Palestine Polytechnic University

College of Engineering

Evaluating the Reliability worth Indices of Electrical Medium Voltage Network

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ABSTRACT

In this study, the reliability assessment of Medium-Voltage (MV) distribution network is investigated. The study examines tow practical part of the MV network in the North East of England and Palestine. The network used in this study is the radial distribution system, which represents typical urban distribution systems consisting of residential and industrial customers. The degree of reliability of supply is measured by the frequency, duration and magnitude of disturbances to the electricity supply. Both system indices and system worth indices are calculated and evaluated. In addition, the degree of reliability of five case studies is conducted, which can investigate the effects of automation, ageing and load growth then we collected real data from the local network and apply the mathematical methods using 'MATLAB' program.

خلاصة

يتلخص هذا البحث في تطوير طرق لتقييم مخاطر أنظمة توزيع الطاقة. تتعامل هذه الدراسة مع شبكة الجهد المتوسط (MV) حيث يتم تقديم طريقة رياضية ، تم تقييم الموثوقية لشبكة توزيع الجهد المتوسط في شمال شرق إنجلترا وفلسطين ، الذي يمثل أنظمة التوزيع الحضرية النموذجية التي تتكون من عملاء سكني وصناعي. الشبكة المستخدمة في هذه الدراسة هي نظام التوزيع الشعاعي ، ويتم قياس درجة موثوقية الشبكة من خلال عدة عوامل تكرار القطع ومدة الاضطرابات وعددها في الإمداد بالكهرباء. تساهم هذه الدراسة في قياس مخاطر الشبكة الكلية (TNR) ، وايجاد التكلفة المترتبة على هذه المخاطر ، والمساهمة في ايجاد حلول لتقليل هذه المخاطر، في البداية افترضنا قيم معينة ، بالإضافة إلى ذلك ، يتم إجراء درجة موثوقية خمس دراسات حالة ، والتي يمكننا التحقيق في آثار الأتمتة والشيخوخة ونمو الحمل ثم عملنا على جمع بيانات حقيقية من الشبكة المحلية وتطبيق المعادلات الرياضية على هذه القيم باستخدام برنامج ' MATLAB '

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
CAIDI	Customer Average Interruption Duration Index
CI	Customer Interruption
CML	Customer Minutes Lost per year
DG	Distribution Generation
DNO	Distribution Network Operation
ECOST	Expected Customer Interruption Cost
EENS	Expected Energy Not Supply
EHV	Extra High Voltage
ENA	Energy Network Associations
ENS	Energy Not Supplied
EPS	Electrical Power System
ESI	Electrical Supply Industry
LV	Low Voltage
MV	Medium Voltage
NAFIRS	National Fault and Interruption Reporting Scheme
NG	National Grid
NPV	Net Present Values
OFGEM	Office of The Gas and Electricity Markets
PBR	Performance Based Regulation
RcT	Reclosing time
RpT	Replacement time
RT	Repair time
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SwT	Switching time
TNR	Total Network Risk

1

CHAPTER ONE

INTRODUCTION

1.1 Background

The electrical power system (EPS) Is a combination of generation, In addition to its transmission and distribution networks The distribution system It usually starts with the distribution substation that substations fed by one or more subtransmission lines. In some cases, high-voltage transmission line fed directly the distribution substation is in which case, most likely, there is not a subtransmission system. This varies from country to country and from company to company. One or more primary feeders serve by distribution substation. With a rare exception, the feeders are radial, which means that there is only one path for power to flow from the distribution substation to the user. [1] All of the above are subjected to many events such as accident, randomly failures in assets, increasing power outage due to adverse weather and increase network risk duo to aging components. It's difficult to control these kinds of events, but these events must be taken when deciding the level of distribution at which the system should survive. Otherwise EPS is complicated system from the operation passing through infrastructures points of view, despite all of the above; the end customers should provide with reliable and continuous power supply. With a view to enhance the EPSs performance. Their reliability should be subject to improvement.. This can happen through increasing the investment, reinvestment and maintenance. In the end, however, the losing electricity economic affect adversely on both the electric supply utility and the end users.

1.2 Objective

The main objective of this thesis is to develop risk assessment methods of power distribution systems. This study treats with Medium Voltage (MV) network where mathematical method is presented. The supply reliability degree is measured by the frequency, duration and magnitude of disturbances to the electrical supply. Both system indices and system worth indices are calculated and evaluated.

The main goal of the research is to study the above method and test network by apply this method to test their feasibility. A good network test would be a single representative section of a Medium Voltage (MV) network. By apply a method that works well on MV networks, there will be an ability to have deep understand of MV distribution networks and sort the circuit failure and risk. On the other hand, it will allow a more comprehensive understanding of network risk and hopefully the development of alternative ways to quantify network risk, which can be applied to wide range of real distribution systems. As well as it can be used to predict how the system is expected to behave in the future. Furthermore, to investigate the possibility and advantage that could be gained to by applying new automated technology to reduce customer outage and total network risk (TNR), the benefits of alternate system design and reinforcement, expansions plans and the related cost worth benefit of the alternatives.

1.3 Terminology

The following list of some fundamental terminologies definitions and fundamental terms that used in the study.

- Risk is “the uncertain measure that some specified loss occurs” [2]
- Reliability “Reliability is the probability that a product will operate or ‹a service will be provided properly for a specified period of time (design life) Under the design operating conditions (such as temperature , load , Volt . . .) without failure. ” [3]
- Redundancy is “more than one independent opportunity for a piece of equipment to carry out a desired function” [4]; active redundancy is obtained if one or more reserve items operate in parallel; passive redundancy is obtained if one or more reserve items are in cold standby [5]
- Failure rate is “merely an approximation of the actual failure” [6] ; The failure rate function can be interpreted as the probability (risk) of failure in an infinitesimal unit interval of time. [7]
- Failure is “The action or state of not functioning” [8]
- Repair time is “time counted from the moment the component fails to the moment it is returned to an operable condition. Also known as outage duration, down time or restoration time” [9]
- Probability: “measure of the likelihood that an event will occur” [10]
- Quantitative analysis is “a technique that make use of historical performance of existing systems for prediction of future performance”
- Qualitative analysis is “a technique that is based on experience of design and operating engineers”.
- Unavailability is “The system unavailability is expressed as the probability sum of covered faults and uncovered faults”.
- Reliability cost is “the investment cost needed to achieve a certain level of reliability”

1.4 Motivation

The study of (Evaluating the Reliability worth Indices of Electrical Medium Voltage Network) and apply method to evaluate the electrical power system and gives advice to the best choice, In terms of error (interruption and fault) and the economic situation.

In our study, we will use new technology, Try each scenario individually, which aims to show the results of each scenario and each system cost.

1.5 Related work

“Evaluating the Reliability worth Indices of Electrical Medium Voltage Network” In this study, the reliability assessment of Medium-Voltage (MV) distribution network is investigated. The study examines one practical part of the MV network in the North East of England. The network used in this study is the radial distribution system, which represents typical urban distribution systems consisting of residential and industrial customers. The degree of reliability of supply is measured by the frequency, duration and magnitude of disturbances to the electricity supply. Both system indices and system worth indices are calculated and evaluated. In addition, the degree of reliability of five case studies is conducted, which can investigate the effects of automation, ageing and load growth.

"Electrical Network Risk Project –Location the Maximum Risk" Eng. Maher Al-Maghalseh provides an overview of the electricity industry in UK and the electrical distribution network. The basic impact of the power protection system is briefly described. The dissertation also provides an introduction of risk in electrical distribution systems. This includes definitions and an overview of risk assessment methodologies. Furthermore, the basic reliability analysis applied to electrical distribution system is clearly described.

1.6 Research Outline

Chapter 1 afford necessary background and an introduction to reliability and risk assessment of a distribution system. In addition explain definitions to some fundamental terminologies and terms used in the research.

Chapter 2 briefly described the basic impact of the power protection system. The chapter also provides an introduction of risk in electrical distribution systems. This includes definitions and an overview of risk assessment methodologies.

Chapter 3 Gives a description of reliability analytical methods, which applied to test distribution system. The chapter also investigate the effect of protection equipment's, alternative supply, automation and asset aging on system reliability indices. A summary of results from performed studies are included in this chapter.

Chapter 4 presents the reliability assessment of the practical distribution network and sensitively analysis.

Chapter 5 discuss practical cases to analyses and review the results

1.7 Time Table

ID	Task	Week No.																																
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**29**	**30**	**31**	**32**	**33**
1	Project start																																
2	Weekly reports and meetings																																
3	**Read relevant Literature**																																
4	Select the idea																																
5	Gathering information																																
6	**Start with Preliminary work**																																
7	Methodology overview																																
12	**Write a code & Results**																																
20	**Study practical Case study**																																
21																																	
22	Analysing results																																
23	**Prepare first draft report**																																
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25																																	
26	Handing Preliminary work																																
27	Feedback and correction of Preliminary work																																
28	Handing case study																																
29	Conclusions and future works																																
30	**Preparing final report**																																
31	Necessary modifications																																
32	Discussions																																
33	Introduction																																
34	Appendices																																
35	|Modification																																
36	Handing final draft																																

2

CHAPTER TOW

THE BASIC IMPACT OF THE POWER PROTECTION SYSTEM

2.1 Overview

2.2 System Reliability Evaluation

2.3 Protection System Equipment's

2.4 Failure Mode and Effect Analysis (FMEA)

2.5 Risk Concepts and Definition

2.6 Risk Mitigation

2.1 Overview

This chapter presents review of the basic ideas and methods for evaluating system indices and cost worth indices are described. It provides an overview of the basic concepts associated with reliability and risk assessment. Reliability Methodologies applied to distribution systems and their application are presented. The basic methods of risk mitigation are discussed. In the final the chapter end with conclusions of literatures review.

2.2 System Reliability Evaluation:

The evaluation of reliability indices, are applied first to radial distribution system. The calculation of failure rate and duration time have solved with equations in order to estimate the failure frequencies and restoration time. The research is conducted on practical 33kV and 11kV networks using MATLAB program. This methodology helps to apply and analytic more practical systems and to carry out an increasing number of sensitivity and complex studies. The methodology tends to concentrate in practice on evaluation at the generation and composite generation and transmission system levels. Which presents a method to calculate optimal value of load point indices in an electrical distribution system in order to minimize interruption cost.

2.3 Protection System

All power systems include protection devices, which have significant effect on the distribution network operation and load flow .The main purpose of the protection system devices is to isolate faulty equipment's, protect the system's components, sectionalize the networks for repair purpose and restore power supply by reconfigure network .On the other hand automatic operation of protection devices is sufficient to isolate faulty components in minimum time to minimize damage, as a result minimising the cost of interruption . These mean that the following basics principles have to apply on the protection devices within any power system. The protection devices must be sensitive enough to operate when a fault occurs under minimum faults conditions and be stable enough to operate at maximum rated current, thereby prevent system components from being damage. It must be fast and capable of both closing and opining in term of clearing the fault from the system as quickly as possible in order to minimize the damage to system components. Furthermore in order to improve the reliability of the system, back-up protection has to apply. However there are many devices are employed in power system for protection purpose. These include the following:

- Circuit Breakers: used to detect and interrupt a short circuit fault current. Breakers can be remotely operated and has no limit in the number of time it can operate.
- Disconnectors: these are mechanical switches, must be apple to carry rated. These used to isolate faults are of two kinds; those that can be operated with power on and that can't. Disconnectors can't be operated for short circuit.
- Earth switches: these are mechanical switches capable of carrying a rated short-circuit current. Earth switches are used to eliminate fault current.
- Fuses: these must be able to carrying a load current without deterioration and must be able to interrupt a short circuit current. Fuses are very effective and used to protect certain equipment. The major disadvantage of fuses is that they require replacement before the power supply.

There are two kinds of faults in the components in power systems, passive and active faults. Active fault, which are triggered the protection equipment's such as short circuit, while passive faults are such faults don't give rise to a short circuit current.

2.3.1 Circuit breaker function

A circuit breaker must be capable to make and break all the load and fault currents that it might be subjected to at the specific installation. Key factors with circuit breakers performance are; opening (break) and closing (make) time, rated continuous current-carrying capability, rated dynamic short circuit withstand capability, rated thermal short circuit withstand capability, maximum operation voltage and rated operation sequence. Earlier, the small-oil circuit breakers were common on medium-voltage indoor installations and air-blast or oil breakers in outdoor installations. Today, these technologies have been re-placed with SF6-gas and vacuum technologies. SF6-gas is dominating with outdoor installations, whereas with indoor installations both vacuum and SF6-gas technologies are utilized.

Switchgears advantages over standalone circuit breakers

- The ability to control the rated current and tripping over current.
- Voltage, current and power measurements.
- Could be easily connected to SCADA (RTU) system.
- The ability for smart control of tripping and reclosing activities.
- Availability of fuses, disconnect switches, earth switches.

Each switchgear unit came with sub control panel that allow the electrical personnel to calibrate internal components including the circuit breaker on system's rated quantities (voltage, current and power), these control panels could be connected to utility SCADA system in order to monitor and control these quantities and the state of each circuit breaker.

2.3.2 HV HRC Fuse

HRC high voltage fuses are used to protect transformers, capacitor banks, cable networks and overhead lines against short-circuits. HRC HV fuses protect switchgears from thermal and electromagnetic effects of heavy short-circuit currents by limiting the peak current values (cut-off characteristics) and interrupting the currents in several milliseconds.

2.3.3 Switch- Disconnector

Used to ensure that an electrical circuit is completely de-energized for service or maintenance.

2.3.4 Alternative Supply

Many typically distribution systems are connected as meshed circuit, are normally operated to as radial system using normally operating open point. The utility can supply power to the customer from either direction. However after the failed elements are isolated from the system; service of some load point is restored through the main supply while others load points are restored by alternative supply.

2.4 Failure Mode and Effect Analysis (FMEA)

FMEA is a structured way to analyse the system. The identification fault modes and the type of outage time (RcT, SwT, RpT or RT) for each load points are ranked and determined according to the risk associated with each fault mode. Some load points affected only by a switching time at a certain failure event while others will be unsupplied during the whole replacement or repair time. These can be identified by using FMEA method. However FMEA is one of the first systematic techniques for failure analysis and it requires system understanding about constrains under which the system operate. This presented the basic structure is to list the fault can occur in the system and how the protection system deal with this fault and the system impact of each fault.

2.5 Risk Concepts and Definition

The risk has to be defined. In international standard IES 60300-3-9 , risk is defined as “the combination of the frequency, or probability of occurrence and the consequence of a specified event (That is defined to do harm)”. Blake has expressed the network risk in terms of frequency interruption monitored by the regulator Office of The Gas and Electricity Markets (OFGEM), as the average number of Customer Interruption (CI) per 100 customers per year. alternatively, also it can expressed in term of average interruption of 10 minutes twice per year gives an annual total of 20 Customer Minutes Lost per year (CML). Andrews et al defined the major hazard assessment risk as “the probability of specific undesired events (explosion or toxic/radioactive release)”.

Further he defined the risk quantitatively as “the product of the consequence of a specific incident and the probability over a time period or frequency of its occurrence”.

The risk could be performed using three questions:

1. What can go wrong (event)?
2. How likely is this to happen (by probability analysis)?
3. What are the consequences (by consequence or impact of analysis)?

In the three parts of risk assessments are defined:

- Risk identification: Process of recognizing that a hazard exists and defining its characteristics.
- Risk analysis: systematic use of availability information to identify hazard and to estimate the risk to individuals or populations, property or the environment.
- Risk evaluation: process in which judgments are made on the tolerability of the risk on the basis of risk analysis and taking into account factors such environmental aspects.

From these definitions, it can be seen that the risk is defined as the probability of an event over the time period (frequency of its occurrence) multiplied by consequences. Consequences could be expressed in term of customer outages. In the present research, we concerned with evaluating the frequency of incidents, which have major safety implication by the use of probabilistic methods.

2.6 Risk Mitigation

Different approaches are used to evaluate risk mitigation. These could include replacement, network reinforcement, increasing automation and network reconfiguration, maintenance, distributed generation, energy storage and active network management.

3

CHAPTER THREE

Methodology

3.1 Overview

3.2 Radial Distribution System

3.3 Distribution System Indices

3.4 Reliability Worth Indices

3.5 Customer Costs

3.1 Overview

In this chapter, we are going to discuss Radial distribution system and explain the Distribution System Indices and the Reliability Worth Indices of systems, and review the Customer Costs.

3.2 Radial Distribution System

Electrical networks are typically of two types, radial or interconnected. A distribution circuit uses main feeders and lateral distribution. A main feeder originates from the subtansmission substation and passes through the major load points and is constructed using single, parallel or meshed circuit. Many typical distribution systems are connected as a single circuit and are referred as radial system. Other systems are connected as meshed circuit, are normally operated to as radial system using normally operating open point. The utility can supply power to the customer from either direction, If one source of power fails, switches are thrown (automatically or manually), and power can be fed to customers from the other source. Furthermore in the event of power failures due to faults on the line, the utility has only to find the fault and switch around it to restore service. The fault itself can then be repaired with a minimum of customer interruptions. The outage durations due to the component failure are reduced by protection and sectionalizing schemes. The time taken to isolate a fault component by isolation and switching action is termed as switching/restoration time. The alternate open point operation is used in the case of failure or due to a component maintenance outage. Radial system is popular due to their simple design and low cost.

3.3 Distribution System Indices

The distribution system has traditionally been characterized as the most unglamorous component. In the last half of the twentieth century, the distribution system reliability evaluated and determined on an annual basis can be grouped into two categories. The load point indices and system indices.

There are three fundamental parameters in the evaluation of load point indices, these are the average failure rate or average annual outage frequency, λ_i , the average outage time r_i , and the average annual unavailability or average annual outage time, U_i , are given by.

The approach used in this study to conduct redial distribution system reliability assessment is to perform a failure modes and effects analysis utilizing the following equation at each load point p:

$$\lambda_p = \sum_{i=1}^{N} \lambda_i \qquad \text{...........(3.1)}$$

$$U_p = \sum_{i=1}^{N} \lambda_i r_i \qquad \text{...........(3.2)}$$

r_i is the correction time, which is the expected RT, RpT, SwT or RcT depending parameter setting and system's configuration, how the components are located relative the load point and type of fault.

$$r_p = \frac{U_p}{\lambda_p} \qquad \text{...........(3.3)}$$

Where N denotes the number of outage events affecting load point p.

The severity of an outage event depends on the components under outage, their relative importance and their location in the network. An outage event may affect only small area (bus) of the system or a large area (feeder). It is important to identify the areas of the system which have poor reliability.

However the system indices can be calculated by using weighted average of the individual load point indices, which are necessary to identify the weak points in the system and help to establish and predict optimum response to design changes of the system under steady state condition. There are many indices for measuring reliability. Among the system indices, the customer-based reliability indices are ones most commonly used. These indices weight each customer equally. For example, a household customer is given as much importance as an industrial customer. It would be evaluated irrespective of whether a household customer or industrial customer. The most common customer- based reliability indices are the System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Frequency Index (CAIDI), Energy Not Supplied (ENS) or, Expected Energy Not Supply (EENS), Average Service Availability Index (ASA) and the complementary Average Service Unavailability index (ASUI). The basic definition and mathematical formulations of these indices are given below.

- SAIFI, or System Average Interruption Frequency Index, is the average frequency of sustained interruption per customer over a predefined area. It is total number of customer interruptions divided by the total number of customer served.

$$SAIFI = \frac{\sum_{i\in R} \lambda_i N_i}{\sum_{i\in R} N_i} \quad \text{...........(3.4)}$$

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

$$CAIDI = \frac{\sum_{i\in R} U_i N_i}{\sum_{i\in R} N_i \lambda_i} \quad \text{...........(3.5)}$$

- SAIDI, or System Average Interruption Duration Index, is commonly referred to as customer minutes of interruption or customers hours, and is designed to provide information as to the average time the customers are interrupted. It is the sum of the restoration time for each interruption event times the number of interrupted customers for each interruption event divided by the total number of customers.

$$SAIDI = \frac{\sum_{i \in R} U_i N_i}{\sum_{i \in R} N_i} \qquad \text{………..(3.6)}$$

Numerically: $SAIDI = CAIDI \times SAIFI$ ………..(3.7)

SAIDI and CAIFI are indices that measure the availability of supply (duration of the interruption), while SAIFI and CAIDI are indices that measure the reliability (frequency of interruption) of the supply.

- ENS, Energy Not Supplied or EENS, Expected Energy Not Supply. It is the sum of energy not supplied by the system. To estimate consequences for the customers, reliability worth indices as Expected Customer Interruption Cost (ECIO) or interrupted Energy assessment rate (IEAR) are often used.

$$ENS = \sum_{i \in R} U_i L_i \qquad \text{………..(3.8)}$$

- ASAI, Average Service Availability Index. It is the ratio of the total number of customer hours that service was available during a year to the total customer hours demanded. The complement of this index is the system ASUI.

$$ASAI = \frac{\sum_{i \in R} 8760 N_i - \sum_{i \in R} U_i N_i}{\sum_{i \in R} 8760 N_i} \quad \ldots\ldots\ldots\ldots(3.9)$$

The notations used in the above equations are defined below:

λ_i: Interruption frequency at load point i

N_i: Number of customer at load point i

U_i: Annual unavailability or outage time at load point i

R: Set of load points in the consider system

3.4 Reliability Worth Indices

The electrical supply industry (ESI) recognised reliability worth indices to evaluate the reliability in the distribution network reflects to customer's viewpoint. The most presented indices, the availability and security, are defined as the minutes lost per customer, which can be expressed in terms of the average duration of interruption as the customer minutes lost (CML) per year and the frequency of interruption, which can be expressed in terms of average number of customer interruption (CI) per 100 connected consumers per year. Which are used as standard for the present study.

The reliability worth indices are estimated for the each load point in the system as:

- Customer Interruption (CI)

$$CI = \lambda_i \times CI(cost\ per\ customer) \times N_i \qquad \text{………….(3.10)}$$

CI is referred to SAIFI as

$$CI = SAIFI \ \times CI(cost\ per\ customer) \times \sum N_i \qquad \text{………….(3.11)}$$

- Customer Minutes Lost (CML)

$$CML = \ U_i \ \times CML\ (\ customer\ minute\ lost\ cost) \times N_i \times 60\ (min/h) \qquad \text{………….(3.12)}$$

CI is referred to SAIDI as

$$CML = SAIDI \ \times CML(cost) \times 60(min/h) \times \sum N_i \qquad \text{………….(3.13)}$$

- Customer Repair (CR)

$$CR = SAIFI \times (repair\ cost) \qquad \dots\dots\dots\dots(3.14)$$

The Total Network Risk can be expressed as

$$TNR = CI + CML + CR \qquad \dots\dots\dots\dots(3.15)$$

3.5 Customer Costs

The customer interruption cost is an input to the cost-benefit analysis, and it is needed in order to find an economically adequate level of reliability. Several approaches have been utilized to assess the cost of power interruption. These include analytical method, case studies and survey approach. There is no universally adopted approach; often Distribution Network Operators (DNOs) seek customer survey for interruption cost information in their planning activities.

4

CHAPTER FOUR

Case Study

4.1 Network configuration

4.2 CONCLUSION

4.1 Network configuration

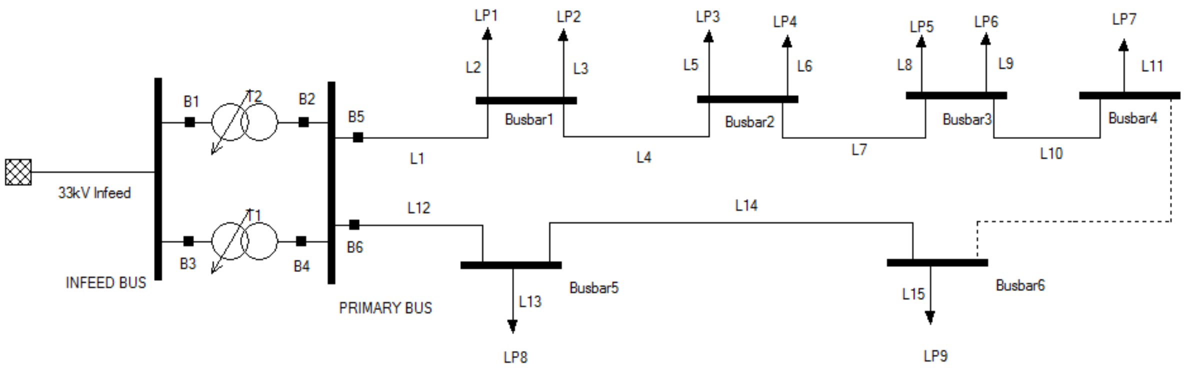


Figure 4. 1 Network configuration 1

Permanent ground fault on L7. The fault triggers the relay that operates B5. During the switching time (SwT) LP1 – LP7 are affected. When the fault has been located L7 can be isolated by opining its disconnectors and LP5 – LP7 can be fed by closing the disconnectors on L16.

Permanent ground fault on L15. The fault triggers the relay that operates B6. During the switching time (SwT) LP8 – LP9 are affected. The fault is isolated by opining the disconnectors on L15. LP8 – LP9 can be fed through the ordinary supply route while LP9 is affected during the repair time (RT).

Permanent short circuit fault on T1. The fault will trigger B3. The reclosing sequence of B2 will show the operator that the fault is permanent, LP1 – LP9 will be affected during the switching time (SwT) that will transfer the in feed to T2.

Temporary fault on L14. The fault will trigger B3, but the re-closing sequence of B3 will show that the fault was temporary and when reclosed continue the operation. LP8 – LP9 will be affected during the reclosing time (RcT).

Permanent short circuit on lateral 11/0.4 kV transformer. The fuse located over the transformer is triggered and its load point is affected during the repair time or the time it takes to replace the transformer. Since the repair time for the transformer are rather long, the most common way to deal with transformer fault is either to replace it or rely on a backup transformer.

Active fault on B5. The short circuit of B5 will trigger B2, LP1 –LP9 are affected during the switching time, during which B5 is isolated and the disconnector on L16 is closed so that LP1 – LP7 can be fed through the alternative supply route.

Passive fault on B5. The passive fault in B5 will open B5, no protection device are triggered, LP1 – LP7 are affected during the switching time, during which B5 is isolated and the disconnector on L16 is closed, then LP1 – LP7 can be fed through the alternative supply point.

Basic Component Reliability Data

To evaluate the reliability model basic component data for the failure rate and restoration process are needed. Average failure rates are adopted from (National Fault Data/UK) and restoration times are adopted from. These are given in the Table 4. 1

Table 4. 1 Reliability data for system components

Components	**λp [f/yr.]**	**λT [f/yr.]**	**RpT [h]**	**RT [h]**	**SwT [h]**	**RcT [h]**
			Transformers			
33/11 kV	0.002	0.05	15	-	1	0.083
11/0.4 kV	0.002	-	10	200	1	-
			Breakers			
33 kV	0.001	0.02	4	4	1	0.083
11 kV	0.0033	0.06	4	4	1	0.083
			Overhead lines			
11 kV	0.091	-	5	5	1	-
			Cables			
11 kV	0.051	-	30	30	3	-

In Table 4. 1 λ_p is permanent (total) failure rate (f/yr.) for lines/cables (f/yr.km), λ_T is the temporary failure rate (f/yr.) for line/cables (f/yr.km).

In the system the numbers of the customers and the average demand at each load point is presented in Table 4. 2. The lengths of 15 overhead lines/cables in the system given in Table 4. 3.

Table 4. 2 Table Load Point Data

Load point	Number of customers	Average load (KW)
LP1	210	240
LP2	210	240
LP3	210	240
LP4	220	260
LP5	180	200
LP6	100	110
LP7	50	60
LP8	400	500
LP9	450	500

Table 4. 3 Length of the overhead lines/cables in the system

Length Km	Feeder section number
0.6	L2, L6, L14
0.75	L1, L4, L7, L9, L12
0.8	L3, L5, L8, L11, L13, L15

Practically the failure rate in lines and cables found that it is approximately proportional to their length. As described in Table 1 a failure rate of overhead lines are 91 per 100 km of length while a failure rate of the cables are 51 per 100 km of length. Using these basic data and the line lengths shown in Table 4. 3 gives the fault rate both in cables and overhead line, which also shown in Table 4. 4.

Table 4. 4 Fault rate in cables and overhead lines

Section Main	Length Km	overhead line λ (f/yr.)	Cable λ (f/yr.)

1	0.75	0.06825	0.03825
4	0.75	0.06825	0.03825
7	0.75	0.06825	0.03825
10	0.6	0.0546	0.0306
12	0.75	0.06825	0.03825
14	0.6	0.0546	0.0306
	Distribution section		
2	0.6	0.0546	0.0306
3	0.8	0.0728	0.0408
5	0.8	0.0728	0.0408
6	0.6	0.0546	0.0306
8	0.8	0.0728	0.0408
9	0.75	0.06825	0.03825
11	0.8	0.0728	0.0408
13	0.8	0.0728	0.0408
15	0.8	0.0728	0.0408

4.2 CONCLUSION

The study examines one practical part of the MV network in the North East of England. The network used in this study is the radial distribution system, which represents typical urban distribution systems consisting of residential and industrial customers. Five case studies were considered and evaluated. The study investigates the possibilities and advantages that could be gained by applying automated feeder operation in order to improve the reliability indices and reduce the number and length of outages. A reliability analysis and calculation of the new solution was performed Through the Matlab program. It was found that the automated operation solutions has a significant impact on reducing the outage time and then improve the customer service. This also contributes to saving in power as well as reducing the TNR. On the other hand.

5

CHAPTER Five

CASE STUDY

5.1 Background

5.2 Study of the performance of the system (Case 1).

5.3 Study the effect of automation (Case 2)

5.4 Study the effect of ageing and load growth (Case 3)

5.5 Study the effect of automation with ageing (Case 4)

5.6 Study the effect of load growth (Case 5)

5.7 Result and Discussion

5.8 Case North East England

5.9 Case HEBCo

5.1. Background

Distribution system used in the case study examines one practical part of the MV network The network used in this study is the radial distribution system, which represents typical urban distribution systems consisting of residential and industrial customers. Reliability analysis methods have been proposed in several studies and references as the primary tool to handle these kinds of risks. The probabilistic methodologies and simulation approaches to calculate and rank the risk are discussed in detail by Billinton . Another paper used sequential Monte Carlo Simulation Technique in order to enhance the reliability evaluation for complex distribution systems. The indicators were found based on several methods from Monte Carlo and Billinton for the MV evaluation system, and the indicators that give a high-efficiency system evaluation were observed based on the size of the tests and systems and their conformity with reality. The relevant part of the network configuration is shown in **Figure 5. 1**.The system‟s network configuration has looped feeders that under normal operating conditions are operated as three radial feeders with two open points. The first point is between LP7 in feeder 1 and LP10 in feeder 2, while the second open point is between LP7 in feeder 1 and LP18 in feeder 3. However, each feeder is basically an 11 kV system that is fed at 33 kV from the substation (PRIMARY) and has both 11 kV and 0.4 kV load points. The 0.4 kV system is connected to each 11/0.4 kV transformer. The basic configuration of the protection system is so that each feeder is equipped with breakers B1, B2 and B3 to protect the substation. There are fuses located on both sides of 11/0.4 kV transformers to protect and prevent a transformer fault affecting the rest of the system, while the disconnectors are used to isolate the line. In the network included residential and industrial customers at load points as the **Table 5. 1** demonstrates. Yet, the lengths of the 20 cables in the system explained in the **Table 5. 2**

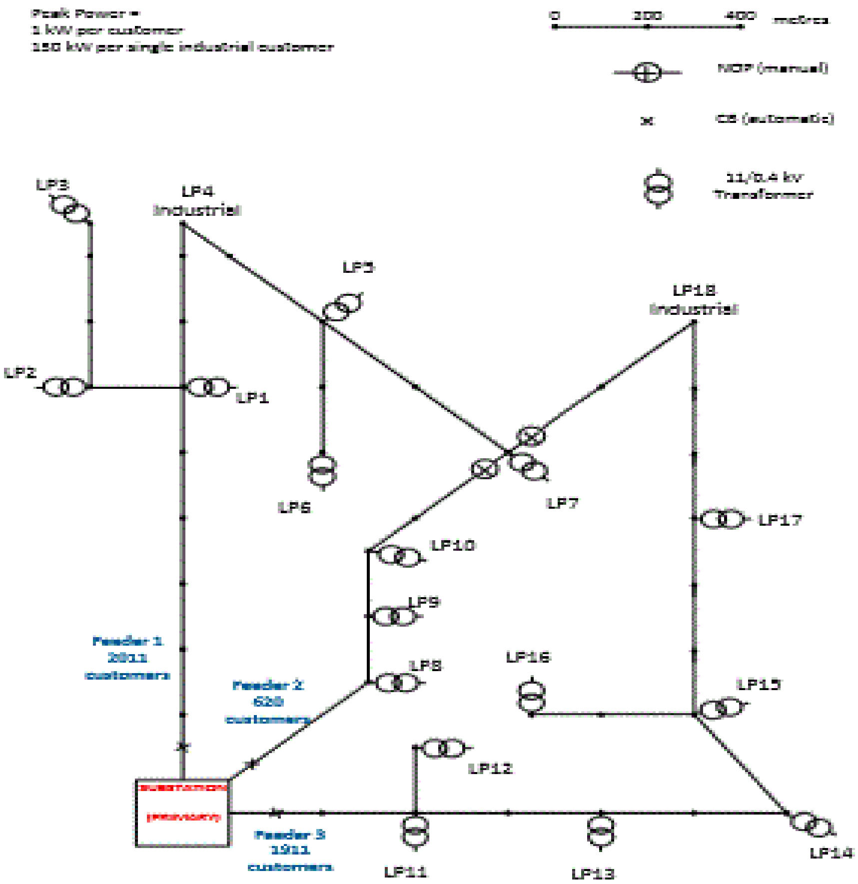


Figure 5. 1 case study system scheme

Table 5. 1 Load point data for case study system

Load points	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
# of Customers	430	140	230	1	450	310	450	230
Customers Type	R	R	R	I	R	R	R	R

Load points	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
#of Customers	150	440	210	220	200	300	280	260	1
Customers Type	R	R	R	R	R	R	R	R	I

Table 5. 2 Lengths of the cables in the system

NO	Length (Km)	Cable section
1	**0.2**	**L2, L9, L10, L13**
2	**0.3**	**L5, L8, L16**
3	**0.4**	**L6, L7, L12, L14, L15, L17**
4	**0.5**	**L3, L4**

5 **1.2** **L1**

In order to evaluate the reliability model, the basic component data for the failures, the time of the operation needed to deal with each failure mode, and restoration process are needed. In addition, the data of maintenance and replacement intensity are essential elements for sufficient evaluation. These are given in Table 4. 1, where average failure rates and the restoration time for the components are adopted from the NAFIRS report24. Five case studies were considered for comparing the results of the proposed methods.

5.2. Study of the performance of the system, with its original layout , no changes implemented to any components (Case 1).

The feeders are operated radially and are connected through normally open points. In this case, any line section outage can be manually isolated and the rest of the line sections can be manually energized from the alternative feeder. It is assumed that the feeders and substation will be unrestricted in capacity and will not be overloaded. The results show that the load point failures rate depends only on the component's failure rate not the restoration times. Consequently, the probability of any number of failures per year at each load point can be predicted. This is done by using the following formula:

$$P_n = \frac{(\lambda t)^n e^{-\lambda t}}{n!} \qquad \text{...........(5.1)}$$

The notations used in the above equation are, λ, average failure rate of each load point, n, number of failures, t, time (per year for example). The above equation is used to evaluate the probability for the number of failures occurring in 1, 10 and 30 years at each load point.

5.3. Study the effect of automation (Case 2)

The system is introduced by feeder automation by placing automated Ring Main Units (RMU) at intervals along the feeder; it is possible to disconnect only faulted sections of line and those beyond them. The number of customers affected is minimized as well as giving a more accurate indication of the fault location. A development of automatic RMU is the automatic re-closer. This device opens when a fault is sensed and subsequently re-closes according to a present sequence. In this case any line section outage can be automatically sectionalized and isolated, while the rest of the line sections can be automatically energized from alternative supply feeders. It is assumed that the sectionalizing activities do not disrupt any of the load point on the feeder.

5.4. Study the effect of ageing and load growth (Case 3)

In this case equipment failure rates are calculated with load growths over 25 years. The numbers of customers are assumed to increase by 1% annually. It is assumed that any line section outage can be manually isolated and the rest of the line sections can be manually energized from the alternative feeder. Also, it is assumed that there are no restrictions in feeders and that substation capacity will not be overloaded.

5.5. Study the effect of automation with ageing (Case 4)

The equipment failure rate and load growth over 25 years have been calculated. In this case it is assumed that any line section outage can be automatically isolated and the remaining line sections can be automatically energised. Also, there are no restrictions to feeders, or substation capacity and that they will not be overloaded.

5.6. Study the effect of load growth (Case 5)

The equipment failure rate over 25 years is calculated. In this case, it is assumed that the load growth over the 25 years will be double. Any line section outage can be manually isolated and the remaining line sections can be manually energised. Also, it is assumed that there are no restrictions to feeders and substation capacity and that they will not be overloaded.

5.7. Result and Discussion

The reliability indices of load points and the reliability indices of the system and TNR. It can be seen that installing the automated radial feeders, significantly reduces the TNR and improves both the distribution system and load point indices compared with manual operation. Consequently, maintenance and replacement of some components is necessary. Similar results were found in case 4. In case 3, the results clearly show that deterioration of failure rates as equipment ages has a negative impact on reliability indices for both load points and system indices. Therefore it is necessary to maintain and replace specific components in order to slow the ageing process in the network. In case 5, the reliability indices for the system are increased significantly. This is because of the variation of load point annual outage time (U), which depends on the repair time of faulted sections and switching activities. These vary from one point to another, and depend on the load that has been disconnected and the available transfer capacity. The reliability indices for load points and system, reliability worth indices and total network risk are calculated and evaluated in five different case studies for distribution system. The indices can also be illustrated in diagrams, which are clearly depicted in Figure 5. 2 to Figure 5. 6 The SAIFI is the average time that a system customer experiences an outage during the year and only depends on the component failure time distribution. However, it is interesting to investigate how significant the change of SAIFI is in percentage compared to Case 1. As shown in Figure 5. 2 it starts with 0.1275 (interruption/customer yr) in Case 1 and remains constant in Case 2, then increased significantly, reaching almost 48% in Case 3. This remains constant with 0.1884 in 4th and 5th cases. These results are expected, since the failure rate of components increased significantly due to the components ageing, which are assumed in the 3rd, 4th and 5th case.

5.8. Case North East England

Table 5. 3 Indices For North East England Case

	Calculated Result	Real Result
SAIFI	0.1884	0.1884
SAIDI	1.0351	1.0351
CAIDI	5.4938	5.4938
ENS	10.0777	10.0777
AENS	2.2188	2.2188
TNR	34098	34098

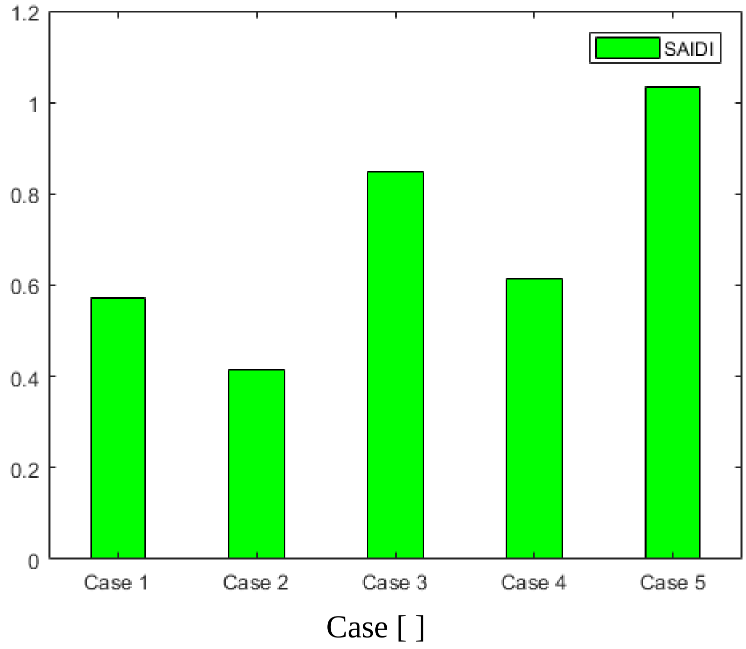


Figure 5. 2 Case North East England SAIDI

The SAIDI mainly measures the total duration of an interruption for the average customer during a given time period, which is normally per year. Figure 5. 2 shows calculated values for SAIDI under five different cases. The percent changes of SAIDI compared to Case 1 are investigated. However, it starts with 0.5734 (hours/customer yr), then decreases reaching almost 28% in Case 2. It increases significantly reaching 48% in Case 3, and then it increases slowly reaching around

7% in Case 4 compared with Case 1 but decreases reaching 27% compared with Case3. In Case 5, it increases significantly, reaching 82% compared with Case 1 and 70% compared with Case 4. The results clearly show that SAIDI depends on failure rate of components, which is increased significantly in 3rd, 4th and 5th case due to components aging. Furthermore, it depends on restoration time, which is decreased significantly in case 2 and case 4 due to automated operation.

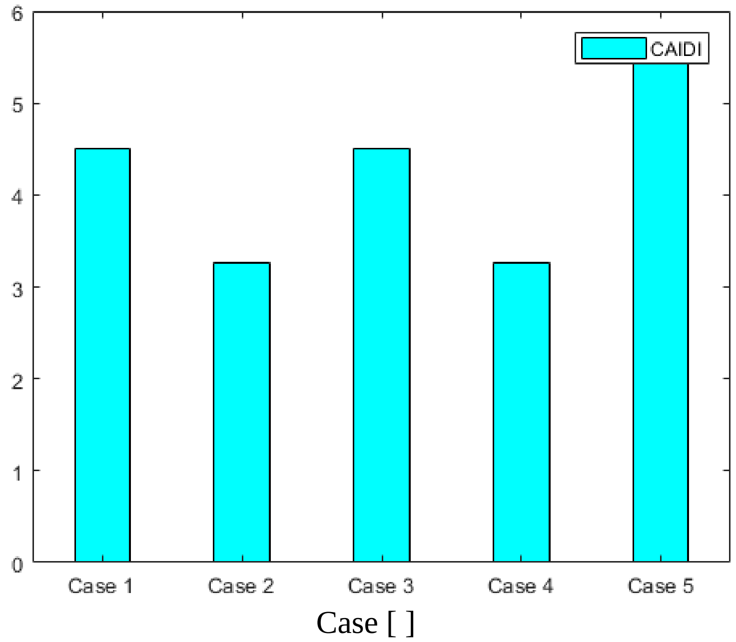


Figure 5. 3 Case North East England CAIDI

CAIDI over five case studies. The results show that it is more sensitive to automated operation. The percentage changes of CAIDI compared to Case 1 start with 4.4957 (h/CI), and then decreases reaching around 28% in Case 2. In Case 3, it remains the same as Case 1 but increases reaching 37% compared with Case 2, while in Case 4 it decreases again reaching 28% compared with Case 1. In Case 5, it increases, reaching 27% compared with Case 1 and it increases significantly, reaching 70%, compared with Case 4. However, CAIDI is reduced in Case 2 compared with Case 1, despite both cases having the same average failure rate and number of customers. The reason is that the faults have a shorter repair time in Case 2 due to automated operation. This means that the average repair time for affected customers is shorter. The same comparison is between Case 3 and Case 4. Figure 5. 4 also shows ENS, which is non-linearly related to average failure rate, restoration time and average load at each load point.

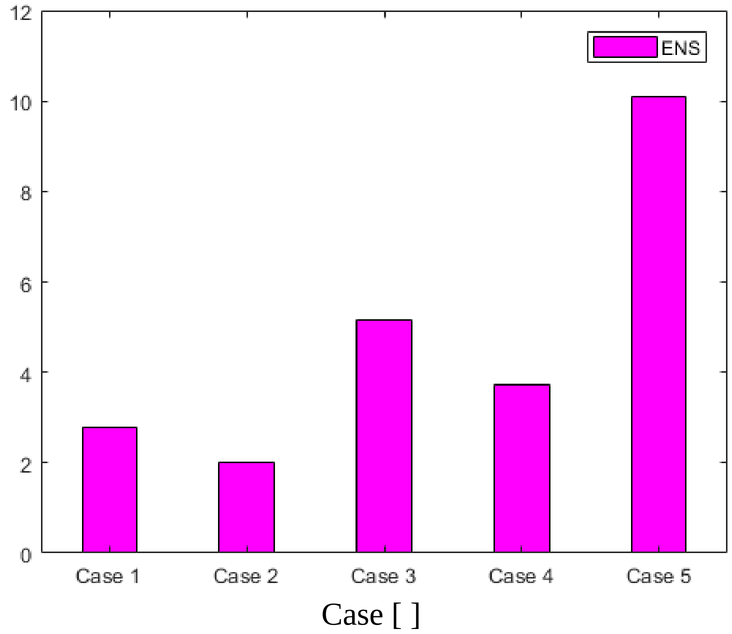


Figure 5. 4 Case North East England ENS

The percentage changes of ENS compared to Case 1 are investigated: the results show that it starts with 2.79 (MWH/yr), then decreases reaching almost 28% in Case 2 it increases significantly reaching 85% in Case 3 compared to Case 1 and around 156% compared with Case 2 In Case 4 it increases, reaching almost 39% compared to Case 1 but it decreases, reaching around 27% compared with Case 3. In the last case it increases significantly reaching 264% compared to Case 1 and around 173% compare with Case 4.

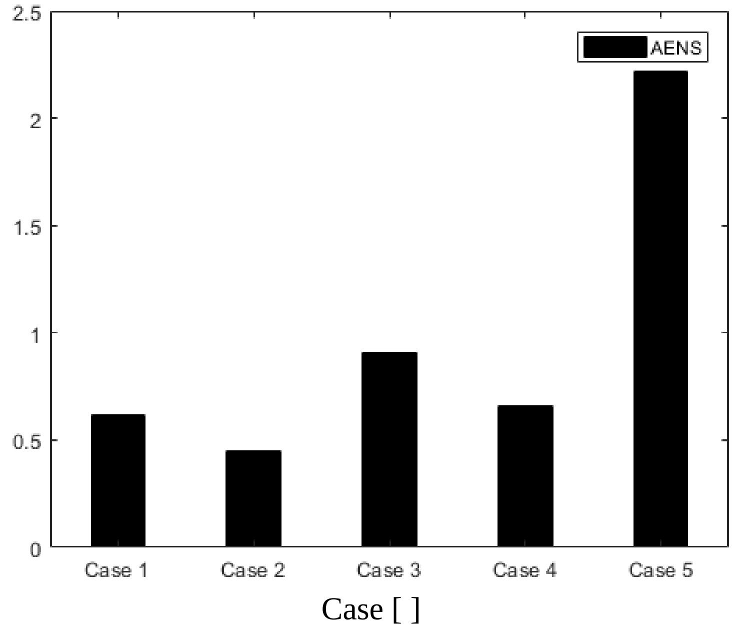


Figure 5. 5 Case North East England ANES

The percentage changes of ANES compared to Case 1 are investigated: the results show that it starts with 0.6146 (MWH/yr), then decreases reaching almost 28% in Case 2; it increases significantly reaching 85% in Case 3 compared to Case 1 and around 156% compared with Case 2. In Case 4 it increases, reaching almost 39% compared to Case 1 but it decreases, reaching around 27% compared with Case 3. In the last case it increases significantly reaching 264% compared to Case 1 and around 173% compare with Case 4.

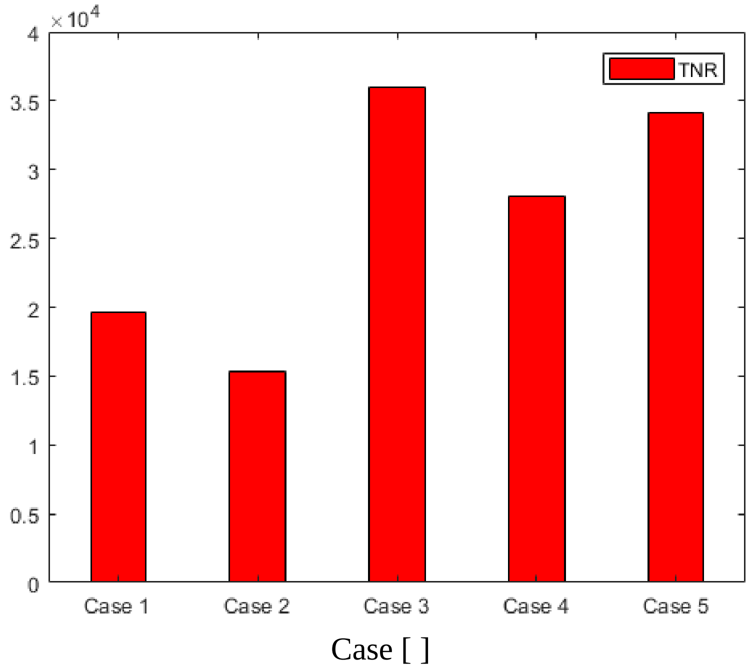


Figure 5. 6 Case North East England TNR

The TNR is mainly an aggregate of CI, CML and CR, and depends on SAIFI and SAIDI distributions. It can be seen from Figure 5. 6 that the TNR starts with £19.612, and then decreases reaching around 22% in Case 2. This is because SAIDI decreases too. In Case 3, it increases significantly, reaching almost 84%. The reason that both SAIFI and SAIDI increased by 47% is due to the components ageing. In Case 4, it increases, reaching 43% compared with Case 1, but it decreases by 22% compared with Case 3 while in Case 5, it increases by 76% compared with Case 1, and increases reaching 22% compared with Case 4.

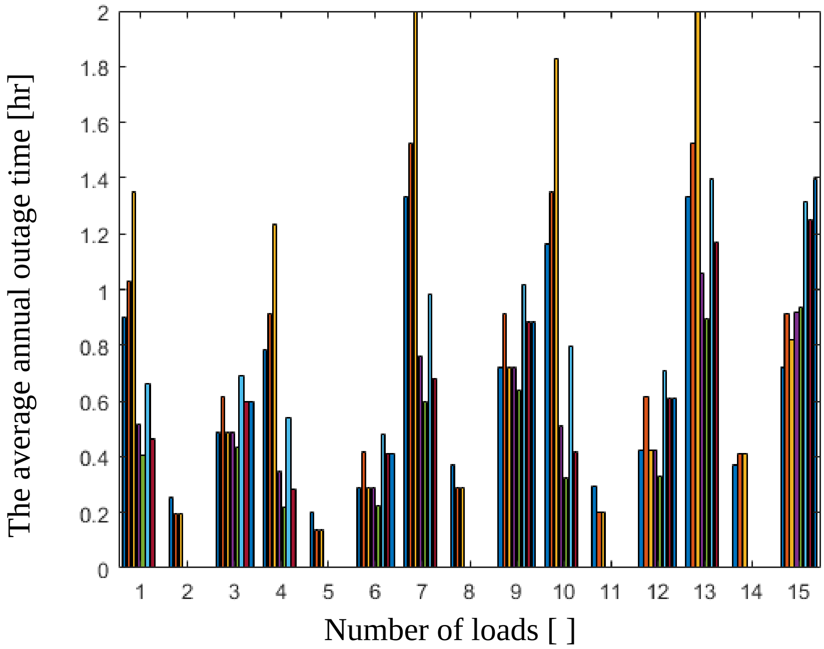


Figure 5. 7 average annual outage time

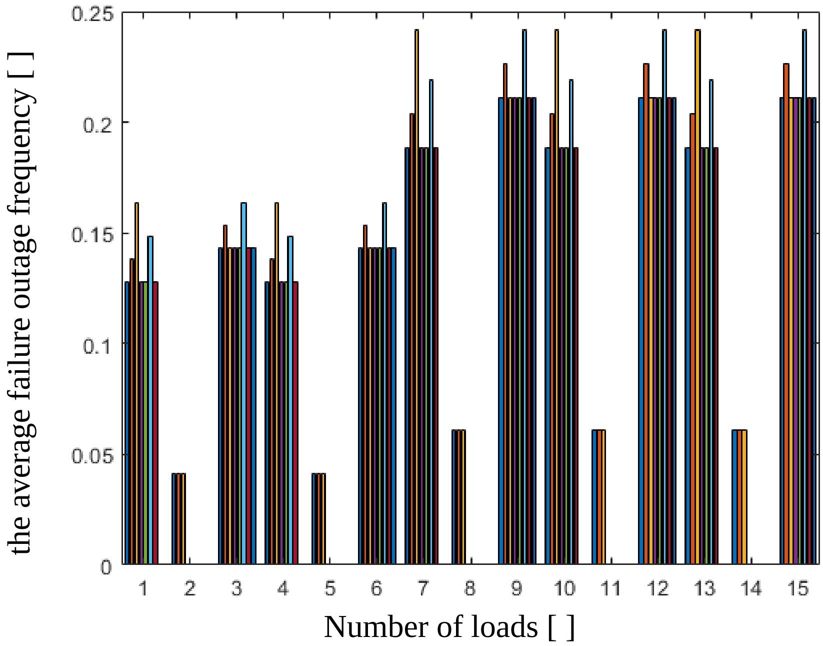


Figure 5. 8 average failure

For Scenario 1

	Calculated Result	Real Result
SAIFI	0.1275	0.1275
SAIDI	0.5734	0.5734
CAIDI	4.497	4.497
ENS	2.7914	2.7914
AENS	0.6146	0.6146
TNR	19613	19613

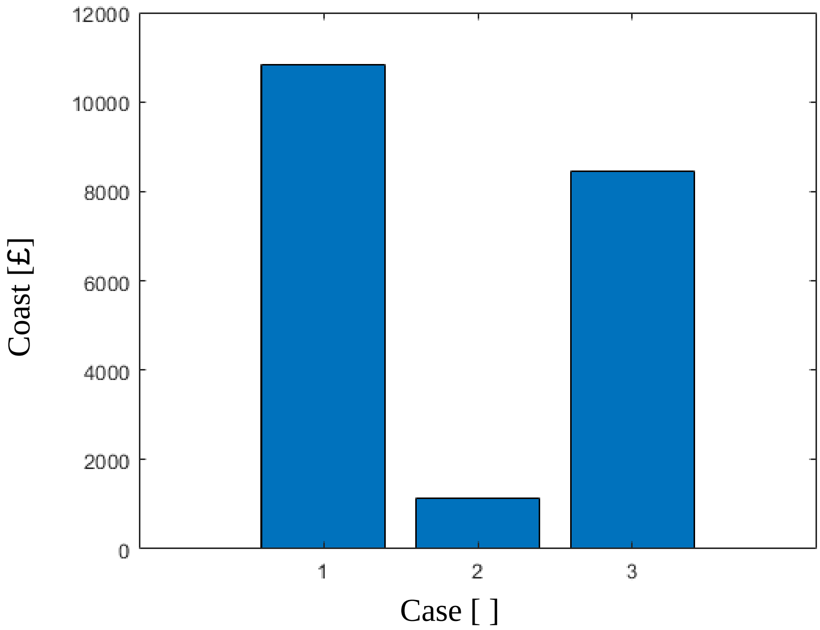


Figure 5. 9 Scenario 1 North East England TNR

The TNR is mainly an aggregate of CI, CML and CR, and depends on SAIFI and SAIDI distributions. It can be seen from Figure 5. 9 that the TNR starts with £ 10817.9, and then decreases reaching around 90% in **feeder** 2. This is because SAIDI decreases too. In **feeder** 3, it increases significantly, reaching almost 22%. The reason that both SAIFI and SAIDI increased is due to the components ageing

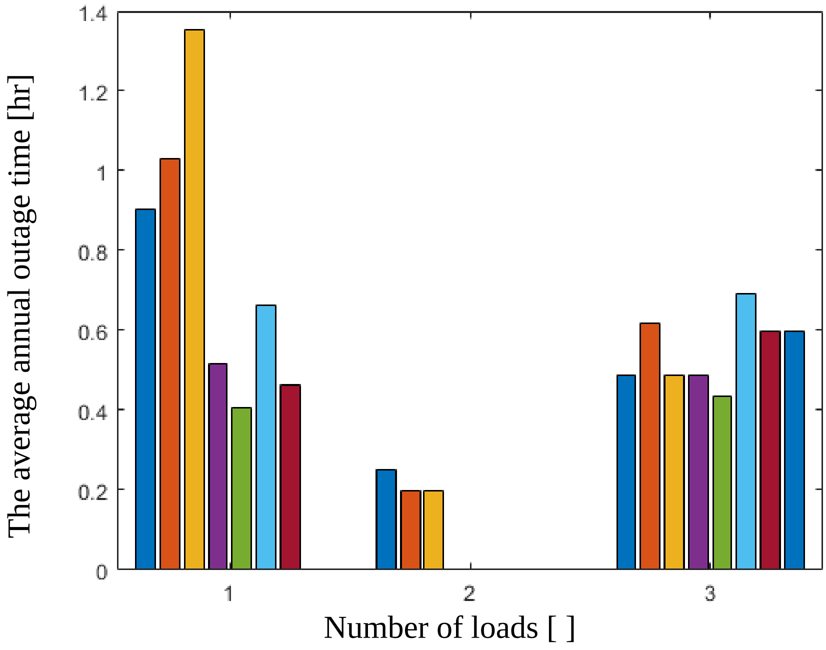


Figure 5. 10 average annual outage time

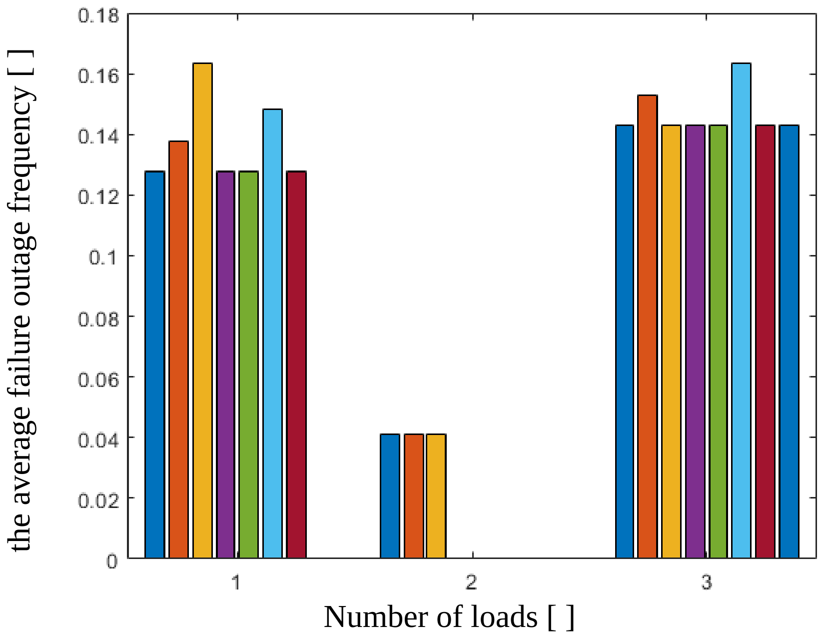


Figure 5. 11 average failure

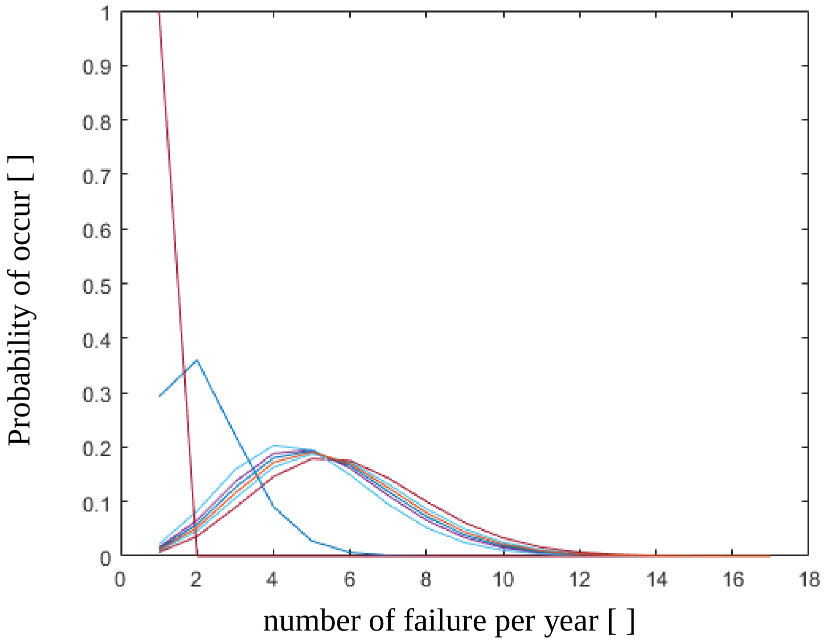


Figure 5. 12 Average failure probability

The notations used in the above equation are, λ, average failure rate of each load point, n, number of failures, t, time (per year for example). The above equation is used to evaluate the probability for the number of failures occurring in 1, 10 and 30 years at each load point. The calculated results for the number of failures at each load point for the system are given in Figure 5. 12 Average number of failures per (A) 10 years and (B) 30 years.

For Scenario 2

	Calculated Result	**Real Result**
SAIFI	0.1275	0.1275
SAIDI	0.4157	0.4157
CAIDI	3.259	3.259
ENS	2.0231	2.0231
AENS	0.4454	0.4454
TNR	15314	15314

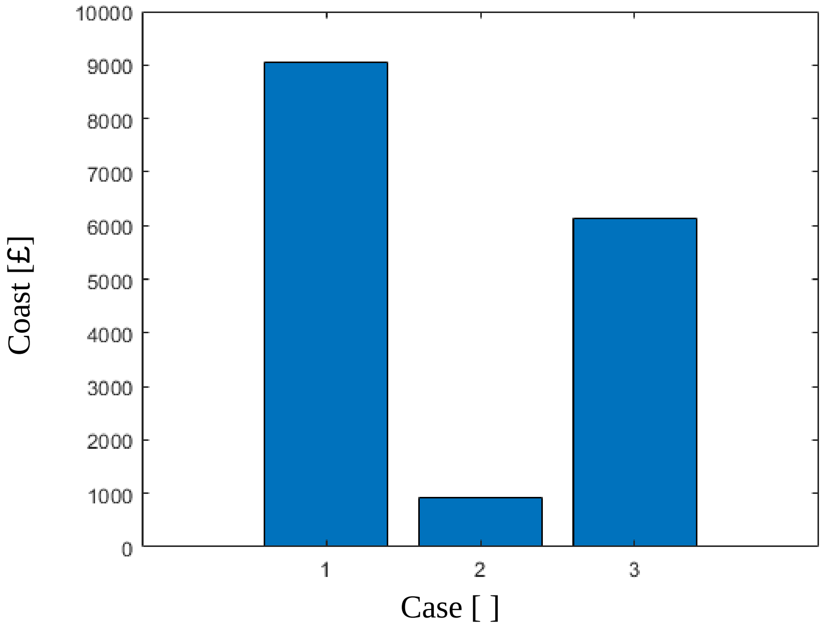


Figure 5. 13 Scenario 2 North East England TNR

The TNR is mainly an aggregate of CI, CML and CR, and depends on SAIFI and SAIDI distributions. It can be seen from Figure 5. 13 that the TNR starts with £ 19775.7and then decreases reaching around 90% in **feeder** 2. This is because SAIDI decreases too. In **feeder** 3, it decreases significantly, reaching almost 32%. This is because SAIDI decreases too

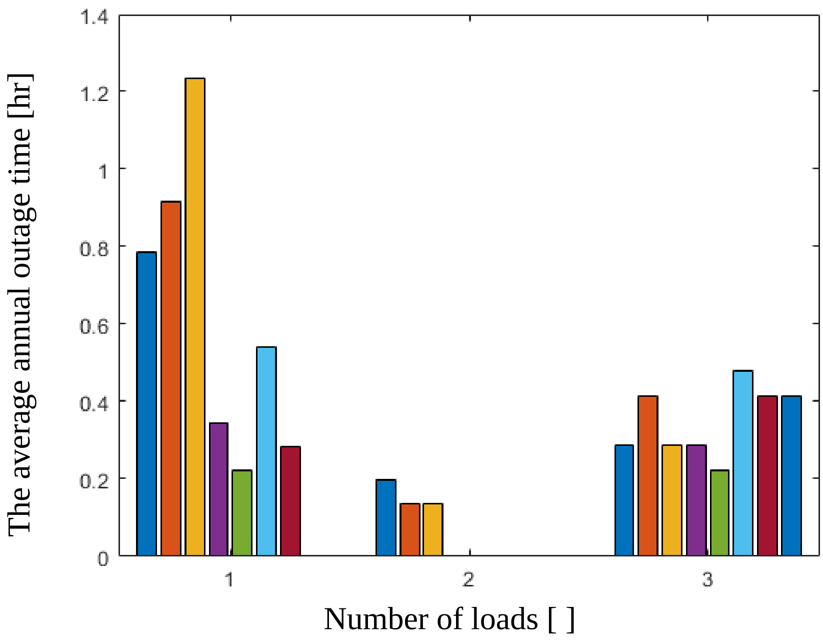


Figure 5. 14 average annual outage time

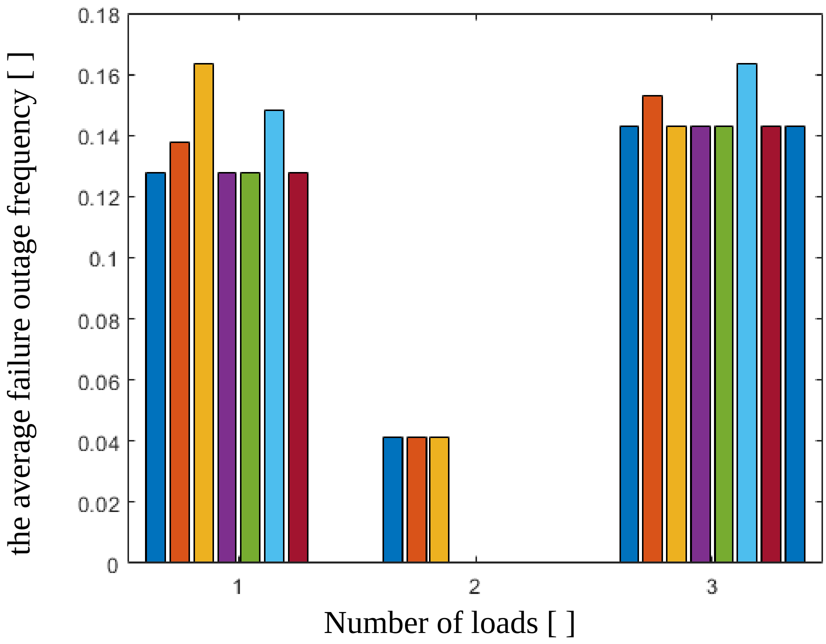


Figure 5. 15 average failure

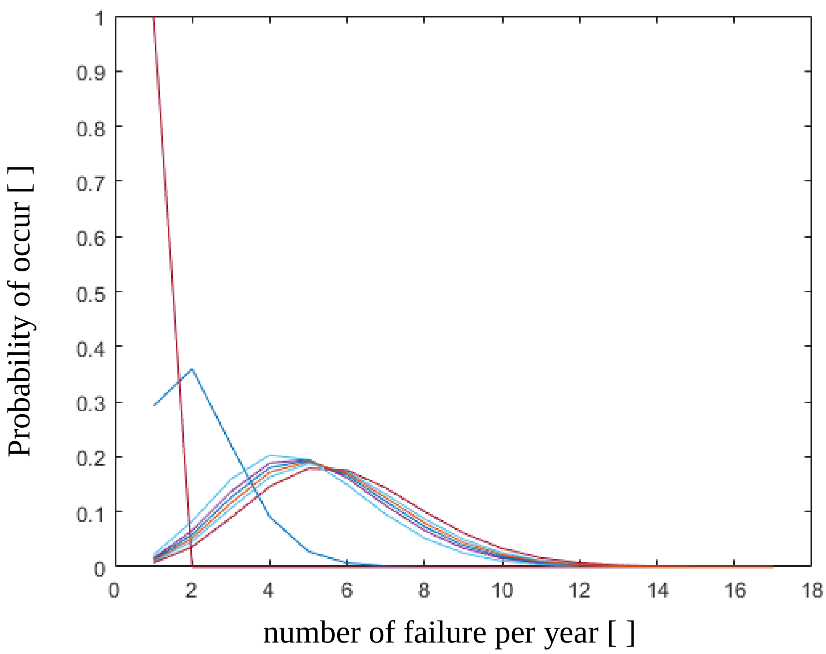


Figure 5. 16 Average failure probability

The notations used in the above equation are, λ, average failure rate of each load point, n, number of failures, t, time (per year for example). The above equation is used to evaluate the probability for the number of failures occurring in 1, 10 and 30 years at each load point. The calculated results for the number of failures at each load point for the system are given in Figure 5. 16 Average number of failures per (A) 10 years and (B) 30 years.

For Scenario 3

	Calculated Result	Real Result
SAIFI	0.1884	0.1884
SAIDI	0.8471	0.8471
CAIDI	4.4957	4.4957
ENS	5.1545	5.1545
AENS	0.9079	0.9079
TNR	36027.9	36027.9

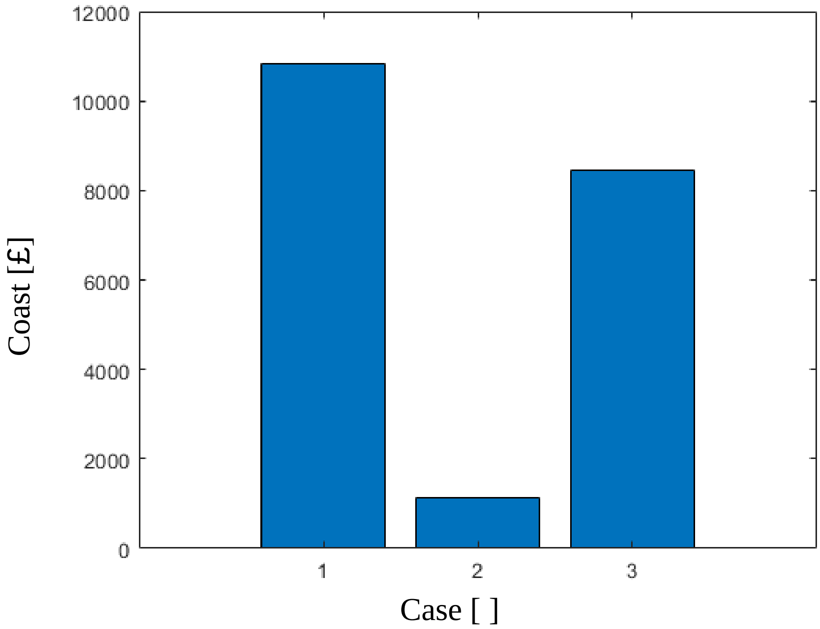


Figure 5. 17 Scenario 3 North East England TNR

The TNR is mainly an aggregate of CI, CML and CR, and depends on SAIFI and SAIDI distributions. It can be seen from Figure 5. 17 that the TNR starts with £ 19775.7and then decreases reaching around 90% in **feeder** 2. This is because SAIDI decreases too. In **feeder** 3, it decreases significantly, reaching almost 22%. This is because SAIDI decreases too

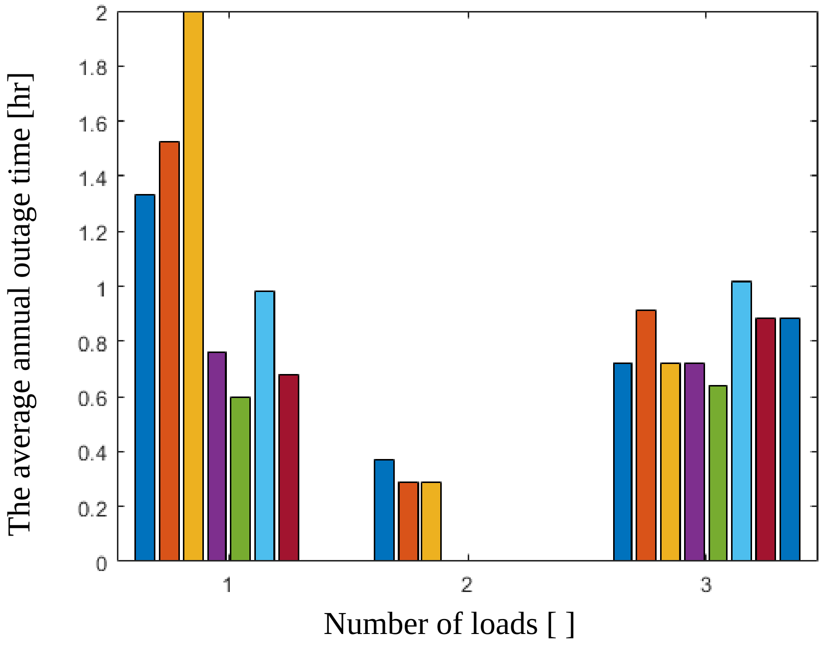


Figure 5. 18 average annual outage time

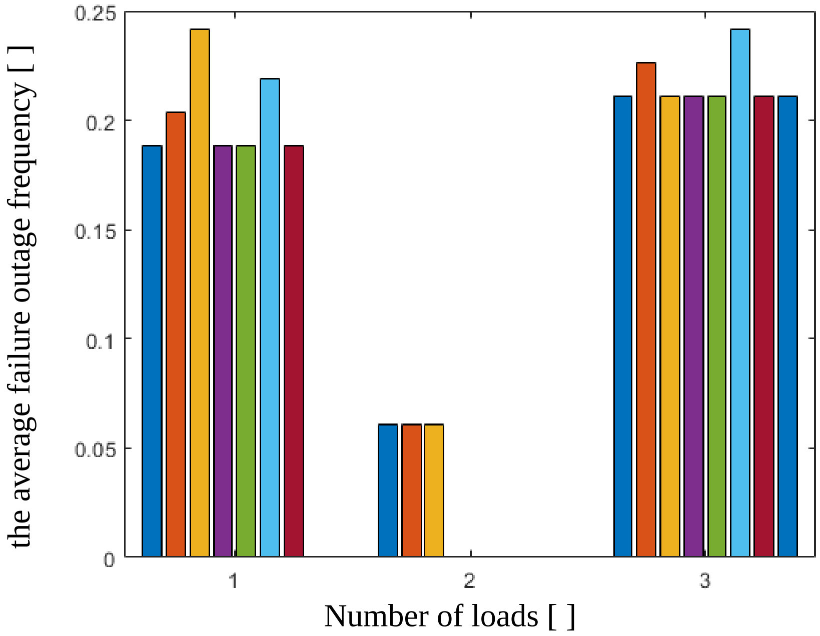


Figure 5. 19 average failure

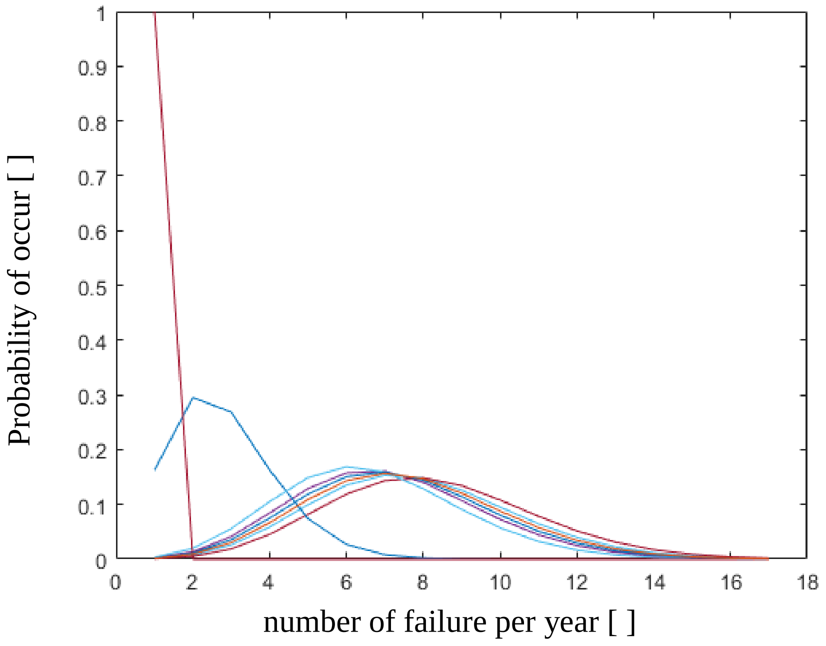


Figure 5. 20 Average failure probability

The notations used in the above equation are, λ, average failure rate of each load point, n, number of failures, t, time (per year for example). The above equation is used to evaluate the probability for the number of failures occurring in 1, 10 and 30 years at each load point. The calculated results for the number of failures at each load point for the system are given in Figure 5. 20 Average number of failures per (A) 10 years and (B) 30 years

For Scenario 4

	Calculated Result	Real Result
SAIFI	0.1884	0.1884
SAIDI	0.6141	0.6141
CAIDI	3.2590	3.2590
ENS	3.7358	3.7358
AENS	0.6580	0.6580
TNR	28090.5	28090.5

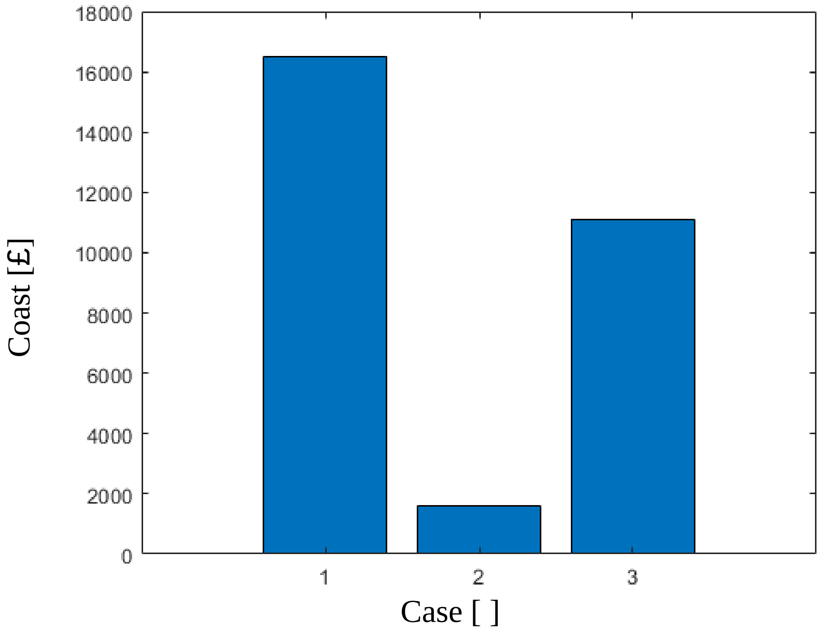


Figure 5. 21 Scenario 4 North East England TNR

The TNR is mainly an aggregate of CI, CML and CR, and depends on SAIFI and SAIDI distributions. It can be seen from Figure 5. 21 that the TNR starts with £ 16510.4 and then decreases reaching around 90% in **feeder** 2. This is because SAIDI decreases too. In **feeder** 3, it decreases significantly, reaching almost 32%. This is because SAIDI decreases too

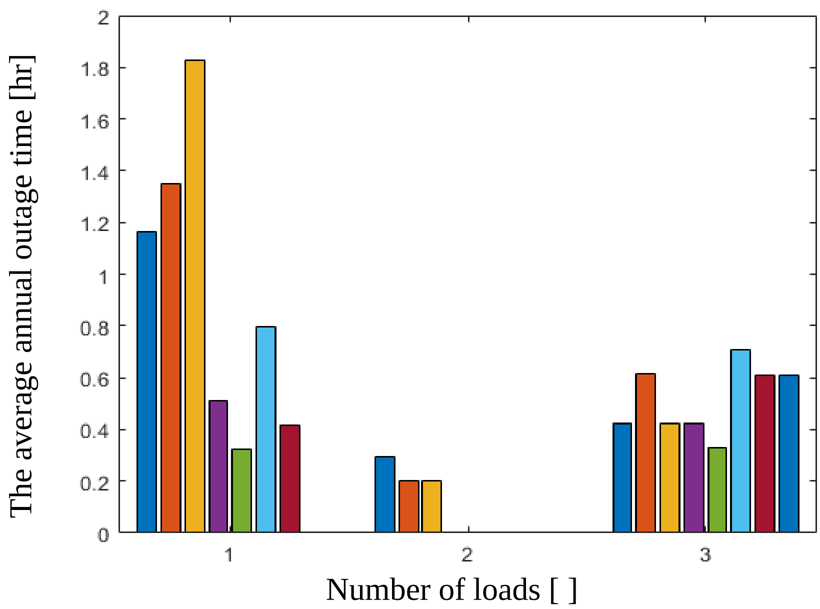


Figure 5. 22 average annual outage time

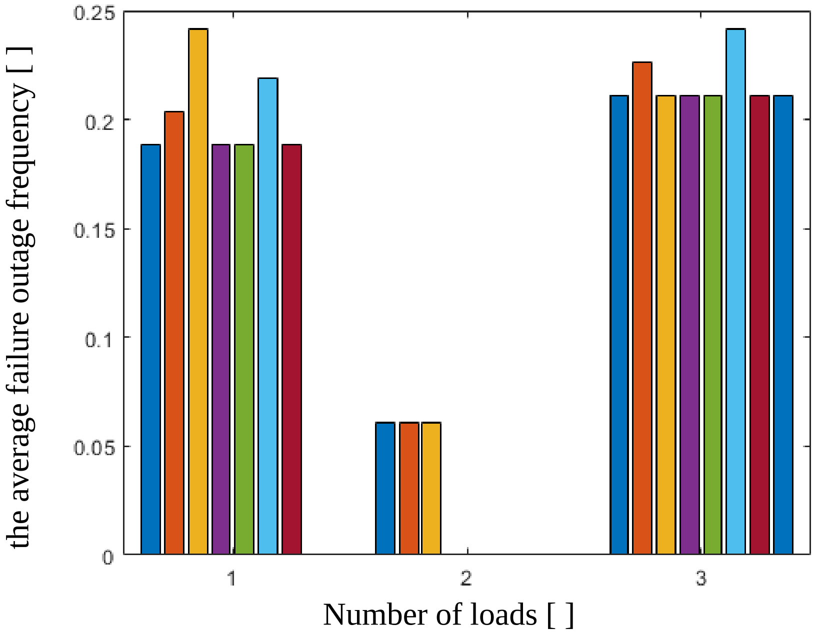


Figure 5. 23 average failure

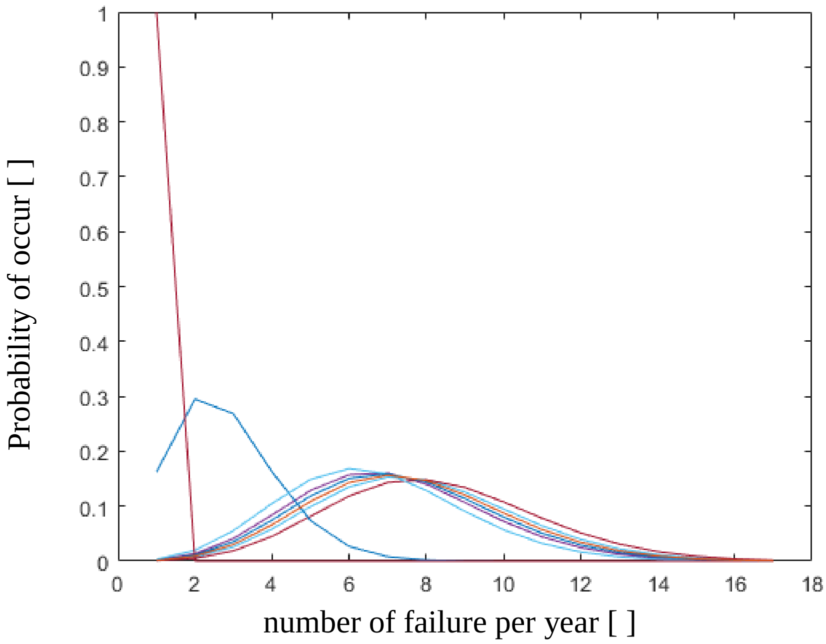


Figure 5. 24 Average failure probability

The notations used in the above equation are, λ, average failure rate of each load point, n, number of failures, t, time (per year for example). The above equation is used to evaluate the probability for the number of failures occurring in 1, 10 and 30 years at each load point. The calculated results for the number of failures at each load point for the system are given in Figure 5. 24 Average number of failures per (A) 10 years and (B) 30 years.

For Scenario 5

	Calculated Result	Real Result
SAIFI	0.1884	0.1884
SAIDI	1.0351	1.0351
CAIDI	5.4938	5.4938
ENS	10.0777	10.0777
AENS	2.2188	2.2188
TNR	34098.2	34098.2

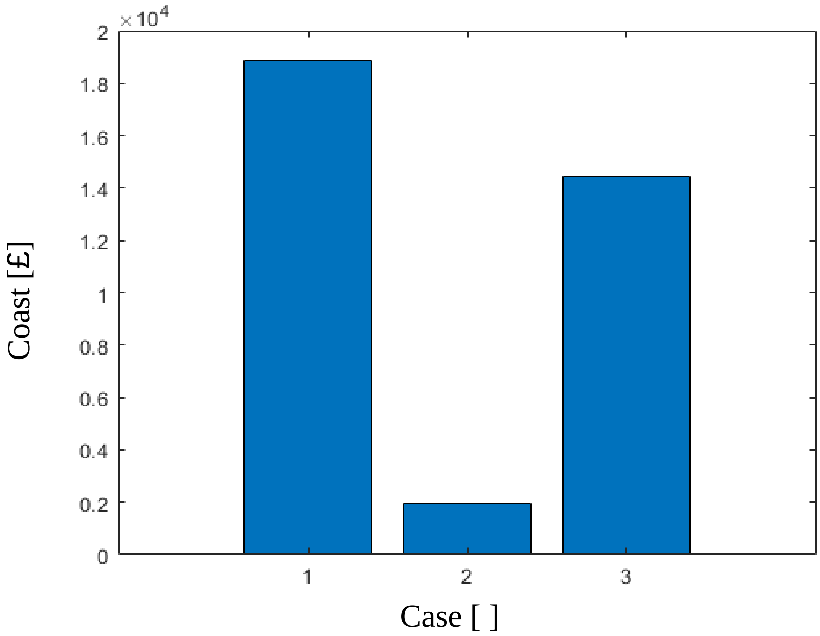


Figure 5. 25 Scenario 4 North East England TNR

The TNR is mainly an aggregate of CI, CML and CR, and depends on SAIFI and SAIDI distributions. It can be seen from Figure 5. 25 that the TNR starts with £ 18863.6 and then decreases reaching around 90% in **feeder** 2. This is because SAIDI decreases too. In **feeder** 3, it decreases significantly, reaching almost 23%. This is because SAIDI decreases too

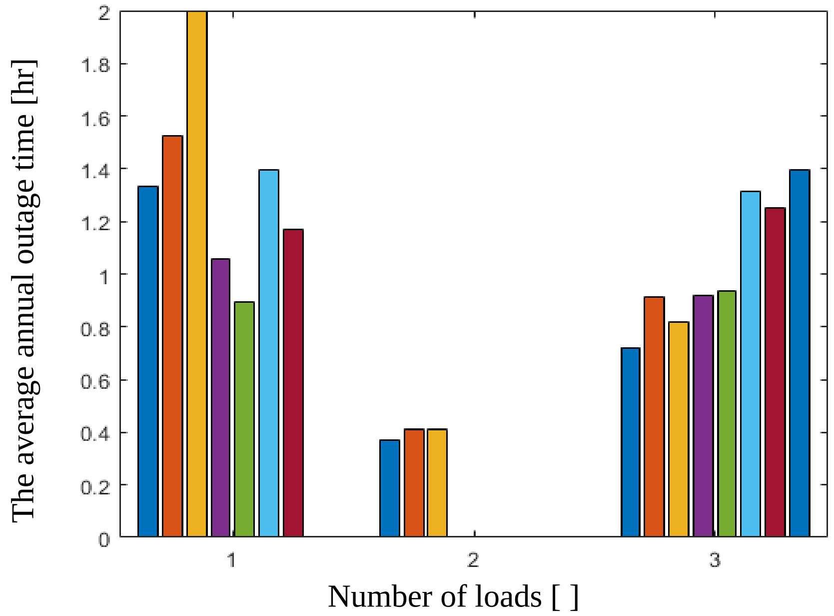


Figure 5. 26 average annual outage time

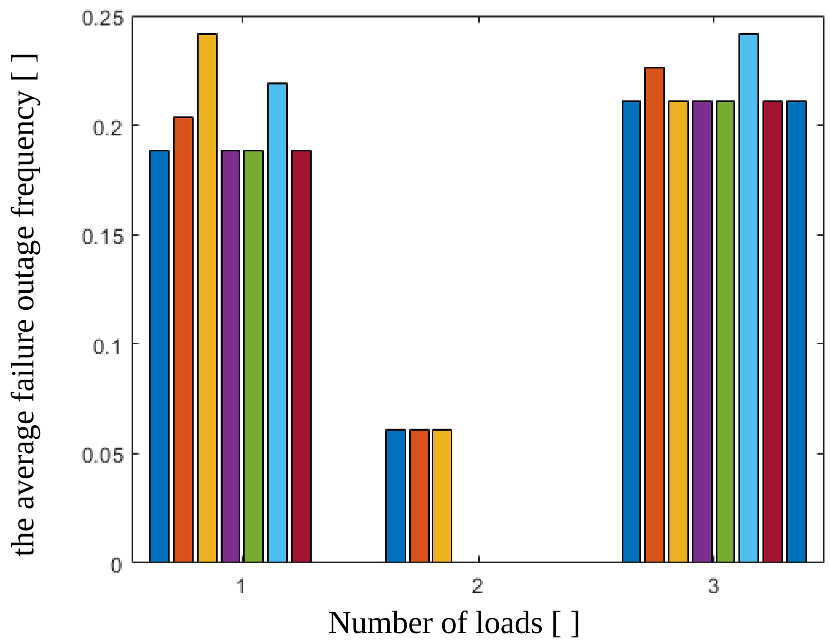


Figure 5. 27 average failure

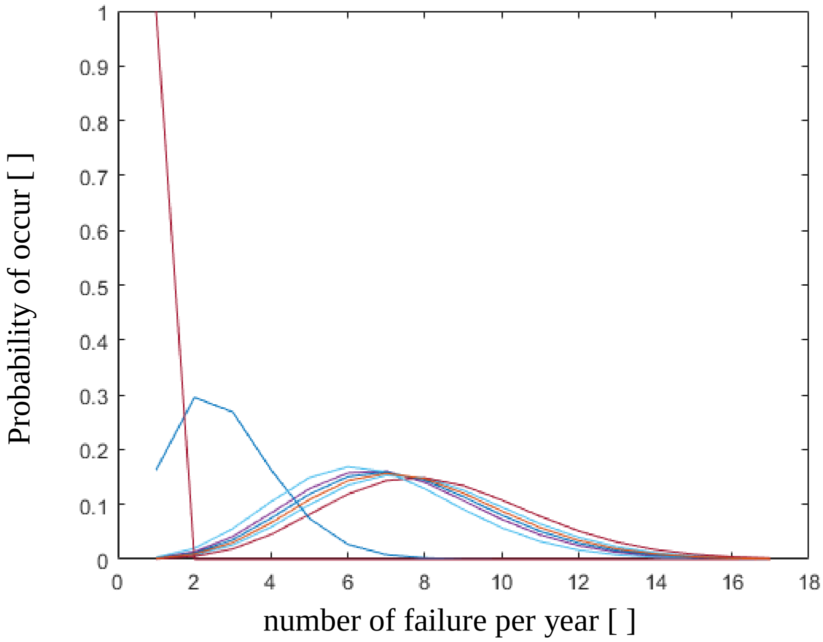


Figure 5. 28 Average failure probability

The notations used in the above equation are, λ, average failure rate of each load point, n, number of failures, t, time (per year for example). The above equation is used to evaluate the probability for the number of failures occurring in 1, 10 and 30 years at each load point. The calculated results for the number of failures at each load point for the system are given in Figure 5. 28 Average number of failures per (A) 10 years and (B) 30 years.

5.9. Case HEBCo

Open point is between LP7 in feeder 1. However, each feeder is basically an 11 kV system that is fed at 33 kV from the substation (PRIMARY) and has both 11 kV and 0.4 kV load points. The 0.4 kV system is connected to each 11/0.4 kV transformer. The basic configuration of the protection system is so that each feeder is equipped with breakers B1 and B2 , to protect the substation. There are fuses located on both sides of 11/0.4 kV transformers to protect and prevent a transformer fault affecting the rest of the system, while the disconnectors are used to isolate the line.

This data reflects the reliability of the system every month during the year, where values such as the annual duration, and the imposition of values such as time period and number of customers were neglected, thus, a modification of the MATLAB code was made. In other words, part of the code was abbreviated

```
%TNRSYSTEM=0
%lamdaTR=0.002%input('Average failure rate for Transformer=')
%TimeTR=5.1%input('Average outage time for Transformer=')
%lamdaCB=0.0033%input('Average failurerate for Circute Breaker=')
%TimeCB=4%input('Average outage time for Circuit Breaker=')
lamda=1%input('Average failure rate for cable =')
cost=6%input('CI cost per customer (£):')
ccm=0.1%input('CML customer/min (£):')
ti=60%input('Time of the Interruption per Minutes(hour to min):')
crc=4000%input('CR cost  £:')
%year=25%input('Year =')
%Avg=0.01%%input('average growth load=')
%flu=0.8
%pint=0.05
%R0=lamda*flu
%Ra=(lamda-R0)/(1+pint)^40
%R1=lamdaTR*flu
%R2=(lamdaTR-R1)/(1+pint)^40
%inturrTR=R1+(R2*((1+pint)^(40+year)))
%RZCB=lamdaCB*flu
%RACB=(lamdaCB-RZCB)/(1+pint)^40
%inturrCB=RZCB+(RACB*((1+pint)^(40+year)))
%inturrCABLE=R0+(Ra*((1+pint)^(40+year)))
```

However, accurate results from the new methodology have been presented

	Calculated Result	Real Result	Error
SAIFI	**937.02000**	**940.61000**	**0.3816000000%**
SAIDI	**784.97380**	**786.01344**	**0.1322670000%**
CAIDI	**83.77330**	**84.00000**	**0.2698809524%**
ASAI	**87.89000**	**87.87000**	**0.0227600000%**

Based on the data and results achieved in the British system and the HEBCO system and based on the matching of the results we proceeded to evaluate the Om Al-Dalya transformer.

Om Al-Dalya

This examines one practical part of the MV network in the Palestine The network used in this study is the radial distribution system, which represents typical urban distribution systems consisting of residential and industrial customers. The first point is between LP3 in feeder Almakana and LP11 in feeder Mafrak Alsaheb , and LP10 in feeder Concrete Zalloum and LP7 in feeder ,Polytechnic. However, each feeder is basically an 11 kV system that is fed at 33 kV from the substation (PRIMARY) and has both 11 kV and 0.4 kV load points. The 0.4 kV system is connected to each 11/0.4 kV transformer. The basic configuration of the protection system is so that each feeder is equipped with breakers B1, B2 , B3and B4 to protect the substation. There are fuses located on both sides of 11/0.4 kV transformers to protect and prevent a transformer fault affecting the rest of the system, while the disconnectors are used to isolate the line.

In order to evaluate the reliability model, the basic component data for the failures, the time of the operation needed to deal with each failure mode, and restoration process are needed. In addition, the data of maintenance and replacement intensity are essential elements for sufficient evaluation. These are given in Table 5. 4 where average failure rates and the restoration time for the components are adopted from the NAFIRS report, five cases were considered for comparing the results of the proposed methods.

Table 5. 4 basic component data for the failures

Components	Λp [f/yr]	λT [f/yr]	RpT [h]	RT [h]	SwT/Aut [h]	SwT/Man [h]	RcT [h]
			Transformers				
33/11 kV	0.002	0.05	15	-	0.667	1.783	0.083
11/0.4 kV	0.002	-	15	5.1	0.667	1.783	-
			Breakers				
33 kV	0.001	0.02	4	4	1		0.083
11kV	0.0033	0.06	4	4	1		0.083
			Overhead lines				
11kV	0.091	-	5	5	0.667	1.783	-
			Cables				
11 kV	0.051	-	30	12.58	0.667	1.783	-

This transformer contains four feeders (Almakana ,Mafrak Alsaheb , Concrete Zalloum ,Polytechnic) , Cutting ratio is adopted depending on the length of the line , The number of consumers is dependent on the size of the adapter, Due to the lack of data, interrupting time was taken from the British system

Mafrak Alsaheb			
Name	**Length**	**Number of customer**	**Load per person**
Mafrak Alsaheb	0.410	30	30
Atrash	0.175	18	18
Atrash	0.365	12	12
Bahaa	0.670	30	30
Al Etisalat	0.370	1	1
Eysa shabana	0.300	30	30
Eysa shabana	0.165	12	12
Eysa shabana	0.175	12	12
Mashrw	0.560	18	18
Karaj	0.640	1	1
Municipality	0.080	1	150

Concrete Zalloum			
Name	**Length**	**Number of customer**	**Load per person**
Hamza Jamel	0.670	18	18
Concrete Zalloum	0.360	1	150
Concrete Zalloum	0.200	1	150
Concrete Zalloum	0.320	29	4350
LS	0.890	18	18
LS	0.094	1	1
LS	0.090	29	29
LS	0.170	18	18
Naseer Jamel	0.032	18	18
Naseer Jamel	0.170	8	8

Almakana			
Name	**Length**	**Number of customer**	**Load per person**
Almakana	1	1	1
Jame	0.4	12	12
Jame	0.22	8	8

Polytechnic			
Name	**Length**	**Number of customer**	**Load per person**
PPU	1.380	1	150
PPU	0.235	29	4350
Ganem	0.200	1	1
PPU	0.184	1	150
PPU	0.184	1	150
PPU	0.105	29	29
Shawer	0.184	18	18

Table 5. 5 Indices For The Om Al-Dalya System Case

	Calculated Result
SAIFI	0.2484

SAIDI	1.5687
CAIDI	6.3161
ENS	27.5939
AENS	67.7982
TNR	5430.6000

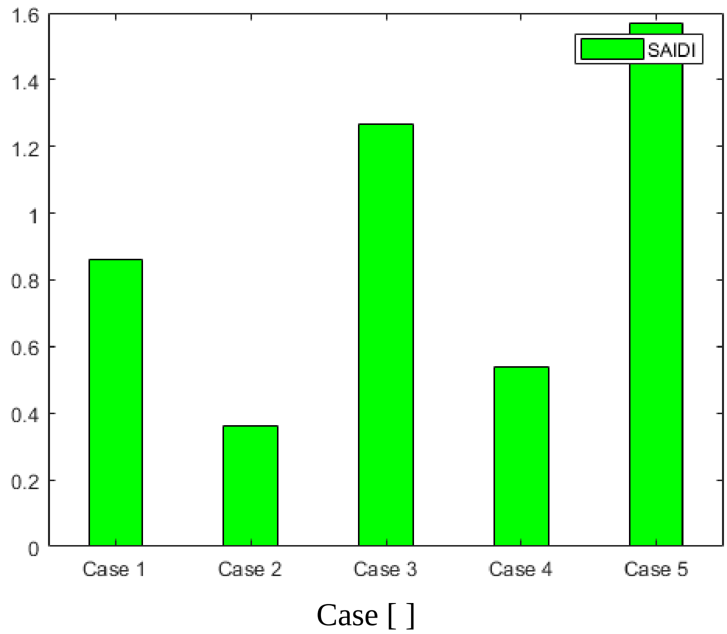
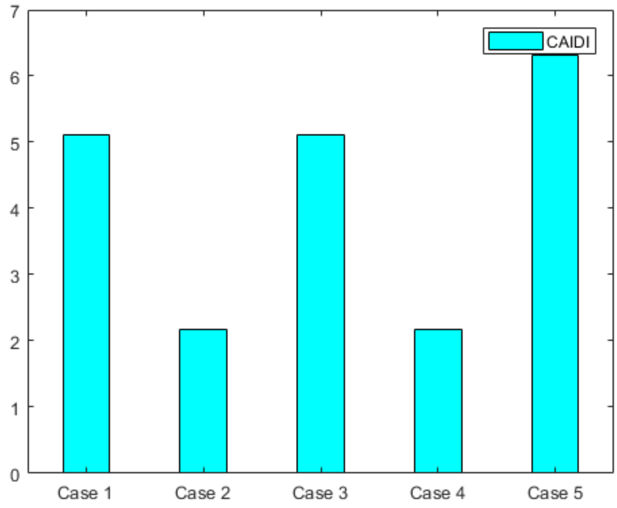


Figure 5. 29 Om Al-Dalya SAIDI

The SAIDI mainly measures the total duration of an interruption for the average customer during a given time period, which is normally per year. Figure 5. 29 shows calculated values for SAIDI under five different cases. The percent changes of SAIDI compared to Case 1 are investigated. However, it starts with 0.8587 (hours/customer yr), then decreases reaching almost 57% in Case 2. It increases significantly reaching 48% in Case 3, and then it increases slowly reaching around 59% in Case 4 compared with Case 1 but decreases reaching 57% compared with Case3. In Case 5, it increases significantly, reaching 82% compared with Case 1 and 191% compared with Case 4. The results clearly show that SAIDI depends on failure rate of components, which is increased significantly in 3rd, 4th and 5th case due to components aging. Furthermore, it depends on restoration time, which is decreased significantly in case 2 and case 4 due to automated operation.



Case [ ]

Figure 5. 30 Om Al-Dalya CAIDI

shows CAIDI over five case studies. The results show that it is more sensitive to automated operation. The percentage changes of CAIDI compared to Case 1 start with 5.1079 (h/CI), and then decreases reaching around 57% in Case 2. In Case 3, it remains the same as Case 1 but increases reaching 137% compared with Case 2, while in Case 4 it decreases again reaching 57% compared with Case 1. In Case 5, it increases, reaching 23% compared with Case 1 and it increases significantly, reaching 192%, compared with Case 4. However, CAIDI is reduced in Case 2 compared with Case 1, despite both cases having the same average failure rate and number of customers. The reason is that the faults have a shorter repair time in Case 2 due to automated operation. This means that the average repair time for affected customers is shorter. The same comparison is between Case 3 and Case 4. Figure 5. 32 also shows ENS, which is non-linearly related to average failure rate, restoration time and average load at each load point.

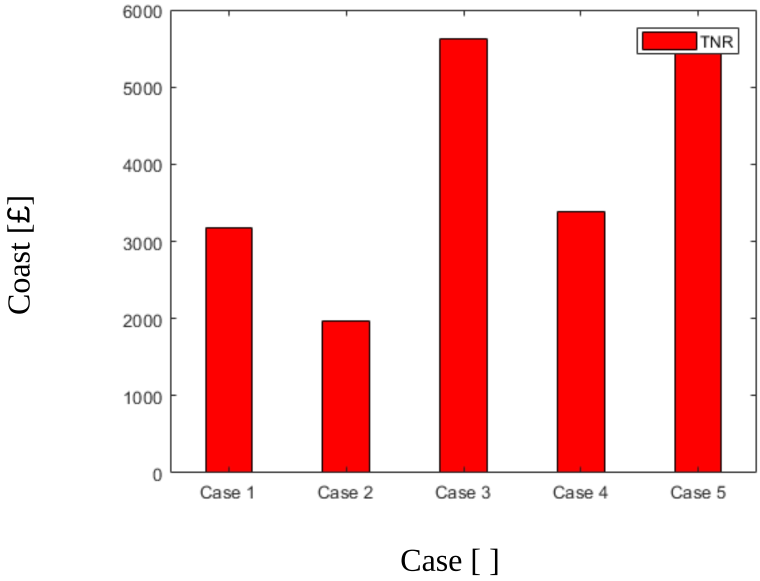


Figure 5. 31 Om Al-Dalya TNR

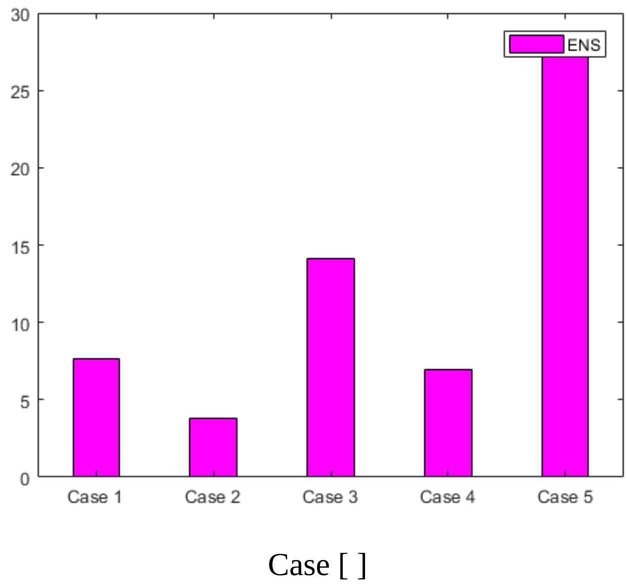
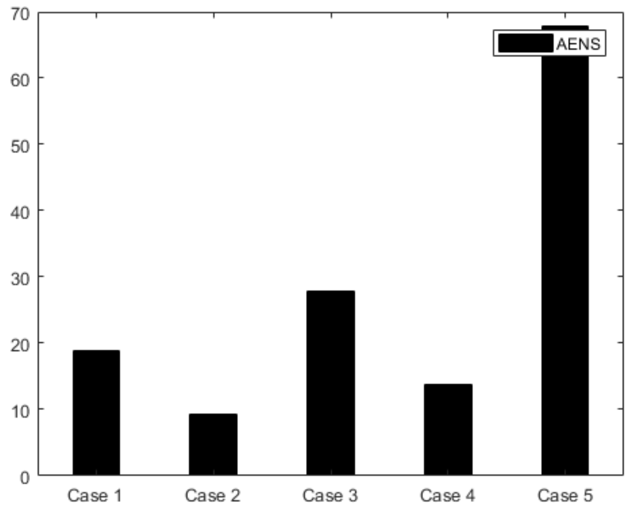


Figure 5. 32 Om Al-Dalya ENS

The percentage changes of ENS compared to Case 1 are investigated: the results show that it starts with 7.6650 (MWH/yr), then decreases reaching almost 51% in Case 2; it increases significantly reaching 85% in Case 3 compared to Case 1 and around 275% compared with Case 2 In Case 4 it increases, reaching almost 10% compared to Case 1 but it decreases, reaching around

50% compared with Case 3. In the last case it increases significantly reaching 260% compared to Case 1 and around 295% compare with Case 4.



Case [ ]

Figure 5. 33 Om Al-Dalya ANES

The percentage changes of ENS compared to Case 1 are investigated: the results show that it starts with 18.8330 (MWH/yr), then decreases reaching almost 51% in Case 2; it increases significantly reaching 85% in Case 3 compared to Case 1 and around 275% compared with Case 2 In Case 4 it increases, reaching almost 10% compared to Case 1 but it decreases, reach in around 50% compared with Case 3. In the last case it increases significantly reaching 260% compared to Case 1 and around 295% compare with Case 4. Case 1, and increases reaching 60% compared with Case 4.

TNR	
Case1	**3180.1**
Case2	**1971.3**
Case3	**5623.9**
Case4	**3391.8**
Case5	**5430.6**

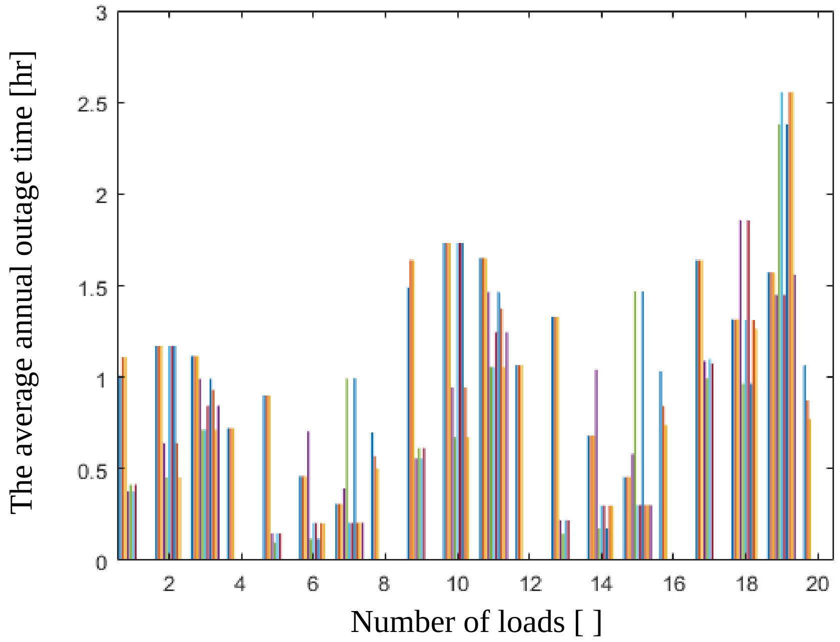


Figure 5. 34 average annual outage time

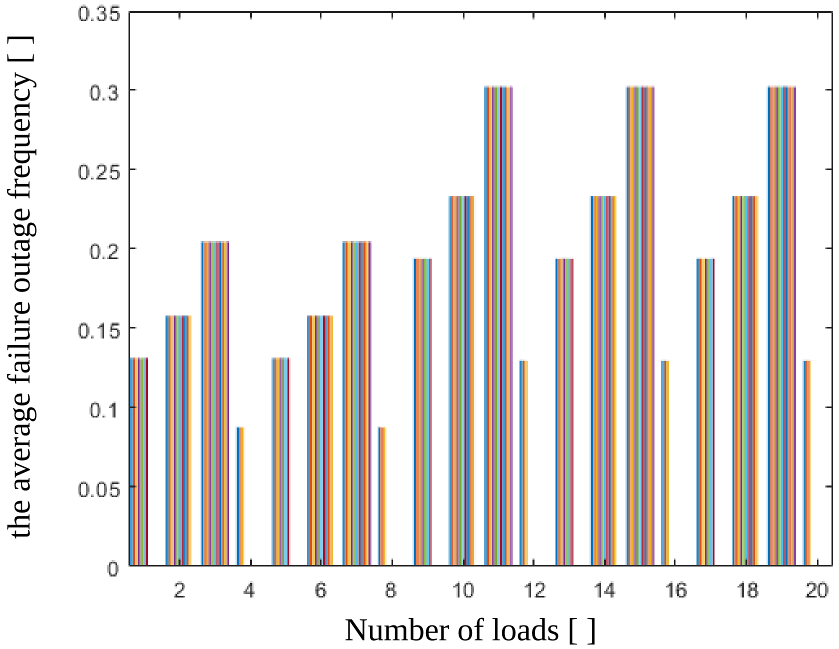


Figure 5. 35 average failure

For Scenario 1

	Calculated Result
SAIFI	0.1681
SAIDI	0.8587
CAIDI	5.1079
ENS	7.6650
AENS	18.8330
TNR	3180.1

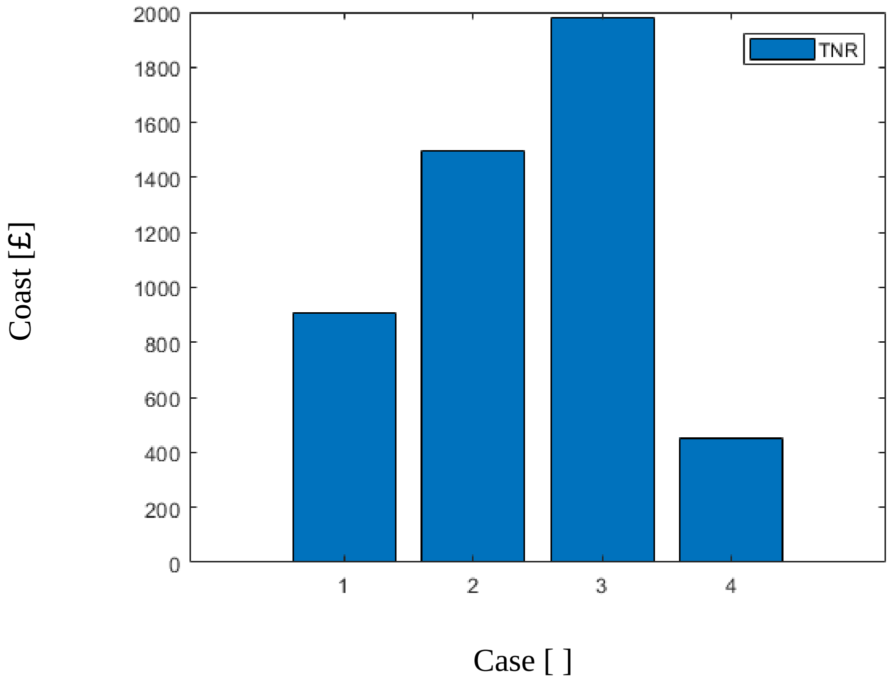


Figure 5. 36 Scenario 1 Om Al-Dalya TNR

The TNR is mainly an aggregate of CI, CML and CR, and depends on SAIFI and SAIDI distributions. It can be seen from Figure 5. 36 that the TNR starts with £ 930, and then increases reaching around 40% in feeder 2. In feeder 3, it increases significantly, reaching almost 68%. The reason that both SAIFI and SAIDI increased is due, and then decreases reaching around 40% in feeder 4. This is because SAIDI decreases too. components ageing .

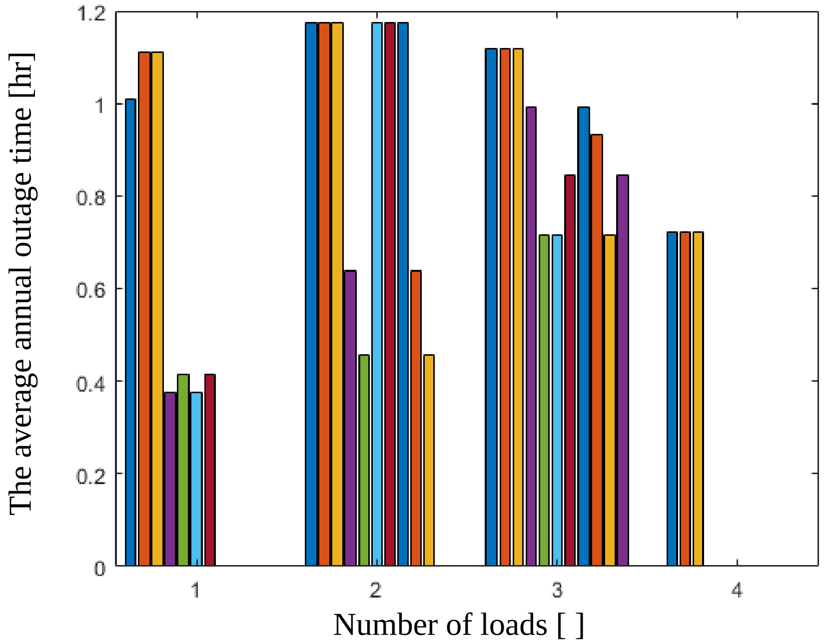


Figure 5. 37 average annual outage time

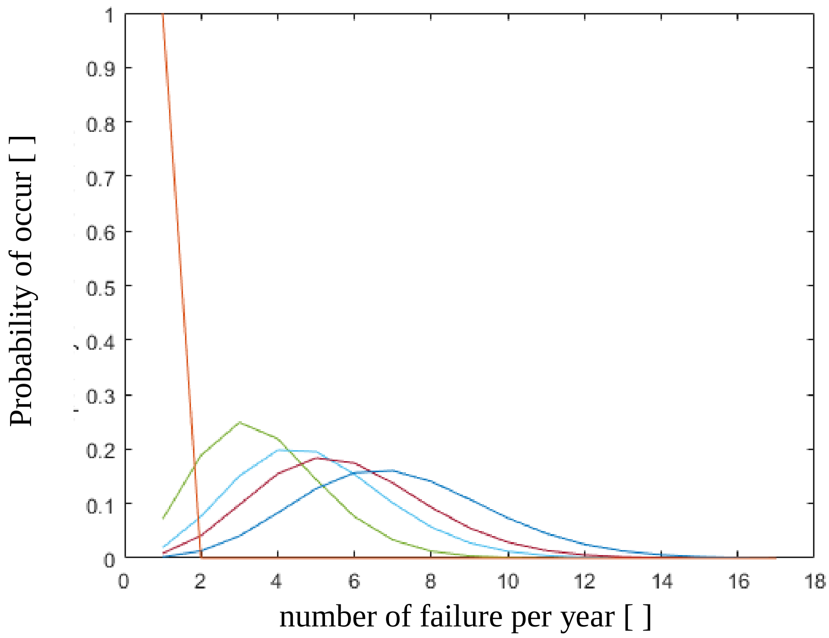


Figure 5. 38 Average failure probability

The notations used in the above equation are, λ, average failure rate of each load point, n, number of failures, t, time (per year for example). The above equation is used to evaluate the probability for the number of failures occurring in 1, 10 and 30 years at each load point. The calculated results for the number of failures at each load point for the system are given in Figure 5. 38 Average number of failures per (A) 10 years and (B) 30 years.

For Scenario 2

	Calculated Result
SAIFI	0.1681
SAIDI	0.3637
CAIDI	2.1636
ENS	3.7787
AENS	9.2842
TNR	1971.3000

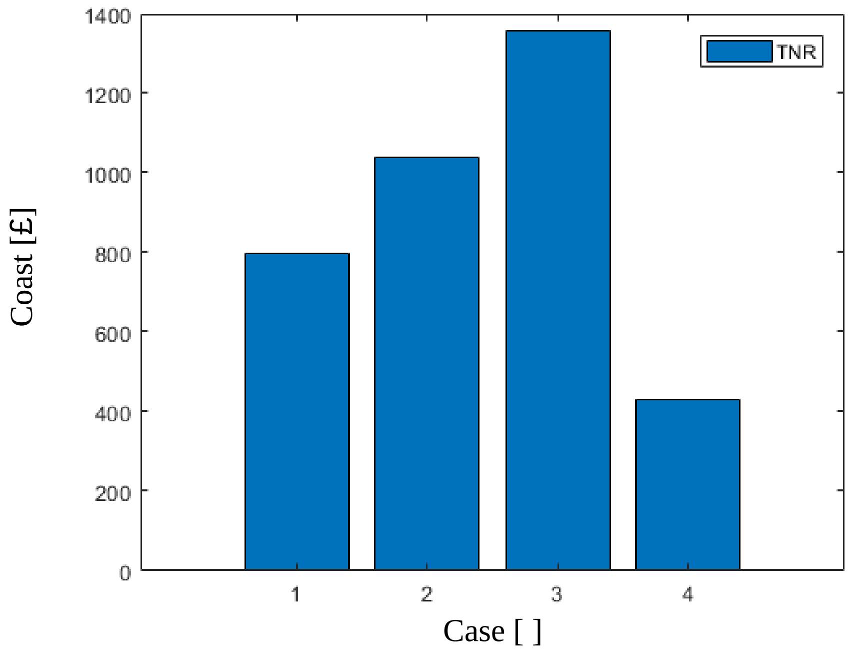


Figure 5. 39 Scenario 2 Om Al-Dalya TNR

The TNR is mainly an aggregate of CI, CML and CR, and depends on SAIFI and SAIDI distributions. It can be seen from Figure 5. 39 that the TNR starts with £805, and then increases reaching around 20% in feeder 2. In feeder 3, it increases significantly, reaching almost47%. The reason that both SAIFI and SAIDI increased is due, and then decreases reaching around 38% in feeder 4. This is because SAIDI decreases too. components ageing .

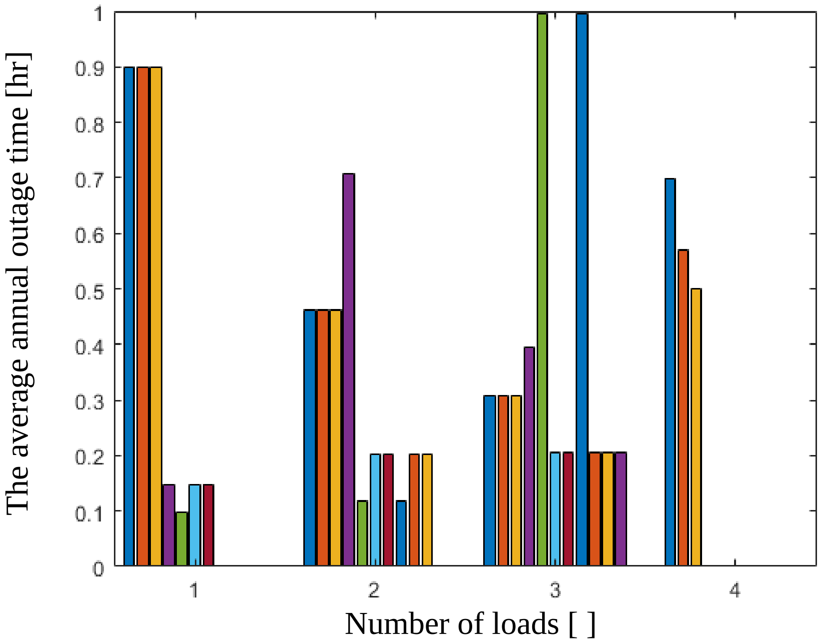


Figure 5. 40 average annual outage time

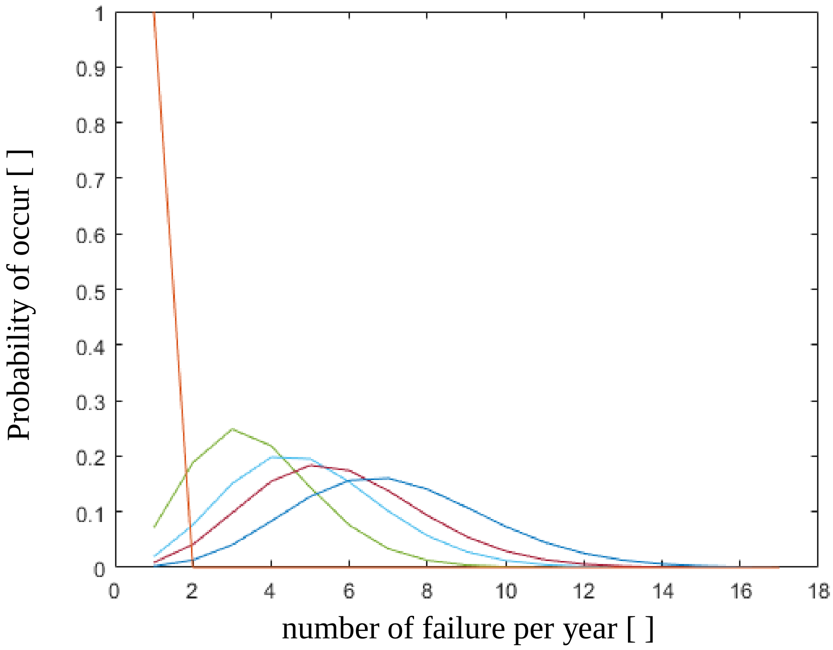


Figure 5. 41 Average failure probability

The notations used in the above equation are, λ, average failure rate of each load point, n, number of failures, t, time (per year for example). The above equation is used to evaluate the probability for the number of failures occurring in 1, 10 and 30 years at each load point. The calculated results for the number of failures at each load point for the system are given in Figure 5. 41   Average number of failures per (A) 10 years and (B) 30 years.

For Scenario 3

	Calculated Result
SAIFI	0.2484
SAIDI	1.2686
CAIDI	5.1079
ENS	14.1542
AENS	27.8215
TNR	5623.9000

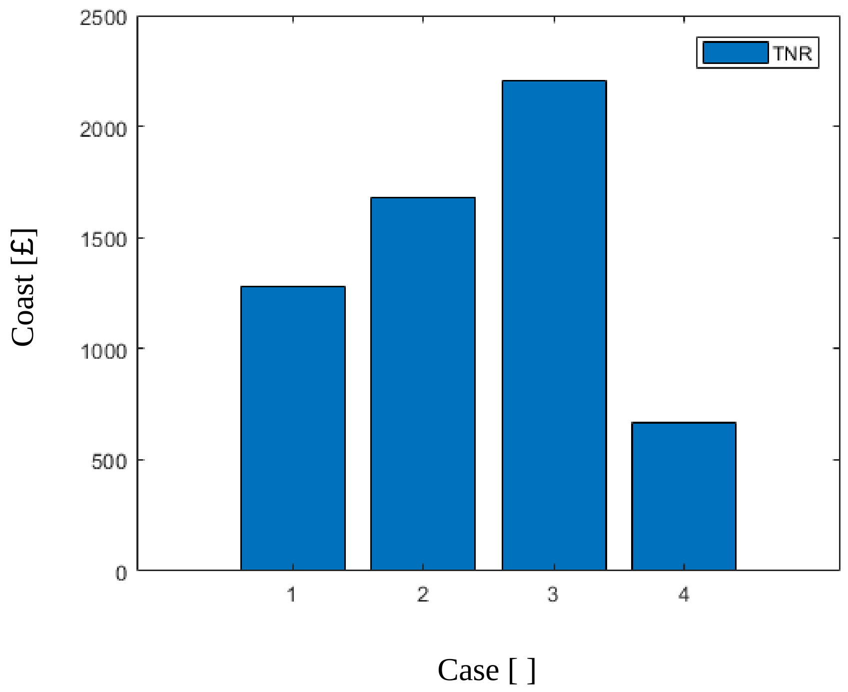


Figure 5. 42 Scenario 3 Om Al-Dalya TNR

The TNR is mainly an aggregate of CI, CML and CR, and depends on SAIFI and SAIDI distributions. It can be seen from Figure 5. 42   that the TNR starts with £1343, and then increases reaching around 15% in feeder 2. In feeder 3, it increases significantly, reaching almost 40%. The reason that both SAIFI and SAIDI increased is due, and then decreases reaching around 47% in feeder 4. This is because SAIDI decreases too. components ageing .

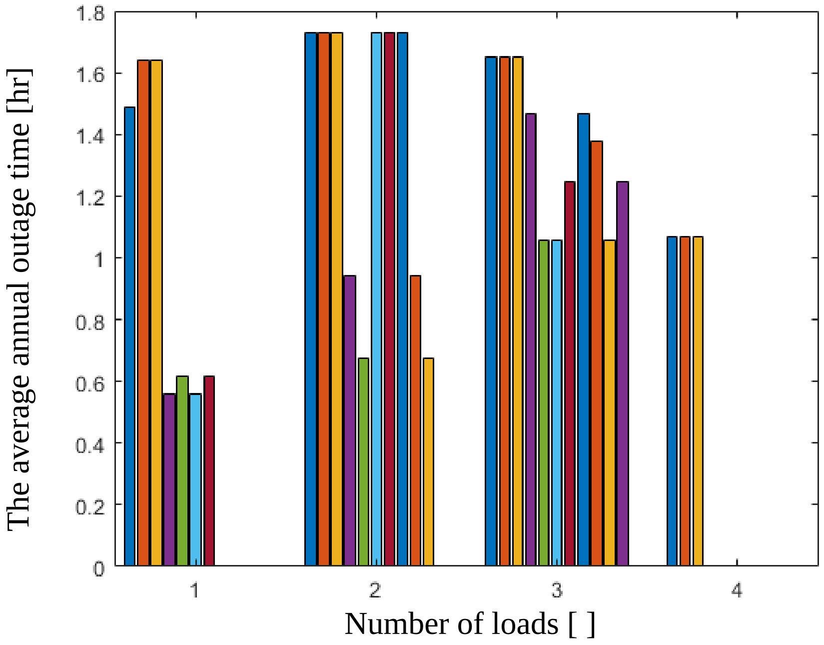


Figure 5. 43 average annual outage time

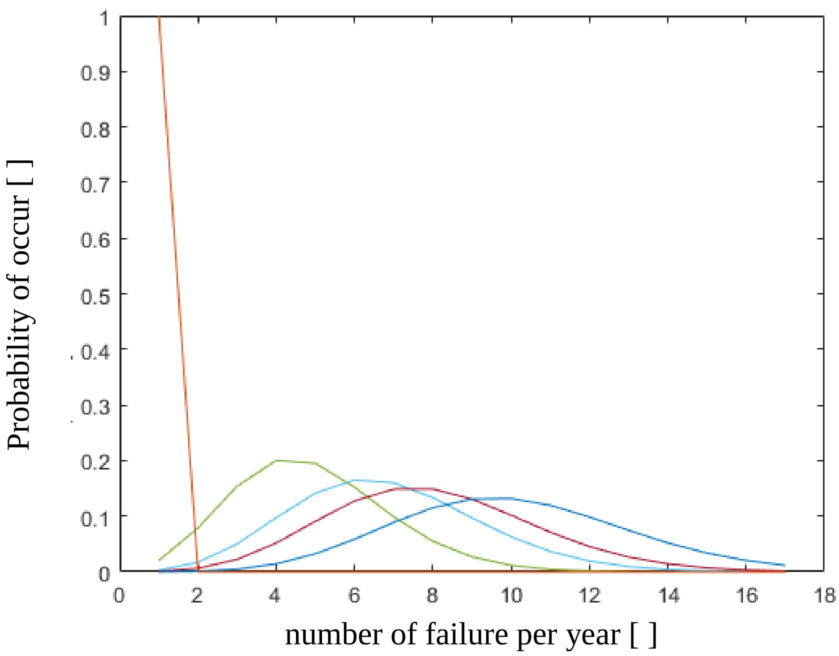


Figure 5. 44 Average failure probability

The notations used in the above equation are, λ, average failure rate of each load point, n, number of failures, t, time (per year for example). The above equation is used to evaluate the probability for the number of failures occurring in 1, 10 and 30 years at each load point. The calculated results for the number of failures at each load point for the system are given in Figure 5. 44 Average number of failures per (A) 10 years and (B) 30 years **.**

For Scenario 4

	Calculated Result
SAIFI	0.2484
SAIDI	0.5374
CAIDI	2.1636
ENS	6.9777
AENS	13.7154
TNR	**3391.8**

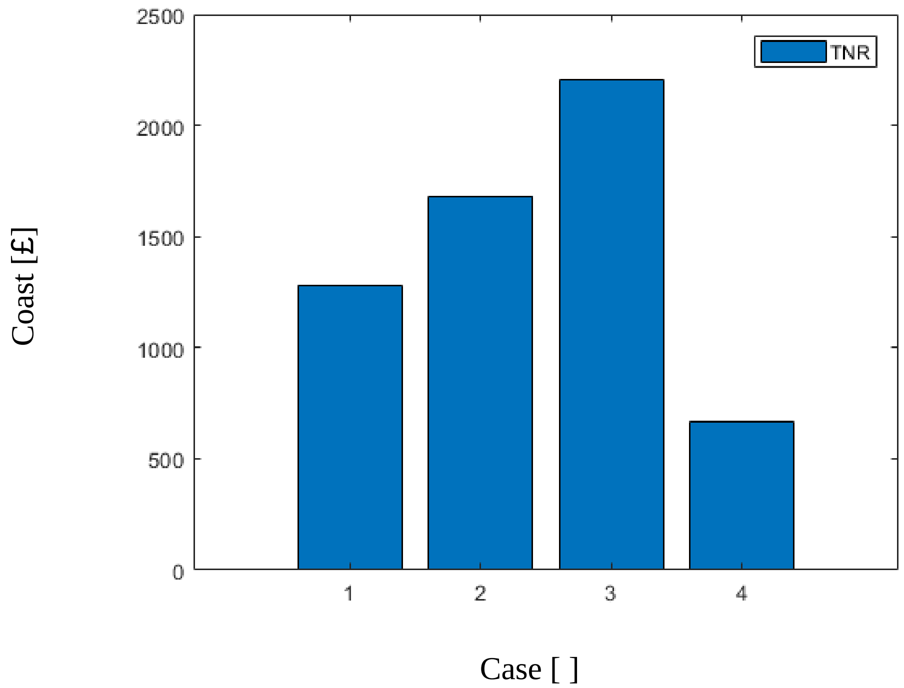


Figure 5. 45 Scenario 4 Om Al-Dalya TNR

The TNR is mainly an aggregate of CI, CML and CR, and depends on SAIFI and SAIDI distributions. It can be seen from Figure 5. 45   that the TNR starts with £1380, and then increases reaching around 17% in feeder 2. In feeder 3, it increases significantly, reaching almost 38%. The reason that both SAIFI and SAIDI increased is due, and then decreases reaching around 47% in feeder 4. This is because SAIDI decreases too. components ageing

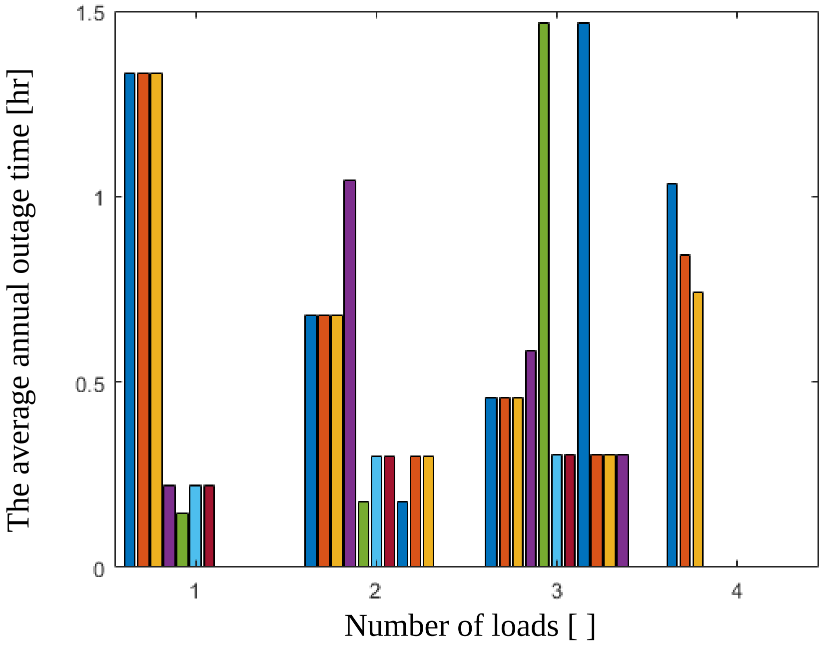


Figure 5. 46 average annual outage time

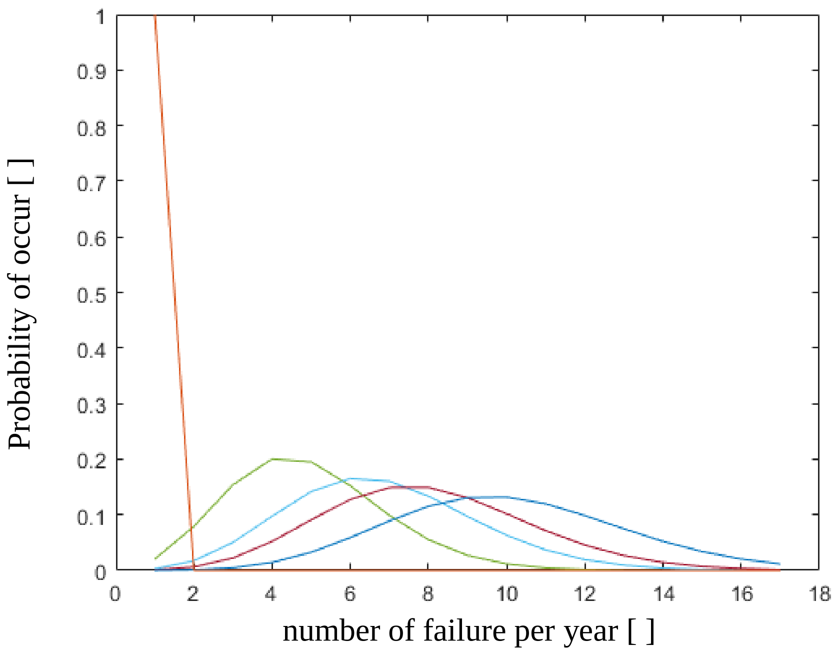


Figure 5. 47 Average failure probability

The notations used in the above equation are, λ, average failure rate of each load point, n, number of failures, t, time (per year for example). The above equation is used to evaluate the probability for the number of failures occurring in 1, 10 and 30 years at each load point. The calculated results for the number of failures at each load point for the system are given in Figure 5. 47 Average number of failures per (A) 10 years and (B) 30 years.

For Scenario 5

	Calculated Result
SAIFI	0.2484
SAIDI	1.5687
CAIDI	6.3161
ENS	27.5939
AENS	67.7982
TNR	5430.6000

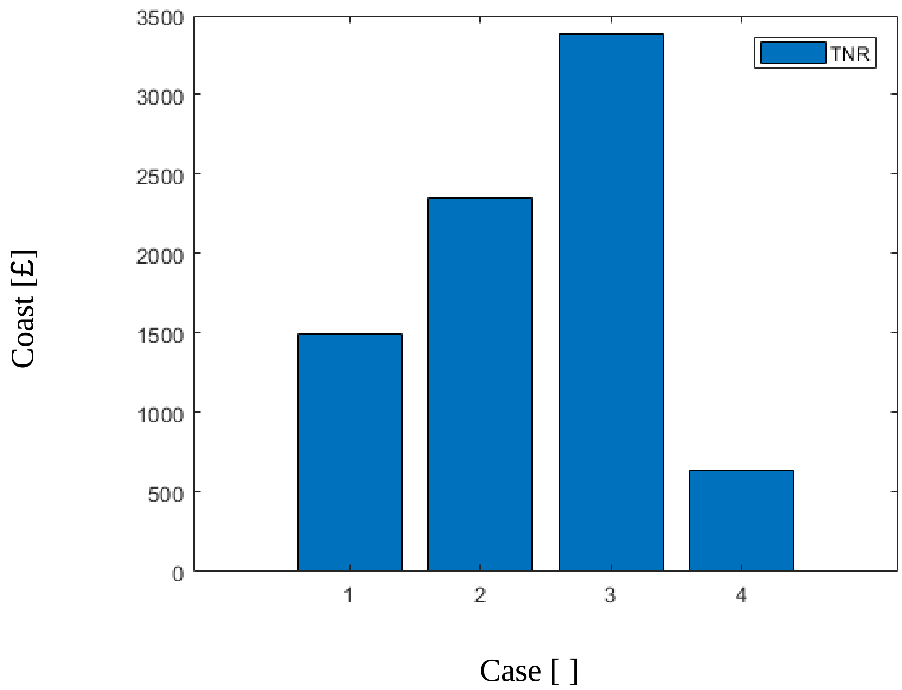


Figure 5. 48 Scenario 5 Om Al-Dalya TNR

The TNR is mainly an aggregate of CI, CML and CR, and depends on SAIFI and SAIDI distributions. It can be seen from Figure 5. 48 that the TNR starts with £1380, and then increases reaching around 28% in feeder 2. In feeder 3, it increases significantly, reaching almost 62%. The reason that both SAIFI and SAIDI increased is due, and then decreases reaching around 57% in feeder 4. This is because SAIDI decreases too. components ageing.

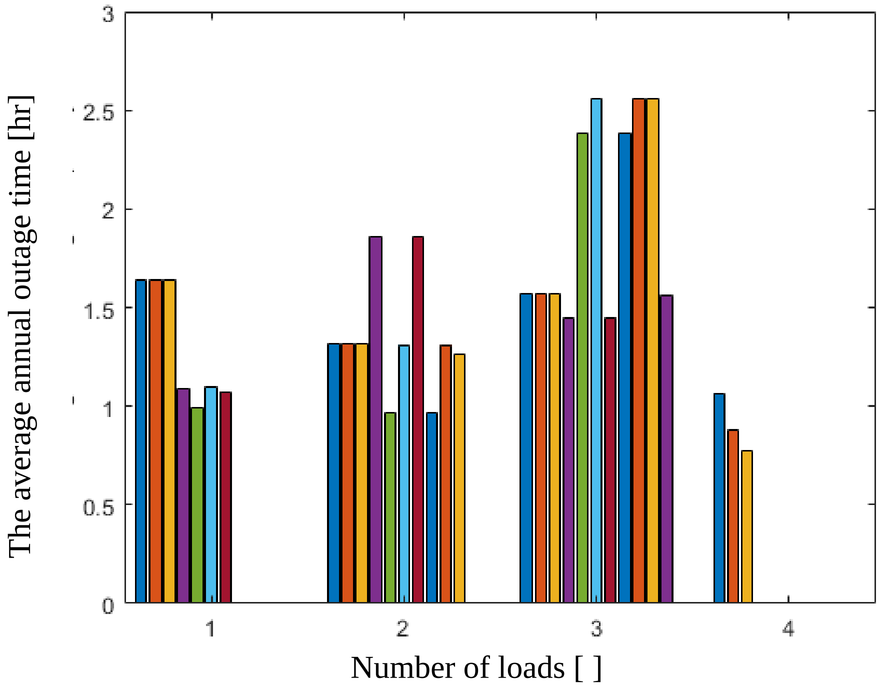


Figure 5. 49 average annual outage time

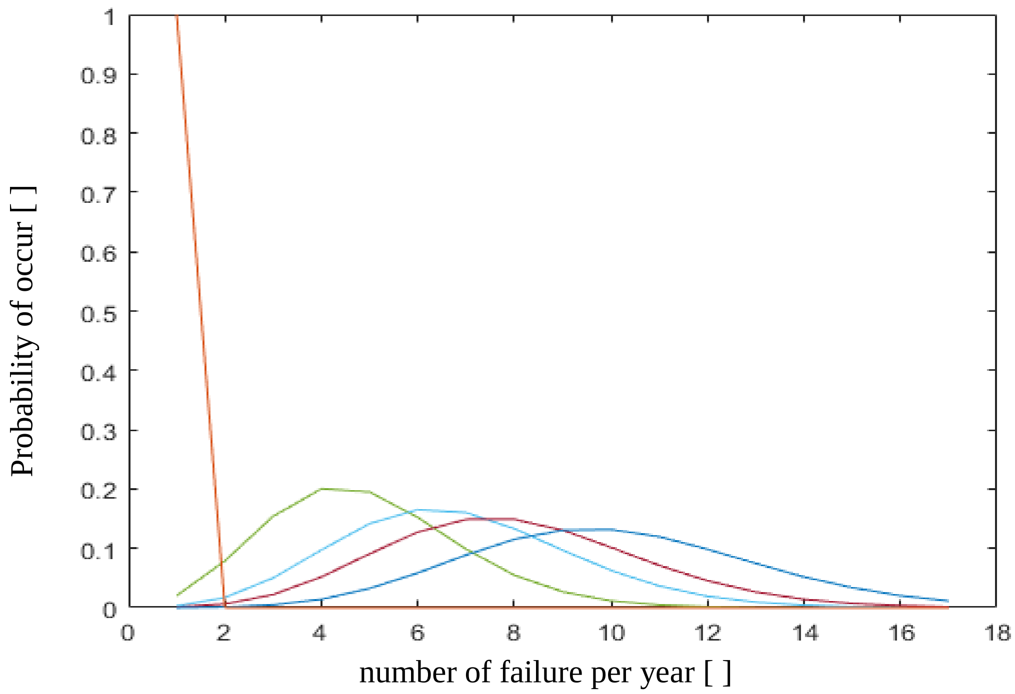


Figure 5. 50 Average failure probability

The notations used in the above equation are, λ, average failure rate of each load point, n, number of failures, t, time (per year for example). The above equation is used to evaluate the probability for the number of failures occurring in 1, 10 and 30 years at each load point. The calculated results for the number of failures at each load point for the system are given in Figure 5. 50 Average number of failures per (A) 10 years and (B) 30 years.

Recommendations

- Increase data collection by using SCADA systems.
- Reinforcement the network by using protection devices.
- Build research unit for the distribution companies.
- Rise the knowledge of 'MATLAB' software usage for the engineers in the distribution companies.
- Expend the study with new cases for eg. (selco.) In addition, compare the results.
- Publish the study results for the researcher and students.
- Develop the 'MATLAB'code and add GUI for the data entering.

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APPENDIX A

MATLAB Program code

This appendix presents the MATLAB Program code for load point's indices

```
c=input('#Circuit Breaker :')
d=input('#Section"Data":')
sum1=0
sum2=0
sum3=0
sum4=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c
    disp('load for Point:')
    disp(k)
    for z=1 :d
        disp('#Data')
        disp(z)
        x=input('Interruption frequency at load point i"?i(f/yr)":')
        y=input('Interruption outage time at load point i"ri(hours)":')
        u=y*x
        sum1=x+sum1
        sum3=sum3+u
        sum2=sum2+y
        disp('*********')
    end
    disp('++++++++++++++')
    ni(k)=input('Number of customer at load point i"Ni":')
    lai(k)=input('cost per customer"lai":')
    sum4=ni(k)+sum4
    sum5=lai(k)+sum5
    lamdaNi=sum1*ni(k)
    sum6=lamdaNi+sum6
    uini=sum3*ni(k)
    sum7=uini+sum7
    LaiUi=lai(k)*sum3
    sum8=LaiUi+sum8
    disp('____________________________')
    sum1=0
    sum2=0
    sum3=0
end
SAIFI=sum6/sum4
SAIDI=sum7/sum4
CAIDI=sum7/sum6
ENS=sum8/1000
```

```
AENS=sum8/sum4
ASAI=(sum4*8760-sum7)/(sum4*8760)
ASUI=1-ASAI
cost=input('CI cost per customer (£):')
CI=sum6*cost
ccm=input('CML customer/min (£):')
ti=input('Time of the Interruption per Minutes(hour to min):')
CML=sum7*ti*ccm
crc=input('CR cost  £:')
CR=(sum6/sum4)*crc
TNR=CI+CML+CR
disp('Case 2')
c=input('#Circuit Breaker with Fuse:')
d=input('#Section"Data":')
sum1=0
sum2=0
sum3=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c
    disp('load for Point:')
    disp(k)
    for z=1 :d
        disp('#Data')
        disp(z)
        x=input('Interruption frequency at load point i"?i(f/yr)":')
        y=input('Interruption outage time at load point i"ri(hours)":')
        u=y*x
        sum1=x+sum1
        sum2=sum2+y
        sum3=sum3+u
        disp('*********')
    end
    disp('++++++++++++++')
    lamdaNi=sum1*ni(k)
    sum6=lamdaNi+sum6
    uini=sum3*ni(k)
    sum7=uini+sum7
    LaiUi=lai(k)*sum3
    sum8=LaiUi+sum8
    disp('____________________________')
    sum1=0
    sum2=0
    sum3=0
end
SAIFI2=sum6/sum4
SAIDI2=sum7/sum4
CAIDI2=sum7/sum6
ENS2=sum8/1000
AENS2=sum8/sum4
ASAI2=(sum4*8760-sum7)/(sum4*8760)
ASUI2=1-ASAI2
```

```
CI2=sum6*cost
CML2=sum7*ti*ccm
CR2=(sum6/sum4)*crc
TNR2=CI2+CML2+CR2
disp('Case 3')
c=input('#Circuit Breaker with Fuse and Disconector :')
d=input('#Section"Data":')
sum1=0
sum2=0
sum3=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c
    disp('load for Point:')
    disp(k)
    for z=1 :d
        disp('#Data')
        disp(z)
        x=input('Interruption frequency at load point i"?i(f/yr)":')
        y=input('Interruption outage time at load point i"ri(hours)":')
        u=y*x
        sum1=x+sum1
        sum2=sum2+y
        sum3=sum3+u
        disp('*********')
    end
    disp('+++++++++++++++')
    lamdaNi=sum1*ni(k)
    sum6=lamdaNi+sum6
    uini=sum3*ni(k)
    sum7=uini+sum7
    LaiUi=lai(k)*sum3
    sum8=LaiUi+sum8
    disp('____________________________')
    sum1=0
    sum2=0
    sum3=0
end
SAIFI3=sum6/sum4
SAIDI3=sum7/sum4
CAIDI3=sum7/sum6
ENS3=sum8/1000
AENS3=sum8/sum4
ASAI3=(sum4*8760-sum7)/(sum4*8760)
ASUI3=1-ASAI3
CI3=sum6*cost
CML3=sum7*ti*ccm
CR3=(sum6/sum4)*crc
TNR3=CI3+CML3+CR3
disp('Case 4')
c=input('#Circuit Breaker with Fuse, Disconector and load Transfer :')
d=input('#Section"Data":')
```

```
sum1=0
sum2=0
sum3=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c
    disp('load for Point:')
    disp(k)
    for z=1 :d
        disp('#Data')
        disp(z)
        x=input('Interruption frequency at load point i"?i(f/yr)":')
        y=input('Interruption outage time at load point i"ri(hours)":')
        u=y*x
        sum1=x+sum1
        sum2=sum2+y
        sum3=sum3+u
        disp('*********')
    end
    disp('+++++++++++++++')
    lamdaNi=sum1*ni(k)
    sum6=lamdaNi+sum6
    uini=sum3*ni(k)
    sum7=uini+sum7
    LaiUi=lai(k)*sum3
    sum8=LaiUi+sum8
    disp('____________________________')
    sum1=0
    sum2=0
    sum3=0
end
SAIFI4=sum6/sum4
SAIDI4=sum7/sum4
CAIDI4=sum7/sum6
ENS4=sum8/1000
AENS4=sum8/sum4
ASAI4=(sum4*8760-sum7)/(sum4*8760)
ASUI4=1-ASAI4
CI4=sum6*cost
CML4=sum7*ti*ccm
CR4=(sum6/sum4)*crc
TNR4=CI4+CML4+CR4
disp('Case 5')
c=input('#Circuit Breaker with Disconector:')
d=input('#Section"Data":')
sum1=0
sum2=0
sum3=0
sum5=0
sum6=0
sum7=0
sum8=0
```

```
for k=1 :c
    disp('load for Point:')
    disp(k)
    for z=1 :d
        disp('#Data')
        disp(z)
        x=input('Interruption frequency at load point i"?i(f/yr)":')
        y=input('Interruption outage time at load point i"ri(hours)":')
        u=y*x
        sum1=x+sum1
        sum2=sum2+y
        sum3=sum3+u
        disp('*********')
    end
    disp('++++++++++++++')
    lamdaNi=sum1*ni(k)
    sum6=lamdaNi+sum6
    uini=sum3*ni(k)
    sum7=uini+sum7
    LaiUi=lai(k)*sum3
    sum8=LaiUi+sum8
    disp('____________________________')
    sum1=0
    sum2=0
    sum3=0
end
SAIFI5=sum6/sum4
SAIDI5=sum7/sum4
CAIDI5=sum7/sum6
ENS5=sum8/1000
AENS5=sum8/sum4
ASAI5=(sum4*8760-sum7)/(sum4*8760)
ASUI5=1-ASAI5
CI5=sum6*cost
CML5=sum7*ti*ccm
CR5=(sum6/sum4)*crc
TNR5=CI5+CML5+CR5
disp('Case 6')
c=input('#Circuit Breaker with load transfer:')
d=input('#Section"Data":')
sum1=0
sum2=0
sum3=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c
    disp('load for Point:')
    disp(k)
    for z=1 :d
        disp('#Data')
        disp(z)
        x=input('Interruption frequency at load point i"?i(f/yr)":')
```

```
        y=input('Interruption outage time at load point i"ri(hours)":')
        u=y*x
        sum1=x+sum1
        sum2=sum2+y
        sum3=sum3+u
        disp('*********')
    end
    disp('++++++++++++++')
    lamdaNi=sum1*ni(k)
    sum6=lamdaNi+sum6
    uini=sum3*ni(k)
    sum7=uini+sum7
    LaiUi=lai(k)*sum3
    sum8=LaiUi+sum8
    disp('_____________________________')
    sum1=0
    sum2=0
    sum3=0
end
SAIFI6=sum6/sum4
SAIDI6=sum7/sum4
CAIDI6=sum7/sum6
ENS6=sum8/1000
AENS6=sum8/sum4
ASAI6=(sum4*8760-sum7)/(sum4*8760)
ASUI6=1-ASAI6
CI6=sum6*cost
CML6=sum7*ti*ccm
CR6=(sum6/sum4)*crc
TNR6=CI6+CML6+CR6
disp('Case 7')
c=input('#Circuit Breaker with load transfer and Disconnted:')
d=input('#Section"Data":')
sum1=0
sum2=0
sum3=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c
    disp('load for Point:')
    disp(k)
    for z=1 :d
        disp('#Data')
        disp(z)
        x=input('Interruption frequency at load point i"?i(f/yr)":')
        y=input('Interruption outage time at load point i"ri(hours)":')
        u=y*x
        sum1=x+sum1
        sum2=sum2+y
        sum3=sum3+u
        disp('*********')
    end
```

```
    disp('++++++++++++++')
    lamdaNi=sum1*ni(k)
    sum6=lamdaNi+sum6
    uini=sum3*ni(k)
    sum7=uini+sum7
    LaiUi=lai(k)*sum3
    sum8=LaiUi+sum8
    disp('____________________________')
    sum1=0
    sum2=0
    sum3=0
end
SAIFI7=sum6/sum4
SAIDI7=sum7/sum4
CAIDI7=sum7/sum6
ENS7=sum8/1000
AENS7=sum8/sum4
ASAI7=(sum4*8760-sum7)/(sum4*8760)
ASUI7=1-ASAI7
CI7=sum6*cost
CML7=sum7*ti*ccm
CR7=(sum6/sum4)*crc
TNR7=CI7+CML7+CR7
disp('Case 8')
c=input('#Circuit Breaker with Fuse and Load T:')
d=input('#Section"Data":')
sum1=0
sum2=0
sum3=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c
    disp('load for Point:')
    disp(k)
    for z=1 :d
        disp('#Data')
        disp(z)
        x=input('Interruption frequency at load point i"?i(f/yr)":')
        y=input('Interruption outage time at load point i"ri(hours)":')
        u=y*x
        sum1=x+sum1
        sum2=sum2+y
        sum3=sum3+u
        disp('*********')
    end
    disp('++++++++++++++')
    lamdaNi=sum1*ni(k)
    sum6=lamdaNi+sum6
    uini=sum3*ni(k)
    sum7=uini+sum7
    LaiUi=lai(k)*sum3
    sum8=LaiUi+sum8
```

```
    disp('____________________________')
    sum1=0
    sum2=0
    sum3=0
end
SAIFI8=sum6/sum4
SAIDI8=sum7/sum4
CAIDI8=sum7/sum6
ENS8=sum8/1000
AENS8=sum8/sum4
ASAI8=(sum4*8760-sum7)/(sum4*8760)
ASUI8=1-ASAI8
CI8=sum6*cost
CML8=sum7*ti*ccm
CR8=(sum6/sum4)*crc
TNR8=CI8+CML8+CR8
disp('The Result Is:')
disp('Case 1 :')
disp('Circuit Breaker :')
disp('System Average Interruption Frequency Index(SAIFI):')
disp(SAIFI)
disp('System Average Interruption Duration Index(SAIDI):')
disp(SAIDI)
disp('Customer Average Interruption Duration Index(CAIDI):')
disp(CAIDI)
disp('Energy Not Supplied (ENS):')
disp(ENS)
disp('Expected Energy Not Supply (EENS):')
disp(AENS)
disp('Average Service Availability Index (ASA):')
disp(ASAI)
disp('Average Service Unavailability index (ASUI):')
disp(ASUI)
disp('Customer Interruption (CI):')
disp(CI)
disp('Customer Minutes Lost (CML):')
disp(CML)
disp('Customer Repair (CR):')
disp(CR)
disp('The Total Network Risk can be expressed (TNR):')
disp(TNR)
disp('Case 2 :')
disp('Circuit Breaker with Fuse :')
disp('System Average Interruption Frequency Index(SAIFI):')
disp(SAIFI2)
disp('System Average Interruption Duration Index(SAIDI):')
disp(SAIDI2)
disp('Customer Average Interruption Duration Index(CAIDI):')
disp(CAIDI2)
disp('Energy Not Supplied (ENS):')
disp(ENS2)
disp('Expected Energy Not Supply (EENS):')
disp(AENS2)
disp('Average Service Availability Index (ASA):')
```

```
disp(ASAI2)
disp('Average Service Unavailability index (ASUI):')
disp(ASUI2)
disp('Customer Interruption (CI):')
disp(CI2)
disp('Customer Minutes Lost (CML):')
disp(CML2)
disp('Customer Repair (CR):')
disp(CR2)
disp('The Total Network Risk can be expressed (TNR):')
disp(TNR2)
disp('Case 3 :')
disp('Circuit Breaker with Fuse and Disconector  :')
disp('System Average Interruption Frequency Index(SAIFI):')
disp(SAIFI3)
disp('System Average Interruption Duration Index(SAIDI):')
disp(SAIDI3)
disp('Customer Average Interruption Duration Index(CAIDI):')
disp(CAIDI3)
disp('Energy Not Supplied (ENS):')
disp(ENS3)
disp('Expected Energy Not Supply (EENS):')
disp(AENS3)
disp('Average Service Availability Index (ASA):')
disp(ASAI3)
disp('Average Service Unavailability index (ASUI):')
disp(ASUI3)
disp('Customer Interruption (CI):')
disp(CI3)
disp('Customer Minutes Lost (CML):')
disp(CML3)
disp('Customer Repair (CR):')
disp(CR3)
disp('The Total Network Risk can be expressed (TNR):')
disp(TNR3)
disp('Case 4 :')
disp('Circuit Breaker with Fuse, Disconector and load Transfer  :')
disp('System Average Interruption Frequency Index(SAIFI):')
disp(SAIFI4)
disp('System Average Interruption Duration Index(SAIDI):')
disp(SAIDI4)
disp('Customer Average Interruption Duration Index(CAIDI):')
disp(CAIDI4)
disp('Energy Not Supplied (ENS):')
disp(ENS4)
disp('Expected Energy Not Supply (EENS):')
disp(AENS4)
disp('Average Service Availability Index (ASA):')
disp(ASAI4)
disp('Average Service Unavailability index (ASUI):')
disp(ASUI4)
disp('Customer Interruption (CI):')
disp(CI4)
disp('Customer Minutes Lost (CML):')
```

```
disp(CML4)
disp('Customer Repair (CR):')
disp(CR4)
disp('The Total Network Risk can be expressed (TNR):')
disp(TNR4)
disp('Case 5 :')
disp('Circuit Breaker with Disconector  :')
disp('System Average Interruption Frequency Index(SAIFI):')
disp(SAIFI5)
disp('System Average Interruption Duration Index(SAIDI):')
disp(SAIDI5)
disp('Customer Average Interruption Duration Index(CAIDI):')
disp(CAIDI5)
disp('Energy Not Supplied (ENS):')
disp(ENS5)
disp('Expected Energy Not Supply (EENS):')
disp(AENS5)
disp('Average Service Availability Index (ASA):')
disp(ASAI5)
disp('Average Service Unavailability index (ASUI):')
disp(ASUI5)
disp('Customer Interruption (CI):')
disp(CI5)
disp('Customer Minutes Lost (CML):')
disp(CML5)
disp('Customer Repair (CR):')
disp(CR5)
disp('The Total Network Risk can be expressed (TNR):')
disp(TNR5)
disp('Case 6 :')
disp('Circuit Breaker with load transfer :')
disp('System Average Interruption Frequency Index(SAIFI):')
disp(SAIFI6)
disp('System Average Interruption Duration Index(SAIDI):')
disp(SAIDI6)
disp('Customer Average Interruption Duration Index(CAIDI):')
disp(CAIDI6)
disp('Energy Not Supplied (ENS):')
disp(ENS6)
disp('Expected Energy Not Supply (EENS):')
disp(AENS6)
disp('Average Service Availability Index (ASA):')
disp(ASAI6)
disp('Average Service Unavailability index (ASUI):')
disp(ASUI6)
disp('Customer Interruption (CI):')
disp(CI6)
disp('Customer Minutes Lost (CML):')
disp(CML6)
disp('Customer Repair (CR):')
disp(CR6)
disp('The Total Network Risk can be expressed (TNR):')
disp(TNR6)
disp('Case 7 :')
```

```
disp('Circuit Breaker with load transfer and Disconnted :')
disp('System Average Interruption Frequency Index(SAIFI):')
disp(SAIFI7)
disp('System Average Interruption Duration Index(SAIDI):')
disp(SAIDI7)
disp('Customer Average Interruption Duration Index(CAIDI):')
disp(CAIDI7)
disp('Energy Not Supplied (ENS):')
disp(ENS7)
disp('Expected Energy Not Supply (EENS):')
disp(AENS7)
disp('Average Service Availability Index (ASA):')
disp(ASAI7)
disp('Average Service Unavailability index (ASUI):')
disp(ASUI7)
disp('Customer Interruption (CI):')
disp(CI7)
disp('Customer Minutes Lost (CML):')
disp(CML7)
disp('Customer Repair (CR):')
disp(CR7)
disp('The Total Network Risk can be expressed (TNR):')
disp(TNR7)
disp('Case 8 :')
disp('Circuit Breaker with Fuse and Load Transfer :')
disp('System Average Interruption Frequency Index(SAIFI):')
disp(SAIFI8)
disp('System Average Interruption Duration Index(SAIDI):')
disp(SAIDI8)
disp('Customer Average Interruption Duration Index(CAIDI):')
disp(CAIDI8)
disp('Energy Not Supplied (ENS):')
disp(ENS8)
disp('Expected Energy Not Supply (EENS):')
disp(AENS8)
disp('Average Service Availability Index (ASA):')
disp(ASAI8)
disp('Average Service Unavailability index (ASUI):')
disp(ASUI8)
disp('Customer Interruption (CI):')
disp(CI8)
disp('Customer Minutes Lost (CML):')
disp(CML8)
disp('Customer Repair (CR):')
disp(CR8)
disp('The Total Network Risk can be expressed (TNR):')
disp(TNR8)
tnrr=input('tnr=')
tnrr2=input('tnr2=')
tnrr3=input('tnr3=')
tnrr4=input('tnr4=')
tnrr5=input('tnr5=')
tnrr6=input('tnr6=')
tnrr7=input('tnr7=')
```

```
tnrr8=input('tnr8=')
t=categorical({'Case1','case2','case3','case4','case5','case6','case7','case8'})
o=[tnrr tnrr2 tnrr3 tnrr4 tnrr5 tnrr6 tnrr7 tnrr8]
bar(t,o)
```

APPENDIX B

Appendix of HEBCo

```
%x=zeros(1000,1000)
%y=zeros(1000,1000)
%u=zeros(1000,1000)
%len=zeros(1000,1000)
SUMCUSTOMER=0
%cust=0
SUMSAIFI=0
SUMSAIDI=0
SUMLAIA=0
%TNRSYSTEM=0
%lamdaTR=0.002%input('Average failure rate for Transformer=')
%TimeTR=5.1%input('Average outage time for Transformer=')
%lamdaCB=0.0033%input('Average failurerate for Circute Breaker=')
%TimeCB=4%input('Average outage time for Circuit Breaker=')
lamda=1%input('Average failure rate for cable =')
cost=6%input('CI cost per customer (£):')
ccm=0.1%input('CML customer/min (£):')
ti=60%input('Time of the Interruption per Minutes(hour to min):')
crc=4000%input('CR cost  £:')
%year=25%input('Year =')
%Avg=0.01%%input('average growth load=')
%flu=0.8
%pint=0.05
%R0=lamda*flu
%Ra=(lamda-R0)/(1+pint)^40
%R1=lamdaTR*flu
%R2=(lamdaTR-R1)/(1+pint)^40
%inturrTR=R1+(R2*((1+pint)^(40+year)))
%RZCB=lamdaCB*flu
%RACB=(lamdaCB-RZCB)/(1+pint)^40
%inturrCB=RZCB+(RACB*((1+pint)^(40+year)))
%inturrCABLE=R0+(Ra*((1+pint)^(40+year)))
P=9%input('Time Period =')
Nt=46500%input('Presumed Number of custemer =')
f=12%input('# Of Feeder :')
sum0=0
for x1=1 :f
    disp('Month :')
    disp(x1)
c(x1)=input('#Load Point :')
mat1(:,x1)=1%input('the length=')
%mat2(:,x1)=input('Number of customer at load point i"Ni":')
mat3(:,x1)=1%input('cost per customer"lai":')
y0=input('data =')
```

```
y1=y0(:,1)
ni=y0(:,2)
lai=mat3(:,x1)
len=mat1(:,x1)
sum1=0
sum2=0
sum3=0
sum4=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c(x1)
    disp('Month: ')
    disp(x1)
    disp('load for Point:')
    disp(k)
%n(k)=ni(k,2)
%lai1(k)=lai(k)
     x=1%len*lamda




        u=y1.*ni%mat2(:,1)
        %x=1./(y1(:,k)./u)
        %x(isnan(x))=0
      %  x=sum(x)+lamdaTR+lamdaCB
       % y1(:,k)=sum(y1(:,k))+TimeTR+TimeCB
        u=sum(u)%+(lamdaTR.*TimeTR)+(lamdaCB.*TimeCB)
        p1(x1,k)=u
        sum0=u+sum0
     %   i1(x1,k)=x
       % if (x1==1)
       % p11(k)=u

       % i11(k)=x
       % end
       % if (x1==2)
       %     p12(k)=u

       %     i12(k)=x
      %  end
      %  if (x1==3)
        %    p13(k)=u

        %    i13(k)=x
      %  end

        disp('*********')

    disp('++++++++++++++')
```

```
    sum4=ni(k)+sum4
    sum5=lai+sum5
    lamdaNi=x*ni(k)
    sum6=lamdaNi+sum6
  uini=u%*ni(k)
   sum7=uini+sum7
    LaiUi=lai*u
    sum8=LaiUi+sum8
    disp('____________________________')
    x=0
    y=0
   % u=0
end
SAIFI=sum6/sum4
SAIDI=sum7/sum4
 CAIDI=sum7/sum6
ENS=sum8/1000
AENS=sum8/sum4
ASAI=(sum4*12*30*P-sum7)/(sum4*12*30*P)%////8760
ASUI=1-ASAI
CI=sum6*cost
CML=sum7*ti*ccm
CR=(sum6/sum4)*crc
if (k==c(x1))

      disp('----------------------------------------------')
     disp('*************************************************')
     disp('case 1')
     disp('the feeder :')
     disp(x1)

TNR1(x1)=CI+CML+CR
disp('the TNR of the feeder =')
disp(TNR1(x1))
disp('****************************************')
disp('-----------------------------------------')
end
SAIFIFEEDER(x1)=sum4*SAIFI
SAIDIFEEDER(x1)=sum4*SAIDI
%LAIAFEEDER(x1)=sum5*SAIDI
%SUMLAIA=LAIAFEEDER(x1)+SUMLAIA
SUMSAIFI=SAIFIFEEDER(x1)+SUMSAIFI
SUMSAIDI=u+SUMSAIDI %+SAIDIFEEDER(x1)
ENS1=SUMLAIA/1000
CISYSTEM=cost*SUMSAIFI
CMLSYSTEM=ti*ccm*SUMSAIDI
SUMCUSTOMER=SUMCUSTOMER+sum4
SAIFIUNDERN1=SUMSAIFI/Nt%SUMCUSTOMER
SAIDI1=SUMSAIDI/Nt%SUMCUSTOMER
CAIDI1=SAIDI1/SAIFIUNDERN1
AENS1=SUMLAIA/SUMCUSTOMER
ASAI1=(SUMCUSTOMER*24*30*P-SUMSAIDI)/(Nt*24*30*P)
ASAI2=1-(SUMSAIDI/(Nt*24*30*P))
CRSYSTEM=crc*SAIFIUNDERN1
```

```
TNRSYSTEM1=CISYSTEM+CMLSYSTEM+CRSYSTEM
if (x1==f)
  disp('///////////////////////////////////////////////')
  disp('*******************************************')
disp('TNR for the System=')
disp(TNRSYSTEM1)
  disp('*******************************************')
  disp('///////////////////////////////////////////////')
end
end
%t=size(i1)
%w1=t(1)
%w2=t(2)
%o=w1*w2
%i11=reshape(i1,1,o)
%for e=1 :16
 %   s=i11(e)
  %  for n1=0 :16
   %     v1(n1+1,e)=(((s*30)^n1)*exp(-1*s*30))/factorial(n1)


    %end
%end
%t=categorical({'load point1','load point2','load point3','load point4','load
point5','load point6','load point7','load point8','load point9','load
point10','load point11','load point12','load point13','load point14','load
point15','load point16','load point17','load point18'})
%o=[p11(1), p11(2) ,p11(3) ,p11(4) ,p11(5) ,p11(6) ,p11(7) ,p12(1) ,p12(2),
p12(3), p13(1), p13(2), p13(3), p13(4), p13(5),  p13(6), p13(7), p13(8)]
%bar(t,o)
%t=categorical({'feeder1','feedrer2','feeder3'})
%o=[TNR(1),TNR(2),TNR(3)]
%bar(t,o)
bar(TNR1)
bar(p1)
%bar(i1)
%plot(v1)
%SUMSAIFI=0
%SUMSAIDI=0
%SUMLAIA=0
disp('case1')
disp('TNR OF Feeders =')
disp(TNR1)
bar(TNR1)
legend('TNR')
disp('SAIFI OF THE SYSTEM =')
disp(SAIFIUNDERN1)
disp('ASAI CALCULATED =')
disp(ASAI1)
disp('ASAI REAL =')
disp(ASAI2)
disp('SAIDI OF THE SYSTEM =')
disp(SAIDI1)
disp('CAIDI OF THE SYSTEM =')
```

```
disp(CAIDI1)
disp('ENS OF THE SYSTEM =')
disp(ENS1)
disp('AENS OF THE SYSTEM =')
disp(AENS1)
disp('TNR OF SYSTEM =')
disp(TNRSYSTEM1)
```

Appendix of Case study

```
%x=zeros(1000,1000)
%y=zeros(1000,1000)
%u=zeros(1000,1000)
len=zeros(1000,1000)
SUMCUSTOMER=0
cust=0
SUMSAIFI=0
SUMSAIDI=0
SUMLAIA=0
TNRSYSTEM=0
lamdaTR=0.002%input('Average failure rate for Transformer=')
TimeTR=5.1%input('Average outage time for Transformer=')
lamdaCB=0.0033%input('Average failurerate for Circute Breaker=')
TimeCB=4%input('Average outage time for Circuit Breaker=')
lamda=0.051%input('Average failure rate for cable =')
cost=6%input('CI cost per customer (£):')
ccm=0.1%input('CML customer/min (£):')
ti=60%input('Time of the Interruption per Minutes(hour to min):')
crc=4000%input('CR cost  £:')
year=25%input('Year =')
Avg=0.01%%input('average growth load=')
flu=0.8
pint=0.05
R0=lamda*flu
Ra=(lamda-R0)/(1+pint)^40
R1=lamdaTR*flu
R2=(lamdaTR-R1)/(1+pint)^40
inturrTR=R1+(R2*((1+pint)^(40+year)))
RZCB=lamdaCB*flu
RACB=(lamdaCB-RZCB)/(1+pint)^40
inturrCB=RZCB+(RACB*((1+pint)^(40+year)))
inturrCABLE=R0+(Ra*((1+pint)^(40+year)))
f=input('# Of Feeder :')
for x1=1 :f
c(x1)=input('#Load Point :')
mat1(:,x1)=input('the length=')
mat2(:,x1)=input('Number of customer at load point i"Ni":')
mat3(:,x1)=input('cost per customer"lai":')
```

```
y1=input('Interruption outage time at load point i"ri(hours)":')
ni=mat2(:,x1)
lai=mat3(:,x1)
len=mat1(:,x1)
sum1=0
sum2=0
sum3=0
sum4=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c(x1)
    disp('Feeder: ')
    disp(x1)
    disp('load for Point:')
    disp(k)
n(k)=ni(k)
lai1(k)=lai(k)
        x=len*lamda




        u=x.*y1(:,k)
        x=1./(y1(:,k)./u)
        x(isnan(x))=0
        x=sum(x)+lamdaTR+lamdaCB
        y1(:,k)=sum(y1(:,k))+TimeTR+TimeCB
        u=sum(u)+(lamdaTR.*TimeTR)+(lamdaCB.*TimeCB)
        p1(x1,k)=u
        i1(x1,k)=x
       % if (x1==1)
       % p11(k)=u

       % i11(k)=x
       % end
       % if (x1==2)
       %     p12(k)=u

       %     i12(k)=x
      %  end
      %  if (x1==3)
        %    p13(k)=u

        %    i13(k)=x
      %  end

        disp('*********')

    disp('++++++++++++++')


    sum4=n(k)+sum4
```

```
    sum5=lai1(k)+sum5
    lamdaNi=x*n(k)
    sum6=lamdaNi+sum6
    uini=u*n(k)
    sum7=uini+sum7
    LaiUi=lai1(k)*u
    sum8=LaiUi+sum8
    disp('____________________________')
    x=0
    y=0
    u=0
end
SAIFI=sum6/sum4
SAIDI=sum7/sum4
CAIDI=sum7/sum6
ENS=sum8/1000
AENS=sum8/sum4
ASAI=(sum4*8760-sum7)/(sum4*8760)
ASUI=1-ASAI
CI=sum6*cost
CML=sum7*ti*ccm
CR=(sum6/sum4)*crc
if (k==c(x1))

      disp('----------------------------------------------')
     disp('*************************************************')
     disp('case 1')
     disp('the feeder :')
     disp(x1)

TNR1(x1)=CI+CML+CR
disp('the TNR of the feeder =')
disp(TNR1(x1))
disp('****************************************')
disp('-----------------------------------------')
end
SAIFIFEEDER(x1)=sum4*SAIFI
SAIDIFEEDER(x1)=sum4*SAIDI
LAIAFEEDER(x1)=sum5*SAIDI
SUMLAIA=LAIAFEEDER(x1)+SUMLAIA
SUMSAIFI=SAIFIFEEDER(x1)+SUMSAIFI
SUMSAIDI=SAIDIFEEDER(x1)+SUMSAIDI
ENS1=SUMLAIA/1000
CISYSTEM=cost*SUMSAIFI
CMLSYSTEM=ti*ccm*SUMSAIDI
SUMCUSTOMER=SUMCUSTOMER+sum4
SAIFIUNDERN1=SUMSAIFI/SUMCUSTOMER
SAIDI1=SUMSAIDI/SUMCUSTOMER
CAIDI1=SAIDI1/SAIFIUNDERN1
AENS1=SUMLAIA/SUMCUSTOMER
CRSYSTEM=crc*SAIFIUNDERN1
TNRSYSTEM1=CISYSTEM+CMLSYSTEM+CRSYSTEM
if (x1==f)
  disp('///////////////////////////////////////////////')
```

```
  disp('*******************************************')
disp('TNR for the System=')
disp(TNRSYSTEM1)
  disp('*******************************************')
  disp('///////////////////////////////////////////////')
end
end
t=size(i1)
w1=t(1)
w2=t(2)
o=w1*w2
i11=reshape(i1,1,o)
for e=1 :16
    s=i11(e)
    for n1=0 :16
        v1(n1+1,e)=(((s*30)^n1)*exp(-1*s*30))/factorial(n1)


    end
end
%t=categorical({'load point1','load point2','load point3','load point4','load
point5','load point6','load point7','load point8','load point9','load
point10','load point11','load point12','load point13','load point14','load
point15','load point16','load point17','load point18'})
%o=[p11(1), p11(2) ,p11(3) ,p11(4) ,p11(5) ,p11(6) ,p11(7) ,p12(1) ,p12(2),
p12(3), p13(1), p13(2), p13(3), p13(4), p13(5),  p13(6), p13(7), p13(8)]
%bar(t,o)
%t=categorical({'feeder1','feedrer2','feeder3'})
%o=[TNR(1),TNR(2),TNR(3)]
%bar(t,o)
bar(TNR1)
bar(p1)
bar(i1)
plot(v1)
SUMSAIFI=0
SUMSAIDI=0
SUMLAIA=0
disp('Case 2')
TimeTR=0.25%input('Average outage time for Transformer')
TimeCB=0.25%input('Average outage time for CiBreaker')

for x1=1 :f
c(x1)=input('#Load Point :')
 y2=input('Interruption outage time at load point i"ri(hours)":')
ni=mat2(:,x1)
lai=mat3(:,x1)
len=mat1(:,x1)
sum1=0
sum2=0
sum3=0
sum4=0
sum5=0
sum6=0
sum7=0
```

```
sum8=0
for k=1 :c(x1)
    disp('Feeder: ')
    disp(x1)
    disp('load for Point:')
    disp(k)
n(k)=ni(k)
lai1(k)=lai(k)
        x=len*lamda
        u=x.*y2(:,k)
        x=1./(y2(:,k)./u)
        x(isnan(x))=0
        x=sum(x)+lamdaTR+lamdaCB
        y2(:,k)=sum(y2(:,k))+TimeTR+TimeCB
        u=sum(u)+(lamdaTR.*TimeTR)+(lamdaCB.*TimeCB)
        p2(x1,k)=u
        i2(x1,k)=x
      %  if (x1==1)
       % p21(k)=u

       % i21(k)=x
        %end
        %if (x1==2)
         %   p22(k)=u

          %  i22(k)=x
        %end
        %if (x1==3)
         %   p23(k)=u

          %  i23(k)=x
        %end

        disp('*********')

    disp('++++++++++++++')


    sum4=n(k)+sum4
    sum5=lai1(k)+sum5
    lamdaNi=x*n(k)
    sum6=lamdaNi+sum6
    uini=u*n(k)
    sum7=uini+sum7
    LaiUi=lai1(k)*u
    sum8=LaiUi+sum8
    disp('____________________________')
    x=0
    y=0
    u=0
end
SAIFI=sum6/sum4
SAIDI=sum7/sum4
CAIDI=sum7/sum6
```

```
ENS=sum8/1000
AENS=sum8/sum4
ASAI=(sum4*8760-sum7)/(sum4*8760)
ASUI=1-ASAI
CI=sum6*cost
CML=sum7*ti*ccm
CR=(sum6/sum4)*crc
if (k==c(x1))

      disp('-----------------------------------------------')
     disp('**************************************************')
     disp('case 2')
     disp('the feeder :')
     disp(x1)

TNR2(x1)=CI+CML+CR
disp('the TNR of the feeder =')
disp(TNR2(x1))
disp('*****************************************')
disp('------------------------------------------')
end
SAIFIFEEDER(x1)=sum4*SAIFI
SAIDIFEEDER(x1)=sum4*SAIDI
LAIAFEEDER(x1)=sum5*SAIDI
SUMLAIA=LAIAFEEDER(x1)+SUMLAIA
SUMSAIFI=SAIFIFEEDER(x1)+SUMSAIFI
SUMSAIDI=SAIDIFEEDER(x1)+SUMSAIDI
ENS2=SUMLAIA/1000
CISYSTEM=cost*SUMSAIFI
CMLSYSTEM=ti*ccm*SUMSAIDI
%%SUMCUSTOMER=SUMCUSTOMER+sum4
SAIFIUNDERN2=SUMSAIFI/SUMCUSTOMER
SAIDI2=SUMSAIDI/SUMCUSTOMER
CAIDI2=SAIDI2/SAIFIUNDERN2
AENS2=SUMLAIA/SUMCUSTOMER
CRSYSTEM=crc*SAIFIUNDERN2
TNRSYSTEM2=CISYSTEM+CMLSYSTEM+CRSYSTEM
if (x1==f)
  disp('////////////////////////////////////////////////')
  disp('********************************************')
disp('TNR for the System=')
disp(TNRSYSTEM2)
  disp('********************************************')
  disp('////////////////////////////////////////////////')
end
end
t=size(i2)
w1=t(1)
w2=t(2)
o=w1*w2
i22=reshape(i2,1,o)
for e=1 :16
    s=i22(e)
    for n1=0 :16
```

```
        v2(n1+1,e)=(((s*30)^n1)*exp(-1*s*30))/factorial(n1)


    end
end
%t=categorical({'load point1','load point2','load point3','load point4','load
point5','load point6','load point7','load point8','load point9','load
point10','load point11','load point12','load point13','load point14','load
point15','load point16','load point17','load point18'})
%o=[p21(1), p21(2) ,p21(3) ,p21(4) ,p21(5) ,p21(6) ,p21(7) ,p22(1) ,p22(2),
p22(3), p23(1), p23(2), p23(3), p23(4), p23(5),  p23(6), p23(7), p23(8)]
%bar(t,o)
%t=categorical({'feeder1','feedrer2','feeder3'})
%o=[TNR2(1),TNR2(2),TNR2(3)]
%bar(t,o)
bar(TNR2)
bar(p2)
bar(i2)
plot(v2)
SUMSAIFI=0
SUMSAIDI=0
SUMLAIA=0
disp('Case 3')
TimeTR=5.1%input('
TimeCB=4%input('
for x1=1 :f

c(x1)=input('#Load Point :')
y3=input('Interruption outage time at load point i"ri(hours)":')
ni=mat2(:,x1)
lai=mat3(:,x1)
len=mat1(:,x1)
ni=ni+(ni*Avg)*year
lai=lai+(lai*Avg)*year
sum1=0
sum2=0
sum3=0
sum4=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c(x1)
    disp('Feeder: ')
    disp(x1)
    disp('load for Point:')
    disp(k)
n(k)=ni(k)
lai1(k)=lai(k)
        x=len*inturrCABLE
        u=x.*y3(:,k)
        x=1./(y3(:,k)./u)
        x(isnan(x))=0
        x=sum(x)+inturrTR+inturrCB
```

```
        y3(:,k)=sum(y3(:,k))+TimeTR+TimeCB
        u=sum(u)+(inturrTR.*TimeTR)+(inturrCB.*TimeCB)
         p3(x1,k)=u
        i3(x1,k)=x
       % if (x1==1)
        %p31(k)=u

        %i31(k)=x
        %end
        %if (x1==2)
         %   p32(k)=u

          %  i32(k)=x
        %end
        %if (x1==3)
         %   p33(k)=u

          %  i33(k)=x
        %end

        disp('*********')

    disp('++++++++++++++')


    sum4=n(k)+sum4

    sum5=lai1(k)+sum5
    lamdaNi=x*n(k)
    sum6=lamdaNi+sum6
    uini=u*n(k)
    sum7=uini+sum7
    LaiUi=lai1(k)*u
    sum8=LaiUi+sum8
    disp('____________________________')
    x=0
    y=0
    u=0
end
SAIFI=sum6/sum4
SAIDI=sum7/sum4
CAIDI=sum7/sum6
ENS=sum8/1000
AENS=sum8/sum4
ASAI=(sum4*8760-sum7)/(sum4*8760)
ASUI=1-ASAI
CI=sum6*cost
CML=sum7*ti*ccm
cust=sum4+cust
CR=(sum6/sum4)*crc
if (k==c(x1))

      disp('----------------------------------------------')
     disp('**************************************************')
```

```
     disp('case 3')
     disp('the feeder :')
     disp(x1)

TNR3(x1)=CI+CML+CR
 disp('the TNR of the feeder =')
disp(TNR3(x1))
disp('****************************************')
disp('-----------------------------------------')
end
SAIFIFEEDER(x1)=sum4*SAIFI
SAIDIFEEDER(x1)=sum4*SAIDI
LAIAFEEDER(x1)=sum5*SAIDI
SUMLAIA=LAIAFEEDER(x1)+SUMLAIA
SUMSAIFI=SAIFIFEEDER(x1)+SUMSAIFI
SUMSAIDI=SAIDIFEEDER(x1)+SUMSAIDI
ENS3=SUMLAIA/1000
CISYSTEM=cost*SUMSAIFI
CMLSYSTEM=ti*ccm*SUMSAIDI
SUMCUSTOMER=cust
SAIFIUNDERN3=SUMSAIFI/SUMCUSTOMER
SAIDI3=SUMSAIDI/SUMCUSTOMER
CAIDI3=SAIDI3/SAIFIUNDERN3
AENS3=SUMLAIA/SUMCUSTOMER
CRSYSTEM=crc*SAIFIUNDERN3
TNRSYSTEM3=CISYSTEM+CMLSYSTEM+CRSYSTEM
if (x1==f)
  disp('///////////////////////////////////////////////')
  disp('******************************************')
disp('TNR for the System=')
disp(TNRSYSTEM3)
  disp('******************************************')
  disp('///////////////////////////////////////////////')
end
end
t=size(i3)
w1=t(1)
w2=t(2)
o=w1*w2
i33=reshape(i3,1,o)
for e=1 :16
    s=i33(e)
    for n1=0 :16
        v3(n1+1,e)=(((s*30)^n1)*exp(-1*s*30))/factorial(n1)


    end
end
%%o=[p31(1), p31(2) ,p31(3) ,p31(4) ,p31(5) ,p31(6) ,p31(7) ,p32(1) ,p32(2),
p32(3), p33(1), p33(2), p33(3), p33(4), p33(5),  p33(6), p33(7), p33(8)]
%bar(t,o)
%t=categorical({'feeder1','feedrer2','feeder3'})
%o=[TNR3(1),TNR3(2),TNR3(3)]
%bar(t,o)
```

```
bar(TNR3)
bar(p3)
bar(i3)
plot(v3)
SUMSAIFI=0
SUMSAIDI=0
SUMLAIA=0
disp('Case 4')
TimeTR=0.25%input('Average outage time for Transformer=')
TimeCB=0.25%input('Average outage time for Circuit Breaker=')
for x1=1 :f

c(x1)=input('#Load Point :')
 y4=input('Interruption outage time at load point i"ri(hours)":')
ni=mat2(:,x1)
lai=mat3(:,x1)
len=mat1(:,x1)
ni=ni+(ni*Avg)*year
lai=lai+(lai*Avg)*year
sum1=0
sum2=0
sum3=0
sum4=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c(x1)
    disp('Feeder: ')
    disp(x1)
    disp('load for Point:')
    disp(k)
n(k)=ni(k)
lai1(k)=lai(k)
        x=len*inturrCABLE
        u=x.*y4(:,k)
        x=1./(y4(:,k)./u)
        x(isnan(x))=0
        x=sum(x)+inturrTR+inturrCB
        y4(:,k)=sum(y4(:,k))+TimeTR+TimeCB
        u=sum(u)+(inturrTR.*TimeTR)+(inturrCB.*TimeCB)
        p4(x1,k)=u
        i4(x1,k)=x
        %if (x1==1)
       % p41(k)=u

       % i41(k)=x
      %  end
      %  if (x1==2)
        %    p42(k)=u

        %    i42(k)=x
       % end
      %  if (x1==3)
```

```
      %      p43(k)=u

      %      i43(k)=x
      %  end

        disp('*********')

    disp('++++++++++++++')


    sum4=n(k)+sum4
    sum5=lai1(k)+sum5
    lamdaNi=x*n(k)
    sum6=lamdaNi+sum6
    uini=u*n(k)
    sum7=uini+sum7
    LaiUi=lai1(k)*u
    sum8=LaiUi+sum8
    disp('____________________________')
    x=0
    y=0
    u=0
end
SAIFI=sum6/sum4
SAIDI=sum7/sum4
CAIDI=sum7/sum6
ENS=sum8/1000
AENS=sum8/sum4
ASAI=(sum4*8760-sum7)/(sum4*8760)
ASUI=1-ASAI
CI=sum6*cost
CML=sum7*ti*ccm
CR=(sum6/sum4)*crc
if (k==c(x1))

      disp('----------------------------------------------')
     disp('*************************************************')
     disp('case 4')
     disp('the feeder :')
     disp(x1)

TNR4(x1)=CI+CML+CR
disp('the TNR of the feeder =')
disp(TNR4(x1))
disp('****************************************')
disp('-----------------------------------------')
end
SAIFIFEEDER(x1)=sum4*SAIFI
SAIDIFEEDER(x1)=sum4*SAIDI
LAIAFEEDER(x1)=sum5*SAIDI
SUMLAIA=LAIAFEEDER(x1)+SUMLAIA
SUMSAIFI=SAIFIFEEDER(x1)+SUMSAIFI
SUMSAIDI=SAIDIFEEDER(x1)+SUMSAIDI
ENS4=SUMLAIA/1000
```

```
CISYSTEM=cost*SUMSAIFI
CMLSYSTEM=ti*ccm*SUMSAIDI
%SUMCUSTOMER=SUMCUSTOMER+sum4
SAIFIUNDERN4=SUMSAIFI/SUMCUSTOMER
SAIDI4=SUMSAIDI/SUMCUSTOMER
CAIDI4=SAIDI4/SAIFIUNDERN4
AENS4=SUMLAIA/SUMCUSTOMER
CRSYSTEM=crc*SAIFIUNDERN4
TNRSYSTEM4=CISYSTEM+CMLSYSTEM+CRSYSTEM
if (x1==f)
  disp('///////////////////////////////////////////////')
  disp('*******************************************')
disp('TNR for the System CASE (4)=')
disp(TNRSYSTEM4)
  disp('*******************************************')
  disp('///////////////////////////////////////////////')
end
end
t=size(i4)
w1=t(1)
w2=t(2)
o=w1*w2
i44=reshape(i4,1,o)
for e=1 :16
    s=i44(e)
    for n1=0 :16
        v4(n1+1,e)=(((s*30)^n1)*exp(-1*s*30))/factorial(n1)


    end
end
%t=categorical({'load point1','load point2','load point3','load point4','load
point5','load point6','load point7','load point8','load point9','load
point10','load point11','load point12','load point13','load point14','load
point15','load point16','load point17','load point18'})
%o=[p41(1), p41(2) ,p41(3) ,p41(4) ,p41(5) ,p41(6) ,p41(7) ,p42(1) ,p42(2),
p42(3), p43(1), p43(2), p43(3), p43(4), p43(5),  p43(6), p43(7), p43(8)]
%bar(t,o)
%t=categorical({'feeder1','feedrer2','feeder3'})
%o=[TNR4(1),TNR4(2),TNR4(3)]
%bar(t,o)
bar(TNR4)
bar(p4)
bar(i4)
plot(v4)
SUMSAIFI=0
SUMSAIDI=0
SUMLAIA=0
custend=0
SUMCUSTOMER=0
disp('Case 5')
TimeTR=5.1%input('Average outage time for Transformer=')
TimeCB=4%input('Average outage time for Circuit Breaker=')
for x1=1 :f
```

```
c(x1)=input('#Load Point :')
 y5=input('Interruption outage time at load point i"ri(hours)":')
ni=mat2(:,x1)
lai=mat3(:,x1)
len=mat1(:,x1)
ni=ni
lai=lai.*2
sum1=0
sum2=0
sum3=0
sum4=0
sum5=0
sum6=0
sum7=0
sum8=0
for k=1 :c(x1)
    disp('Feeder: ')
    disp(x1)
    disp('load for Point:')
    disp(k)
n(k)=ni(k)
lai1(k)=lai(k)
        x=len*inturrCABLE
        u=x.*y5(:,k)
        x=1./(y5(:,k)./u)
        x(isnan(x))=0
        x=sum(x)+inturrTR+inturrCB
        y5(:,k)=sum(y5(:,k))+TimeTR+TimeCB
        u=sum(u)+(inturrTR.*TimeTR)+(inturrCB.*TimeCB)
        p5(x1,k)=u
        i5(x1,k)=x


        disp('*********')

    disp('++++++++++++++')


    sum4=n(k)+sum4
    sum5=lai1(k)+sum5
    lamdaNi=x*n(k)
    sum6=lamdaNi+sum6
    uini=u*n(k)
    sum7=uini+sum7
    LaiUi=lai1(k)*u
    sum8=LaiUi+sum8
    disp('____________________________')
    x=0
    y=0
    u=0
end
SAIFI=sum6/sum4
SAIDI=sum7/sum4
```

```
CAIDI=sum7/sum6
ENS=sum8/1000
AENS=sum8/sum4
ASAI=(sum4*8760-sum7)/(sum4*8760)
ASUI=1-ASAI
CI=sum6*cost
CML=sum7*ti*ccm
custend=sum4+custend
CR=(sum6/sum4)*crc
if (k==c(x1))

      disp('---------------------------------------------')
     disp('************************************************')
     disp('case 5')
     disp('the feeder :')
     disp(x1)

TNR5(x1)=CI+CML+CR
disp('the TNR of the feeder =')
disp(TNR5(x1))
disp('****************************************')
disp('----------------------------------------')
end
SAIFIFEEDER(x1)=sum4*SAIFI
SAIDIFEEDER(x1)=sum4*SAIDI
LAIAFEEDER(x1)=sum5*SAIDI
SUMLAIA=LAIAFEEDER(x1)+SUMLAIA
SUMSAIFI=SAIFIFEEDER(x1)+SUMSAIFI
SUMSAIDI=SAIDIFEEDER(x1)+SUMSAIDI
ENS5=SUMLAIA/1000
SAIDI5=SUMSAIDI/custend
CISYSTEM=cost*SUMSAIFI
CMLSYSTEM=ti*ccm*SUMSAIDI
SUMCUSTOMER=custend
SAIFIUNDERN5=SUMSAIFI/SUMCUSTOMER
AENS5=SUMLAIA/SUMCUSTOMER
CAIDI5=SAIDI5/SAIFIUNDERN5
CRSYSTEM=crc*SAIFIUNDERN5
TNRSYSTEM5=CISYSTEM+CMLSYSTEM+CRSYSTEM
if (x1==f)
  disp('//////////////////////////////////////////////')
  disp('******************************************')
disp('TNR for the System CASE (5)=')
disp(TNRSYSTEM5)
  disp('******************************************')
  disp('//////////////////////////////////////////////')
end
end
t=size(i5)
w1=t(1)
w2=t(2)
o=w1*w2
i55=reshape(i5,1,o)
for e=1 :16
```

```
    s=i55(e)
    for n1=0 :16
        v5(n1+1,e)=(((s*30)^n1)*exp(-1*s*30))/factorial(n1)


    end
end
bar(TNR5)
bar(p5)
bar(i5)
plot(v5)
disp('Case 1')
bar(p1)
disp('Case 2')
bar(p2)
disp('Case 3')
bar(p3)
disp('Case 4')
bar(p4)
disp('Case 5')
bar(p5)
disp('case1')
disp('TNR OF Feeders =')
disp(TNR1)
bar(TNR1)
legend('TNR')
disp('SAIFI OF THE SYSTEM =')
disp(SAIFIUNDERN1)
disp('SAIDI OF THE SYSTEM =')
disp(SAIDI1)
disp('CAIDI OF THE SYSTEM =')
disp(CAIDI1)
disp('ENS OF THE SYSTEM =')
disp(ENS1)
disp('AENS OF THE SYSTEM =')
disp(AENS1)
disp('TNR OF SYSTEM =')
disp(TNRSYSTEM1)
disp('case2')
disp('TNR OF Feeders =')
disp(TNR2)
bar(TNR2)
legend('TNR')
disp('SAIFI OF THE SYSTEM =')
disp(SAIFIUNDERN2)
disp('SAIDI OF THE SYSTEM =')
disp(SAIDI2)
disp('CAIDI OF THE SYSTEM =')
disp(CAIDI2)
disp('ENS OF THE SYSTEM =')
disp(ENS2)
disp('AENS OF THE SYSTEM =')
disp(AENS2)
disp('TNR OF SYSTEM =')
```

```
disp(TNRSYSTEM2)
disp('case3')
disp('TNR OF Feeders =')
disp(TNR3)
bar(TNR3)
legend('TNR')
disp('SAIFI OF THE SYSTEM =')
disp(SAIFIUNDERN3)
disp('SAIDI OF THE SYSTEM =')
disp(SAIDI3)
disp('CAIDI OF THE SYSTEM =')
disp(CAIDI3)
disp('ENS OF THE SYSTEM =')
disp(ENS3)
disp('AENS OF THE SYSTEM =')
disp(AENS3)
disp('TNR OF SYSTEM =')
disp(TNRSYSTEM3)
disp('case4')
disp('TNR OF Feeders =')
disp(TNR4)
bar(TNR4)
legend('TNR')
disp('SAIFI OF THE SYSTEM =')
disp(SAIFIUNDERN4)
disp('SAIDI OF THE SYSTEM =')
disp(SAIDI4)
disp('CAIDI OF THE SYSTEM =')
disp(CAIDI4)
disp('ENS OF THE SYSTEM =')
disp(ENS4)
disp('AENS OF THE SYSTEM =')
disp(AENS4)
disp('TNR OF SYSTEM =')
disp(TNRSYSTEM4)
disp('case5')
disp('TNR OF Feeders =')
disp(TNR5)
bar(TNR5)
legend('TNR')
disp('SAIFI OF THE SYSTEM =')
disp(SAIFIUNDERN5)
disp('SAIDI OF THE SYSTEM =')
disp(SAIDI5)
disp('CAIDI OF THE SYSTEM =')
disp(CAIDI5)
disp('ENS OF THE SYSTEM =')
disp(ENS5)
disp('AENS OF THE SYSTEM =')
disp(AENS5)
disp('TNR OF SYSTEM =')
disp(TNRSYSTEM5)
disp('SAIFI Between The Systems')
t=categorical({'Case 1' , 'Case 2','Case 3','Case 4','Case 5'})
```

```
o=[SAIFIUNDERN1,SAIFIUNDERN2,SAIFIUNDERN3,SAIFIUNDERN4,SAIFIUNDERN5]
bar(t,o,0.40,'black')
legend('SAIFI')
disp('SAIDI Between The Systems')
t=categorical({'Case 1' , 'Case 2','Case 3','Case 4','Case 5'})
o=[SAIDI1,SAIDI2,SAIDI3,SAIDI4,SAIDI5]
bar(t,o,0.40,'green')
legend('SAIDI')
disp('CAIDI Between The Systems')
t=categorical({'Case 1' , 'Case 2','Case 3','Case 4','Case 5'})
o=[CAIDI1,CAIDI2,CAIDI3,CAIDI4,CAIDI5]
bar(t,o,0.40,'cyan')
legend('CAIDI')
disp('ENS Between The Systems')
t=categorical({'Case 1' , 'Case 2','Case 3','Case 4','Case 5'})
o=[ENS1,ENS2,ENS3,ENS4,ENS5]
bar(t,o,0.40,'magenta')
legend('ENS')
disp('AENS Between The Systems')
t=categorical({'Case 1' , 'Case 2','Case 3','Case 4','Case 5'})
o=[AENS1,AENS2,AENS3,AENS4,AENS5]
bar(t,o,0.40,'black')
legend('AENS')
disp('TNR Between The Systems')
t=categorical({'Case 1' , 'Case 2','Case 3','Case 4','Case 5'})
o=[TNRSYSTEM1,TNRSYSTEM2,TNRSYSTEM3,TNRSYSTEM4,TNRSYSTEM5]
bar(t,o,0.40,'red')
legend('TNR')
disp('Ui average annual outage time Ui  Between The Systems')
t=[p1;p2;p3;p4;p5]
bar(t)
disp('λi average failure rate or average annual outage frequency λi   Between
The Systems')
t=[i1;i2;i3;i4;i5]
bar(t)
disp('the probability of n failures/yr at load point Case 1')
plot(v1)
disp('the probability of n failures/yr at load point Case 2')
plot(v2)
disp('the probability of n failures/yr at load point Case 3')
plot(v3)
disp('the probability of n failures/yr at load point Case 4')
plot(v4)
disp('the probability of n failures/yr at load point Case 5')
plot(v5)
```