on the society. However, a distribution power system is cheap and the power outages that happened have a localized effect. Also, the customer failure statistics indicates to that the distribution power system creates the biggest participation for the customer supply unavailability. Whereas, the main target of a power system is to supply the electric energy for the customers at less cost and with high reliable way. So, the maintenance and planning have to pay attention in reliability of the power systems by decreasing the power outages. As well as the power outages always are having a strong economic impact on the generating source and the customers that are connected. Where, the outages mean that the generating units are working without exploitation for their output power and will be dissipated power from the source view. Also, the loads that are connected on the far side will take low power supply time because of the outages from the customer view. So, the distribution system will be unreliable even though both the generating and transmission systems have more reliable. Therefore, this truth explains that the great importance of the reliability revaluation for large areas of the distribution power networks by lowering the investment requirements. So, the attention has to be towards an improvement or an enhancement for the distribution power networks reliability. That is similar to that of generating and transmission systems in order to achieve more satisfaction for the customer but without an extra investment cost. Finally, the reliability assessment issue for the distribution power system is interesting with the improved performance at the customer side [12].

2.1 Reliability Indices Evaluation

The traditional theory for the reliability assessment and main parameters that are used to calculate the reliability of the distribution power system can be classified into, basic indices and system reliability indices. The basic or load point indices are represented by the failure frequency rate of the load point (λ), the failure duration rate of the load point (r) and the annual average of unavailability or outage (U). On the other hand there are a set of system reliability indices involving the (sustained and momentary) interruption indices and the energy oriented indices. Also, the basic and system reliability indices are calculated statistically on the annual basis. Whereas, the random working nature for the power system during the time makes these indices for any particular period or for one year are numerical values. So, their functions of the failure frequency rates, failure duration rate and annual average of unavailability are nonlinear. Consequently, it is easy to calculate the average values in relation to these statistical functions. Finally, these statistical functions or mathematic tools are developed to be used for the radial distribution power system [12], [18].

2.2 Basic Reliability Indices in Radial Distribution Power System

As long as the radial distribution power system consists of a string of equipment for each load point such as lines, cables, disconnects (isolators), buses, and so on. The customer that is connected to a certain load point of a radial distribution power system requires to whole equipment between the supply source side and his side to be operating. Therefore, the concept of series systems will be applied to these series radial distribution power systems or subsystems [18].

For illustration, the three basic reliability parameter equations or basic indices are shown below for average failure frequency rate (λ series) which it is measured in fault per year (fault/year). Moreover, the average failure duration rate (r series) is measured in hours or (Hours). Finally, the annual average outage (U series) is measured in hours per year (Hours/year). However, the three basic indices of the load points are obtained for specific period by these equations during the operation or by testing the equipment [12]:

$$\boldsymbol{\lambda\, series} = \boldsymbol{\Sigma\, \lambda} \mathrm{i} \tag{2.1}$$

$$\boldsymbol{U\, series} = \boldsymbol{\Sigma\, \lambda} \mathrm{i}\, \boldsymbol{r} \mathrm{i} \tag{2.2}$$

$$\boldsymbol{r\, series} = \frac{\boldsymbol{U\, series}}{\boldsymbol{\lambda\, series}} = \frac{\sum \boldsymbol{\lambda} \mathrm{i}\, \boldsymbol{r} \mathrm{i}}{\sum \boldsymbol{\lambda} \mathrm{i}} \tag{2.3}$$

Consequently, the previous three equations for the basic reliability indices of the series load points are similar to the radial system. However, the radial distribution system is series system structure and it can get its basic reliability indices directly [12], [18].

2.3 System Reliability Indices in Radial Distribution Power System

Previously, the three basic reliability indices for the load point assessment are directly important with respect to the load point’s view. But, the overall system assessment will be evaluated for the series or radial distribution power system by the system reliability indices. In addition, the system reliability indices give the efficiency or the adequacy for the radial distribution power system supply and indicate to the radial system working continuity [12]. So, the definitions and equations for the system reliability indices may be divided into [1]:

2.3.1 The Sustained Interruption Indices

This class is describing the system indices when the load points of the radial distribution power system or subsystem are experienced of permanent failure rates. Consequently, this class is including the following system indices [1], [5]:

- **System Average Interruption Frequency Index (SAIFI)**

This index is referring to the average number of permanent interruptions which are tested via the load point or the customer during specific period (usually one year). Moreover, this index value is measured in interruptions per customer during the year or (interruptions/customer. year). These terms are changed according to the number of customers and the tested interruptions with respect to the service region [19]. For instance, system average interruption frequency index for a distribution feeder referred to the average value of the interruptions number on connected customers to the feeder during one year. So, the index of system average interruption frequency is known in equation (2.4); [1]:

$$SAIFI = \frac{Sumation\ of\ the\ Customer\ Interruptions}{Total\ number\ of\ the\ Utilized\ Customers} \tag{2.4}$$

For computing this index, we need the data of permanent interruptions for system equipment for one year. Also we require the customers that have suffered from these permanent interruptions during the specific period. Moreover, the denominator represents the total number of the customers in the same system or subsystem [12]. Therefore, the SAIFI index is obtained from the equation (2.5), [1]:

$$\boldsymbol{SAIFI} = \frac{\sum Ni}{NT} \tag{2.5}$$

Whereas Ni is the number of customers that are interrupted by each interruption event over the specific time, and NT is the total number of the customers that are in the same system, subsystem or area. Moreover, the way to enhance or improve the SAIFI for any system may have done by decreasing the number of permanent interruptions. Also, that improvement may be done via a suitable maintenance work for every one of the equipment in the distribution system. Additionally, the improvement for SAIFI may be achieved by usage of automation mode and by development for protective components. Finally, through improvement process it helps to detect and senses the faults and to remove a significant part of these expected faults. Of which without that it moves to a sustained outage situation [5], [19].

- **System Average Interruption Duration Index (SAIDI)**

  This index refers to the average value for the time which is the customer has an interruption during a specific time equaling to one year. This system average interruption duration index SAIDI is usually measured for customer in minutes or hours for each interruption of one year or (minute/customer. year) [12]. Moreover, the SAIDI is the average interruption duration for each utilized customer in specific studied system during a year is shown in equation (2.6). Also, it is known by dividing the summation of the customer interruption duration in one year to the total number of the utilized customers [1].

$$SAIDI = \frac{Summation\ for\ Durations\ of\ the\ Customer}{Total\ Number\ of\ Customer\ Utilized} \tag{2.6}$$

This system index SAIDI may be improved by decreasing the interruptions number or by reducing the interruptions duration. Also, it may be using of automation mode as another method to improve this index [12]. Finally, the system average interruption duration index SAIDI for a specific utility area could be represented in equation (2.7) as following [1]:

$$\boldsymbol{SAIDI} = \frac{\sum ri\ Ni}{NT} \tag{2.7}$$

Where, Ni represents the number of interrupted customers per interruption event during a specific time or for one year. Additionally, NT represents the total number of customers in the studied area. Also, ri represents the switching time for each interruption event [1]. However, the number of affected customers and the time that is required to restore the work again for each interruption event are important factors for calculating this index. Also, the restoration or switching time consists of the time which is required to notice the outage, the time for determining the location and the time that is required to repair the fault and turning it on [12], [19].

- **Customer Average Interruption Duration Index (CAIDI)**

This index represents the average value of interruption duration for the customers who are interrupted during one year. Moreover, the CAIDI index is measured in minutes per customer interruption or (minute/customer interruption). This index is known by dividing the summation of interruption durations for each interrupted customer by the total number of customers that have been suffered from one or many interruptions during one year [12]. Currently, the CAIDI index represents the ratio of SAIDI index to SAIFI index as shown in equations (2.8) and (2.9) respectively [1]. However, this index is the average value for the time which is required for service restoration to the customers after the permanent interruption is happened.

$$CAIDI = \frac{Summation\ for\ Customer\ Interruption\ Duration}{Total\ Number\ of\ Customer\ Interruptions} \tag{2.8}$$

Also, the CAIDI may be enhanced or improved by decreasing the duration of interruption by the maintenance working team quickly. Finally, the value of this index for any system service is known as follows [1]:

$$CAIDI = \frac{\sum ri\, Ni}{\sum Ni} = \frac{SAIDI}{SAIFI} \qquad (2.9)$$

Whereas, Ni represents the number of interrupted customers for each interruption event during a specific period and ri is the switching time of every interruption event [1].

So, the system reliability indices such that SAIFI, SAIDI, and CAIDI are expressing the sustained interruption statistics by the system customers view. Moreover, the customer types as a load points are classified into residential, industrial, governmental, commercial, agricultural, and others. Also, the customer types are buying the electric energy service do not be based on customer number. So, the service may be supplied for a customer in high average power as the commercial type customer. Finally, the CAIDI index value sometimes is not representing the ratio of SAIDI value to SAIFI value. Because of the improvement process that is related to the duration time of maintenance only [19].

- **Average Service Availability Index (ASAI)**

The ASAI or the system average service availability index produces the ratio of the service availability when the customer has an electric power during the specific period. Moreover, it is measured in per cent or (%) because it is always representing a percentage ratio. However, if the ASAI produces a high ratio that means we could obtain the performance of the reliability achievement in a higher value [19]. Finally, the equations (2.10) and (2.11) respectively are the formulations for calculating the value of this index for any utility system as follow [1]:

$$ASAI = \frac{Customer\ Hours\ of\ Service\ Availability}{Customers\ Hours\ of\ Service\ Demand} \quad \% \qquad (2.10)$$

$$\boldsymbol{ASAI = 1 - \frac{\sum ri\ Ni}{8760\ NT} = 1 - \frac{SAIDI}{8760}} \quad \% \qquad (2.11)$$

There are exactly (8760) hours in a non-leap standard year, and (8784) hours in a leap standard year [1]. Moreover, ri represents the switching time and Ni represents the interrupted customers. Finally, NT represents the total number of the utilized customers.

2.3.2 The Momentary Interruption Indices

This class is describing the system indices when the load points of the radial distribution system or subsystem are suffered from the momentary failure frequency rates. Moreover, momentary faults are occurred due to environmental and operational reasons that cause transient currents in equipment of distribution power system. Consequently, this class is including the following system indices [1], [5]:

- **Momentary Average Interruption Frequency Index (MAIFI)**

This index MAIFI or the momentary average interruption frequency index; shows the average frequency of the momentary interruptions that are occurred because of some reasons. These reasons are represented by an environmental factors such as lightning, storms, wind, ice, wildlife, rain and others as well as the component transient faults itself. Also, the MAIFI is measured in momentary interruptions per customer during the year or (momentary interruptions/customer. year). However, the mathematical form or the equation for this index MAIFI is shown in equation (2.12), [1].

$$MAIFI = \frac{\sum Number\ of\ Customer\ Momentary\ Interruptions}{Total\ Number\ of\ Customers\ Utilized} \qquad (2.12)$$

Also, in order to calculate this index, we can use the equation (2.13) as:

$$\boldsymbol{MAIFI} = \frac{\sum \boldsymbol{IMi\ Nmi}}{\boldsymbol{NT}} \tag{2.13}$$

Whereas, the parameter IM is representing the momentary interruptions number and Nm is the number of interrupted customers for each momentary interruption event during the specific study period. Finally, NT is total number of the utilized customers.

- **Momentary Average Interruption Event Frequency Index (MAIFIe)**

This index MAIFIe or the momentary average interruption event frequency index refers to the frequency average of the momentary interruption events. So, it is measured in momentary events per customer during the year or (momentary events/customer. year). More, this index includes the momentary events account and differs to that MAIFI in times of operations number for automatic devices only. Finally, the mathematical form for MAIFIe index is shown in equation (2.14) as following [1], [12]:

$$MAIFIe = \frac{\sum Number\ of\ Customer\ Momentary\ Events}{Total\ Number\ of\ Customers\ Utilized} \tag{2.14}$$

Also, in order to calculate this index we can use the equation (2.15) as following [1]:

$$MAIFIe = \frac{\sum IMEi\ Nmi}{NT} \tag{2.15}$$

Whereas, the parameter IME is representing the times number of the momentary interruption and the other parameters are similar to that of the equation (2.13).

2.3.3 The Energy Oriented Indices

Currently, the most important indices that are required to calculate the load average and energy assessment are the oriented indices. Moreover, in order to get the average value of the load (Lav) for each load point we can obtain that from the equation (2.16) as follow [1], [12]:

$$\boldsymbol{Lav = Lp\,.\,f = Lp.\frac{Real\ Generated\ Power}{Maximum\ Generated\ Power}} \tag{2.16}$$

Whereas:

Lav: is the load average value of the load point.

Lp: is the peak value of the load demand.

f: is the load factor.

- **Energy not Supplied Index (ENS)**

This index ENS or the expected energy not supplied may be evaluated by using the following equation of (2.17) below [1]. Moreover, it is measured in megawatt or kilo watt for an hour per year or (kw.hr/year) [12], [18].

$$\boldsymbol{ENS = \sum Lavi\,.\,Ui} \tag{2.17}$$

Where:

Lav: represents the demand load average for the load point i.
U: represents the annual outage time for the load point i in a year.

- **Average Energy not Supplied Index (AENS)**

This index AENS or the average energy not supplied of the system is evaluated by using of the equation (2.18), below [1]. Moreover, it is measured in megawatt or kilo watt for an hour per customer during one year or (kw.hr/customer. year), [12].

$$\boldsymbol{AENS} = \frac{Total\ Amount\ for\ Energy\ Not\ Supplied}{Total\ Number\ for\ the\ Utilized\ Customers} = \frac{\sum \boldsymbol{Lavi\,.Ui}}{\sum \boldsymbol{Ni}} \tag{2.18}$$

Where:

Lav: represents the average value of the load demand for load point i.
U: is the average value for the annual average outage time of the load point i.
N: is the number of the experienced customers at load point i.

Consequently, in spite of many indices and the other indices which were mentioned previously. Moreover, there are so many new indices that may be derived statistically according to their necessity to make the assessment for any service area. Generally, there are five important system indices that used in reliability assessment to this work which are enough to test the reliability improvement [5], [18]:

- SAIDI or the system average interruption duration index for sustained outages.
- SAIFI or the system average interruption frequency index for sustained outages.
- MAIFI or the momentary average interruption frequency index for momentary outages.
- AENS or the average energy not supplied index for system sustained outages, but this index depends on ENS index or energy not supplied index directly.
- ASAI or the average service availability index which is represented in percentage ratio to give the availability ratio for any served system, subsystem or area by the previous mentioned indices during a specific study period.

At the end, it is worth of mention that the specific study period has to be based and determined in order to include the data information and for getting precise results. However, the most common of researches and studies take into consideration that the standard year is a better specific testing period. Finally, the standard year equals to (8760) hours for non-leap year and it equals to (8784) hours for leap year [1], [12].

2.4 Interruption Reasons

In general, customer interruptions have always occurred due to broad scope of the phenomena such including of the component failures, animals, trees, weather vicissitudes and the human errors. Moreover, the previous reasons represent the main causes that effect on the distribution system reliability. Also, if we know its ratio and effects through studying them that will let us to understand how we can improve the distribution system reliability. Where, we can enhance distribution system reliability by modeling this system or by optimizing through computer programming or by utilizing of new technical devices. Finally, for its importance we illustrate these reasons or causes in next sections obviously [5], [20].

2.4.1 The Component Failures

Firstly, each part of the component in the distribution power system may be faulted during the operation. Also, when we have installed the equipment initially a part of this equipment may fail because of the weak manufacture or damage during the movement or because of the incorrect installation. Moreover, even the good equipment may fail because of the high currents, high voltages, harmful animals, the bad weather and cause of other most common reasons. In addition, the component occasionally gets breakdown because of some reasons like the chronological life, the thermal life, case of the chemical decomposition, case of the contamination and case of the mechanical causes [5]. However, the most common equipment which are exposed to fail and effect directly on the reliability assessment for the distribution power system that may be mentioned in following summary:

- **Transformer Failure**

The transformer effects on the distribution power system reliability are happened by two obvious ways which are the failures and overloads. More, the transformer’s failures may affect on thousands of connected customers to that transformer as a load point. When these problems have been occurring the other transformers withstand the interrupted load instead of failed transformer. However, it is important to take into consider two essential matters in loading which are the knowledge of transformer ratings and the thermal life or age. Moreover, the transformer ratings depend on the expected age for the winding insulator at a specific temperature. Whereas, these ratings consider the ambient temperature about 30°C and the average value for the temperature of windings is 60°C. Also, the age of a transformer is always known as the time that is needed for the mechanical strengthening of any insulation material in order to decrease about 50% of its mechanical strengthening. In addition, this decreasing or the mechanical strengthening loss gets when the polymer of insulator breaks down because of the heat. The transformer has many secondary parts which may also fail and reduce the transformer reliability as the cracked insulator, lack of oil ratio, and others according to the class of transformer [5], [21].

- **The Underground Cable**

The most important reason that makes failure and related to the underground cable is the electrochemical and water treeing. More, the water treeing happens when the moisture follows in the existence of an electric field which reduces the dielectric strengthening of the cable insulator. Whenever, the moisture penetrates the dielectric like cross-linked polyethylene (XLPE) a breakdown similar to a tree shape occurs and decreases the capability of voltage withstand for that cable. Therefore, the insulator strengthening of the cable have been degrading and the transient voltages which are happened because of the lightning or switching that may be result in the dielectric breakdown. Finally, the treeing process intensity is related to thermal life whereby the absorbed moisture may happen in fast when the temperatures being high quickly [5], [22].

- **The Overhead Line**

Generally, the most common damaging reasons of the overhead lines are the external such as animal effects, vegetation presence and the bad weather. Where, the non-insulated conductor can withstand high temperatures. So that it is damaged in higher currents more than the insulated conductor. More, these high currents have been causing many results as line sag, conductor anneal, reducing the tensile strength, conductor burning, and others [5]. All the previous causes lead to reduction of the reliability for the overhead lines because they increase the occurrence of the failure and the need for repairing the faulted lines. So, the high current always has to be cleared in fast before it has been burning out the overhead line and equipment. Moreover, the optimal line has thermal time constants from 5 to 20 minutes to give a chance for the momentary overload current without it leads towards the sag and breakdown eventually [5], [23].

- **The Circuit Breaker**

The circuit breaker is sophisticated device which may fail in several various methods. Where, it may be failed because of an internal fault spontaneously or it opens when it has not to open or it fails to open when it has to open or it fails to close when it has to close and so on. So, the circuit breaker has to open when its relay indicates to fault occurrence directly [24].

Also, the circuit breaker may be failed in opening or closing because of the faulted control wiring or due to uncharged actuators or it is stuck. Moreover, the circuit breaker may be also suffering of the internal faults which are resulted in the dielectric breakdown similar to those are happening in the transformer. Finally, we can check the dielectric strength by certain tests and the last are changing according to the insulating interface for the circuit breaker type such as air, oil, SF6 gas or vacuum [5], [8], [24].

- **The Lightning Arrester**

Generally, the surge arresters are classified into two types that are silicon carbide and metal oxide varistor (MOV). More, silicon carbide type has been failing more than metal oxide varistor because of the air existence in the gap. Whenever, the moisture come in the air gap so it causes corrosion. As a result that it decreases the voltage withstand for the air gap of the arrester. Moreover, the thermal expansion because of the water vapor plus high amount of heat may be driven to damaging mechanical compression for the interior part of the surge arrester. Also, that results to a big failure with normal or over voltage cases. Finally, the other secondary failure modes that related with surge arresters are the puncture, thermal runaway and cracking due to compression [5], [25].

- **The Insulator and the Bushing**

The insulator and bushing are made of three main materials which are glass, porcelain and polymeric. Moreover, the insulator and bushing faults are related with the dielectric breakdown whereas the insulator lets the current to be an arc across the device. Also, the dielectric breakdown in the bushing lets the current to be an arc from the internal conductor to the outside of the device. In addition, these currents may be small or great have been leading to less impedance arc which is forming a short circuit current and results in a fault or failure in the insulator. Finally, these insulators and bushings may be losing their dielectric strengthening gradually when they are unveiled for contamination like the sea salt, fertilizer, pollution, desert sand and salt fog [5], [26].

2.4.2 The Animal Effects

Currently, the animal effect is representing one of the common greatest reasons that impact on the customer interruptions in wide areas of the electricity service. More, the problems due to animal factor are various and they have an effect on the distribution system reliability. Moreover, the reliability cares about the service continuity improvement and it has different strategies against many classes of animals. However, the most important types that animals are the gopher, mice and rats as well as the birds, squirrel, large animals and so on [5].

For instance, the squirrels impact (specially the gray squirrel) on reliability for overhead system that are existed in forest and the wooded regions. Moreover, this animal does not climb the network poles directly but it jumps by the near tree to these poles and then causes a grounding fault or a phase to phase conductor. So, for preventing these problems or faults by using common way is setting up a plastic animal protector on the insulators and bushings [27].

Additionally, we have another group of animals that includes the mice, rats and gophers. Meanwhile, the mice and rats continue in chewing the isolator inside the components cabinets and ducts to cause the grounding faults. So, we can prevent that by some techniques. Also, these techniques may be done by sealing on these cabinets and ducts or by using ultrasonic devices to detect them or by making audio alarm or by setting up traps. On the other hand, the gophers are digging their path into tunnel that is including the cables and insulators so that they cause grounding faults. Anyway, the ways to control on this animal effect is hard hence there are some techniques are used to reduce them by traps or by poisoned baits or by poisonous gas or by ultrasonic devices.

The birds are also be taken into consider as the one of fault causes where the main situations that are represented in bird nesting, birds roosting, raptors wings or woodpeckers. Where, the bird nesting situation has been happening in different equipment of distribution power system to cause a grounding fault. The birds roosting situation happens when the bird has been taking a rest or wait for its prey at a component. This may result in a fault because of bird touching with conductors or it touches conductor with the earth. Also, the raptor wings with long span do different faults by making a conductive bridge between two conductors or conductor with the earth. Finally, the woodpeckers always have been making holes in tree and so because of that we could not use wooded poles for the power system in these regions. Therefore, the usage of a steel pole is the optimal solution to keep a good network of the system against this situation [5], [27].

Finally, it is worth mentioning that large animals such as the cattle, horses, oxen, and bears where they have spontaneous activities for these creatures as rubbing collisions and sometimes climbing the wooded poles. So, all the previous activities and so on have been causing big outages for the distribution power network. Therefore, protection methods have to be used for processing all these natural problems such as using fences around the poles or using a steel pole type in specific areas.

In conclusion, there are another more types of animals that may impact on the reliability of the distribution power system and causing big outages. However, the most important thing there are also more researches and studies to get the suitable techniques in the face of the natural activities of these animals [5], [27].

2.4.3 The Bad Weather Conditions

The bad or severe weather conditions have been including of the phenomena which are describing the most effects on the power system reliability. They are studied and applied to give the impacts of their environmental factors such as the winds, lightning, icing, the extreme heat and earthquakes [20].

- **The Winds Impact**

The term (wind storms) indicates to the (linear winds) which blow down the objects or the trees or the poles of overhead networks. Also, they indicate to the (circular winds) as the cyclone. Therefore, the storm intensity is a function of permanent wind velocity, storm speed, wind trend and the storm length. So, the components failure state increases directly proportional to the wind speed. Where, the pressure on the tree or pole is increasing with the square value for the wind speed. Additionally, for blowing on all the trees or poles leads to that wind effects on many types of conductor motions which have been relating directly to the reliability. Where, these effects lead to two terms are swinging and galloping which are associated with the overhead conductors as a result indirectly. Where, the swinging is similar to a pendulum motion for the spaced conductors and when the swing increases so it results to the touched phase conductors and this is called a "blowout" to cause a fault [5]. Also, the blowout state may be decreased by increasing the phase spacing or the span tension. On the other hand, galloping is happening when the ice is accumulated on the conductors and to make an airfoil to give a chance for the air to do a vertical force on conductor span. So, the galloping makes the forces on the conductors or tower lines and hence these forces are doing the conductor sag for pole or tower. However, the galloping may be reduced by increasing the conductor tension or by putting dampers [5], [29].

- **The Lightning Impact**

As it is known, a lightning strike happens when the voltage value between the cloud and the ground has been exceeding the electrical air resistance. So, the generated current which has been obtained becomes more than (30,000) ampere and these strokes always consist of several discharges during a fraction of a second. Moreover, in order to protect from these strikes so the service must be protected by a shield wire or by a surge arrester at each pole or transformer. However, these lightning strikes are not striking the distribution network components directly. Usually, they strike another objects as the trees or buildings near to distribution network. Currently, the current passes from these clouds to near objects and a magnetic field which has enough fluctuation for inducing a voltage inside the near conductors. However, this induced voltage magnitude is too lower than the direct strike situation and the flashover may be avoided by using the trapped application of shield wire and the arresters [5], [30].

- **The Ice Impact**

Naturally, the ice storm happens when the rain be cooled and frozen upon the limbs of tree or overhead conductors to form an ice layer. Moreover, this ice building masses upon the conductors as a weighted physical load and up on supported structures. This process is increasing the cross sectional area which is exposed to the air. So, the mixture of the ice and air converts the conductors to gallop. In addition, the ice may break the conductor to jump on the near phase conductor which is located above it [31]. Finally, the ice accumulation upon the trees may be let the branches or trunks to break and then falls on to the conductors of the network. Therefore, the overhead distribution systems have to be designed where the conductor and structure strength are able to accommodation for the expected icing and winds conditions [5], [31].

- **The Heat Impact**

The heat storm has been always exceeding the hot weather and this exceeded results to an extra demand for operating the air conditioning loads. So, this intersection of high loading and the continuous operation for equipment results in overloads and losing for equipment age. Moreover, this overloading leads to the component failure, peak loading and that causes to more outages. For heat storm that the maximum power of the distribution system may be producing a high drop state in voltage [32]. Therefore, the majority of recent distribution system studies test the peak loads during the summer season and it is designed according to the higher expected temperature. For instance, few of the electrical services designs depend on the annual average maximum temperature and also the others designs based on the hottest day during five or ten years. Finally, the better design for the distribution power system based on a (100) year heat storm but it is rather expensive [5], [32].

- **The Earthquake Impact**

As it is worth to mention, the earthquake is a rupture that happens because of a previous geological fault. Moreover, the rupture gives a vibrated pulse wave into the earth and it is making horizontal and vertical ground motions. Additionally, if the frequency of earthquake pulse waves is corresponding to an oscillatory way for the distribution system structure so it will generate great forces, vibrated motion and the damage will be obtained. For instance, an earthquake happened in Japan with magnitude (7.2) according to Richter scale and it damaged about (10,000) distribution system poles. More, the service is cut out for more than a million people and for about three days as well as its cost (2.3) billion dollar to repair all the destroyed electrical utilities. Finally, the strong earthquake also is not a general situation. But it may be destroying the distribution power systems and it may be causing the safety hazards as well as great customer outages [5].

- **The Fires Impact**

The fires factor is another impact on wooden poles in distribution power system. More, if the wooded pole flared up by a fire source it will lose its mechanical strength and also it will be ready for falling over. At the end, if the fire reaches to the top of the wooded pole so the transformer or equipment will has been burnt and it lose their age and also getting big problems [5], [32].

2.4.4 The Trees Effect

The trees represent the most important factor like the lightning and the animal. Where, these three reasons are most important for customer interruptions in the services. However, there are many failure ways related to the trees factor and may be summarized as following [5], [33]:

1) Mechanical destroying by breaking off limb or trunk of a tree to fall on the overhead conductors and it bridges the two overhead conductors.
2) The faults because of the animal when it use its way by the trees towards the poles of the distribution network.
3) The faults because of tree growing where the tree limb tries to place each two conductors one closes to other.
4) The faults that due to the wind, when it blows the tree limbs towards the conductors for touching each other or because of the tree trimming.

2.4.5 The Human Effects

The human effects also have been causing the customer interruptions in distribution power system. Occasionally, some of these interruptions are intentional such as the scheduled durations for service outages and the vandalism but the other interruptions are unintentional such as the traffic accidents, errors due to operation process and the dig in processes [5].

For instance, the scheduled outages of intentional interruptions are represented by the programmed interruptions. More, these are happening according to shutdowns that are occurred in generating units or because of the expansion planning for the distribution power feeders or network. However, the customers suffer from these scheduled outages although it is necessary. Finally, if the customers previously have been known about these scheduled times so they will take all the hedges during these outages time [34].

For intentional outages, the annual programmable periods of the maintenance are important for increasing the reliability of system or network. Additionally, these repair periods are required to upgrade the aging parts or components in the distribution power network in order to reduce the future failures and for improving the reliability.

The vandalism or the mischief has been happening when the people do gunshot in direct of the radial distribution network. Anyway, the ceramic parts for an insulator or a pushing are broken due to that as well as the wires may be break down. All these activities interrupt the service and make losses in the distribution power network.

Unintentional errors happen also when the vehicular accident collides into a pole of the distribution network resulting in a big problem. Additionally, the results for these events are not known and the service may be interrupted for long time.

Also, for the unintentional faults the dig in of excavations that may be cutting the equipment such as the cable which hence interrupts the utility. So, it is important before doing these processes to take the underground diagrams for the network to prevent like these accidents [5], [34].

Finally, the service outages because the errors that have been happening by the operational workers such as the switching errors, indirect faults or direct faults. However, all the previous mistakes may be done but they are regarded intentional errors or faults [5].

In conclusion, in font there are many efforts and studies are searching about better modes in order to remove or control on them. By researches and studies, the temporary or momentary faults that are happening because of transient currents due to the most past factors or impacts and these momentary faults responsible 70% of the total customer interruptions [5],[6].

2.5 Summary

In this chapter we have discussed the reliability assessment for distribution power system. More, we focus on the nonlinear equations to evaluate the three basic indices and also the system reliability indices for radial distribution power network. Also, we have illustrated the main types for system indices of sustained interruption, momentary interruption and energy oriented indices. Then, we have explained the interruption reasons in order to cover their effects on distribution power system and how to protect it.

CHAPTER THREE

THE BASIC STRUCTURE

3.1 The Three Phase Tripping Recloser

A recloser is a self-controlled power switch device for automatically interrupting and reclosing tripping of the A.C. circuit, with a predetermined sequence of opening and reclosing followed by resetting, hold-closed or lock out operation [6].

As it is worth to mention, the 3-phase tripping recloser device is always commonly used to clear the temporary faults in nature that are occurred in the distribution power networks. Moreover, these momentary faults have been representing 70% of the total faults. So, the overhead feeder line should be protected by setting the recloser up on the feeder head [4], [5] and [6].

If we put the 3-phase tripping recloser on a radial feeder will improve the reliability indices of the components that are located downstream of this recloser. Also, the customers will be protected in the face of the permanent faults while they are protected and may have not sensing about temporary faults effects. In addition, the most important function that is introduced by this recloser is clearing the momentary faults without to lead into repair [4], [9].

Also, this recloser with 3-phase tripping is an overhead and outdoor device and less investment cost with respect to other types. This power switch has simple grounding circuit so that it may be used mainly in networks as well as in substation without impacts on relays grounding circuits in substation. Finally, this type has little equipment failures compared to other types of recloser [9].

3.2 The Circuit Breaker

Circuit breaker is an important power switch and it is one of the most elements for protection and switching equipment where it has been detecting and removing the faults in distribution power network. Moreover, it has three main types according to the material that is used for extinguish the spark of overload or fault current and they are (SF6) type, oiled type and vacuum type. Additionally, from the previous experimental tests that the circuit breaker of SF6 type is better one among the others [8], [24].

Currently, the manual and motor switch mode types are the most common devices in usage. However, the circuit breaker is an air break device and it is not designed for automatic operation but for the local operation or sometimes by remote. In addition, this power switch device is useful for manual switching against faulted lines but its problem always with the time. Because the manually switching operation let the circuit breaker takes up more than one hour in order to make restoration so that it effects on the reliability negatively [8].

3.3 The Momentary Outages Ratio

Most of the interruptions that occur in power systems due to the distribution power system problems generally and it have been estimated for 90% of power system interruptions [5]. Practically, the momentary outages that impact on distribution power system are estimated for 70% of the total distribution power system interruptions due to the impacts of interruption reasons that were mentioned in chapter two [4], [5] and [6]. Consequently, for this work we have been using this percentage ratio in our calculations and analysis.

3.4 The Network Model

Major common type of distribution power system is the radial distribution power network. This type has been covering large areas of distribution power system utility so that we have addressing in this work. Also, the standard radial distribution power network data for Roy Billinton Test System (Bus 2) 4-Feeder of RBTS has been used and specified for educational researches purposes and analytical studies [3]. Moreover, all the important feeder loading data for this (Bus 2) 4-Feeder of standard radial distribution power network RBTS are recorded in table (3.1) for illustration. Finally, FMEA technique has been used for reliability assessment analyzing in MATLAB environment for this standard radial distribution power network.

Table 3.1 Feeder loading data for radial distribution power network of RBTS (Bus 2) 4-Feeder

Feeder Number	Load Points Number	Average Load MW	Peak Load MW	Customers Number
F1	1-2-3-4-5-6-7	3.645	5.934	652
F2	8-9	2.150	3.50	2
F3	10-11-12-13-14-15	3.106	5.0570	632
F4	16-17-18-19-20-21-22	3.390	5.5090	622

As a result, the total load points number for RBTS (Bus 2) 4-Feeder is (22) load points and the customers are (1908). Also, the overall peak load and average load are (20) and (12.291) MW respectively as well as the peak and average capacity of the source (11) kilo volt are (50) and (30) MW respectively.

3.5 The Work Methodology

At the beginning, we calculated the three essential parameters for each load points that are connected to the radial feeder from the three equations of (2.1), (2.2) and

(2.3) respectively. Then, we calculated the average value of the load for each load points from the equation (2.16) as a delivery step for the next.

Consequently, we have now two situation models are the main circuit breaker or main (C.B.) and the 3-phase tripping recloser or main (R) respectively [7]. Both of these two situations are complementary for our methodology but each one is discrete in applying and operation. However, we could show the two situations and their associated equations respectively as the following;

3.5.1 The Main (C.B.) Situation

While all failure rates lead to permanent outages, then this situation is subjected to the following scenario equations;

$$\boldsymbol{\lambda i = \lambda p + \lambda t} \qquad fault/year \tag{3.1}$$

$$\boldsymbol{ri = rp = rt} \qquad hour \tag{3.2}$$

$$\boldsymbol{rsw = 0.5} \qquad hour$$

Then, we applied the equations of (2.7), (2.5), (2.17), (2.18) and (2.11) to compute SAIDI, SAIFI, ENS, AENS and ASAI indices respectively. However, MAIFI index of the equation of (2.13) equals to (zero) because the main C.B. has no an automatic reclosing trip to clear the momentary faults type.

3.5.2 The Main (R) Situation

For this situation the following scenario equations are applying;

$$\boldsymbol{\lambda p = 0.3\ \lambda i} \qquad fault/year \tag{3.3}$$

$$\boldsymbol{\lambda t = 0.7\ \lambda i} \qquad fault/year \tag{3.4}$$

$$\boldsymbol{ri = rp} \qquad hour \tag{3.5}$$

$$\boldsymbol{rt = 0} \qquad hour$$

$$\boldsymbol{rsw = 0.5} \qquad hour$$

Then, we apply the equations of (2.7), (2.5), (2.17), (2.18), (2.13) and (2.11) to compute SAIDI, SAIFI, ENS, AENS, MAIFI and ASAI indices respectively.

Where:

λi: represents the total failure frequency rates.

λp: represents the permanent failure frequency rates.

λt: represents the temporary failure frequency rates.

ri: represents the total failure duration rates.

rp: represents the permanent failure duration rates.

rt: represents the temporary failure duration rates.

rsw: represents the switching or restoration time which is required to isolate the equipment in order to repair it and to return the main C.B. or the main R on again so it is assumed to be (0.5) hour.

Finally, each situation takes the same standard basic parameters for (Bus 2) 4-Feeder data of RBTS [3]. But according to previous methodology and power switch characteristics. Then, for each situation of the system (feeder or network) that the reliability indices calculations are subjected to FMEA technique and for standard specific study period is one year or (8760) hour.

3.6 Failure Mode and Effect Analysis Technique (FMEA)

The analytical techniques that are required to analyze and compute distribution power system reliability for computing the nonlinear indices equations are mathematical advanced tools. However, the better tool in order to analyze the power distribution system reliability has been depending on the failure mode and effect analysis FMEA. The most important characteristics for this approach it addresses all the components one by one. Also, this technique takes all the possible failure modes and determines the impact for each component on load points in the network. Also, the failure events and fault type of equipment in the distribution power feeder or network could be analyzed and computed by this tool. Where, the final resultant of the failure events has been introducing in order to calculate the three basic load points indices [2]. Where, the FMEA approach uses the three mentioned equations of (1, 2 and 3) in chapter number two that are related to the serial load points parameters (λ, r, U) through the radial system (feeder or network). It is worth to say that the FMEA technique has been working for computing a big range of radial distribution power networks. However, if this computing process is done by manually that will be so hard and it takes much time to achieve it. Therefore, the computers are capable for doing these huge computations processes in ease and in faster way by using of this technique [2], [12].

By the utilization of the failure mode and effect analysis FMEA so we could experience some improvements in radial distribution power feeders in order to get better results for our work into the radial RBTS (Bus 2) 4-Feeder [3].

We have used MATLAB program to simulate our work by applying this technique for the radial distribution power feeder discretely. This FMEA tool has achieved and calculated all the various indices for our standard radial distribution power network and according to methodology. However, we get five indices that are represented in SAIDI, SAIFI, MAIFI, AENS, and ASAI as well as it included ENS index.

3.7 The Work Assumptions

Naturally, any researched work requires to some useful assumptions during the study for its methodology in order to limit the main idea in solving the problem. More, the actual and rational assumptions lead to enhance the work towards the accurate results. Therefore, our thesis is subjected to the following axiomatic assumptions:

a) The specific study period is the standard benchmarking time which is one year or (8760) day.

b) Reliability assessment has been focused on for the (Bus 2) 4-Feeder or (11) kilo volt side of RBTS radial distribution power network.
c) The recloser is typical and working for just one trip or event to get results successfully so it has been subjected to the simulated empirical tests.
d) No load transfer for the load points.
e) The probability of failure rate is zero for all the protected and switching devices.
f) Restoration or switching time for repair crew to isolated the faulted equipment and return the main power switch ON again to work is (0.5) hour.
g) Based ratio for momentary faults is 70% according to the ratio average in benchmark book for (60% to 80%) in [5].

3.8 Application to the Radial Distribution Power Feeder

At the beginning we experience by applying the optimal circuit breaker power switch at the supplying point of the radial distribution power feeder or the head point. This circuit breaker has become now the main breaker or main circuit breaker C.B. for the radial distribution power feeder [8]. For illustrating, this is shown in figure (3.1) which is associated to the first radial power distribution feeder for our radial distribution power network (Bus 2) Feeder NO: 1. Then, we have been operating this first radial distribution power feeder in independent operation to get its reliability indices as a series system. Where, the main C.B. has been working as the main switch for this radial feeder. However, the system reliability indices that we require to get them are five indicators of SAIDI, SAIFI, MAIFI, AENS and ASAI. Additionally, we have been assuming the switching or restoration time a half hour (0.5 Hour) for each overhead section line switch (S). Because that is required in order to disconnect the line switch to isolate the fault sector and to return the main breaker to switch on again.

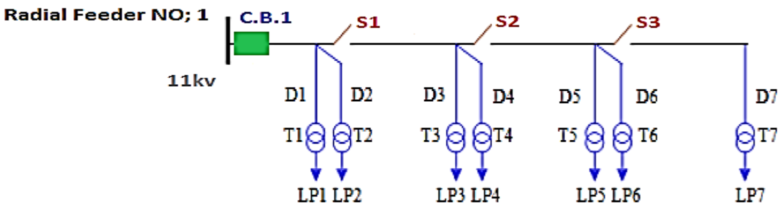

Figure 3.1 Applying the circuit breaker at the head for 1st radial feeder of Bus 2

After that we repeated the past test in the same previous procedure but in presence for the 3-phase tripping recloser instead of the main circuit breaker. For illustrating, this is shown in figure (3.2) and also it is related to the same first radial distribution power feeder of our radial network.

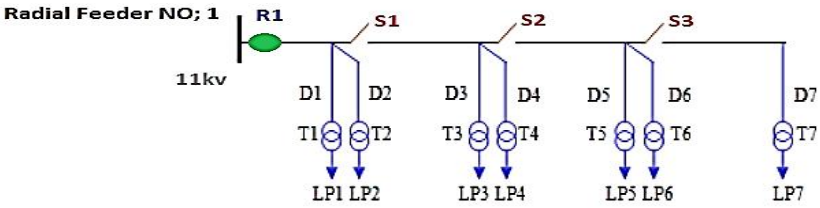

Figure 3.2 Applying 3Ph-tripping recloser at the head for 1st radial of Bus 2

Now, the 3-phase tripping recloser has become the main power switch or the main recloser R situation [7]. By the discrete operation for the same radial distribution power feeder but with the main R situation also we get the results for reliability indices again.

From the two previous situations; we could detect that the reliability indices results have been changed according to the main power switch situation with respect to the resultant reliability indices. So, we could summarize them as the following points:

1. The minutes of the SAIDI index have been decreased for the main recloser situation compared to the main circuit breaker situation.
2. The number of interruptions of SAIFI index has been also decreased for the main recloser situation compared to that of the main circuit breaker situation.
3. The number of interruptions of MAIFI index has been increased for main recloser situation, while the value for this index became (zero) for the main circuit breaker situation.
4. The value for the AENS index is decreased positively for the main recloser compared to the high value for the main circuit breaker situation.
5. The average service availability index ASAI gets better result in 3-phase tripping recloser situation as a main power switch rather than the main circuit breaker and according to four nines rule [1].

Obviously, we could note that the changing for any equipment of the radial distribution power feeder will be reflecting its impact on feeder's reliability indices.

3.9 Application to the Radial Distribution Power Network

In previous we have discussed the two tested situations for the main circuit breaker C.B. and the main 3-phase tripping recloser R respectively. To get the results of the reliability indices are produced for the radial distribution power feeder. Now, we experience these two situations but for the entire radial distribution power network operation. Of which the total impacts have been reflected on overall this radial distribution power network. For the same past procedure that is applied on the radial feeder, we repeat it again but for the radial distribution power network of (Bus 2) RBTS, 4-Feeder.

For this, we could apply the main C.B. situation for each radial distribution power feeder in (Bus 2) network. As shown in figure (3.3) and to operate this radial network with four feeders to get the system (the radial network) reliability indices results. These output results indicate to the impact that is reflected on the overall radial distribution power network by existing of the main C.B. on load points.

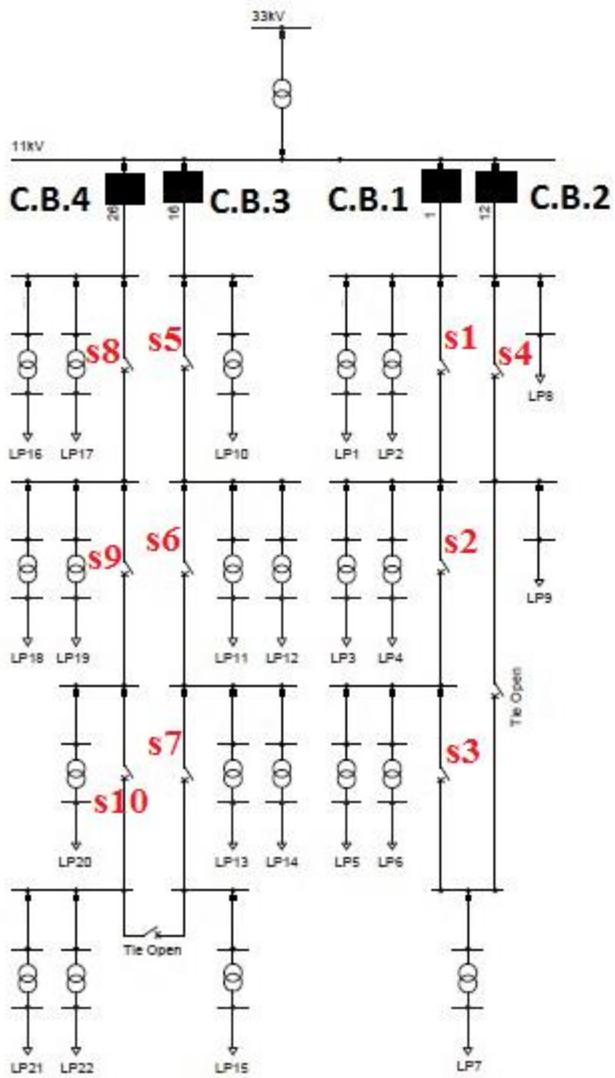

Figure 3.3 Applying the circuit breaker at the head for each radial feeder of Bus 2

Then, we repeat again the test by applying the main 3-phase tripping recloser R situation for each radial distribution power feeder of (Bus 2) network instead of the past main circuit breakers as shown in figure (3.4). After that we replaced each main C.B. by another main recloser R and we operate the entire radial distribution power network with four radial feeders to get the radial network reliability indices results. Also, these output results refer to impact that is reflected on the load points of the overall radial network by existing of the main (R) [9].

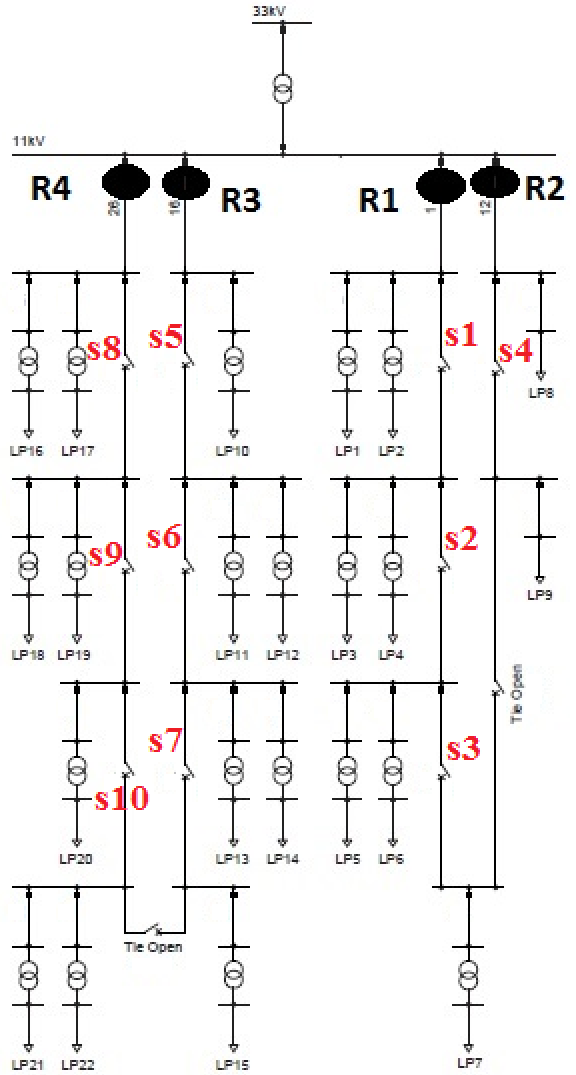

Figure 3.4 Applying 3ph-tripping recloser at the head for each radial feeder of Bus 2

Finally, from the two situations results we noted that we get same improvement in the recloser situation compared to the breaker situation in radial feeder test but for different values.

In conclusion, the service companies always do some calculations for its reliability assessment in order to decide which radial feeder requires to main recloser to improve its reliability. However, these tests and calculations are done at the same network operation and mostly their decisions are made according to the investment cost for these advanced technique equipment.

3.10 The Radial Distribution Power Network Improvement

For improving overall radial distribution power network to enhance the reliability indices, we make another test for our radial distribution power network of RBTS, (Bus 2) 4-Feeder. Where, we experience all the likelihoods that may be expected for applying the main power switch (Main C.B. or Main R or various) on the head points for the fourth radial feeders. After the operation we note there is a changing for reliability indices according to apply the main power switches probabilities. Finally, according to the results we can decide which case may be selected where the indices values which are the better criteria to announce the good case. However, the reliability concept is requiring for achieving the best reliability improvement while lowering the investment requirements.

Therefore, this work links between best invested case and reliability indices where the lower amount of the expected energy not supply ENS is done. In this way our work could select the good two cases and then determine the better case for enhancing achievement.

Generally, most of the distribution power networks compose distribution power system are radial structured. In order to improve the reliability indices for large areas of this type so we have to solve this problem in less invested number of improving equipment. In addition, high ratio of distribution power networks interruptions are momentary faults type. So, the usage of developed equipment in a great number for each branch in radial distribution power network is not feasible.

Therefore, the optimum operational location for this major common type of network is more important. So, we have to select for a practical and developed power switch technique but is not costly to its benefit for enhancing the service reliability. All are mentioned encourage us for using this methodology to enhance the reliability for these large areas of radial distribution power network to obtain better reliability indices.

3.11 Summary

In this chapter we have been explaining the work methodology where we starting in the 3-phase tripping recloser and circuit breaker summaries. Moreover, we have focused on the momentary outages as a subject for the recloser as well as its ratio. Then, it addressed the radial distribution power feeder and the radial network model and how to apply the main power switches. Then, it has shown the work assumptions in order to orient the reader into the substantial target. Also, it illustrated the FMEA technique for analyzing and simulating this work in MATLAB program. Finally, it has made series of radial feeder and network tests and also the empirical likelihoods to find the better case for enhancing reliability indices of the radial distribution power network of RBTS (Bus 2), 4-Feeder.

CHAPTER FOUR

THE INDICES RESULTS FOR THE RADIAL FEEDER

Now, in this chapter we present the tested operational work related to the reliability assessment for just individual radial distribution power feeder. In the next steps we will take the radial distribution power feeder as a discrete system and analyze it to extract its reliability indices by FMEA technique. Therefore, we will take the cases results one by one according to the two situations that are the main C.B. and main R assembled in one simulated figure for each index. However, all the tested results are done and simulated in MATLAB program environment as the following:

4.1 Applying to the First Radial distribution Power Feeder

The simulation by FMEA technique in MATLAB program for applying the two situations of main C.B. and main R respectively on the head of first radial distribution feeder we can get the operational reliability index for SAIDI which is illustrated in figure (4.1).

Consequently, we have obtained (455.5) minutes for SAIDI index of main C.B. situation to represent the outage period per customer during the year. Meanwhile, we have obtained (136.65) minutes for SAIDI index of main R situation to represent the outage period per customer in year. Therefore, in the main R situation is better than of main C.B. situation for this index. In conclusion, the outage period minutes for the main R situation, is less than the main C.B. situation.

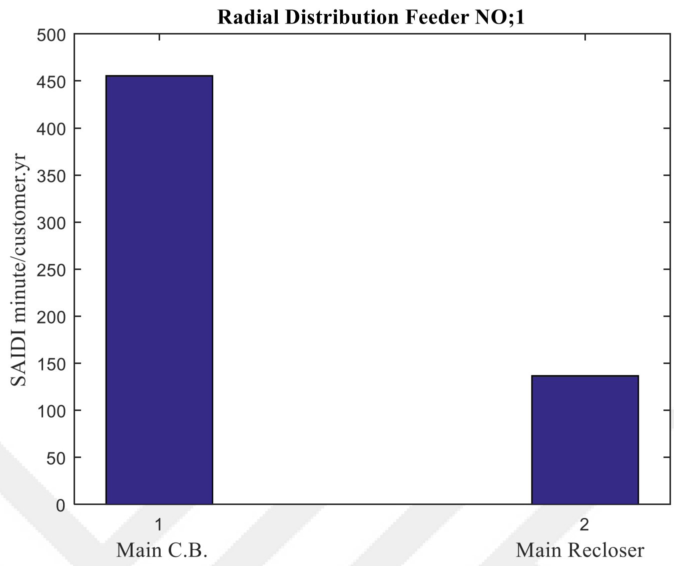

Figure 4.1 SAIDI bars of 1st radial distribution feeder for two discrete situations

Also, the simulation for applying the two situations of main C.B. and main R respectively on the head of the first radial distribution feeder; we can get the operational reliability index for SAIFI that is illustrated in figure (4.2).

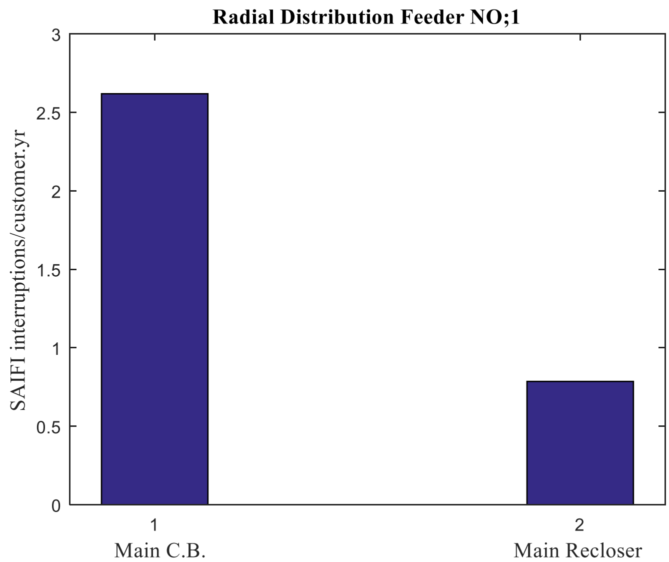

Figure 4.2 SAIFI bars of 1st radial distribution feeder for two discrete situations

As shown, we have obtained (2.6184) interruptions per customer in year for SAIFI index of main C.B. situation to represent the interrupted frequency. Meanwhile, we have obtained (0.78553) interruptions per customer in year for SAIFI index of main R situation to represent the interrupted frequency. Therefore, in the main R situation is better than of main C.B. situation for this index. In conclusion, the frequency interruptions for the main R situation, is less than the main C.B. situation.

Then, we experienced the MAIFI index and the simulation for applying the two situations of main C.B. and main R respectively on the head of the first radial distribution feeder. Where, we could get the operational reliability index for MAIFI that is illustrated in figure (4.3).

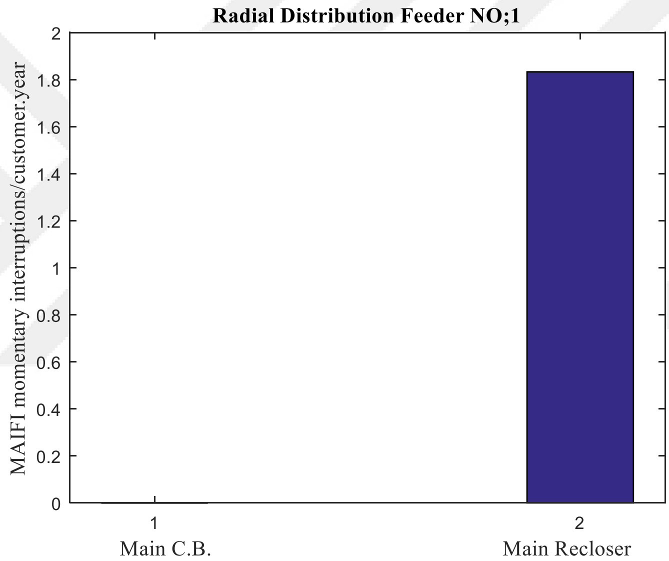

Figure 4.3 MAIFI bars of 1st radial distribution feeder for two discrete situations

Obviously, we have obtained (zero) momentary interruptions per customer in year for MAIFI index of main C.B. situation to represent the interrupted frequency. Meanwhile, we have obtained (1.8329) momentary interruptions per customer in year for MAIFI index of the main R situation to represent the momentary interrupted customer frequency. So, in the main R situation we got a considerable value for MAIFI while the main C.B. situation we got (zero) value for this index. In conclusion, the recloser R is an automatic power switch has cleared the momentary interruptions spontaneously but the circuit breaker has not this characteristic. Finally, from this simulation for applying the two situations of main C.B. and main R respectively on the head of the first radial distribution power feeder we can get the operational reliability index of AENS that is illustrated in figure (4.4) below.

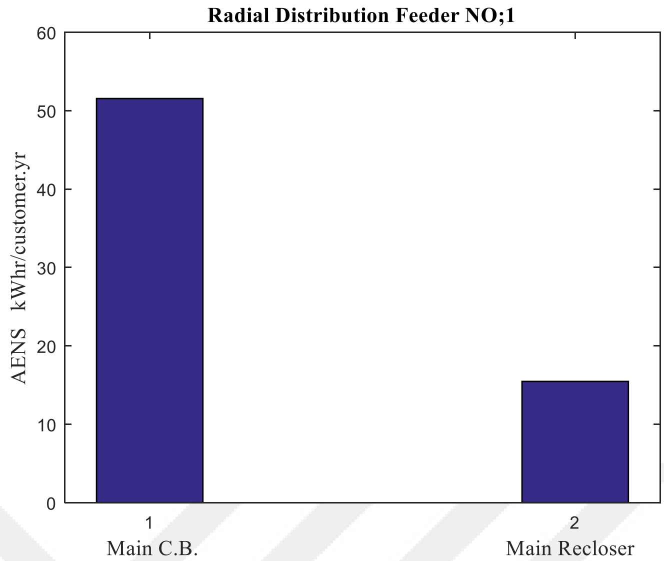

Figure 4.4 AENS bars of 1st radial distribution feeder for two discrete situations

As shown, we obtained (51.542) kilo watt hour per customer in year for AENS index of main C.B. situation to represent the interrupted energy. Meanwhile, we obtained (15.463) kilo watt hour per customer in year for AENS index of main R situation to represent the average interrupted energy. Therefore, the main R situation is better than of main C.B. situation for this index. In conclusion, the average expected energy due to outages for the main R situation is less than the main C.B. situation.

Table 4.1 Reliability indices results of 1st radial distribution feeder for two discrete operational situations

Situation	SAIDI_F1 Min/cust.y	SAIFI_F1 Int./cust.y	MAIFI_F1 Mo.int./cust.y	AENS_F1 Kwh./cust.y	ASAI_F1 %
Main C.B. 1	455.5	2.6184	0	51.542	99.913
Main R 1	136.65	0.78553	1.8329	15.463	99.974

In conclusion, we can summarize all the previous results in table (4.1) of which is including the ASAI index as a resultant for the two tested situations when they are operated separately. All in all, we have obtained accepted and practical results in replacement the main C.B. by the main R for the first radial distribution power feeder in two separated operational situations.

As it is worth to mention that, the value of CAIDI index does not change between the two situations. It means the same minutes per customer interruptions result which is obtained for each situation. Because the required time that crew needs for repairing and it is assumed as constant for each sustained fault event.

4.2 Applying to the Radial distribution Power Feeders Individually

Previously, we applied the two situations on the first radial distribution power feeder for two situations of the separated operation. Again, we will repeat the past experimental steps on each individual radial distribution power feeder by simulating process also in MATLAB program to get their reliability indices. However, we will operate each radial distribution power feeder in discrete operation for each situation as we did in the past item for the first radial feeder. As given, our radial network RBTS (Bus 2) has four radial distribution power feeder. Therefore, we will experience them one by one for each situation and collect the results in one figure for each index to see the changes.

Firstly, we have been simulating them by the FMEA technique in MATLAB program by applying the two situations of main C.B. and main R respectively on the head for each radial distribution feeder individually. Then we could get the operational reliability index for SAIDI which is illustrated in figure (4.5) after we have been operating each radial distribution power feeder separately and for each situation. Where, we can note from the figure (4.5) there is decreasing for the interrupted customer minutes of the SAIDI for each single radial feeder from the main C.B. situation to main R situation. Because of the super speed reclosing trip that is against the momentary faults for each radial feeder. Consequently, the main R situation has been reducing the interrupted customer minutes of the SAIDI which leads in order to enhance the radial distribution feeder reliability. Finally, the interrupted customer minutes that are reduced or eliminated by the main R representing the outage time for the customers because of the momentary or temporary interruptions reasons.

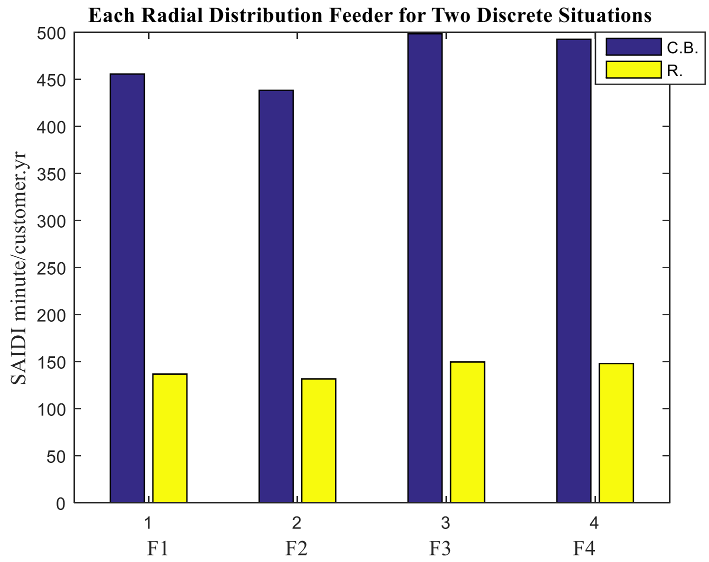

Figure 4.5 SAIDI bars of each radial distribution feeder for two discrete situations

After that, we can also get the operational reliability index of SAIFI which is illustrated in figure (4.6) for the same way for operation or the procedure.

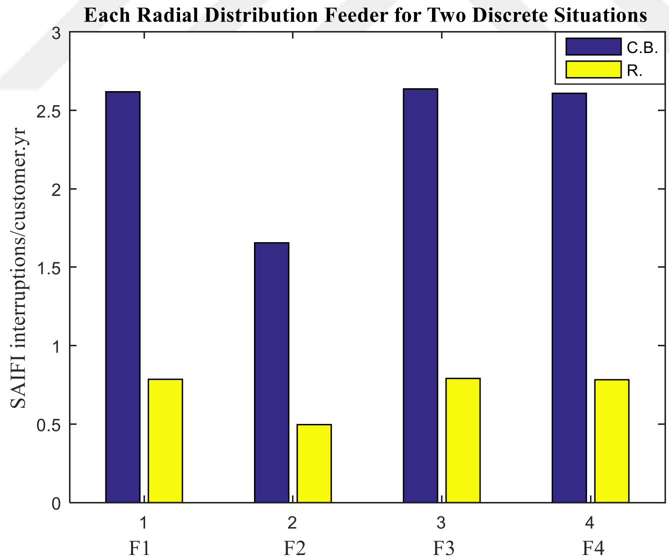

Figure 4.6 SAIFI bars of each radial distribution feeder for two discrete situations

Where, we could also observe from the figure (4.6) there is decreasing for the customer interruptions of SAIFI for each single radial feeder from the main C.B. situation to the main R situation. Because of the super speed reclosing trip that is versus the momentary faults for each radial feeder. Consequently, the main R situation reduces the customer interruptions of the SAIFI which leads to reinforce the radial distribution feeder reliability.

Finally, the eliminated customer interruptions by the main R situation are representing the outage frequency for the customers because of the momentary interruptions reasons.

As it is worth to mention, the MAIFI always be zero value for the main C.B. which is not automatic switch as the recloser so that the momentary outages convert to sustained outages when they are occurred. For this reason, only the main R situation is processing the momentary events or interruptions so this index MAIFI is calculated so that it has a value.

Therefore, we can show in figure (4.7) the values of MAIFI for the main R situation for each radial distribution power feeder individually.

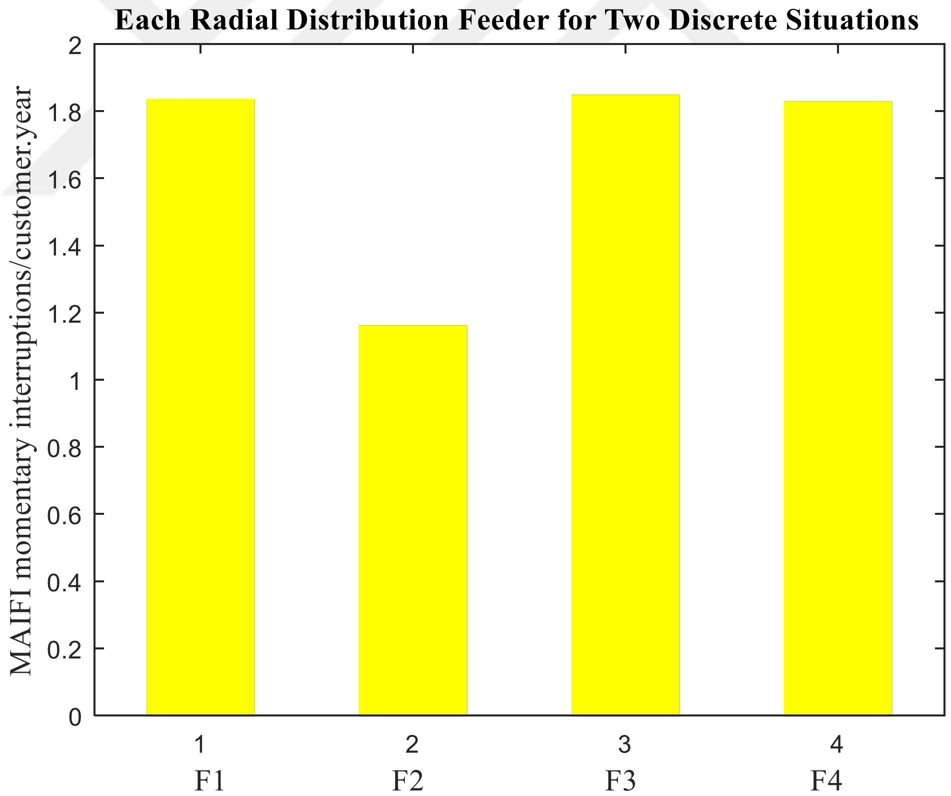

Figure 4.7 MAIFI bars of each radial distribution feeder for discrete main (R) situation

For this, we can now summarize the reliability indices results for the four radial distribution power feeders. That are operated individually and for two separated situations by using the main power switch in the tables (4.2), (4.3) and (4.4) respectively. Additionally, these tables are involving the other reliability indices results by our FMEA technique for the AENS and ASAI as we did in past test of the first radial distribution power feeder procedure.

As it is worth to mention that, the value of CAIDI index does not change between the two situations which it means the same minutes per customer interruptions result that is obtained for each situation. Because the required time that crew needs for repairing is assumed constant for each sustained fault event.

Table 4.2 Reliability indices results for 2nd radial distribution feeder of two discrete operational situations

Situation	SAIDI_F2 Min/cust.y	SAIFI_F2 Int./cust.y	MAIFI_F2 Mo.int./cust.y	AENS_F2 Kwh./cust.y	ASAI_F2 %
Main C.B. 2	438.22	1.6555	0	7735.1	99.917
Main R 2	131.47	0.49665	1.1589	2320.5	99.975

Table 4.3 Reliability indices results for 3rd radial distribution feeder of two discrete operational situations

Situation	SAIDI_F3 Min/cust.y	SAIFI_F3 Int./cust.y	MAIFI_F3 Mo.int./cust.y	AENS_F3 Kwh./cust.y	ASAI_F3 %
Main C.B. 3	498.31	2.6369	0	47.388	99.905
Main R 3	149.49	0.79107	1.8458	14.216	99.972

Table 4.4 Reliability indices results for 4th radial distribution feeder of two discrete operational situations

Situation	SAIDI_F4 Min/cust.y	SAIFI_F4 Int./cust.y	MAIFI_F4 Mo.int./cust.y	AENS_F4 Kwh./cust.y	ASAI_F4 %
Main C.B. 4	492.41	2.6088	0	53.699	99.906
Main R 4	147.72	0.78265	1.8262	16.11	99.972

In summary, it is worth noting that all the obtained reliability indices results may be not compared to each other because they are different in its customer type number, average demand power, equipment number as well as the number of fuses, protected switches, section switches but the most important issue is the entire radial distribution power feeder has been improved at less investment requirements.

CHAPTER FIVE

THE INDICES RESULTS FOR THE RADIAL NETWORK

Progressively, for this chapter we have produced the tested operational work associated with the reliability assessment for the radial distribution power network operation. So, in the coming steps we will take the overall radial distribution power network of RBTS (Bus 2) and 4-Feeder as a discrete system and analyze it to extract its reliability indices by FMEA technique. Therefore, we will get the results for the same previous two situations which are the main C.B. and main R assembled in one simulated figure for each index. However, all the testing results are simulated in MATLAB program environment as the following:

5.1 Applying to the Radial Distribution Power Network

This simulation is tested by the FMEA technique in MATLAB program for applying the two situations of main C.B. and main R respectively upon the head for each one of four radial distribution power feeders of the overall radial network. Moreover, as we said that our standard radial distribution power network is RBTS (Bus 2) 4-Feeder is the tested and simulated system for analyzing.

However, we will operate overall radial distribution power network for each previous situation separately. Firstly, we can get the operational reliability index of SAIDI which is illustrated in figure (5.1).

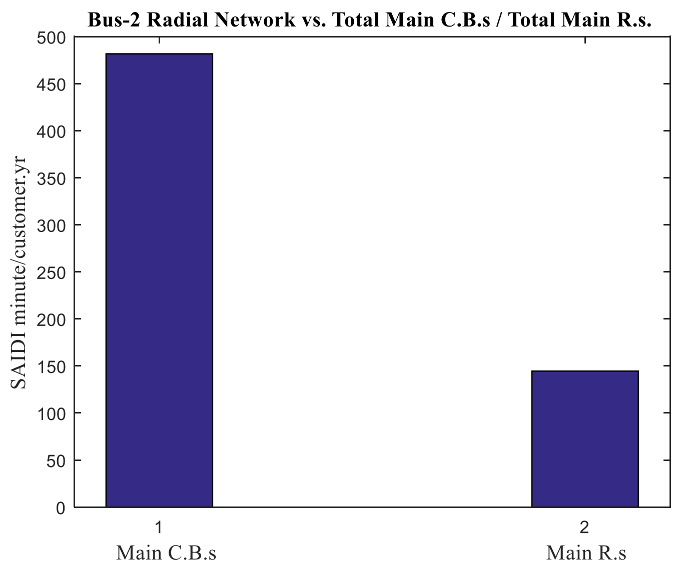

Figure 5.1 SAIDI bars of the radial (Bus 2) network for two discrete situations

So, we have obtained (481.7) minutes for the SAIDI index of the total main C.B. situation to represent the outage period per customer in the year. However, we have obtained (144.51) minutes for SAIDI index of the total main R situation to represent the outage period per customer during year. Therefore, in the total main R situation is better than of total main C.B. situation for this index. In conclusion, the outage period minutes for total main R situation are less than total main C.B. situation.

The simulation has been applying for two situations of total main C.B. and total main R respectively on the head of each radial feeder for overall radial network. Where, we can get the operational reliability index of SAIFI that is illustrated in figure (5.2).

As shown, from the figure (5.2) we got (2.6204) interruptions per customer in year for SAIFI index of the total main C.B. situation to represent the interrupted customer frequency. However, we have obtained (0.78612) interruptions per customer in year for SAIFI index of the total main R situation to represent the interrupted customer frequency. So, in the total main R situation is better than the total main C.B. situation for this index. In conclusion, the interruptions frequency for the total main R situation is less than the total main C.B. situation.

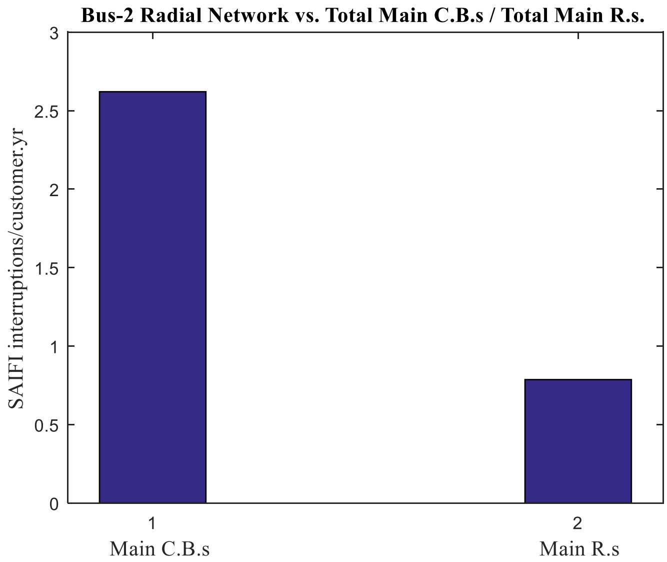

Figure 5.2 SAIFI bars of the radial (Bus 2) network for two discrete situations

Then we have tested the MAIFI and the simulation for applying the two situations of total main C.B. and total main R respectively on the head of each radial distribution feeder of radial network. Therefore, we could get the operational reliability index of MAIFI that is illustrated in figure (5.3).

Therefore, we have obtained (zero) momentary interruptions per customer during the year for MAIFI index by main C.B. situation to represent the interrupted customer frequency. Meanwhile, we have obtained (1.8343) momentary interruptions per customer interrupted during the year for MAIFI index by the total main R situation to represent the momentary interrupted customer frequency.

As worth to mention, in the total main R situation has a considerable value for MAIFI while the total main C.B. situation has zero value for this index. In conclusion, the recloser R is an automatic power switch and has been clearing the momentary interruptions spontaneously but the circuit breaker has not this characteristic.

Also, we could note that the SAIFI value is decreasing from (2.6204) interruptions per customer in year to (0.78612) interruptions per customer in year and the MAIFI value is increasing from (zero) value to (1.8343) momentary interruptions per customer in year for the main C.B. situation to the main R respectively. Consequently, we can understand that in main C.B. situation all the interruptions are sustained behavior while in main R situation each interruption type are recognized obviously because of super speed trip.

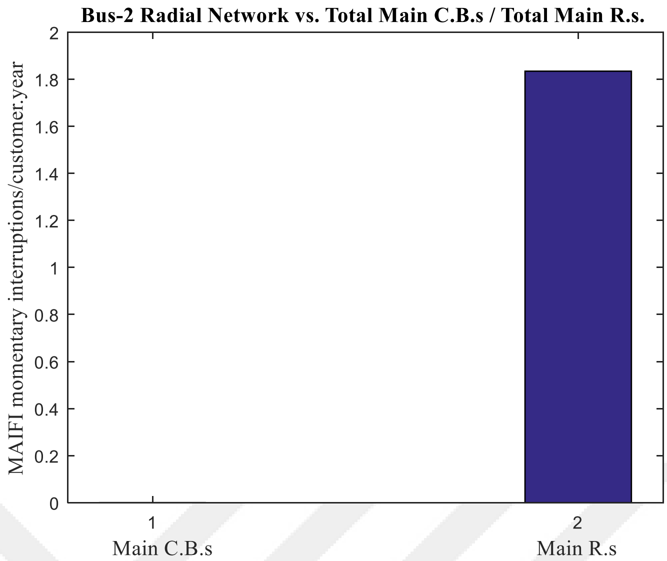

Figure 5.3 MAIFI bars of the radial (Bus 2) network for two discrete situations

Finally, from this simulation for applying the two situations on total main C.B. and the main R cases respectively when the power switch is installed upon the head of each radial feeder for radial (Bus 2) network and so we can get the operational reliability index for AENS that is shown in figure (5.4).

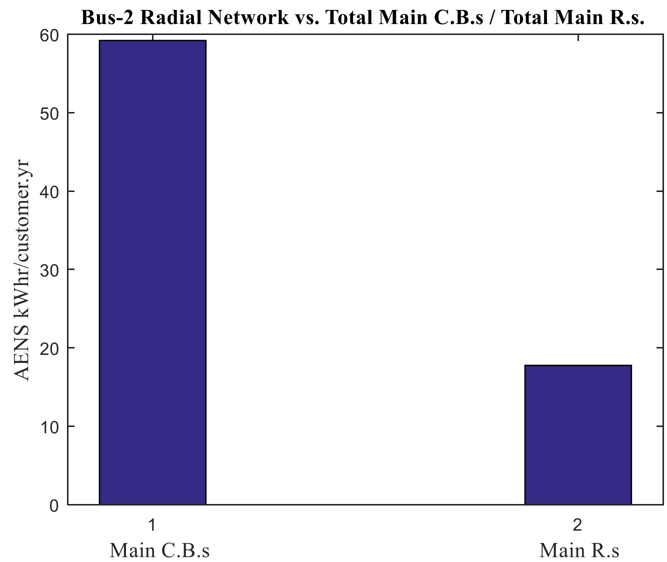

Figure 5.4 AENS bars of the radial (Bus 2) network for two discrete situations

As shown, we have obtained (59.194) kilo watt hour per interrupted customer during the year for AENS index of total main C.B. situation to represent the average interrupted energy. Meanwhile, we have obtained (17.758) kilo watt hour per customer in year for AENS index of total main R situation to represent the average interrupted energy.

In conclusion, we can summarize all previous results in table (5.1) which is including the ASAI index as a resultant for the two total testing situations when they are operated in discrete way. All in all, we have gotten accepted and practical results in replacement the total main C.B. by the total main R for the overall radial distribution power network in two separated operational situations.

Table 5.1 Reliability indices results for radial (Bus 2) network of two discrete situations

Situation	SAIDI Min/cust.y	SAIFI Int./cust.y	MAIFI Mo.int./cust.y	AENS Kwh./cust.y	ASAI %
Main C.B.s	481.7	2.6204	0	58.923	99.908
Main R.s	144.51	0.78612	1.8343	17.677	99.973

5.2 Improving to the Radial Distribution Power Network

In this step, we will experience our radial distribution power network which is RBTS (Bus 2), 4-Feeder. For detecting the improvement case where we have been applying the various main power switch up on the head for each radial distribution feeder. That means we will use both of main C.B. and main R in different likelihoods to get the better case for radial distribution power network reliability assessment.

Consequently, the overall expected likelihoods for (4) feeders are (16) cases for covering all the likelihoods of using both situations for all radial network feeders. More, each radial distribution power feeder withstands one of two likelihoods. That means either main C.B. or main R. Also, these cases for likelihoods of the radial distribution power network operation will be simulated as in previous work steps according to the methodology. Finally, from the indices results for the (16) improving cases we can decide which one is the better with respect to others.

The simulation by FMEA technique in MATLAB program for applying the sixteen (16) likelihoods respectively that set up on the head of the radial distribution network feeders. Firstly, for getting operational reliability index SAIDI which is illustrated in figure (5.5).

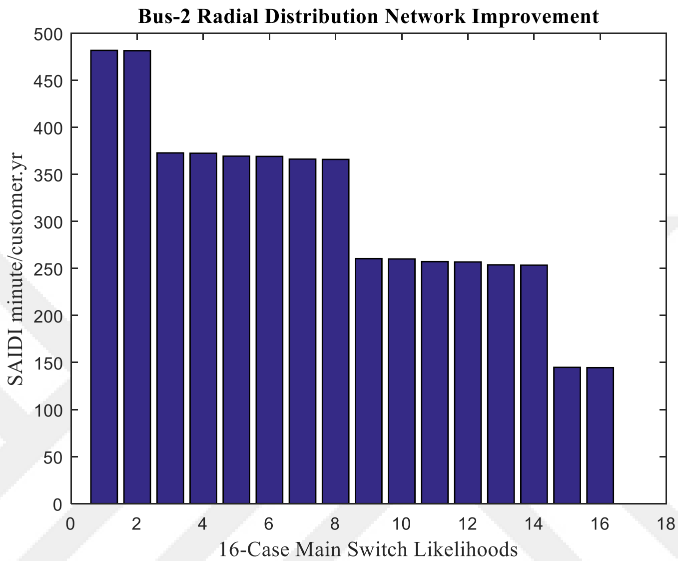

Figure 5.5 SAIDI bars of the radial (Bus 2) network improving for 16-main power switch likelihoods

Then, by the same simulation and the same 16-cases of likelihoods in order to test the radial (Bus 2) network so we can get the operational reliability index for SAIFI, which is shown in figure (5.6).

As it is worth to note, the results for the indices of the sixteen (16) cases of improvement likelihoods tests are arranged according to improvement cases with respect to the index results. However, the illustrated arrangement for index results is done by MATLAB program through the simulation to ease comparison.

Also, we can get the operational reliability index for MAIFI, which is illustrated in figure (5.7).

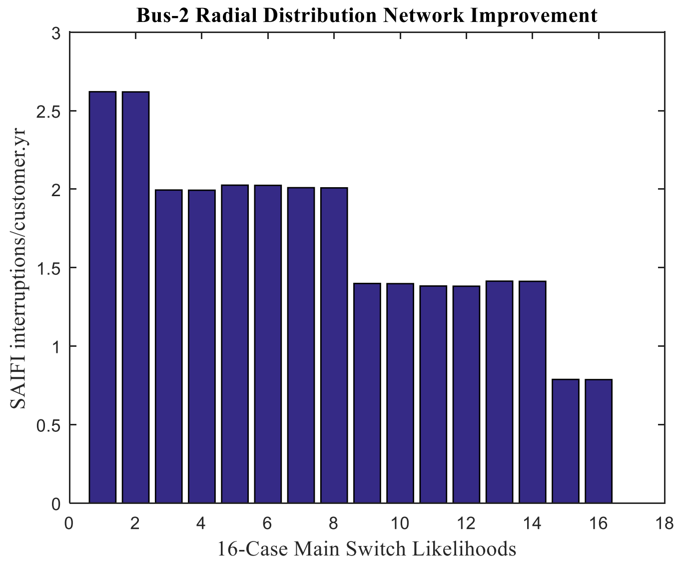

Figure 5.6 SAIFI bars of the radial (Bus 2) network improving for 16-main power switch likelihoods

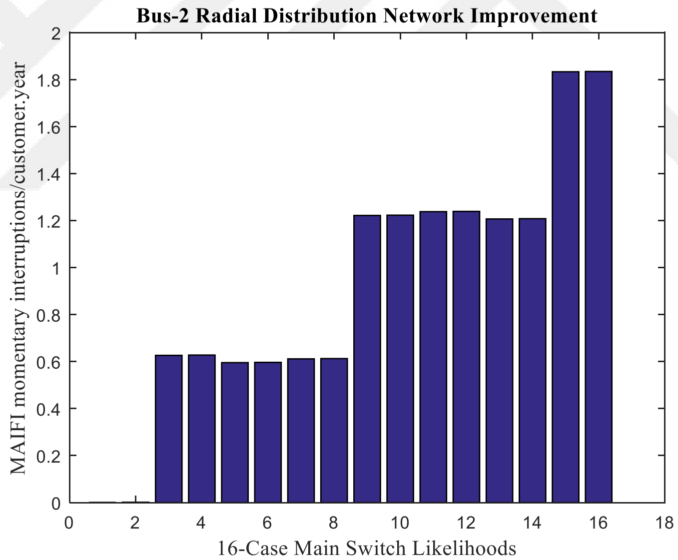

Figure 5.7 MAIFI bars of the radial (Bus 2) network improving for 16-main power switch likelihoods

As it is worth to mention that, the value of CAIDI index does not change between the two situations. That means the same minutes per customer interruptions result which is obtained for each situation. Because of the required time that crew needs for repairing so it is assumed to be constant for each sustained fault event.

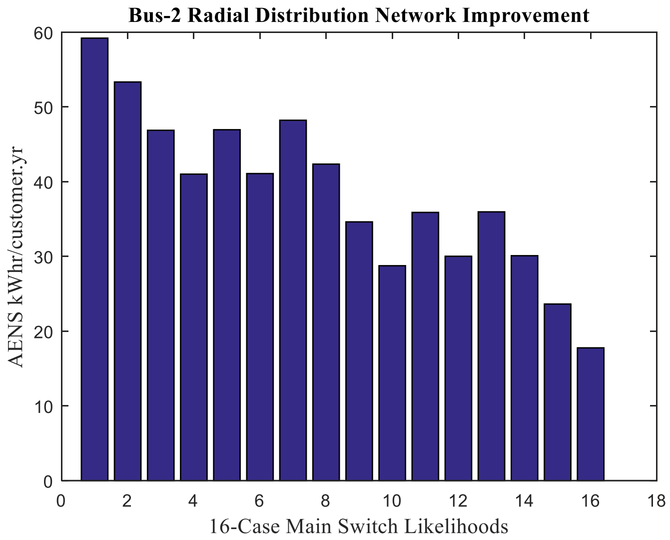

Figure 5.8 AENS bars of the radial (Bus 2) network improving for 16-main power switch likelihoods

In conclusion, we can summarize all the sixteen (16) improvement cases results in table (5.2) which is including the ASAI index as a resultant for each case when they have been operated in discrete mode.

Table 5.2 Reliability indices results for radial (Bus 2) network improvement; for 16-case likelihoods

Main Recloser	SAIDI Min/cust.y	SAIFI Int./cust.y	MAIFI Mo.int./cust.y	AENS Kwh./cust.y	ASAI %
None Recloser	481.7	2.6204	0	58.923	99.908
R2	481.38	2.6192	0.0012147	53.247	99.908
R1	372.74	1.9941	0.62634	46.594	99.929
R1 + R2	372.42	1.9929	0.62755	40.919	99.929
R4	369.33	2.0251	0.59533	46.669	99.93
R2 + R4	369.01	2.0239	0.59654	40.994	99.93
R3	366.16	2.009	0.61141	47.936	99.93
R2 + R3	365.83	2.0078	0.61262	42.26	99.93
R1 + R4	260.37	1.3987	1.2217	34.34	99.95
R1 + R2 +R4	260.05	1.3975	1.2229	28.665	99.951
R1 + R3	257.2	1.3827	1.2377	35.607	99.951
R1 + R2 +R3	256.88	1.3814	1.239	29.931	99.951
R3 + R4	253.79	1.4137	1.2067	35.682	99.952
R2 + R3 + R4	253.47	1.4125	1.2079	30.006	99.952
R1 + R3 + R4	144.83	0.78734	1.8331	23.353	99.972
R1+R2+R3+R4	144.51	0.78612	1.8343	17.677	99.973

5.3 The Better Case Selection

By depending on the past (16) likelihoods cases for improving the radial distribution power network of RBTS (Bus 2) 4-Feeder we could select the two better cases for (R1+R3+R4) case and (R1+R2+R3+R4) case from the overall likelihoods. Also, we can see their reliability indices shapes in figure (5.9) and their values are stated in table (5.3).

However, these two cases have reliability indices results close to each other for four (4) indices of SAIDI, SAIFI, MAIFI and ASAI. But they have different values for AENS index. Where, the AENS index value for (R1+R3+R4) case equals to

(23.624) kilo watt hour per interrupted customer during the year. But the AENS index value for (R1+R2+R3+R4) case equals to (17.758) kilo watt hour per interrupted customer in year. So, the second case is better because it has a big difference equals to (5.866) kilo watt of average expected energy not supplied for per interrupted customer that connected to this radial distribution power network in year.

Table 5.3 Reliability indices results of improved (Bus 2) radial network; for (R1+R3+R4), and (R1+R2+R3+R4) cases

Main Recloser	SAIDI Min/cust.y	SAIFI Int./cust.y	MAIFI Mo.int./cust.y	AENS Kwh./cust.y	ASAI %
(R1+R3+R4)	144.83	0.78734	1.8331	23.353	99.972
(R1+R2+R3+R4)	144.51	0.78612	1.8343	17.677	99.973

Therefore, the case for existing of four (4) main reclosers of 3-phase tripping recloser for each radial distribution power feeder is the better case to improve the reliability indices for this radial distribution power network. Finally, this case also represents the better one for improvement achieving while lowering the investment requirements because we have proved that we utilized of just one 3-phase tripping recloser for each radial distribution feeder head of radial RBTS (Bus 2) network.

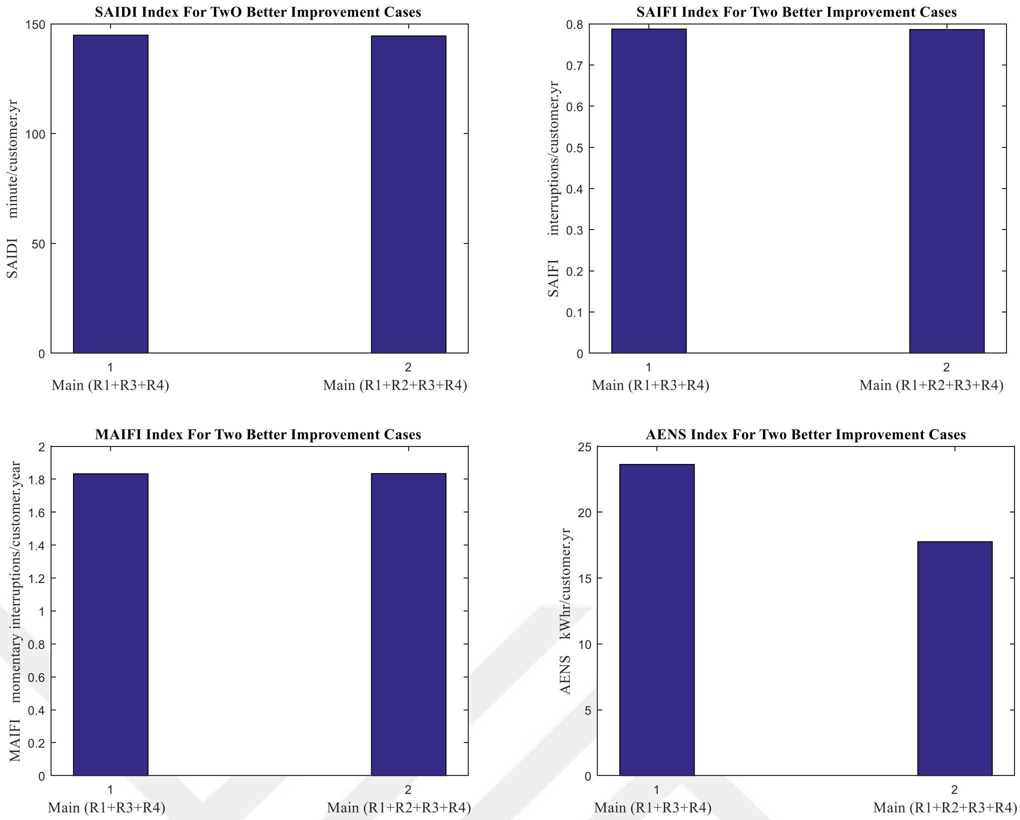

Figure 5.9 SAIDI, SAIFI, MAIFI, and AENS Reliability Indices of radial (Bus 2) network for two better improvement cases

Finally, for reliability enhancement ratio against the 3-phase tripping reclosers number to previous improved radial distribution power network cases. So, we could present figure (5.10) according to our reliability enhancement equation in (2.11) and the cases of recloser we are used in table (5.2). For this percentage enhancement ratio we observed how it has been and matching with the 3-phase tripping reclosers effects for the improved cases of radial distribution power network.

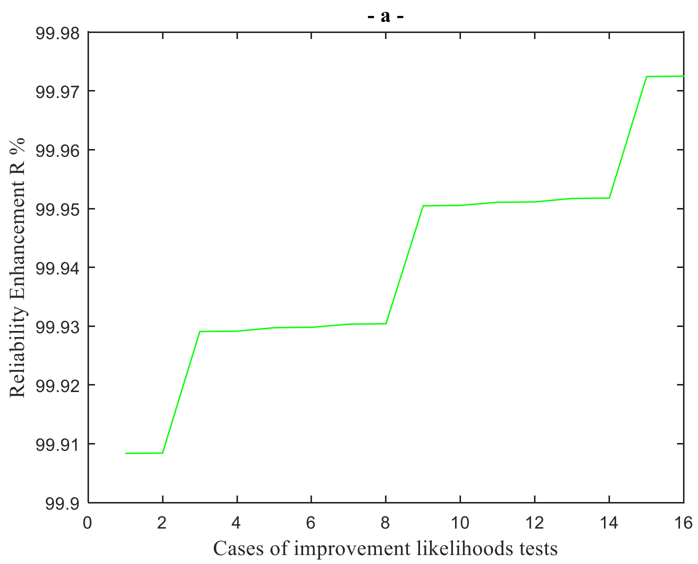

Figure (5. 10 a) Enhancement ratio against the improving 3-Phase Tripping Recloser cases that are used for improved radial (Bus 2), 4-Feeder of RBTS.

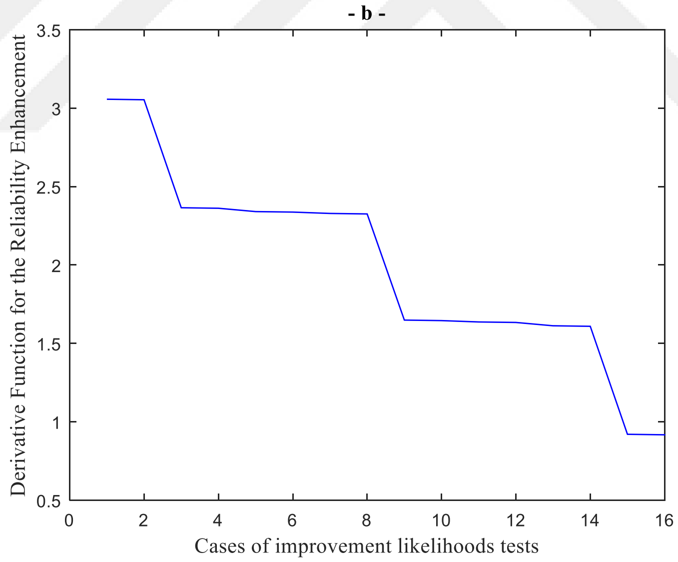

Figure (5.10 b) Derivative function for the enhancement ratio against the improving 3-Phase Tripping Recloser cases are used for improved radial (Bus 2), 4-Feeder of RBTS.

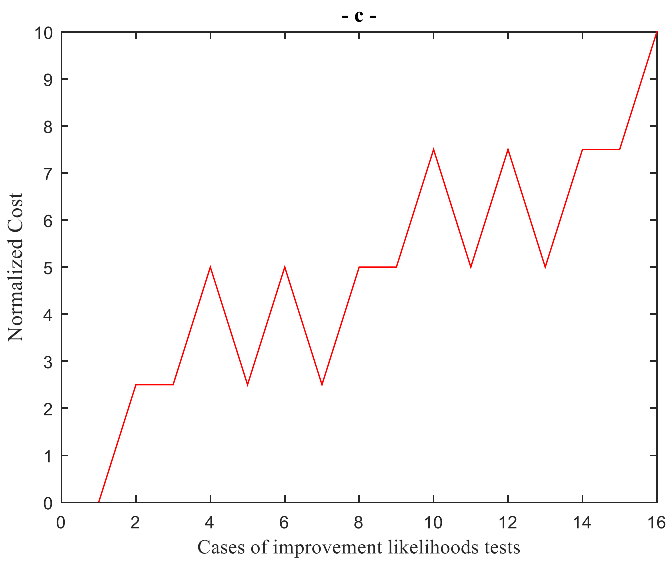

Figure (5. 10 c) Normalized cost against the improving 3-Phase Tripping Recloser cases are used for radial (Bus 2), 4-Feeder of RBTS.

Consequently, we could infer that the better case of the normalized cost (main recloser with respect to main circuit breaker) when we used only one recloser through the likelihood improved cases. Obviously, this is happened as shown in the figure (5.10) at (2, 3, 5 and 7) likelihoods. However, the reclosers of (R1+R2+R3+R4) has the high enhancement ratio of (99.973) % with respect to all system reliability indices while the low enhancement ratio of (99.908) % when there is no recloser. So, the service companies may take any improved case for their radial distribution power networks according to the system reliability index or indices that they desire.

CHAPTER SIX

THE CONCLUSIONS AND FUTURE WORK

6.1 Results and Discussions

In this work, the investigation has been done to enhance the reliability indices for the large areas of radial distribution power networks while lowering the investment requirements. So, we calculated the most important reliability indices that are represented in SAIDI, SAIFI, MAIFI, AENS and ASAI actually.

Being worthy of mention, the empirical improvement process is made over all the radial distribution network feeders to determine the number of 3-phase tripping reclosers that are required to be replaced. Also, this gives the capability for radial distribution network to determine the differences among the reliability indices values for utilities.

Essentially, the work is focused on the automatic elimination of the momentary outages by using the 3-phase tripping recloser. The momentary faults are responsible for 70% of the total overhead faults which are investigated in [4], [5] and [6].

Therefore, the average service availability index ASAI indicated to increasing percentage value when the RBTS (Bus 2) radial distribution power network reliability is improved. Where, the value for ASAI is enhanced from (99.90) to (99.97). Also, it means that minutes of the outages for each interrupted customer decrease from (481.7) minutes to (144.51) minutes. Therefore, we could provide (337.19) minutes or (5.61) hours per interrupted customer during the year.

The momentary average interruption frequency index MAIFI is working with the recloser situation because of the super speed reclosing trip for the recloser switch. Therefore, this index MAIFI was increasing for each improvement case, which is representing the number of momentary customer interruptions that are cleared by the recloser.

It is important to note that, the index AENS has different values during each improvement process, because of the load point type. Where, the load points are classified into several types according to the customer class such as residential, commercial, small users, industrial, agricultural, and governmental. Finally, we have obtained (41.246) kilo watt hour per customer in year through the improvement process.

Consequently, we covered all sides in relation to this work through this discussion to get the target for replacing the 3-phase tripping recloser by the main circuit breaker at less investment requirements. So, we could treat large areas of radial distribution power networks and also the radial part of the meshed distribution power networks.

6.2 The Conclusions

This work has concentrated on the low investment side for using of the advanced technical tools to achieve the reliability enhancement for radial distribution power network. So, this thesis made the use of 3-phase tripping recloser as a main power switch instead of the main circuit breaker up on the head operational point for radial feeders of radial distribution power network. However, if we are making a discussion with respect to recent contributions that are based on the lowering investment views. Conclusively, we could achieve a better convenient work for reliability indices enhancement for large areas of radial distribution power networks.

For example, E. Vidyasagar and others presented the fault passage indicator device which was set upon the three phase overhead lines [13]. Although, they reduced the repair or maintenance time but the number of power outages remains constant, causing them to invest more of these indicators.

Moreover, Hamid SHARIFIAN and others converted the distribution power network into automation mode by the (VIT) automatic switches [14]. But, this way is not practical with respect to large areas of distribution power system due to the cost of large investment.

Additionally, both Ashish Ranjan and J N Rai rearranged the switches' locations for optimal position by (GA) and (PSO) algorithms in the distribution network [15]. But, they did not consider the important impacts of the momentary interruption faults.

Also, Umesh Agarwal and Monika Vardia rearranged the radial distribution power feeder through adding and subtracting some components by specific switches, through (open/close) characteristic [16]. However, if the tow situations (before and after) have not the same load balancing of transfer loads then it is not improving more with respect to the former.

Finally, Saheli Ray and others optimized Differential Search (DS) algorithm and it had obtained faster mathematical analysis with respect to (PSO) algorithm [17]. However, the remote control switches (RCS) are costly when they are invested for each component of the overall radial distribution power networks.

From the previous studies of contributions for recent years, we note that more tools of techniques, modes, and programming algorithms. Where, they addressed the distribution power reliability assessment to enhance reliability indices. However, they are wonderful and fantastic. But, there are large areas of common radial distribution power networks required to be solved for better reliability improvement in cheap ways. Therefore, we have to consider the investment aspects, to get a better reliability improvement at less investment.

Conclusively, we have proved that we could make the usage of just one 3-phase tripping recloser for each radial distribution feeder head of radial RBTS (Bus 2) network. Therefore, this case also represents the better one for improvement achieving while lowering the investment requirements.

In conclusion, we introduced this work to be one of the reliable feasible solutions in considering of the investment respect actually, by using one modern technique for every radial distribution feeder. Also, processing for any radial feeder reflects to overall radial distribution network totally.

For this work, according to what was presented by sequenced testing steps for the improved radial distribution power network of RBTS (Bus 2), 4-Feeder. However, we can extract from the above explanations to summarize the important points as following:

1. Reliability indices enhancement ratio is achieved by 70% for radial distribution power network which is represented the momentary faults ratio actually.
2. The result value for the average service availability index ASAI of the improved radial distribution power network is (99.97) has three nines rank and close to four nines rule, so it is high and accepted.
3. Decreasing the sustained interruption indices values to 30% for the enhancement case result, while the momentary interruption index is increasing to 70% of the same case.
4. For customer satisfaction, SAIDI minutes for outages of interrupted customer is decreasing from 481.7 minutes to 144.51 minutes. So, we have provided 337.19 minutes or 5.61 hours per interrupted customer during the year.
5. Also, we have obtained 41.246 kilo watt hour per customer in year through the improvement process.
6. Therefore, the usage for only one 3-phase tripping recloser for each radial feeder of the improved radial distribution power network achieves the purpose of this work that is the reliability indices enhancement while lowering the investment requirements.

Consequently, this work represents the better one for achieving the reliability indices enhancement case while lowering the investment requirements. , it proved that we could utilize of just one 3-phase tripping recloser instead of the main circuit breaker for each radial feeder in radial distribution power networks.

6.3 The Future Work

In future, we will prepare a new work related to the reliability assessment for radial distribution power network by designing a new delivered program in order to compute the most important indices. Also, the new program will be based on the reliability technique FMEA, which is constructed through in MATLAB-GUI environment. Additionally, the proposed final work that is planned to be a new window contains all necessary reliability indices bottoms to be an ease tool for the electrical engineers to evaluate the reliability indices for the radial distribution network.

So, by this new window it could be to prepare the reports for the reliability assessment for daily, weekly, monthly, yearly or any specific study period. However, this new window only requires insertion of data by the operation crew who are working in radial distribution power network, and then will give us the reliability indices assessment directly.

All in all, this future work is a good step to produce a new tool for radial distribution power reliability assessment. Being an enhancement tool for the utility and getting the customer satisfaction, works monitoring, and monthly reports.

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APPENDICES

APPENDIX A

Implemented Code In MATLAB

```
%% {{In The Name Of ALLAH,The Most Gracious,The Most Merciful}}
%% "ENHANCEMENT OF RELIABILITY INDICES IN RADIAL DISTRIBUTION POWER
NETWORKS WHERE 3-PHASE TRIPPING RECLOSERS ARE USED INSTEAD OF MAIN
CIRCUIT BREAKERS"
%   Qasim Mohammed Abbas Arjane AL JUBORY - Master Student
NO;1406030011 - T.H.C.-
%   THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION INSTITUTE OF
SCIENCE AND TECHNOLOGY.
%   THE DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING.
%   2017
%
%%----- Reliability Data -----%%
%
%% Component reliability data
% 1st Column: Component number
% 2nd Column: Component type (0: Bus/LoadPoint, 1: Breaker, 2:
Overhead Line, 3: Switch, 4: Fuse, 5: Tranformer, 6: TieSwitch, 7:
Linelateral)
% 3rd Column: Permanent failure rate (failures/year)
% 4th Column: Maximum failure rate for condition-depended failure
rate cases (CDFR), expressed in times of permanent failure rate,
e.g. x10
% 5th Column: Probability of operational failure for all equipment &
switches are zero.
% 6th Column: Mean time to repair (hours)
% 7th Column: Mean time to switch (hours)           # Only Switches,
zero for the rest
% 8th Column: Number of customers                   # Only for
LoadPoints, zero for the rest
%   Num CType    FR   Lmax    Prob    MTTR    MSwTime NofCustomers
```

```
mpc.comp_rel = [
    1   0   0.001   1   0   2   0   0;  % SlackBus
    2   0   0.001   1   0   2   0   0;  % Bus2
    3   0   0.001   1   0   2   0   0;  % Bus3
    4   0   0.001   1   0   2   0   0;  % Bus4
    5   0   0.001   1   0   2   0   0;  % Bus5
    6   0   0.001   1   0   2   0   0;  % Bus6
    7   0   0.001   1   0   2   0   0;  % Bus7
    8   0   0.001   1   0   2   0   0;  % Bus8
    9   0   0.001   1   0   2   0   0;  % Bus9
    10  0   0.001   1   0   2   0   0;  % Bus10
    11  0   0.001   1   0   2   0   0;  % Bus11
    12  0   0.001   1   0   2   0   0;  % Bus12
    13  0   0.001   1   0   2   0   0;  % Bus13
    14  0   0.001   1   0   2   0   0;  % Bus14
    15  0   0.001   1   0   2   0   0;  % Bus15
    16  0   0.001   1   0   2   0   210;    % LP1
    17  0   0.001   1   0   2   0   210;    % LP2
    18  0   0.001   1   0   2   0   210;    % LP3
    19  0   0.001   1   0   2   0   1;  % LP4
    20  0   0.001   1   0   2   0   1;  % LP5
    21  0   0.001   1   0   2   0   10; % LP6
    22  0   0.001   1   0   2   0   10; % LP7
    23  0   0.001   1   0   2   0   1;  % LP8
    24  0   0.001   1   0   2   0   1;  % LP9
    25  0   0.001   1   0   2   0   210;    % LP10
    26  0   0.001   1   0   2   0   210;    % LP11
    27  0   0.001   1   0   2   0   200;    % LP12
    28  0   0.001   1   0   2   0   1;  % LP13
    29  0   0.001   1   0   2   0   1;  % LP14
    30  0   0.001   1   0   2   0   10; % LP15
    31  0   0.001   1   0   2   0   10; % LP16
    32  0   0.001   1   0   2   0   200;    % LP17
    33  0   0.001   1   0   2   0   200;    % LP18
    34  0   0.001   1   0   2   0   200;    % LP19
    35  0   0.001   1   0   2   0   1;  % LP20
    36  0   0.001   1   0   2   0   1;  % LP21
    37  0   0.001   1   0   2   0   10; % LP22
    38  1   0.006   1   0   2   0   0;  % BR1
    39  1   0.006   1   0   2   0   0;  % BR2
    40  1   0.006   1   0   2   0   0;  % BR3
    41  1   0.006   1   0   2   0   0;  % BR4
    42  2   0.04875 10  0   5   0   0;  % ML1
    43  2   0.04875 10  0   5   0   0;  % ML2
    44  2   0.04875 10  0   5   0   0;  % ML3
    45  2   0.039   10  0   5   0   0;  % ML4
    46  2   0.04875 10  0   5   0   0;  % ML5
    47  2   0.039   10  0   5   0   0;  % ML6
    48  2   0.04875 10  0   5   0   0;  % ML7
    49  2   0.052   10  0   5   0   0;  % ML8
    50  2   0.039   10  0   5   0   0;  % ML9
    51  2   0.04875 10  0   5   0   0;  % ML10
    52  2   0.052   10  0   5   0   0;  % ML11
    53  2   0.04875 10  0   5   0   0;  % ML12
    54  2   0.04875 10  0   5   0   0;  % ML13
    55  2   0.039   10  0   5   0   0;  % ML14
    56  7   0.039   10  0   5   0   0;  % LAT1
    57  7   0.052   10  0   5   0   0;  % LAT2
    58  7   0.052   10  0   5   0   0;  % LAT3
    59  7   0.039   10  0   5   0   0;  % LAT4
    60  7   0.052   10  0   5   0   0;  % LAT5
```

```
61  7   0.052   10  0   5   0   0;  % LAT6
62  7   0.052   10  0   5   0   0;  % LAT7
63  7   0.052   10  0   5   0   0;  % LAT8
64  7   0.052   10  0   5   0   0;  % LAT9
65  7   0.039   10  0   5   0   0;  % LAT10
66  7   0.04875 10  0   5   0   0;  % LAT11
67  7   0.052   10  0   5   0   0;  % LAT12
68  7   0.04875 10  0   5   0   0;  % LAT13
69  7   0.052   10  0   5   0   0;  % LAT14
70  7   0.039   10  0   5   0   0;  % LAT15
71  7   0.04875 10  0   5   0   0;  % LAT16
72  7   0.039   10  0   5   0   0;  % LAT17
73  7   0.039   10  0   5   0   0;  % LAT18
74  7   0.052   10  0   5   0   0;  % LAT19
75  7   0.052   10  0   5   0   0;  % LAT20
76  7   0.04875 10  0   5   0   0;  % LAT21
77  7   0.052   10  0   5   0   0;  % LAT22
78  3   0.014   1   0   4   0   0;  % SW1
79  3   0.014   1   0    4   0   0;  % SW2
80  3   0.014   1   0    4   0   0;  % SW3
81  3   0.014   1   0    4   0   0;  % SW4
82  3   0.014   1   0    4   0   0;  % SW5
83  3   0.014   1   0    4   0   0;  % SW6
84  3   0.014   1   0    4   0   0;  % SW7
85  3   0.014   1   0    4   0   0;  % SW8
86  3   0.014   1   0    4   0   0;  % SW9
87  3   0.014   1   0    4   0   0;  % SW10
88  4   0.009   1   0    2   0   0;  % FS1
89  4   0.009   1   0    2   0   0;  % FS2
90  4   0.009   1   0    2   0   0;  % FS3
91  4   0.009   1   0    2   0   0;  % FS4
92  4   0.009   1   0    2   0   0;  % FS5
93  4   0.009   1   0    2   0   0;  % FS6
94  4   0.009   1   0    2   0   0;  % FS7
95  4   0.009   1   0    2   0   0;  % FS8
96  4   0.009   1   0    2   0   0;  % FS9
97  4   0.009   1   0    2   0   0;  % FS10
98  4   0.009   1   0    2   0   0;  % FS11
99  4   0.009   1   0    2   0   0;  % FS12
100 4   0.009   1   0    2   0   0;  % FS13
101 4   0.009   1   0    2   0   0;  % FS14
102 4   0.009   1   0    2   0   0;  % FS15
103 4   0.009   1   0    2   0   0;  % FS16
104 4   0.009   1   0    2   0   0;  % FS17
105 4   0.009   1   0    2   0   0;  % FS18
106 4   0.009   1   0    2   0   0;  % FS19
107 4   0.009   1   0    2   0   0;  % FS20
108 4   0.009   1   0    2   0   0;  % FS21
109 4   0.009   1   0    2   0   0;  % FS22
110 5   0.015   15  0    5   0   0;  % TR1
111 5   0.015   15  0    5   0   0;  % TR2
112 5   0.015   15  0    5   0   0;  % TR3
113 5   0.015   15  0    5   0   0;  % TR4
114 5   0.015   15  0    5   0   0;  % TR5
115 5   0.015   15  0    5   0   0;  % TR6
116 5   0.015   15  0    5   0   0;  % TR7
117 5   0.015   15  0    5   0   0;  % TR8
118 5   0.015   15  0    5   0   0;  % TR9
119 5   0.015   15  0    5   0   0;  % TR10
120 5   0.015   15  0    5   0   0;  % TR11
121 5   0.015   15  0    5   0   0;  % TR12
```

```
    122 5   0.015   15  0    5   0   0;  % TR13
    123 5   0.015   15  0    5   0   0;  % TR14
    124 5   0.015   15  0    5   0   0;  % TR15
    125 5   0.015   15  0    5   0   0;  % TR16
    126 5   0.015   15  0    5   0   0;  % TR17
    127 5   0.015   15  0    5   0   0;  % TR18
    128 5   0.015   15  0    5   0   0;  % TR19
    129 5   0.015   15  0    5   0   0;  % TR20
    130 5   0.015   15  0    5   0   0;  % TR21
    131 5   0.015   15  0    5   0   0;  % TR22
    132 6   0   1   0   4    2   0;  % TS1
    133 6   0   1   0   4    2   0;  % TS1
    134 2   0   1   0   5    0   0;  % LNO1
    135 2   0   1   0   5    0   0;  % LNO2
];


                %% -----  Topology Data  -----%%

% NumberOfBranch    [Components in Branch]
mpc.topology = [
    1   1   38  42  2   0;
    2   2   78  43  3   0;
    3   3   79  44  4   0;
    4   4   80  45  5   0;
    5   2   88  56  110 16;
    6   2   89  57  111 17;
    7   3   90  58  112 18;
    8   3   91  59  113 19;
    9   4   92  60  114 20;
    10  4   93  61  115 21;
    11  5   94  62  116 22;
    12  1   39  46  6   0;
    13  6   81  47  7   0;
    14  6   95  63  117 23;
    15  7   96  64  118 24;
    16  1   40  48  8   0;
    17  8   82  49  9   0;
    18  9   83  50  10  0;
    19  10  84  51  11  0;
    20  8   97  65  119 25;
    21  9   98  66  120 26;
    22  9   99  67  121 27;
    23  10  100 68  122 28;
    24  10  101 69  123 29;
    25  11  102 70  124 30;
    26  1   41  52  12  0;
    27  12  85  53  13  0;
    28  13  86  54  14  0;
    29  14  87  55  15  0;
    30  12  103 71  125 31;
    31  12  104 72  126 32;
    32  13  105 73  127 33;
    33  13  106 74  128 34;
    34  14  107 75  129 35;
    35  15  108 76  130 36;
    36  15  109 77  131 37;
    37  5   132 134 7   0;
    38  11  133 135 15  0;
];
```

```
%%  We will calculate the load points indices in regarding the
manual switching period of each main section line and to reclose
Main(Circuit Breaker or Recloser); to assume it 0.5 Hour,for each
permanent failure rate as a repair time;



z2=mpc.comp_rel(1:133,:);
ag=(mpc.bus(16:37,3)./1.6666666667).*1e3;

>> ag

ag =

   1.0e+03 *

     0.5201
     0.5201
     0.5201
     0.5500
     0.5500
     0.4500
     0.4500
     0.9767
     1.1863
     0.5201
     0.5201
     0.4375
     0.5500
     0.5500
     0.4500
     0.4500
     0.4375
     0.4375
     0.4375
     0.5500
     0.5500
     0.4500

>>

p1=z2(:,3).*z2(:,4);p2=p1.*z2(:,6);
z1=[z2(1:133,1),p1,p2];
 nn=[1:157;];
z3=z1([ 1      38    42     2    78    43     3    79    44     4
80      45     5     2    88     56    110     16  2    89     57    111
17    3     90    58    112     18   3     91     59    113     19   4     92
60    114     20     4     93     61    115     21     5     94     62    116
22     1     39     46     6     81     47     7      6     95     63    117
23    7     96     64    118     24    1   40     48    8     82     49    9
83     50    10     84     51     11    8     97     65    119     25     9
98     66    120     26     9     99     67    121     27    10    100     68
122     28     10    101     69    123     29     11    102     70    124     30
1    41     52     12     12     85     53     13     86     54     14     87
55     15     12    103     71    125     31     12    104     72    126     32
13    105     73    127     33     13    106     74    128     34     14    107
75    129     35     15    108     76    130     36     15    109     77    131
37],:);
z=[nn',z3];
```

```
a1=z(5:13,:);b1=z(8:13,:);c1=z(11:13,:);a2=z(53:55,:);a3=z(70:78,:);
b3=z(73:78,:);c3=z(76:78,:);a4=z(114:122,:);b4=z(117:122,:);c4=z(120
:122,:);
l1=[z(1:4,:);z(15:18,:)];l2=[z(1:4,:);z(20:23,:)];l3=[z(1:7,:);z(25:
28,:)];l4=[z(1:7,:);z(30:33,:)];l5=[z(1:10,:);z(35:38,:)];l6=[z(1:10
,:);z(40:43,:)];l7=[z(1:13,:);z(45:48,:)];l8=[z(49:52,:);z(57:60,:)]
;l9=[z(49:55,:);z(62:65,:)];l10=[z(66:69,:);z(80:83,:)];l11=[z(66:72
,:);z(85:88,:)];l12=[z(66:72,:);z(90:93,:)];l13=[z(66:75,:);z(95:98,
:)];l14=[z(66:75,:);z(100:103,:)];l15=[z(66:78,:);z(105:108,:)];l16=
[z(109:112,:);z(124:127,:)];l17=[z(109:112,:);z(129:132,:)];l18=[z(1
09:112,:);z(114:116,:);z(134:137,:)];l19=[z(109:112,:);z(114:116,:);
z(139:142,:)];l20=[z(109:112,:);z(114:119,:);z(144:147,:)];l21=[z(10
9:112,:);z(114:122,:);z(149:152,:)];l22=[z(109:112,:);z(114:122,:);z
(154:157,:)];
fa1=sum(a1(:,3));fb1=sum(b1(:,3));fc1=sum(c1(:,3));fa2=sum(a2(:,3));
fa3=sum(a3(:,3));fb3=sum(b3(:,3));fc3=sum(c3(:,3));fa4=sum(a4(:,3));
fb4=sum(b4(:,3));fc4=sum(c4(:,3));
fl1=sum(l1(:,3));fl2=sum(l2(:,3));fl3=sum(l3(:,3));fl4=sum(l4(:,3));
fl5=sum(l5(:,3));fl6=sum(l6(:,3));fl7=sum(l7(:,3));fl8=sum(l8(:,3));
fl9=sum(l9(:,3));fl10=sum(l10(:,3));fl11=sum(l11(:,3));fl12=sum(l12(
:,3));fl13=sum(l13(:,3));fl14=sum(l14(:,3));fl15=sum(l15(:,3));fl16=
sum(l16(:,3));fl17=sum(l17(:,3));fl18=sum(l18(:,3));fl19=sum(l19(:,3
));fl20=sum(l20(:,3));fl21=sum(l21(:,3));fl22=sum(l22(:,3));
ul1=sum(l1(:,4));ul2=sum(l2(:,4));ul3=sum(l3(:,4));ul4=sum(l4(:,4));
ul5=sum(l5(:,4));ul6=sum(l6(:,4));ul7=sum(l7(:,4));ul8=sum(l8(:,4));
ul9=sum(l9(:,4));ul10=sum(l10(:,4));ul11=sum(l11(:,4));ul12=sum(l12(
:,4));ul13=sum(l13(:,4));ul14=sum(l14(:,4));ul15=sum(l15(:,4));ul16=
sum(l16(:,4));ul17=sum(l17(:,4));ul18=sum(l18(:,4));ul19=sum(l19(:,4
));ul20=sum(l20(:,4));ul21=sum(l21(:,4));ul22=sum(l22(:,4));
u1=ul1+(0.5*fa1);u2=ul2+(0.5*fa1);u3=ul3+(0.5*fb1);u4=ul4+(0.5*fb1);
u5=ul5+(0.5*fc1);u6=ul6+(0.5*fc1);u7=ul7;u8=ul8+(0.5*fa2);u9=ul9;u10
=ul10+(0.5*fa3);u11=ul11+(0.5*fb3);u12=ul12+(0.5*fb3);u13=ul13+(0.5*
fc3);u14=ul14+(0.5*fc3);u15=ul15;u16=ul16+(0.5*fa4);u17=ul17+(0.5*fa
4);u18=ul18+(0.5*fb4);u19=ul19+(0.5*fb4);u20=ul20+(0.5*fc4);u21=ul21
;u22=ul22;
f1=fl1+fa1;f2=fl2+fa1;f3=fl3+fb1;f4=fl4+fb1;f5=fl5+fc1;f6=fl6+fc1;f7
=fl7;f8=fl8+fa2;f9=fl9;f10=fl10+fa3;f11=fl11+fb3;f12=fl12+fb3;f13=fl
13+fc3;f14=fl14+fc3;f15=fl15;f16=fl16+fa4;f17=fl17+fa4;f18=fl18+fb4;
f19=fl19+fb4;f20=fl20+fc4;f21=fl21;f22=fl22;
n1=210;n2=210;n3=210;n4=1;n5=1;n6=10;n7=10;n8=1;n9=1;n10=210;n11=210
;n12=200;n13=1;n14=1;n15=10;n16=10;n17=200;n18=200;n19=200;n20=1;n21
=1;n22=10;
nt1=n1+n2+n3+n4+n5+n6+n7;nt2=n8+n9;nt3=n10+n11+n12+n13+n14+n15;nt4=n
16+n17+n18+n19+n20+n21+n22;nt=nt1+nt2+nt3+nt4;
r1=u1/f1;r2=u2/f2;r3=u3/f3;r4=u4/f4;r5=u5/f5;r6=u6/f6;r7=u7/f7;r8=u8
/f8;r9=u9/f9;r10=u10/f10;r11=u11/f11;r12=u12/f12;r13=u13/f13;r14=u14
/f14;r15=u15/f15;r16=u16/f16;r17=u17/f17;r18=u18/f18;r19=u19/f19;r20
=u20/f20;r21=u21/f21;r22=u22/f22;


%% We will calculate the reliability indices for each feeder by
using Main C.B. via the feasible procedure of failure mode and
effect analysis (FMEA), as following;


SAIDIcb1=((r1*f1*n1)+(r2*f2*n2)+(r3*f3*n3)+(r4*f4*n4)+(r5*f5*n5)+(r6
*f6*n6)+(r7*f7*n7))/nt1;SAIFIcb1=((f1*n1)+(f2*n2)+(f3*n3)+(f4*n4)+(f
5*n5)+(f6*n6)+(f7*n7))/nt1;CAIDIcb1=SAIDIcb1/SAIFIcb1;EENScb1=((r1*f
1*ag(1))+(r2*f2*ag(2))+(r3*f3*ag(3))+(r4*f4*ag(4))+(r5*f5*ag(5))+(r6
```

```
*f6*ag(6))+(r7*f7*ag(7)));AENScb1=EENScb1/nt1;ASAIcb1=(1-
(SAIDIcb1/8760))*(100);ASUIcb1=1-ASAIcb1;
SAIDIcb2=((r8*f8*n8)+(r9*f9*n9))/nt2;SAIFIcb2=((f8*n8)+(f9*n9))/nt2;
CAIDIcb2=SAIDIcb2/SAIFIcb2;EENScb2=((r8*f8*ag(8))+(r9*f9*ag(9)));AEN
Scb2=EENScb2/nt2;ASAIcb2=(1-(SAIDIcb2/8760))*(100);ASUIcb2=1-
ASAIcb2;
SAIDIcb3=((r10*f10*n10)+(r11*f11*n11)+(r12*f12*n12)+(r13*f13*n13)+(r
14*f14*n14)+(r15*f15*n15))/nt3;SAIFIcb3=((f10*n10)+(f11*n11)+(f12*n1
2)+(f13*n13)+(f14*n14)+(f15*n15))/nt3;CAIDIcb3=SAIDIcb3/SAIFIcb3;EEN
Scb3=((r10*f10*ag(10))+(r11*f11*ag(11))+(r12*f12*ag(12))+(r13*f13*ag
(13))+(r14*f14*ag(14))+(r15*f15*ag(15)));AENScb3=EENScb3/nt3;ASAIcb3
=(1-(SAIDIcb3/8760))*(100);ASUIcb3=1-ASAIcb3;
SAIDIcb4=((r16*f16*n16)+(r17*f17*n17)+(r18*f18*n18)+(r19*f19*n19)+(r
20*f20*n20)+(r21*f21*n21)+(r22*f22*n22))/nt4;SAIFIcb4=((f16*n16)+(f1
7*n17)+(f18*n18)+(f19*n19)+(f20*n20)+(f21*n21)+(f22*n22))/nt4;CAIDIc
b4=SAIDIcb4/SAIFIcb4;EENScb4=((r16*f16*ag(16))+(r17*f17*ag(17))+(r18
*f18*ag(18))+(r19*f19*ag(19))+(r20*f20*ag(20))+(r21*f21*ag(21))+(r22
*f22*ag(22)));AENScb4=EENScb4/nt4;ASAIcb4=(1-
(SAIDIcb4/8760))*(100);ASUIcb4=1-ASAIcb4;
SAIDItCB=(((r1*f1*n1)+(r2*f2*n2)+(r3*f3*n3)+(r4*f4*n4)+(r5*f5*n5)+(r
6*f6*n6)+(r7*f7*n7))+((r8*f8*n8)+(r9*f9*n9))+((r10*f10*n10)+(r11*f11
*n11)+(r12*f12*n12)+(r13*f13*n13)+(r14*f14*n14)+(r15*f15*n15))+((r16
*f16*n16)+(r17*f17*n17)+(r18*f18*n18)+(r19*f19*n19)+(r20*f20*n20)+(r
21*f21*n21)+(r22*f22*n22)))/nt;
SAIFItCB=(((f1*n1)+(f2*n2)+(f3*n3)+(f4*n4)+(f5*n5)+(f6*n6)+(f7*n7))+
((f8*n8)+(f9*n9))+((f10*n10)+(f11*n11)+(f12*n12)+(f13*n13)+(f14*n14)
+(f15*n15))+((f16*n16)+(f17*n17)+(f18*n18)+(f19*n19)+(f20*n20)+(f21*
n21)+(f22*n22)))/nt;
CAIDItCB=SAIDItCB/SAIFItCB;
AENStCB=(EENScb1+EENScb2+EENScb3+EENScb4)/nt;
ASAItCB=(1-(SAIDItCB/8760))*(100);
MAIFItCB=0;



%% We will calculate the reliability indices for each radial feeder
by using Main Recloser via the feasible procedure of failure mode
and effect analysis (FMEA), as following;


SAIDIr1=((0.3*r1*f1*n1)+(0.3*r2*f2*n2)+(0.3*r3*f3*n3)+(0.3*r4*f4*n4)
+(0.3*r5*f5*n5)+(0.3*r6*f6*n6)+(0.3*r7*f7*n7))/nt1;SAIFIr1=((0.3*f1*
n1)+(0.3*f2*n2)+(0.3*f3*n3)+(0.3*f4*n4)+(0.3*f5*n5)+(0.3*f6*n6)+(0.3
*f7*n7))/nt1;CAIDIr1=SAIDIr1/SAIFIr1;EENSr1=((0.3*r1*f1*ag(1))+(0.3*
r2*f2*ag(2))+(0.3*r3*f3*ag(3))+(0.3*r4*f4*ag(4))+(0.3*r5*f5*ag(5))+(
0.3*r6*f6*ag(6))+(0.3*r7*f7*ag(7)));AENSr1=EENSr1/nt1;ASAIr1=(1-
(SAIDIr1/8760))*(100);ASUIr1=1-
ASAIr1;MAIFIr1=((0.7*f1*n1)+(0.7*f2*n2)+(0.7*f3*n3)+(0.7*f4*n4)+(0.7
*f5*n5)+(0.7*f6*n6)+(0.7*f7*n7))/nt1;
SAIDIr2=((0.3*r8*f8*n8)+(0.3*r9*f9*n9))/nt2;SAIFIr2=((0.3*f8*n8)+(0.
3*f9*n9))/nt2;CAIDIr2=SAIDIr2/SAIFIr2;EENSr2=((0.3*r8*f8*ag(8))+(0.3
*r9*f9*ag(9)));AENSr2=EENSr2/nt2;ASAIr2=(1-
(SAIDIr2/8760))*(100);ASUIr2=1-
ASAIr2;MAIFIr2=((0.7*f8*n8)+(0.7*f9*n9))/nt2;
SAIDIr3=((0.3*r10*f10*n10)+(0.3*r11*f11*n11)+(0.3*r12*f12*n12)+(0.3*
r13*f13*n13)+(0.3*r14*f14*n14)+(0.3*r15*f15*n15))/nt3;SAIFIr3=((0.3*
f10*n10)+(0.3*f11*n11)+(0.3*f12*n12)+(0.3*f13*n13)+(0.3*f14*n14)+(0.
3*f15*n15))/nt3;CAIDIr3=SAIDIr3/SAIFIr3;EENSr3=((0.3*r10*f10*ag(10))
+(0.3*r11*f11*ag(11))+(0.3*r12*f12*ag(12))+(0.3*r13*f13*ag(13))+(0.3
```

```
*r14*f14*ag(14))+(0.3*r15*f15*ag(15)));AENSr3=EENSr3/nt3;ASAIr3=(1-
(SAIDIr3/8760))*(100);ASUIr3=1-
ASAIr3;MAIFIr3=((0.7*f10*n10)+(0.7*f11*n11)+(0.7*f12*n12)+(0.7*f13*n
13)+(0.7*f14*n14)+(0.7*f15*n15))/nt3;
SAIDIr4=((0.3*r16*f16*n16)+(0.3*r17*f17*n17)+(0.3*r18*f18*n18)+(0.3*
r19*f19*n19)+(0.3*r20*f20*n20)+(0.3*r21*f21*n21)+(0.3*r22*f22*n22))/
nt4;SAIFIr4=((0.3*f16*n16)+(0.3*f17*n17)+(0.3*f18*n18)+(0.3*f19*n19)
+(0.3*f20*n20)+(0.3*f21*n21)+(0.3*f22*n22))/nt4;CAIDIr4=SAIDIr4/SAIF
Ir4;EENSr4=((0.3*r16*f16*ag(16))+(0.3*r17*f17*ag(17))+(0.3*r18*f18*a
g(18))+(0.3*r19*f19*ag(19))+(0.3*r20*f20*ag(20))+(0.3*r21*f21*ag(21)
)+(0.3*r22*f22*ag(22)));AENSr4=EENSr4/nt4;ASAIr4=(1-
(SAIDIr4/8760))*(100);ASUIr4=1-
ASAIr4;MAIFIr4=((0.7*f16*n16)+(0.7*f17*n17)+(0.7*f18*n18)+(0.7*f19*n
19)+(0.7*f20*n20)+(0.7*f21*n21)+(0.7*f22*n22))/nt4;
SAIDItR=(((0.3*r1*f1*n1)+(0.3*r2*f2*n2)+(0.3*r3*f3*n3)+(0.3*r4*f4*n4
)+(0.3*r5*f5*n5)+(0.3*r6*f6*n6)+(0.3*r7*f7*n7))+((0.3*r8*f8*n8)+(0.3
*r9*f9*n9))+((0.3*r10*f10*n10)+(0.3*r11*f11*n11)+(0.3*r12*f12*n12)+(
0.3*r13*f13*n13)+(0.3*r14*f14*n14)+(0.3*r15*f15*n15))+((0.3*r16*f16*
n16)+(0.3*r17*f17*n17)+(0.3*r18*f18*n18)+(0.3*r19*f19*n19)+(0.3*r20*
f20*n20)+(0.3*r21*f21*n21)+(0.3*r22*f22*n22)))/nt;
SAIFItR=(((0.3*f1*n1)+(0.3*f2*n2)+(0.3*f3*n3)+(0.3*f4*n4)+(0.3*f5*n5
)+(0.3*f6*n6)+(0.3*f7*n7))+((0.3*f8*n8)+(0.3*f9*n9))+((0.3*f10*n10)+
(0.3*f11*n11)+(0.3*f12*n12)+(0.3*f13*n13)+(0.3*f14*n14)+(0.3*f15*n15
))+((0.3*f16*n16)+(0.3*f17*n17)+(0.3*f18*n18)+(0.3*f19*n19)+(0.3*f20
*n20)+(0.3*f21*n21)+(0.3*f22*n22)))/nt;
CAIDItR=SAIDItR/SAIFItR;
AENStR=(EENSr1+EENSr2+EENSr3+EENSr4)/nt;
ASAItR=(1-(SAIDItR/8760))*(100);
MAIFItR=(((0.7*f1*n1)+(0.7*f2*n2)+(0.7*f3*n3)+(0.7*f4*n4)+(0.7*f5*n5
)+(0.7*f6*n6)+(0.7*f7*n7))+((0.7*f8*n8)+(0.7*f9*n9))+((0.7*f10*n10)+
(0.7*f11*n11)+(0.7*f12*n12)+(0.7*f13*n13)+(0.7*f14*n14)+(0.7*f15*n15
))+((0.7*f16*n16)+(0.7*f17*n17)+(0.7*f18*n18)+(0.7*f19*n19)+(0.7*f20
*n20)+(0.7*f21*n21)+(0.7*f22*n22)))/nt;


%% We could display the reliability indices for each feeder in
discrete shape in same figure for each situation (Main C.B. & Main
Recloser) %%

%% (1) Firstly, for radial feeder NO;1 we get in disecrete situation
%%


SAIDI_F1=[SAIDIcb1 SAIDIr1];
SAIFI_F1=[SAIFIcb1 SAIFIr1];
MAIFI_F1=[0 MAIFIr1];
AENS_F1=[AENScb1 AENSr1];
ASAI_F1=[ASAIcb1 ASAIr1];


%% (2)&(3) Secondly, for all radial feeders in Bus-2 Network, but in
two discrete situations (Main C.B.'s & Main Reclosers) via the
feasible procedure of failure mode and effect analysis (FMEA), as
following; %%


SAIDI_CB=[SAIDIcb1 SAIDIcb2 SAIDIcb3 SAIDIcb4];
SAIFI_CB=[SAIFIcb1 SAIFIcb2 SAIFIcb3 SAIFIcb4];
```

```
AENS_CB=[AENScb1 AENScb2 AENScb3 AENScb4];
ASAI_CB=[ASAIcb1 ASAIcb2 ASAIcb3 ASAIcb4];

SAIDI_R=[SAIDIr1 SAIDIr2 SAIDIr3 SAIDIr4];
SAIFI_R=[SAIFIr1 SAIFIr2 SAIFIr3 SAIFIr4];
MAIFI_R=[MAIFIr1 MAIFIr2 MAIFIr3 MAIFIr4];
AENS_R=[AENSr1 AENSr2 AENSr3 AENSr4];
ASAI_R=[ASAIr1 ASAIr2 ASAIr3 ASAIr4];



%% (4)    Afterthen, we get total reliability indices for the radial
Bus-2 Network in Bus-2 Network, but in two discrete situations (Main
C.B.'s & Main Reclosers)via the feasible procedure of failure mode
and effect analysis (FMEA), as following; %%



SAIDI=[SAIDItCB SAIDItR];
SAIFI=[SAIFItCB SAIFItR];
MAIFI=[0 MAIFItR];
AENS=[AENStCB AENStR];
ASAI=[ASAItCB ASAItR];



%% (5) Now we evaluate the graduated improvement for the reliability
indices of the radial feeders twards of the complete radial
distribution Bus-2 network through using Main Recloser at each one
step by step ;via the feasible procedure of failure mode and effect
analysis (FMEA), as following;

%%  Bus-2 radial network SAIDI improvement


x1=(((0.3*r1*f1*n1)+(0.3*r2*f2*n2)+(0.3*r3*f3*n3)+(0.3*r4*f4*n4)+(0.
3*r5*f5*n5)+(0.3*r6*f6*n6)+(0.3*r7*f7*n7))+((r8*f8*n8)+(r9*f9*n9))+(
(r10*f10*n10)+(r11*f11*n11)+(r12*f12*n12)+(r13*f13*n13)+(r14*f14*n14
)+(r15*f15*n15))+((r16*f16*n16)+(r17*f17*n17)+(r18*f18*n18)+(r19*f19
*n19)+(r20*f20*n20)+(r21*f21*n21)+(r22*f22*n22)))/nt;
x2=(((r1*f1*n1)+(r2*f2*n2)+(r3*f3*n3)+(r4*f4*n4)+(r5*f5*n5)+(r6*f6*n
6)+(r7*f7*n7))+((0.3*r8*f8*n8)+(0.3*r9*f9*n9))+((r10*f10*n10)+(r11*f
11*n11)+(r12*f12*n12)+(r13*f13*n13)+(r14*f14*n14)+(r15*f15*n15))+((r
16*f16*n16)+(r17*f17*n17)+(r18*f18*n18)+(r19*f19*n19)+(r20*f20*n20)+
(r21*f21*n21)+(r22*f22*n22)))/nt;
x3=(((r1*f1*n1)+(r2*f2*n2)+(r3*f3*n3)+(r4*f4*n4)+(r5*f5*n5)+(r6*f6*n
6)+(r7*f7*n7))+((r8*f8*n8)+(r9*f9*n9))+((0.3*r10*f10*n10)+(0.3*r11*f
11*n11)+(0.3*r12*f12*n12)+(0.3*r13*f13*n13)+(0.3*r14*f14*n14)+(0.3*r
15*f15*n15))+((r16*f16*n16)+(r17*f17*n17)+(r18*f18*n18)+(r19*f19*n19
)+(r20*f20*n20)+(r21*f21*n21)+(r22*f22*n22)))/nt;
x4=(((r1*f1*n1)+(r2*f2*n2)+(r3*f3*n3)+(r4*f4*n4)+(r5*f5*n5)+(r6*f6*n
6)+(r7*f7*n7))+((r8*f8*n8)+(r9*f9*n9))+((r10*f10*n10)+(r11*f11*n11)+
(r12*f12*n12)+(r13*f13*n13)+(r14*f14*n14)+(r15*f15*n15))+((0.3*r16*f
16*n16)+(0.3*r17*f17*n17)+(0.3*r18*f18*n18)+(0.3*r19*f19*n19)+(0.3*r
20*f20*n20)+(0.3*r21*f21*n21)+(0.3*r22*f22*n22)))/nt;
x5=(((0.3*r1*f1*n1)+(0.3*r2*f2*n2)+(0.3*r3*f3*n3)+(0.3*r4*f4*n4)+(0.
3*r5*f5*n5)+(0.3*r6*f6*n6)+(0.3*r7*f7*n7))+((0.3*r8*f8*n8)+(0.3*r9*f
9*n9))+((r10*f10*n10)+(r11*f11*n11)+(r12*f12*n12)+(r13*f13*n13)+(r14
```

```
*f14*n14)+(r15*f15*n15))+((r16*f16*n16)+(r17*f17*n17)+(r18*f18*n18)+
(r19*f19*n19)+(r20*f20*n20)+(r21*f21*n21)+(r22*f22*n22)))/nt;
x6=(((r1*f1*n1)+(r2*f2*n2)+(r3*f3*n3)+(r4*f4*n4)+(r5*f5*n5)+(r6*f6*n
6)+(r7*f7*n7))+((0.3*r8*f8*n8)+(0.3*r9*f9*n9))+((0.3*r10*f10*n10)+(0
.3*r11*f11*n11)+(0.3*r12*f12*n12)+(0.3*r13*f13*n13)+(0.3*r14*f14*n14
)+(0.3*r15*f15*n15))+((r16*f16*n16)+(r17*f17*n17)+(r18*f18*n18)+(r19
*f19*n19)+(r20*f20*n20)+(r21*f21*n21)+(r22*f22*n22)))/nt;
x7=(((r1*f1*n1)+(r2*f2*n2)+(r3*f3*n3)+(r4*f4*n4)+(r5*f5*n5)+(r6*f6*n
6)+(r7*f7*n7))+((r8*f8*n8)+(r9*f9*n9))+((0.3*r10*f10*n10)+(0.3*r11*f
11*n11)+(0.3*r12*f12*n12)+(0.3*r13*f13*n13)+(0.3*r14*f14*n14)+(0.3*r
15*f15*n15))+((0.3*r16*f16*n16)+(0.3*r17*f17*n17)+(0.3*r18*f18*n18)+
(0.3*r19*f19*n19)+(0.3*r20*f20*n20)+(0.3*r21*f21*n21)+(0.3*r22*f22*n
22)))/nt;
x8=(((0.3*r1*f1*n1)+(0.3*r2*f2*n2)+(0.3*r3*f3*n3)+(0.3*r4*f4*n4)+(0.
3*r5*f5*n5)+(0.3*r6*f6*n6)+(0.3*r7*f7*n7))+((r8*f8*n8)+(r9*f9*n9))+(
(r10*f10*n10)+(r11*f11*n11)+(r12*f12*n12)+(r13*f13*n13)+(r14*f14*n14
)+(r15*f15*n15))+((0.3*r16*f16*n16)+(0.3*r17*f17*n17)+(0.3*r18*f18*n
18)+(0.3*r19*f19*n19)+(0.3*r20*f20*n20)+(0.3*r21*f21*n21)+(0.3*r22*f
22*n22)))/nt;
x9=(((0.3*r1*f1*n1)+(0.3*r2*f2*n2)+(0.3*r3*f3*n3)+(0.3*r4*f4*n4)+(0.
3*r5*f5*n5)+(0.3*r6*f6*n6)+(0.3*r7*f7*n7))+((r8*f8*n8)+(r9*f9*n9))+(
(0.3*r10*f10*n10)+(0.3*r11*f11*n11)+(0.3*r12*f12*n12)+(0.3*r13*f13*n
13)+(0.3*r14*f14*n14)+(0.3*r15*f15*n15))+((r16*f16*n16)+(r17*f17*n17
)+(r18*f18*n18)+(r19*f19*n19)+(r20*f20*n20)+(r21*f21*n21)+(r22*f22*n
22)))/nt;
x10=(((r1*f1*n1)+(r2*f2*n2)+(r3*f3*n3)+(r4*f4*n4)+(r5*f5*n5)+(r6*f6*
n6)+(r7*f7*n7))+((0.3*r8*f8*n8)+(0.3*r9*f9*n9))+((r10*f10*n10)+(r11*
f11*n11)+(r12*f12*n12)+(r13*f13*n13)+(r14*f14*n14)+(r15*f15*n15))+((
0.3*r16*f16*n16)+(0.3*r17*f17*n17)+(0.3*r18*f18*n18)+(0.3*r19*f19*n1
9)+(0.3*r20*f20*n20)+(0.3*r21*f21*n21)+(0.3*r22*f22*n22)))/nt;
x11=(((0.3*r1*f1*n1)+(0.3*r2*f2*n2)+(0.3*r3*f3*n3)+(0.3*r4*f4*n4)+(0
.3*r5*f5*n5)+(0.3*r6*f6*n6)+(0.3*r7*f7*n7))+((0.3*r8*f8*n8)+(0.3*r9*
f9*n9))+((0.3*r10*f10*n10)+(0.3*r11*f11*n11)+(0.3*r12*f12*n12)+(0.3*
r13*f13*n13)+(0.3*r14*f14*n14)+(0.3*r15*f15*n15))+((r16*f16*n16)+(r1
7*f17*n17)+(r18*f18*n18)+(r19*f19*n19)+(r20*f20*n20)+(r21*f21*n21)+(
r22*f22*n22)))/nt;
x12=(((r1*f1*n1)+(r2*f2*n2)+(r3*f3*n3)+(r4*f4*n4)+(r5*f5*n5)+(r6*f6*
n6)+(r7*f7*n7))+((0.3*r8*f8*n8)+(0.3*r9*f9*n9))+((0.3*r10*f10*n10)+(
0.3*r11*f11*n11)+(0.3*r12*f12*n12)+(0.3*r13*f13*n13)+(0.3*r14*f14*n1
4)+(0.3*r15*f15*n15))+((0.3*r16*f16*n16)+(0.3*r17*f17*n17)+(0.3*r18*
f18*n18)+(0.3*r19*f19*n19)+(0.3*r20*f20*n20)+(0.3*r21*f21*n21)+(0.3*
r22*f22*n22)))/nt;
x13=(((0.3*r1*f1*n1)+(0.3*r2*f2*n2)+(0.3*r3*f3*n3)+(0.3*r4*f4*n4)+(0
.3*r5*f5*n5)+(0.3*r6*f6*n6)+(0.3*r7*f7*n7))+((r8*f8*n8)+(r9*f9*n9))+
((0.3*r10*f10*n10)+(0.3*r11*f11*n11)+(0.3*r12*f12*n12)+(0.3*r13*f13*
n13)+(0.3*r14*f14*n14)+(0.3*r15*f15*n15))+((0.3*r16*f16*n16)+(0.3*r1
7*f17*n17)+(0.3*r18*f18*n18)+(0.3*r19*f19*n19)+(0.3*r20*f20*n20)+(0.
3*r21*f21*n21)+(0.3*r22*f22*n22)))/nt;
x14=(((0.3*r1*f1*n1)+(0.3*r2*f2*n2)+(0.3*r3*f3*n3)+(0.3*r4*f4*n4)+(0
.3*r5*f5*n5)+(0.3*r6*f6*n6)+(0.3*r7*f7*n7))+((0.3*r8*f8*n8)+(0.3*r9*
f9*n9))+((r10*f10*n10)+(r11*f11*n11)+(r12*f12*n12)+(r13*f13*n13)+(r1
4*f14*n14)+(r15*f15*n15))+((0.3*r16*f16*n16)+(0.3*r17*f17*n17)+(0.3*
r18*f18*n18)+(0.3*r19*f19*n19)+(0.3*r20*f20*n20)+(0.3*r21*f21*n21)+(
0.3*r22*f22*n22)))/nt;
x15=SAIDItR;x16=SAIDItCB;
SAIDIimprove=[x16 x2 x1 x5 x4 x10 x3 x6 x8 x14 x9 x11 x7 x12 x13
x15];
```

```
%% Bus-2 radial network SAIFI improvement

xf1=(((0.3*f1*n1)+(0.3*f2*n2)+(0.3*f3*n3)+(0.3*f4*n4)+(0.3*f5*n5)+(0
.3*f6*n6)+(0.3*f7*n7))+((f8*n8)+(f9*n9))+((f10*n10)+(f11*n11)+(f12*n
12)+(f13*n13)+(f14*n14)+(f15*n15))+((f16*n16)+(f17*n17)+(f18*n18)+(f
19*n19)+(f20*n20)+(f21*n21)+(f22*n22)))/nt;
xf2=(((f1*n1)+(f2*n2)+(f3*n3)+(f4*n4)+(f5*n5)+(f6*n6)+(f7*n7))+((0.3
*f8*n8)+(0.3*f9*n9))+((f10*n10)+(f11*n11)+(f12*n12)+(f13*n13)+(f14*n
14)+(f15*n15))+((f16*n16)+(f17*n17)+(f18*n18)+(f19*n19)+(f20*n20)+(f
21*n21)+(f22*n22)))/nt;
xf3=(((f1*n1)+(f2*n2)+(f3*n3)+(f4*n4)+(f5*n5)+(f6*n6)+(f7*n7))+((f8*
n8)+(f9*n9))+((0.3*f10*n10)+(0.3*f11*n11)+(0.3*f12*n12)+(0.3*f13*n13
)+(0.3*f14*n14)+(0.3*f15*n15))+((f16*n16)+(f17*n17)+(f18*n18)+(f19*n
19)+(f20*n20)+(f21*n21)+(f22*n22)))/nt;
xf4=(((f1*n1)+(f2*n2)+(f3*n3)+(f4*n4)+(f5*n5)+(f6*n6)+(f7*n7))+((f8*
n8)+(f9*n9))+((f10*n10)+(f11*n11)+(f12*n12)+(f13*n13)+(f14*n14)+(f15
*n15))+((0.3*f16*n16)+(0.3*f17*n17)+(0.3*f18*n18)+(0.3*f19*n19)+(0.3
*f20*n20)+(0.3*f21*n21)+(0.3*f22*n22)))/nt;
xf5=(((0.3*f1*n1)+(0.3*f2*n2)+(0.3*f3*n3)+(0.3*f4*n4)+(0.3*f5*n5)+(0
.3*f6*n6)+(0.3*f7*n7))+((0.3*f8*n8)+(0.3*f9*n9))+((f10*n10)+(f11*n11
)+(f12*n12)+(f13*n13)+(f14*n14)+(f15*n15))+((f16*n16)+(f17*n17)+(f18
*n18)+(f19*n19)+(f20*n20)+(f21*n21)+(f22*n22)))/nt;
xf6=(((f1*n1)+(f2*n2)+(f3*n3)+(f4*n4)+(f5*n5)+(f6*n6)+(f7*n7))+((0.3
*f8*n8)+(0.3*f9*n9))+((0.3*f10*n10)+(0.3*f11*n11)+(0.3*f12*n12)+(0.3
*f13*n13)+(0.3*f14*n14)+(0.3*f15*n15))+((f16*n16)+(f17*n17)+(f18*n18
)+(f19*n19)+(f20*n20)+(f21*n21)+(f22*n22)))/nt;
xf7=(((f1*n1)+(f2*n2)+(f3*n3)+(f4*n4)+(f5*n5)+(f6*n6)+(f7*n7))+((f8*
n8)+(f9*n9))+((0.3*f10*n10)+(0.3*f11*n11)+(0.3*f12*n12)+(0.3*f13*n13
)+(0.3*f14*n14)+(0.3*f15*n15))+((0.3*f16*n16)+(0.3*f17*n17)+(0.3*f18
*n18)+(0.3*f19*n19)+(0.3*f20*n20)+(0.3*f21*n21)+(0.3*f22*n22)))/nt;
xf8=(((0.3*f1*n1)+(0.3*f2*n2)+(0.3*f3*n3)+(0.3*f4*n4)+(0.3*f5*n5)+(0
.3*f6*n6)+(0.3*f7*n7))+((f8*n8)+(f9*n9))+((f10*n10)+(f11*n11)+(f12*n
12)+(f13*n13)+(f14*n14)+(f15*n15))+((0.3*f16*n16)+(0.3*f17*n17)+(0.3
*f18*n18)+(0.3*f19*n19)+(0.3*f20*n20)+(0.3*f21*n21)+(0.3*f22*n22)))/
nt;
xf9=(((0.3*f1*n1)+(0.3*f2*n2)+(0.3*f3*n3)+(0.3*f4*n4)+(0.3*f5*n5)+(0
.3*f6*n6)+(0.3*f7*n7))+((f8*n8)+(f9*n9))+((0.3*f10*n10)+(0.3*f11*n11
)+(0.3*f12*n12)+(0.3*f13*n13)+(0.3*f14*n14)+(0.3*f15*n15))+((f16*n16
)+(f17*n17)+(f18*n18)+(f19*n19)+(f20*n20)+(f21*n21)+(f22*n22)))/nt;
xf10=(((f1*n1)+(f2*n2)+(f3*n3)+(f4*n4)+(f5*n5)+(f6*n6)+(f7*n7))+((0.
3*f8*n8)+(0.3*f9*n9))+((f10*n10)+(f11*n11)+(f12*n12)+(f13*n13)+(f14*
n14)+(f15*n15))+((0.3*f16*n16)+(0.3*f17*n17)+(0.3*f18*n18)+(0.3*f19*
n19)+(0.3*f20*n20)+(0.3*f21*n21)+(0.3*f22*n22)))/nt;
xf11=(((0.3*f1*n1)+(0.3*f2*n2)+(0.3*f3*n3)+(0.3*f4*n4)+(0.3*f5*n5)+(
0.3*f6*n6)+(0.3*f7*n7))+((0.3*f8*n8)+(0.3*f9*n9))+((0.3*f10*n10)+(0.
3*f11*n11)+(0.3*f12*n12)+(0.3*f13*n13)+(0.3*f14*n14)+(0.3*f15*n15))+
((f16*n16)+(f17*n17)+(f18*n18)+(f19*n19)+(f20*n20)+(f21*n21)+(f22*n2
2)))/nt;
xf12=(((f1*n1)+(f2*n2)+(f3*n3)+(f4*n4)+(f5*n5)+(f6*n6)+(f7*n7))+((0.
3*f8*n8)+(0.3*f9*n9))+((0.3*f10*n10)+(0.3*f11*n11)+(0.3*f12*n12)+(0.
3*f13*n13)+(0.3*f14*n14)+(0.3*f15*n15))+((0.3*f16*n16)+(0.3*f17*n17)
+(0.3*f18*n18)+(0.3*f19*n19)+(0.3*f20*n20)+(0.3*f21*n21)+(0.3*f22*n2
2)))/nt;
xf13=(((0.3*f1*n1)+(0.3*f2*n2)+(0.3*f3*n3)+(0.3*f4*n4)+(0.3*f5*n5)+(
0.3*f6*n6)+(0.3*f7*n7))+((f8*n8)+(f9*n9))+((0.3*f10*n10)+(0.3*f11*n1
1)+(0.3*f12*n12)+(0.3*f13*n13)+(0.3*f14*n14)+(0.3*f15*n15))+((0.3*f1
6*n16)+(0.3*f17*n17)+(0.3*f18*n18)+(0.3*f19*n19)+(0.3*f20*n20)+(0.3*
f21*n21)+(0.3*f22*n22)))/nt;
xf14=(((0.3*f1*n1)+(0.3*f2*n2)+(0.3*f3*n3)+(0.3*f4*n4)+(0.3*f5*n5)+(
0.3*f6*n6)+(0.3*f7*n7))+((0.3*f8*n8)+(0.3*f9*n9))+((f10*n10)+(f11*n1
```

```
1)+(f12*n12)+(f13*n13)+(f14*n14)+(f15*n15))+((0.3*f16*n16)+(0.3*f17*
n17)+(0.3*f18*n18)+(0.3*f19*n19)+(0.3*f20*n20)+(0.3*f21*n21)+(0.3*f2
2*n22)))/nt;
xf15=SAIFItR;xf16=SAIFItCB;
SAIFIimprove=[xf16 xf2 xf1 xf5 xf4 xf10 xf3 xf6 xf8 xf14 xf9 xf11
xf7 xf12 xf13 xf15];




%% Bus-2 radial network MAIFI improvement


xm1=((0.7*f1*n1)+(0.7*f2*n2)+(0.7*f3*n3)+(0.7*f4*n4)+(0.7*f5*n5)+(0.
7*f6*n6)+(0.7*f7*n7))/nt;
xm2=((0.7*f8*n8)+(0.7*f9*n9))/nt;
xm3=((0.7*f10*n10)+(0.7*f11*n11)+(0.7*f12*n12)+(0.7*f13*n13)+(0.7*f1
4*n14)+(0.7*f15*n15))/nt;
xm4=((0.7*f16*n16)+(0.7*f17*n17)+(0.7*f18*n18)+(0.7*f19*n19)+(0.7*f2
0*n20)+(0.7*f21*n21)+(0.7*f22*n22))/nt;
xm5=((0.7*f1*n1)+(0.7*f2*n2)+(0.7*f3*n3)+(0.7*f4*n4)+(0.7*f5*n5)+(0.
7*f6*n6)+(0.7*f7*n7)+(0.7*f8*n8)+(0.7*f9*n9))/nt;
xm6=((0.7*f8*n8)+(0.7*f9*n9)+(0.7*f10*n10)+(0.7*f11*n11)+(0.7*f12*n1
2)+(0.7*f13*n13)+(0.7*f14*n14)+(0.7*f15*n15))/nt;
xm7=((0.7*f10*n10)+(0.7*f11*n11)+(0.7*f12*n12)+(0.7*f13*n13)+(0.7*f1
4*n14)+(0.7*f15*n15)+(0.7*f16*n16)+(0.7*f17*n17)+(0.7*f18*n18)+(0.7*
f19*n19)+(0.7*f20*n20)+(0.7*f21*n21)+(0.7*f22*n22))/nt;
xm8=((0.7*f1*n1)+(0.7*f2*n2)+(0.7*f3*n3)+(0.7*f4*n4)+(0.7*f5*n5)+(0.
7*f6*n6)+(0.7*f7*n7)+(0.7*f16*n16)+(0.7*f17*n17)+(0.7*f18*n18)+(0.7*
f19*n19)+(0.7*f20*n20)+(0.7*f21*n21)+(0.7*f22*n22))/nt;
xm9=((0.7*f1*n1)+(0.7*f2*n2)+(0.7*f3*n3)+(0.7*f4*n4)+(0.7*f5*n5)+(0.
7*f6*n6)+(0.7*f7*n7)+(0.7*f10*n10)+(0.7*f11*n11)+(0.7*f12*n12)+(0.7*
f13*n13)+(0.7*f14*n14)+(0.7*f15*n15))/nt;
xm10=((0.7*f8*n8)+(0.7*f9*n9)+(0.7*f16*n16)+(0.7*f17*n17)+(0.7*f18*n
18)+(0.7*f19*n19)+(0.7*f20*n20)+(0.7*f21*n21)+(0.7*f22*n22))/nt;
xm11=((0.7*f1*n1)+(0.7*f2*n2)+(0.7*f3*n3)+(0.7*f4*n4)+(0.7*f5*n5)+(0
.7*f6*n6)+(0.7*f7*n7)+(0.7*f8*n8)+(0.7*f9*n9)+(0.7*f10*n10)+(0.7*f11
*n11)+(0.7*f12*n12)+(0.7*f13*n13)+(0.7*f14*n14)+(0.7*f15*n15))/nt;
xm12=((0.7*f8*n8)+(0.7*f9*n9)+(0.7*f10*n10)+(0.7*f11*n11)+(0.7*f12*n
12)+(0.7*f13*n13)+(0.7*f14*n14)+(0.7*f15*n15)+(0.7*f16*n16)+(0.7*f17
*n17)+(0.7*f18*n18)+(0.7*f19*n19)+(0.7*f20*n20)+(0.7*f21*n21)+(0.7*f
22*n22))/nt;
xm13=((0.7*f1*n1)+(0.7*f2*n2)+(0.7*f3*n3)+(0.7*f4*n4)+(0.7*f5*n5)+(0
.7*f6*n6)+(0.7*f7*n7)+(0.7*f10*n10)+(0.7*f11*n11)+(0.7*f12*n12)+(0.7
*f13*n13)+(0.7*f14*n14)+(0.7*f15*n15)+(0.7*f16*n16)+(0.7*f17*n17)+(0
.7*f18*n18)+(0.7*f19*n19)+(0.7*f20*n20)+(0.7*f21*n21)+(0.7*f22*n22))
/nt;
xm14=((0.7*f1*n1)+(0.7*f2*n2)+(0.7*f3*n3)+(0.7*f4*n4)+(0.7*f5*n5)+(0
.7*f6*n6)+(0.7*f7*n7)+(0.7*f8*n8)+(0.7*f9*n9)+(0.7*f16*n16)+(0.7*f17
*n17)+(0.7*f18*n18)+(0.7*f19*n19)+(0.7*f20*n20)+(0.7*f21*n21)+(0.7*f
22*n22))/nt;
xm15=MAIFItR;xm16=MAIFItCB;
MAIFIimprove=[xm16 xm2 xm1 xm5 xm4 xm10 xm3 xm6 xm8 xm14 xm9 xm11
xm7 xm12 xm13 xm15];



%% Bus-2 radial network AENS improvement
```

```
xe1=(EENSr1+EENScb2+EENScb3+EENScb4)/nt;
xe2=(EENScb1+EENSr2+EENScb3+EENScb4)/nt;
xe3=(EENScb1+EENScb2+EENSr3+EENScb4)/nt;
xe4=(EENScb1+EENScb2+EENScb3+EENSr4)/nt;
xe5=(EENSr1+EENSr2+EENScb3+EENScb4)/nt;
xe6=(EENScb1+EENSr2+EENSr3+EENScb4)/nt;
xe7=(EENScb1+EENScb2+EENSr3+EENSr4)/nt;
xe8=(EENSr1+EENScb2+EENScb3+EENSr4)/nt;
xe9=(EENSr1+EENScb2+EENSr3+EENScb4)/nt;
xe10=(EENScb1+EENSr2+EENScb3+EENSr4)/nt;
xe11=(EENSr1+EENSr2+EENSr3+EENScb4)/nt;
xe12=(EENScb1+EENSr2+EENSr3+EENSr4)/nt;
xe13=(EENSr1+EENScb2+EENSr3+EENSr4)/nt;
xe14=(EENSr1+EENSr2+EENScb3+EENSr4)/nt;
xe15=AENStR;xe16=AENStCB;
AENSimprove=[xe16 xe2 xe1 xe5 xe4 xe10 xe3 xe6 xe8 xe14 xe9 xe11 xe7
xe12 xe13 xe15];


%% Bus-2 radial network ASAI improvement


xa1=(1-(x1/8760))*(100);
xa2=(1-(x2/8760))*(100);
xa3=(1-(x3/8760))*(100);
xa4=(1-(x4/8760))*(100);
xa5=(1-(x5/8760))*(100);
xa6=(1-(x6/8760))*(100);
xa7=(1-(x7/8760))*(100);
xa8=(1-(x8/8760))*(100);
xa9=(1-(x9/8760))*(100);
xa10=(1-(x10/8760))*(100);
xa11=(1-(x11/8760))*(100);
xa12=(1-(x12/8760))*(100);
xa13=(1-(x13/8760))*(100);
xa14=(1-(x14/8760))*(100);
xa15=(1-(x15/8760))*(100);
xa16=(1-(x16/8760))*(100);
ASAIimprove=[xa16 xa2 xa1 xa5 xa4 xa10 xa3 xa6 xa8 xa14 xa9 xa11 xa7
xa12 xa13 xa15];



%% (6)   For comparing between the better two chances (using
of:Reclosers NO;1,3,4, and all of them)m we are getting the best
case by utilizing of all, because the last has less AENS.   %%



SAIDIcompare=[x13 x15];
SAIFIcompare=[xf13 xf15];
MAIFIcompare=[xm13 xm15];
AENScompare=[xe13 xe15];
ASAIcompare=[xa13 xa15];
close all,
```

```
%%%%%%%%%%%%%%%%%%%        Results        %%%%%%%%%%%%%%%%%%%



%% (1)  For getting the results for the first radial feeder in
discrete output for its reliability indices by using the Main C.B.
then is replaced by using the Main Recloser; in an output assesment
table, we apply  %%



SAIDI_F1=SAIDI_F1'.*60;SAIFI_F1=SAIFI_F1';MAIFI_F1=MAIFI_F1';AENS_F1
=AENS_F1';MainSwitch={'C.B.1';'R1'};ASAI_F1=ASAI_F1';
Feeder1=table(MainSwitch,SAIDI_F1,SAIFI_F1,MAIFI_F1,AENS_F1,ASAI_F1)

%%
figure, bar(SAIDI_F1,0.25);
%%
figure, bar(SAIFI_F1,0.25);
%%
figure, bar(MAIFI_F1,0.25);
%%
figure, bar(AENS_F1,0.25);



%% (2)  For getting the results for each radial feeder in discrete
output for their reliability indices by using the Main C.B.; in an
output assesment table, we apply  %%



SAIDI_CB=SAIDI_CB'.*60;SAIFI_CB=SAIFI_CB';AENS_CB=AENS_CB';ASAI_CB=A
SAI_CB';MainBreaker={'C.B.1';'C.B.2';'C.B.3';'C.B.4'};
Breakers=table(MainBreaker,SAIDI_CB,SAIFI_CB,AENS_CB,ASAI_CB)

%%
figure, bar(SAIDI_CB,0.5);
%%
figure, bar(SAIFI_CB,0.5);



%% (3)  For getting the results for each radial feeder in discrete
output for their reliability indices by using the Main Recloser; in
an output assesment table, we apply  %%



MainRecloser={'R1';'R2';'R3';'R4'};AENS_R=AENS_R';ASAI_R=ASAI_R';SAI
DI_R=SAIDI_R'.*60;SAIFI_R=SAIFI_R';MAIFI_R=MAIFI_R';
Reclosers=table(MainRecloser,SAIDI_R,SAIFI_R,MAIFI_R,AENS_R,ASAI_R)


%%
```

```
figure, bar(SAIDI_R,0.5);
%%
figure, bar(SAIFI_R,0.5);



%% (4)  For getting the total result for all the radial feeders in
two discrete situations for its reliability indices by using the
Main C.B. then is replaced by using the Main Recloser; in an output
assesment table, we apply  %%


NSAIDI=[SAIDI_CB SAIDI_R];NSAIFI=[SAIFI_CB SAIFI_R];
SAIDI=SAIDI'.*60;SAIFI=SAIFI';MAIFI=MAIFI';AENS=AENS';State={'Circui
t Breakers';'Reclosers'};ASAI=ASAI';
Total=table(State,SAIDI,SAIFI,MAIFI,AENS,ASAI)


%%
figure, bar(SAIDI,0.25);
%%
figure, bar(SAIFI,0.25);
%%
figure, bar(MAIFI,0.25);
%%
figure, bar(AENS,0.25);
%%
figure, bar(NSAIDI);

%%
figure, bar(NSAIFI);

%%
figure, bar(MAIFI_R,0.5);


%% (5)  For getting the results of the Bus-2 radial network to
improve its reliability indices by using all different chances of
Main C.B.'s & Reclosers in an output assesment table, we apply  %%



SAIDIimprove=SAIDIimprove'.*60;SAIFIimprove=SAIFIimprove';MAIFIimpro
ve=MAIFIimprove';AENSimprove=AENSimprove';ASAIimprove=ASAIimprove';
MainReclosers={'None';'R2';'R1';'R1+R2';'R4';'R2+R4';'R3';'R2+R3';'R
1+R4';'R1+R2+R4';'R1+R3';'R1+R2+R3';'R3+R4';'R2+R3+R4';'R1+R3+R4';'R
1+R2+R3+R4'};
Improvement=table(MainReclosers,SAIDIimprove,SAIFIimprove,MAIFIimpro
ve,AENSimprove,ASAIimprove)


%%
figure, bar(SAIDIimprove);
%%
figure, bar(SAIFIimprove);
%%
figure, bar(MAIFIimprove);
%%
```

```
figure, bar(AENSimprove);



%% (6)  For comparing between the better two chances (using
of:Reclosers NO;1,3,4, and all of them)m we are getting the best
case by utilizing of all, because the last has less AENS.   %%



Case={'R1+R3+R4';'R1+R2+R3+R4'};SAIDIcompare=SAIDIcompare'.*60;SAIFI
compare=SAIFIcompare';MAIFIcompare=MAIFIcompare';AENScompare=AENScom
pare';ASAIcompare=ASAIcompare';
GoodCase=table(Case,SAIDIcompare,SAIFIcompare,MAIFIcompare,AENScompa
re,ASAIcompare)

%%
figure, bar(SAIDIcompare,0.25);
%%
figure, bar(SAIFIcompare,0.25);
%%
figure, bar(MAIFIcompare,0.25);
%%
figure, bar(AENScompare,0.25);
%%



%%%%%%%%%%%%%%%%%%%%%%        FINISHED        %%%%%%%%%%%%%%%%%%%%
```

CURRICULUM VITAE

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