Faculty of Electrical Technology and Engineering

Modelling an Inverse Definite Minimum Time Overcurrent (IDMT) Relay Protection Discrimination Schemes for Power System Networks Using PSCAD.

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I declare that this project report entitled “Modelling an Inverse Definite Minimum Time Overcurrent (IDMT) Relay Protection Discrimination Schemes for Power System Networks Using PSCAD” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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DEDICATION

This project stands as a tribute to the unparalleled influence of my cherished parents, my beloved mother, Muzanni Binti Subakhir, and father, Ruzi Bin Omar, whose unwavering commitment and unwavering support have been the bedrock of my academic pursuits. In the tapestry of my educational journey, my mother's profound sacrifices and boundless belief in my capabilities have fuelled my determination, while my father's sagacious guidance and unwavering encouragement have been beacons of wisdom illuminating my path. Their profound love and encouragement have not only shaped my academic accomplishments but have also been instrumental in molding my character. This dedication is an acknowledgment of the profound impact my parents have had on my life, and I am profoundly thankful for their enduring faith in my potential.

ABSTRACT

This thesis focuses on modeling an Inverse Definite Minimum Time (IDMT) overcurrent relay protection discrimination scheme for power system networks using PSCAD software. Overcurrent protection is essential in power systems to detect and mitigate faults, ensuring the reliability and stability of the network. Effective relay coordination is crucial to achieve selective and coordinated operation during fault conditions. This thesis presents an in-depth analysis of various factors that significantly influence the selection of IDMT overcurrent protection schemes for radial networks. The proposed protection scheme is rigorously tested using PSCAD, considering two types of faults: fault between Red to Yellow to Blue and fault between Red to Blue to Yellow to Earth. For simulation purposes, the IEC-255-3 std. moderately inverse IDMT curve characteristic is chosen, and the Power System Computer-Aided Design (PSCAD) software is utilized. The simulation results are compared with the calculated values of Pickup Current/Plug Setting (PS) and Time Multiplier Settings (TMS), demonstrating close agreement between the two. This validation confirms the reliability and accuracy of the calculated parameters for the IDMT relay protection scheme. The results affirm the trustworthiness of the calculated PS and TMS values, enabling power system engineers to implement effective and reliable protection schemes for power system networks.

ABSTRAK

Tesis ini memfokuskan kepada pemodelan skim diskriminasi perlindungan geganti arus lebihan Inverse Definite Time (IDMT) untuk rangkaian sistem kuasa menggunakan perisian PSCAD. Perlindungan arus lebih adalah penting dalam sistem kuasa untuk mengesan dan mengurangkan kerosakan, memastikan kebolehpercayaan dan kestabilan rangkaian. Penyelarasan geganti yang berkesan adalah penting untuk mencapai operasi terpilih dan diselaraskan semasa keadaan kerosakan. Tesis ini membentangkan analisis mendalam tentang pelbagai faktor yang secara signifikan mempengaruhi pemilihan skim perlindungan arus lampau IDMT untuk rangkaian radial. Skim perlindungan yang dicadangkan diuji dengan teliti menggunakan PSCAD, dengan mengambil kira dua jenis kerosakan: kesalahan antara Merah ke Kuning ke Biru dan kesalahan antara Merah ke Biru ke Kuning ke Bumi. Untuk tujuan simulasi, IEC-255-3 std. ciri lengkung IDMT songsang sederhana dipilih, dan perisian Reka Bentuk Bantuan Komputer Sistem Kuasa (PSCAD) digunakan. Keputusan simulasi dibandingkan dengan nilai terkira Tetapan Arus/Plug (PS) dan Tetapan Pengganda Masa (TMS), menunjukkan persetujuan rapat antara kedua-duanya. Pengesahan ini mengesahkan kebolehpercayaan dan ketepatan parameter yang dikira untuk skim perlindungan geganti IDMT. Hasilnya mengesahkan kebolehpercayaan nilai PS dan TMS yang dikira, membolehkan jurutera sistem kuasa melaksanakan skim perlindungan yang berkesan dan boleh dipercayai untuk rangkaian sistem kuasa.

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LIST OF SYMBOLS

α - Constant in time operating relay

β - Constant in time operating relay

% - Percent

LIST OF ABBREVIATIONS

t - Relay operating time in second

k - Time dial or time multiplier setting

I - Current

Is - Pickup current selected

L - Constant

PS - Plus Setting

f - Fault

Top - Operating time for relay

TMS - Time multiplier setting

PSM - Plug setting multiplier

CT - Current Ratio

$MATLAB$ - Matrix laboratory

$PSCAD$ - Power system computer-aided design

$ETAP$ - Electrical transient and analysis program

CB - Circuit breaker

UTM - University Teknologi Malaysia

NOP - Normal Off Point

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Protective relays play a crucial role in ensuring the safety and reliability of the power system, in the event of faults, a relay should detect the abnormal condition and isolates the affected section of the Power System. Inverse Definite Minimum Time (IDMT) relay is one of the most widely used and implemented as overcurrent relay devices in many distribution networks due to its simplicity and reliability [1]. The operating time of an IDMT relay, a form of protection relay, is inversely correlated with the magnitude of the fault current. As a result, when the fault current is high, it operates swiftly, but when the fault current is low, it operates slowly.

To provide the greatest possible level of availability for users, protection discrimination is an important element that must be considered beginning with the design stage of a low-voltage infrastructure. The discrimination Scheme is a protection scheme that is used to coordinate the operation of IDMT relays in a power system network, ensuring that only the relay closest to the fault operates [1]. Discrimination is important in all installations for the comfort of users, however, it is fundamental in installations requiring a high level of service continuity, e.g. industrial manufacturing processes [1]. Industrial installations without discrimination run a series of risks of varying importance including finished-product losses and risk of damage to production.

Every electrical circuit requires overcurrent protection[2]. Overcurrent occurs when the circuit's or equipment's rated amperage capacity is exceeded, caused by overloading, short circuit ground fault, or arc fault [2]. Overcurrent protection is a safety system that terminates currents from exceeding the circuit's or equipment's allowable current rating . There might be serious consequences if a circuit does not have overcurrent protection. Overcurrent, for example, can ruin electronic devices without protection and result in electrical fires, shock, and electrocution. As a result, overcurrent protection devices should be installed in all electrical circuits and equipment to interrupt and open circuits when overcurrent events occur [2].

This project involves analysing the relay's performance in detecting and isolating the portion of the system experiencing the hazard so that the rest of the system can operate normally as fast as possible. In doing so, the equipment will be safeguarded from further damage and more importantly from endangering human life. The study proposed a protection scheme by providing the relay Pickup current/Plug Setting (PS) and Time Multiplier Setting (TMS)/ time dial setting (TDS) for discrimination process. For this study, the IEC-255-3 standard moderately inverse IDMT curve characteristic is chosen for the simulation and to use an actual single line diagram in Univeristy Technology Malaysia (UTM), Johor using the Power System Computer Aided Design (PSCAD). To check the correct operation and discrimination of the respective relays, several faults will be simulated which are faults between Red to Yellow to Blue and fault between Red to Blue to Yellow to Earth.

1.2 Problem Statement

Ensuring the reliability, selectivity, and efficiency of protection relays is the most important in power systems, particularly to mitigate potential impacts on system stability, but they often suffer from issues such as poor selectivity, coordination, and sensitivity. These problems can lead to incorrect tripping of the relays, resulting in a power system outage or damage to equipment..

Therefore, to guarantee a reliable, fast, and safe operation of the overcurrent relay, a study needs to be done on the performance of IDMT relays in the selected area including an analysis of their coordination with other protective devices, sensitivity to a different type of faults and the impact of local area power system factors. The result of this study will help to improve the performance of IDMT relays for overcurrent protection in that area and provide insights for the design and operation of the future power system.

1.3 Project Objective

This project main goals is to propose Definite Minimum Time Overcurrent (IDMT) Relay Protection Discrimination Schemes for Power System Networks Using PSCAD. The following are the specific objectives are as follows:

1. To design and construct a real single-line diagram of a power system using PSCAD software.
2. To simulate the performance of IDMT relays in the University Technology Malaysia system under different types of faults, which are faults between Red to Yellow to Blue and faults between Red to Blue to Yellow to Earth.
3. To analyze and compare the margin between calculated relay tripping time and simulated values for normal inverse time overcurrent.

1.4 Scope of Project

The goal of this project is to apply complicated drawings and data gathered from the industry to simulate into PSCAD software, aiming to spark the design and construction of circuits. Additionally, the project aims to simulate two types of faults, namely between Red to Yellow to Blue and between Red to Blue to Yellow to Earth, based on the provided single-line diagram. Furthermore, the project will involve conducting calculations, in compliance with the IEC-255-3 standard, in order to determine the optimal relay Pickup current/Plug Setting (PS) and Time Multiplier Setting (TMS)/Time Dial Setting (TDS) for the discrimination process.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

To ensure the safe and reliable operation of power systems, protection against faults and abnormal circumstances is essential Protective relays have been frequently used in this situation as an efficient way to detect and isolate defects, as well as to prevent equipment and system damage. The inverse definite minimum time overcurrent (IDMT) relay is a commonly used protective relay that operates based on the magnitude and duration of the current flowing through a power system network [3]. However, it can be difficult to properly discriminate and coordinate IDMT relays, particularly in complicated power networks with several sources and loads.

Computer-based simulation techniques have been more significant in the design and study of power system safety methods in recent years. PSCAD is a widely utilized software that allows the modelling and simulation of power system networks including protective relays [4]. Several research studies in this regard have concentrated on the creation of IDMT relay protection discrimination algorithms utilizing PSCAD. These projects attempt to assess and investigate the IDMT Overcurrent discrimination ability to recognize fault occurrence for normal inverse time overcurrent.

2.2 Faults on Power System

In power system networks, faults are abnormal conditions that can disrupt their normal operation. These can include events such as short circuits or open circuits [5]. When a device, component, or element fails to operate as required, it is often due to physical conditions known as faults. Examples of faults include short circuits or broken wires[5]. Understanding and identifying these faults is crucial to the proper functioning and protection of the power system. By detecting and isolating faults, protective relays can prevent damage to equipment and ensure the system operates safely and reliably. As a result, the study of faults and their effects on power system networks is an important area of research in electrical engineering.

2.2.1 Open Circuit Fault

An open circuit fault is an electrical problem that occurs when current flow is interrupted due to a break or discontinuity in a conductor [5]. This sort of defect can have major consequences on electrical systems, ranging from equipment malfunctioning to system breakdown [5]. An open circuit in one of the conductors of multi-conductor wire results in open conductor faults. As a result, the current flow in one conductor is interrupted, but the other conductors carry on as usual. A two-conductor open fault happens when two of the conductors become open, resulting in unbalanced current flow, and leading to abnormal voltages, and currents. The three conductors open fault, on the other hand, happens when all three conductors in a three-phase system open, resulting in a total loss of power and serious consequences, particularly in critical applications.

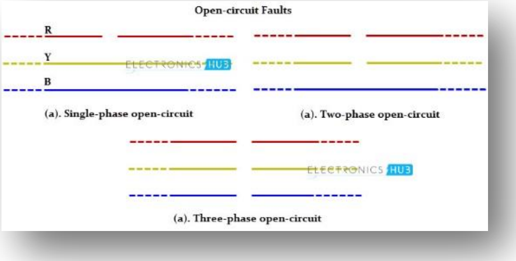


Figure 2.1 Type of Open Circuit Fault

2.2.2 Short Circuit Fault

Short circuit faults are a form of an electrical fault that can develop in a power system when two or more conductors create an unintentional connection [6]. Such errors can lead to excessive current flowing through the conductors, damaging the system or causing equipment to malfunction. Short circuit faults can be divided into two categories, symmetrical and asymmetrical [6]. Symmetrical faults occur when a balanced three-phase fault occurs, whereas asymmetrical faults occur when an unbalanced fault occurs in the system [6].

Table 2.1 Symmetrical and Unsymmetrical Type of Fault

No	Type Of Fault	Short Form	Symmetrical/ Unsymmetrical	Probability of accurance (%)
1.	Three-phase line to ground fault	L-L-L-G	Symmetrical	2-3
2.	Three phase line to line fault	L-L-L	Symmetrical	<1
3.	Single line to ground fault	L-G	Unsymmetrical	70-80
4.	Line to line fault	L-L	Unsymmetrical	15-20
5.	Double line to ground fault	L-L-G	Unsymmetrical	<10

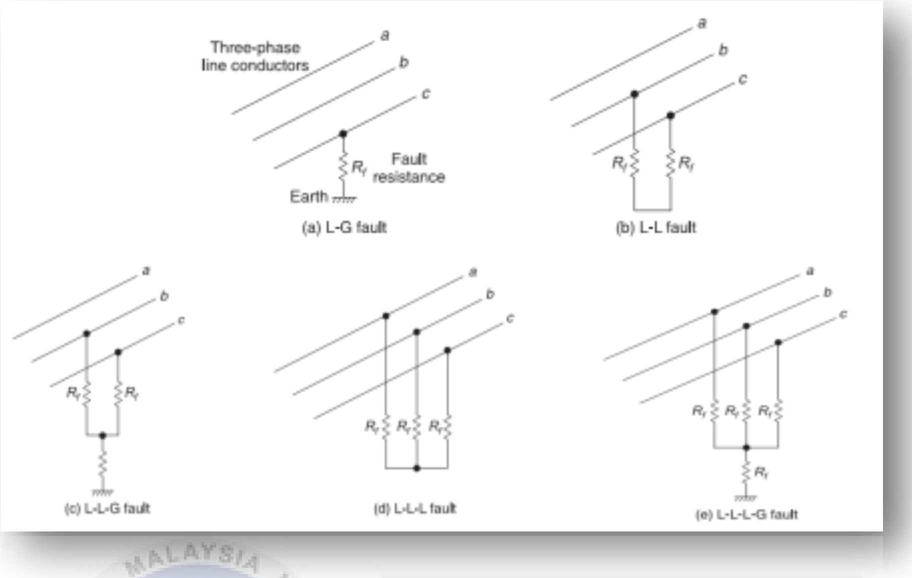


Figure 2.2 Short circuit fault

2.3 Cause of fault

One of the most common types of faults in power systems are caused by weather conditions [2]. These conditions can include lightning strikes, heavy rains, strong winds, salt deposition on overhead lines and conductors, and snow and ice accumulation on transmission lines. These environmental factors can interrupt the power supply and damage electrical installations, causing faults and system failures. For instance, heavy snow and ice accumulation on power lines can lead to the lines sagging, which may cause them to come into contact with trees or other objects, resulting in a short circuit

Equipment failure is a common cause of faults in protection systems. Generators, motors, transformers, and switching devices can all experience short-circuit faults due to a range of factors, including aging, malfunctioning, and insulation failure of cables and windings. These factors can lead to high currents flowing through the equipment, which can result in further damage and potential faults in the protection system. Regular maintenance, inspection, and testing are critical in identifying and addressing potential issues before they cause damage to the equipment or faults in the protection system. Proper education and training of personnel responsible for designing, installing, and maintaining protection systems can also help minimize the likelihood of equipment failure and resulting faults in the protection system.

In addition to equipment failures, human errors can also cause faults in protection systems. Errors such as selecting improper ratings for equipment, forgetting to replace metallic or electrical conducting parts after servicing or maintenance, and switching circuits while they are under servicing can all lead to electrical faults. To prevent such errors, it is important to provide proper education and training to personnel responsible for designing, installing, and maintaining protection systems. Additionally, establishing standard operating procedures, performing regular inspections and tests, and implementing safety measures can all help minimize the likelihood of human errors leading to faults in protection systems.

Fires can also cause faults in protection systems through the smoke they produce. Smoke particles can ionize the air surrounding overhead lines, leading to sparks between the lines or between conductors and insulators. This flashover can cause insulators to lose their insulating capacity due to high voltages, leading to faults in the protection system. To mitigate the risk of fires causing faults, regular inspections of electrical installations and equipment should be conducted to ensure that they are in good working condition. In addition, fire prevention measures should be in place, such as installing smoke detectors and fire suppression systems, to reduce the likelihood of fires occurring in the first place.

2.4 Power System Protection

2.4.1 Function of Power System Protection

A protection system is essential to maintain the safe and efficient operation of a power system [7]. One of the primary functions of a protection system is to detect faults. Faults can occur due to various reasons, such as equipment failures, human errors, weather conditions, or fires, and they can result in power system failures, leading to outages, equipment damage, or even safety hazards. Thus, detecting faults quickly and accurately is crucial to prevent further damage or risks to the system and the users.

Once a fault is detected, the protection system should isolate the faulted component to prevent it from affecting other parts of the system [7]. Isolation can be achieved by tripping a breaker or a switch that disconnects the faulted component from the rest of the system. By isolating the fault, the protection system can ensure that the rest of the system can continue to supply power to the unaffected parts and maintain system stability [7].

After isolating the fault, the protection system can also aim to restore the faulted component to normal operation if possible. This restoration can be automatic or manual, depending on the type of protection system and the severity of the fault. The ultimate goal of the protection system is to continue the power supply for the rest of the system and protect the faulted part from further damage [8]. Thus, a reliable and efficient protection system is critical to ensure the safe and uninterrupted operation of a power system [8].

2.5 Criteria

Protection design is a critical aspect of power system operation, aimed at ensuring the reliability and safety of the system. One of the primary goals of protection design is to maintain the continuity of supply by quickly and accurately identifying and isolating faults in the system [9]. To achieve this, the protection system must be designed with six essential criteria in mind. First, it must be fast, enabling it to respond rapidly to faults to minimize system downtime. Second, it must be reliable, ensuring that it functions correctly and consistently in all conditions. Third, it must be dependable, providing secure and selective protection to prevent unintended interruptions. Fourth, it must be sensitive, and capable of detecting even minor faults in the system. Finally, it must be simple and economical, reducing the complexity and cost of the protection system while maintaining its effectiveness. By meeting these criteria, protection systems can effectively preserve the continuity of power supply while ensuring the safe and reliable operation of the system [9].

2.5.1 Fast

Fault at any point in the system must be detected and isolated rapidly to minimize fault duration and equipment damage [10]. To achieve this, any intentional time delays should be precise, allowing for fault detection and isolation without compromising the protection system's speed and effectiveness. The protection system must also provide fast fault clearance to minimize system interruptions and improve system stability[10]. However, it should not be too slow, which may result in damage to equipment due to prolonged fault current. Conversely, it should not be too fast, which may result in undesired operation. The aim of the protection system is to minimize damage to the equipment due to prolonged fault current, while also ensuring efficient and reliable operation of the system. By balancing speed, precision, and effectiveness, the protection system can achieve its primary objectives and maintain the continuity of power supply while protecting equipment and ensuring safe and reliable system operation[10].

Tabel 2.2 Clearing time in Protection System

Voltage Level	Protection classification	Maximum Fault Clearing Time
500Kv	Main Protection	100 ms
	Backup Protection	1 second(short circuit rating of the primary equipment)
275Kv	Main Protection	100 ms
	Backup Protection	3 second (short circuit rating of the primary equipment)
132kV	Main Protection	150 ms
	Backup Protection	3 second (short circvuit rating of the primary equipment)

2.5.2 Reliable and dependable

Dependability and reliability are two crucial criteria that must be met. Dependability means that the protective device must operate correctly, meaning that it should perform its intended function when required. On the other hand, reliability means that the protection must operate correctly when needed to do so, even after being idle for months or years. Additionally, the protection must be secure, meaning that it should not operate when not required to do so. To ensure that the protection system is operating correctly, a dual protection system comprising a main and a backup system can be implemented to improve reliability and dependability. It is important to note that reliability, dependability, and security apply to the complete protection system as one complete system, including hardware, software, instrument transformers (CT, PT), and circuit breaker, as all components must work together correctly to perform their intended function.

2.5.3 Selective

Selectivity refers to the coordination of protection devices to ensure that a fault at a specific location is cleared by the minimum number of circuit breakers located nearest to the fault location, completely isolating the fault [11]. Selective protection must be able to identify the faulty section and/or phase(s) of the power system accurately. In other words, the protection system must be able to discriminate between normal and abnormal system conditions to prevent unnecessary or false tripping of circuit breakers. This selectivity is necessary to minimize the impact, disruption, and effects of a failure on other healthy parts of the network [11].

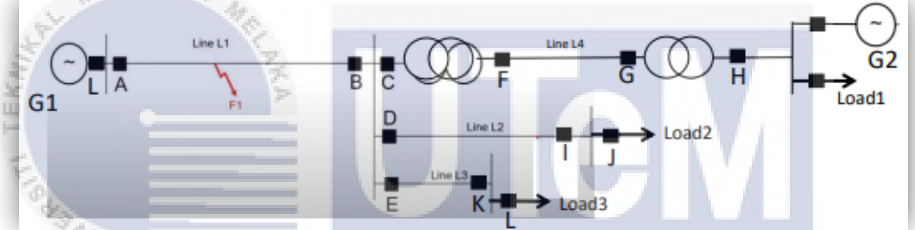


Figure 2.3 Fault to Isolate in a System

- Initially, all CB are in close position & both G1 and G2 is supplying all loads.
- F1 occur and fault current will flow to F1 from G1 and G2. No current will flow to the load.
- Then, A and B should operate to fully isolate the fault and minimize impact to the loads, as long as G2 can supply to all loads. If not, then, there will be stability issues.
- If the A and B failed to OPEN, L and C should OPEN as a backup- BUT all loads will receive no supply.

2.5.4 Sensitive

Sensitivity refers to the protection system's ability to detect and distinguish between normal and faulty system conditions, even when the difference between them is minimal. The sensitivity of the protection system must be set correctly to ensure that it operates reliably when required. A more sensitive system can detect smaller fault currents, increasing its ability to identify and isolate faults accurately. However, if the system is oversensitive, it can become unstable, resulting in unnecessary or false tripping of the circuit breaker. Therefore, it is crucial to balance sensitivity to ensure that the protection system can accurately detect faults while avoiding instability and unnecessary tripping, making sensitivity a key aspect of protection design criteria.

2.5.5 Simple and Economical

Simplicity refers to the protection system's ability to perform its functions correctly while requiring a minimum amount of protection equipment and circuitry. The system should be easy to operate and maintain, and its components should work together to provide reliable protection. At the same time, the system must be economical and cost-effective. The cost of the protection system should be reasonable, appropriate, and in line with the intended function and power system risk assessment. This means that the protection system should provide maximum protection at the minimum/optimum cost, ensuring that the system is both effective and affordable. Thus, simplicity and economy are critical aspects of protection design criteria that must be considered to ensure a reliable and cost-effective protection system.

2.6 Type of Overcurrent Protection Relay

There are many different schemes of overcurrent (o/c) protection that can be utilized to protect power systems and electrical equipment. O/c protection is an essential component of power system protection that is used to detect and isolate faults in the power system [12]. The design and construction technology of the overcurrent relays range from the electromechanical single characteristic inverse curve relay such as induction disk type to the microprocessor-based relay with the choice of multi-characteristic curves. Protective relays are designed to react accordingly based on the results of overcurrent protection device discrimination [12].

2.6.1 Instantaneous Overcurrent Relay

Definite current or “Instantaneous.” overcurrent protection relay operates with a constant operating time, regardless of the current magnitude exceeding the pick-up value. However, there is an unavoidable inherent time delay of a few milliseconds. This small delay, though practically inevitable, does not compromise the overall effectiveness of the relay's operation. By continuously monitoring the current flow, the instantaneous overcurrent protection relay compares the actual current level with a pre-set threshold value. If the current exceeds this threshold, the relay rapidly triggers a trip signal, initiating the disconnection process.

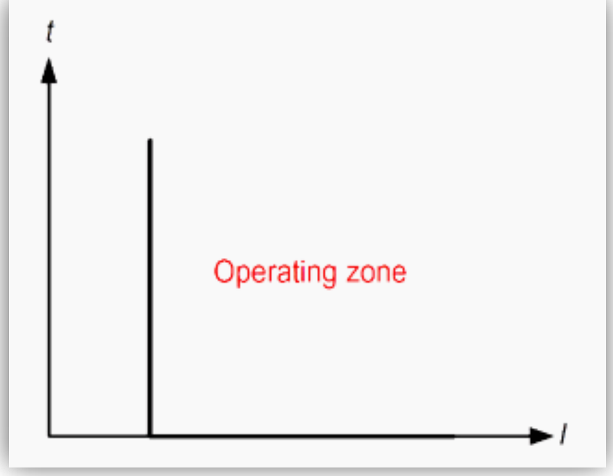


Figure 2.4 Definite-Current Characteristics

In Figure 2.6, coordination of definite-current relays is based on the fact that the fault current varies with the position of the fault because of the difference in the impedance between the fault and the source. That is, the relay located furthest from the source operates for a low current value and the operating currents are progressively increased for the other relays closer to the source.

2.6.2 Definite Minimum Time (DMT) Overcurrent Relay

A definite-minimum-time overcurrent relay operates upon two essential conditions for tripping to occur. Firstly, the fault current must exceed the predetermined setting or pick-up value. This ensures that the relay is activated only when the current exceeds the specified threshold, indicating a potential fault or abnormality in the system [12]. Secondly, the fault must persist for a duration equal to or greater than the time setting of the relay. This time setting allows the relay to differentiate between temporary fluctuations and sustained faults, ensuring that only prolonged faults are detected and acted upon. The DMT Overcurrent Relay offers flexibility in adjusting its settings to handle different current levels.

By using different operating times and employing a time dial setting, the relay can introduce a time delay before it operates once the fault current reaches or exceeds the relay's current setting.These adjustable settings allow for selective tripping, ensuring that the circuit breaker closest to the fault is quickly tripped while the remaining breakers are sequentially tripped with longer time delays, minimizing power supply outages to other load areas. The difference in tripping times for the same current is referred to as the "discrimination margin," enabling better coordination and system reliability [12]. Compared to Instantaneous Overcurrent Relays (Figure 2.7), which operate instantaneously, the major distinction lies in the operating time. The Definite Time Overcurrent Relay operates after a defined time delay (Figure 2.8), providing a predetermined time before tripping occurs.

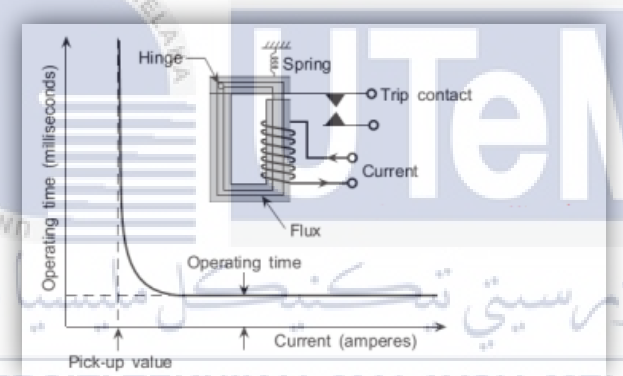


Figure 2.5 Instantaneous overcurrent Relay Characteristic

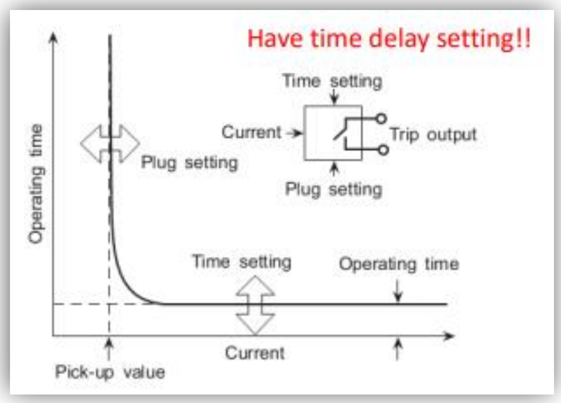


Figure 2.6 Definite-Time Overcurrent Relay Characteristic

2.6.3 Inverse time Overcurrent Protection Relay

In this type of relay, the characteristic feature is that the relay's operating time is inversely proportional to the fault current.. For example, the high current will operate the overcurrent relay faster than the lower one' current. In other words, the more the fault current the lesser will be the time of operation of the Relay [13]. They are available with either standard inverse, very inverse or extremely inverse characteristics as shown in Figure 2.9. The operating time of both overcurrent definite-time relays and overcurrent inverse-time relays must be adjusted in such a way that the relay closer to the fault trips before any other protection. This is known as time grading.

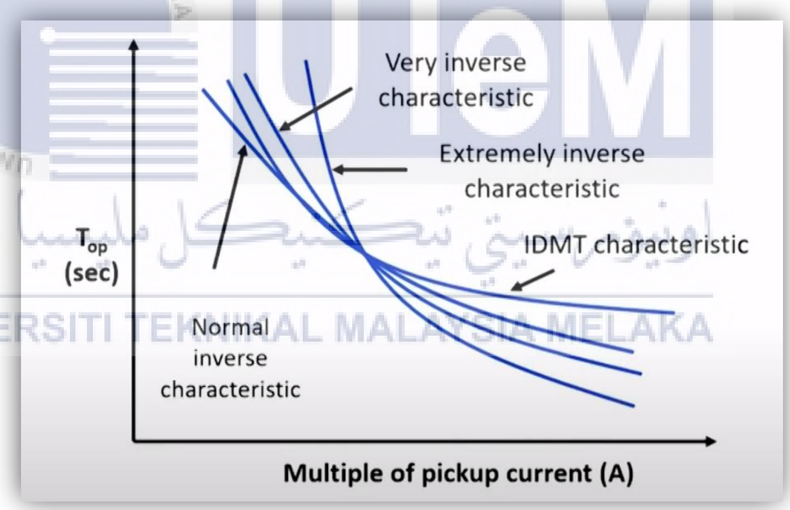


Figure 2.7 Inverse Time Overcurrent Relay Characteristic

2.6.4 Inverse Definite Minimum Time (IDMT) Overcurrent Relay

Overcurrent relays with inverse definite minimum time (IDMT) are widely used due to their simple design and economy. Among the various factors affecting relay operating time, current transformer ratio (CT), plug setting (PS) and time multiplier setting (TMS) are closely related Overcurrent relays are suitable for protecting equipment due to their time curves that allow temporary overload conditions. Relays with an inverse definite minimum time characteristics have inversely proportional operation times based on fault current. These relays are categorized according to their characteristic curves, which determine how fast they operate. According to IEC-255-3 standards, the relays have three IDMT characteristics. Each inverse type can be identified via current and time relationships as shown below [13], [14].

- Standard inverse

$$t_{OP} = TMS\left(\frac{0.14}{\left(\frac{I_{fault}}{I_{pickup}}\right)^{0.02} - 1}\right)$$

- Very inverse

$$t_{OP} = TMS\left(\frac{0.14}{\left(\frac{I_{fault}}{I_{pickup}}\right) - 1}\right)$$

- Extremely inverse

$$t_{OP} = TMS\left(\frac{80}{\left(\frac{I_{fault}}{I_{pickup}}\right)^{2} - 1}\right)$$

2.7 IEC/IEEE Standard for Inverse Time Characteristic Curve for Overcurrent Relay

IEC and IEEE Standards define the operating time mathematically by the following expression and in Figure 2.8:

$$t_{OP} = \left(\frac{k\beta}{\left(\frac{I}{I_S}\right)^{\alpha} - 1} + L \right)$$

Table 2.3 ANSI/IEEE and IEC Constant for Overcurrent Relays

Standard	**Curve Description**	$\boldsymbol{\alpha}$	$\boldsymbol{\beta}$	$\boldsymbol{L}$
IEC Standard	Moderately Inverse	0.02	0.14	0
	Very Inverse	1.00	13.5	0
	Extremly Inverse	2.00	80.00	0
IEE Standard	Moderately Inverse	0.02	0.0515	0.114
	Very Inverse	2.0	19.61	0.491
	Extremly Inverse	2.00	28.2	0.1217

2.8 Calculation in Overcurrent Relay

2.8.1 Plug Setting Multiplier (PSM)

Plug setting multiplier is nothing but a ratio between the actual fault current in the relay operating coil to pick up current [15].

$$PSM = \frac{Fault\ Current}{Relay\ Pickup\ Current}$$

2.8.2 Current setting

A relay's pickup current is adjusted based on these system requirements. Also called the current setting of the relay. This can be achieved by providing an appropriate number of taps in the coil. Plugs can be inserted in different points on the bridge to change the number of active turns in the coil. Currently, relays are set to increase their pickup current by a percentage of the CT secondary current rating.

$$Current\ Setting = \frac{Pickup\ Current}{Rated\ Secondary\ Current\ of\ CT} \times 100\%$$

2.9 Sample of Figure Overcurrent Relay

Figure 2.8 Example of Overcurrent and Feeder Protection

2.10 Standard inverse and very inverse IDMT relay comparison

2.10.1 Standard inverse IDMT relay

In accordance with applicable standards, the accuracy of the operating time ranges from 5 to 7.5% of the nominal operating time[14]. Grading margins of 0.4 to 0.5 seconds can be necessary due to the uncertainty regarding operating time and required operating time[14]. A normal inverse time Overcurrent relay has a relatively small change in time per unit change of current [16]. The application of standard inverse normally used in utility and industrial circuits. In particular, the magnitude of a fault at the time of a fault is heavily influenced by the system's generating capacity.

2.10.2 Very inverse IDMT relay

This inverse IDMT gives more inverse characteristics than inverse IDMT as a standard. Used where there is a reduction in fault current, as the distance from the source increases. Particularly effective with ground faults because of its steep characteristic. Suitable if there is a substantial reduction of fault currents as the fault distance from the power source increases. Very inverse overcurrent relays are particularly suitable if the short circuit current drops rapidly with distance from the substation. The grading margin may be reduced to a value in the range from 0.3 to 0.4 seconds when overcurrent relays with very inverse characteristics are used. Used when fault currents are dependent on fault location and used when fault current is independent of normal changes in generating capacity [16].

2.11 Summary

This literature review project explores the modelling of an Inverse Definite Minimum Time (IDMT) Overcurrent Relay Protection Discrimination Scheme for power system networks. The review discusses the functions, aims, and criteria of a protection system in ensuring the reliable operation of power systems. It also emphasizes the adherence to the IEC-255-3 standard for inverse overcurrent relays. This research involves simple calculations to determine the pickup current, operation time, and time dial setting for the relay. By simulating various fault scenarios, the study aims to assess the scheme's performance, its ability to discriminate between faulted and healthy sections of the power system, and optimize its effectiveness.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter serves as a comprehensive guide to the methodology employed in the project aimed at modelling an Inverse Definite Minimum Time (IDMT) Relay Protection Discrimination Scheme for Power System Networks using PSCAD. The procedure begins with a careful data gathering process to accurately represent real-world scenarios. Finally, the chapter concludes with an in-depth analysis of the circuit model, incorporating suitable parameters tailored to the project's unique requirements, ensuring a robust foundation for the comprehensive modelling and analysis of IDMT relay protection schemes in power system networks.

3.2 Methodology

As illustrated by Figure 3.1, the flowchart provides a visual representation of a meticulously structured methodology, comprising seven distinct steps. The initial stage involves the identification of objectives and formulation of the problem statement, setting the foundation for the entire process. Moving forward, the second step encompasses extensive information gathering, achieved through a thorough literature review and on-site visits to collect real data from power system networks. This phase aims to ensure a comprehensive understanding of real-world scenarios and dynamics.

The third step involves the selection of suitable software for simulating power system circuits, the fourth step delves into relay setup within the chosen software, followed by the fifth step focusing on circuit testing. The sixth step is dedicated to systematic data collection, and, finally, the seventh step involves the critical analysis and comparison of the collected data with theoretical calculations. This comprehensive methodology, composed of these meticulously executed steps, forms the backbone of the project, ensuring a thorough exploration and modelling of the IDMT relay protection discrimination scheme for power system networks.

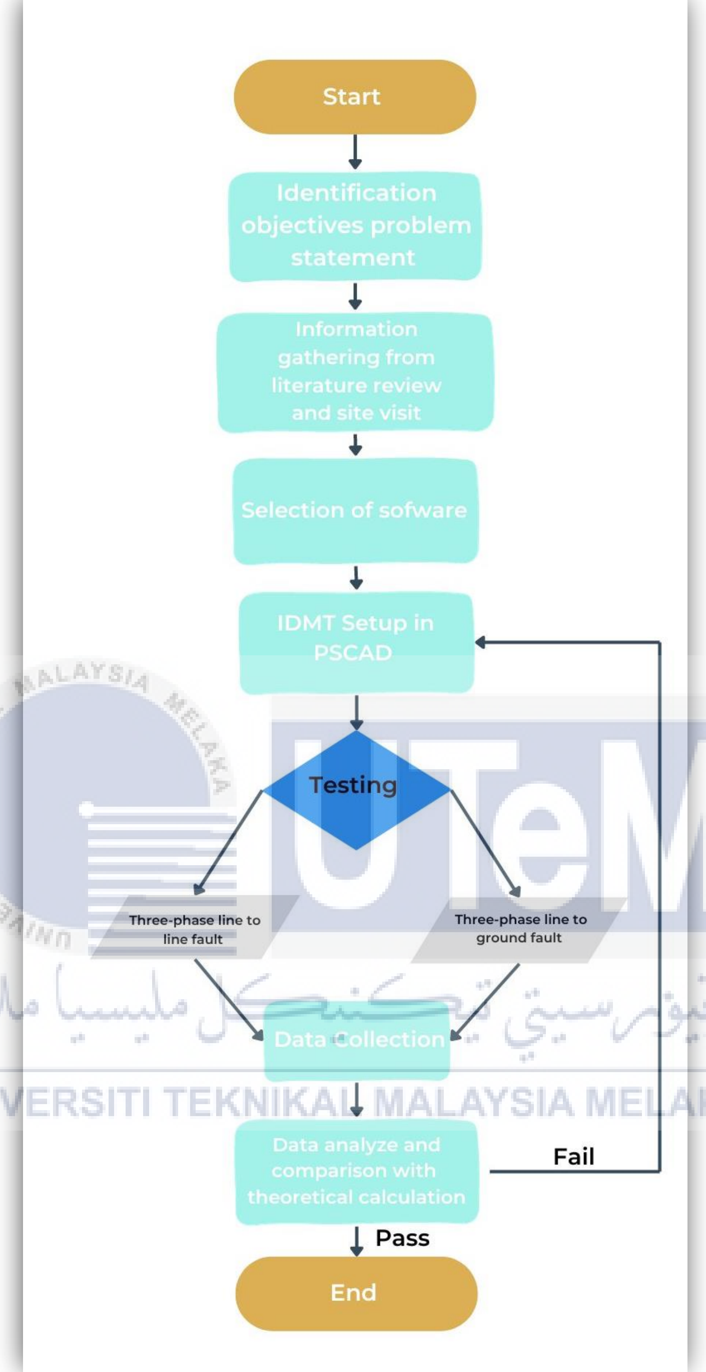


Figure 3.1 Methodology Flowchart

3.3 Information Gathering

3.3.1 From Literature Review

In the data gathering phase of the methodology, an extensive literature review is conducted, encompassing journals, theses, and books related to IDMT relays, fault analysis, standards, and formulas associated with Time Multiplier Settings (TMS) and operating time calculations. This comprehensive exploration aims to establish a profound understanding of the theoretical foundations essential for the project.

3.3.2 Site Visit

Moreover, practical insights have been enriched through site visits and collaborative meetings with electrical engineers at the UTM 123kV system. These engagements are designed to foster a deeper comprehension of power system technology, emphasizing key aspects such as understanding the Normal Off Point (NOP) of the system (Figure 3.2), evaluating transformer ratings, exploring the number of existing bus bars, identifying the brand of relays utilized, and gaining insights into the actual high voltage schematic.

Before embarking on these site visits, a formal request letter (Apendix A) was meticulously prepared and submitted. The formal request, confirmed by Profesor Madya Dr. Hidayat bin Zainuddin, the esteemed Dean of the Faculty of Electrical Technology and Engineering (FTKE), was sent to Seksyen Projek dan Penyenggaraan (SPP) UTM. This procedural step ensures a structured and approved approach to gather essential information, aligning with the project's objectives and maintaining a professional engagement with the relevant authorities at UTM. All the findings from this site visit are show in appendix B-E.

Figure 3.2 Normal Off Point (NOP)

Figure 3.3 Load Meter in UTM Distribution Room

3.4 Selection of software

3.4.1 PSCAD (Power Systems Computer Aided Design)

The usage of PSCAD software for simulating the protection system of an IDMT relay offers several advantages. Firstly, PSCAD provides a highly flexible and customizable environment for simulating complex power systems. It allows for the precise modelling of various components, including the power supply, relay, transformer, and load, enabling a comprehensive analysis of the protection system's behaviour. With PSCAD's extensive library of pre-built models and the ability to create custom models, researchers can accurately replicate real-world scenarios and assess the relay's performance under different fault conditions.

Additionally, PSCAD facilitates the simulation of large-scale power systems with multiple relays, transformers, and loads, enabling a comprehensive assessment of the entire protection scheme. It enables researchers to evaluate the coordination and discrimination aspects between various relays, ensuring that the IDMT relay operates optimally in coordination with other protective devices.

Furthermore, PSCAD allows for the efficient exploration of different time dial settings, pickup current values, and relay configurations. Researchers can easily modify these parameters, simulate various fault scenarios, and analyze the relay's behaviour under different operating conditions.

Overall, the utilization of PSCAD software for simulating the protection system of an IDMT relay offers researchers a powerful and versatile tool to analyze, optimize, and validate the relay's performance in a simulated environment, ultimately leading to improved reliability and effectiveness of the protection system.

3.5 Experimental Setup

3.5.1 Distribution Network Modelling

By referring to the schematic diagram of the distribution network received from Seksyen Projek dan Penyenggaraan (SPP), UTM, the complexity has been reduced. Figure 3.3 illustrates this reduction, showcasing the transformation from the initial 10 complete rings to a more manageable selection of 2 complete rings designated for testing purposes. This strategic simplification facilitates a more straightforward and efficient process of modelling in PSCAD. Additionally, by recognizing that certain rings have the same quantity of relays, redundant testing is avoided, further streamlining the testing procedure for enhanced efficiency and focused outcomes.

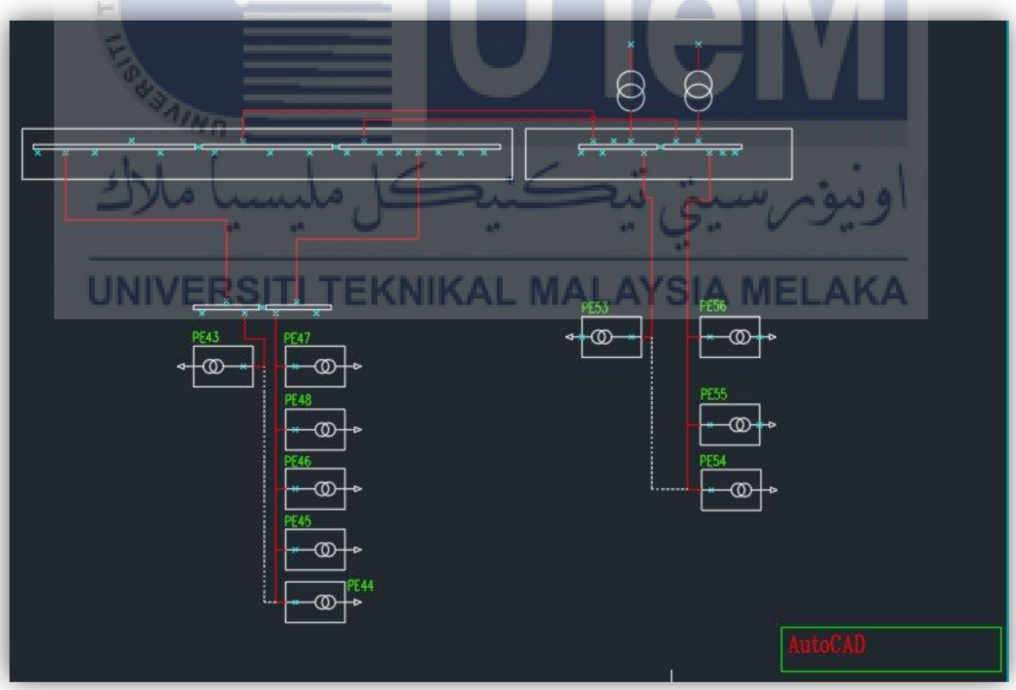


Diagram 3.4 Reduced Circuit in AutoCAD

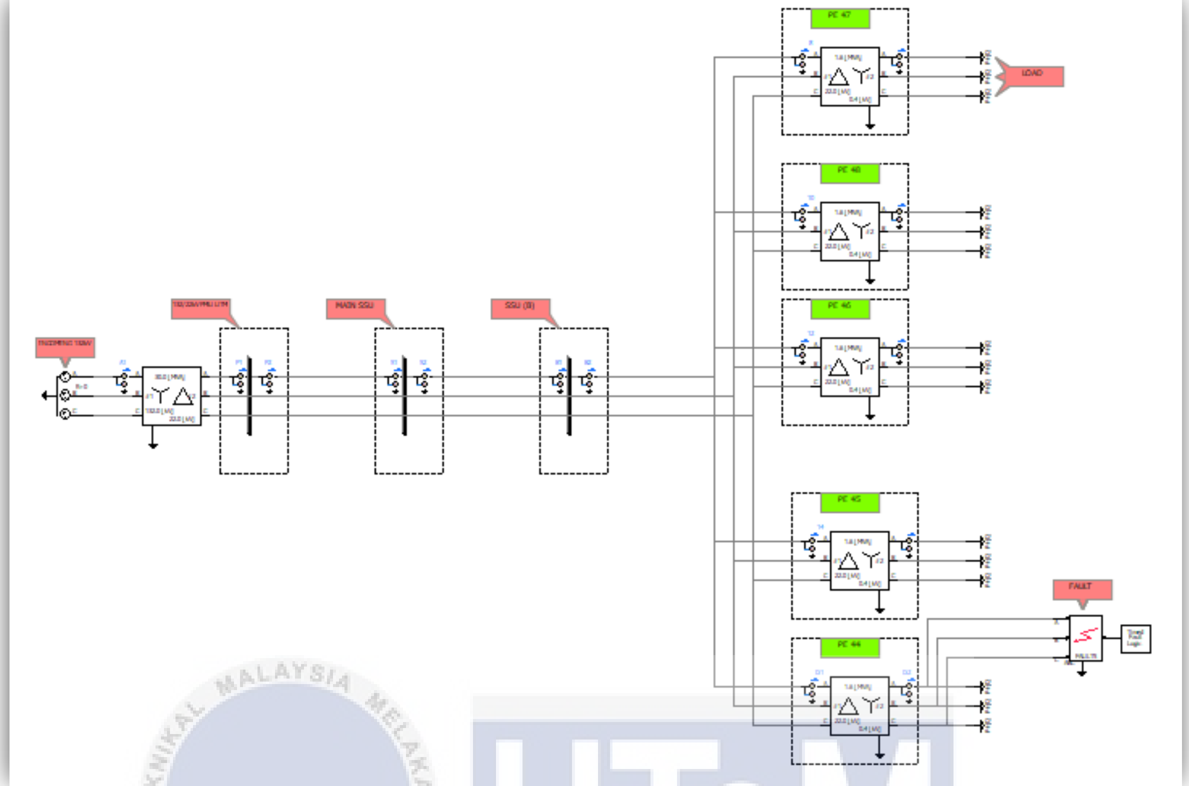


Diagram 3.5 Distribution Network model using PSCAD (Longest)

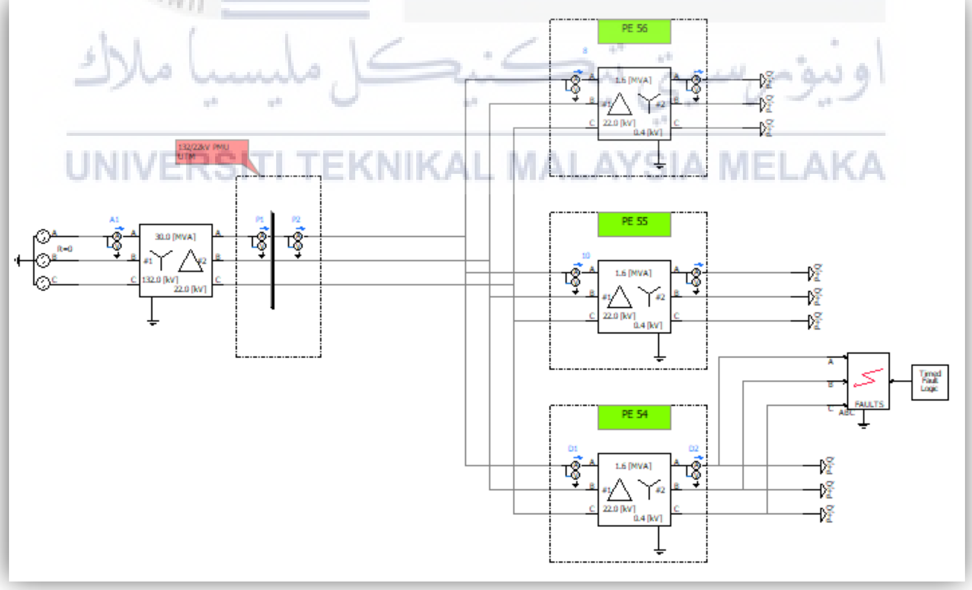


Diagram 3.6 Distribution Network model using PSCAD (Shortest)

3.5.2 Relay Setup

The IEC-255-3 std moderate inverse will be chosen for the Inverse time overcurrent relay setting to run the simulation and use to analyse the data element is defined as a current operated relay produces an inverse time-current characteristic by integrating a function of current with respect to time. The function is defined as a trip when the input current is higher than the Pickup Current and reset when the current is less than the Pickup Current.

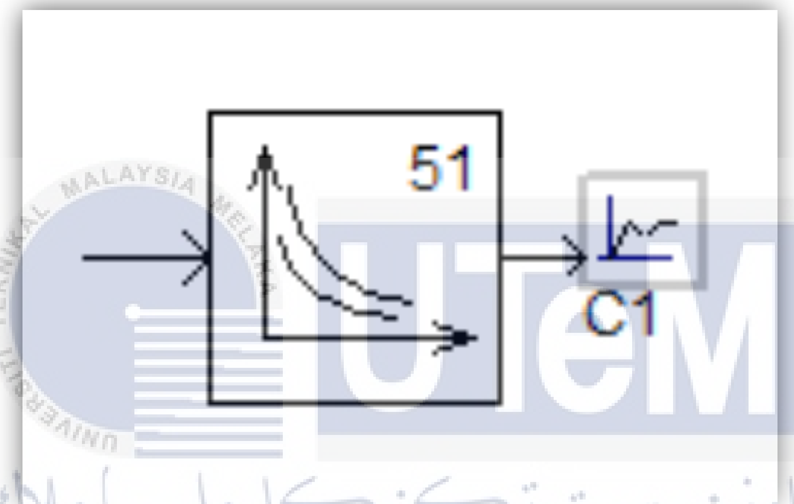
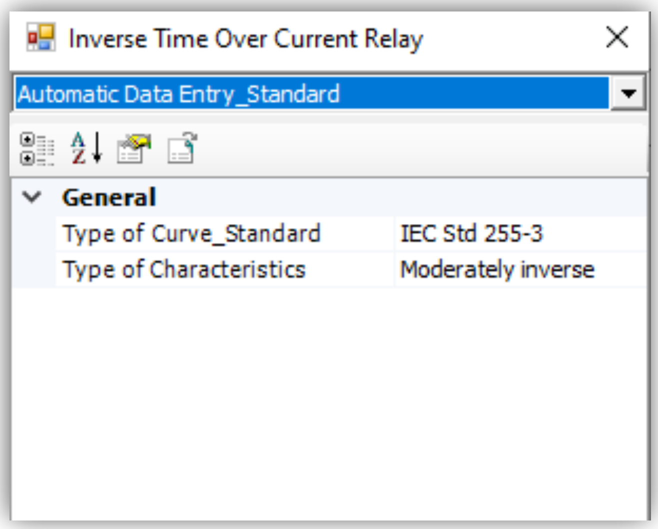


Figure 3.6 Inverse time overcurrent relay block



Inverse Time Over Current Relay

Automatic Data Entry_Standard

General

Type of Curve_Standard: IEC Std 255-3

Type of Characteristics: Moderately inverse

Figure 3.7 Inverse time overcurrent relay setting

3.5.3 Fault Setup

For this part, the fault will be applied at the end of the the circuit with different type of faults which is three phase to ground fault and three phase line to line fault. The fault will be set to a be applied at 0.1 second and the fault duration are 5 second for the simulation. The overcurrent was observed and use for the appropriate current setting for relay.

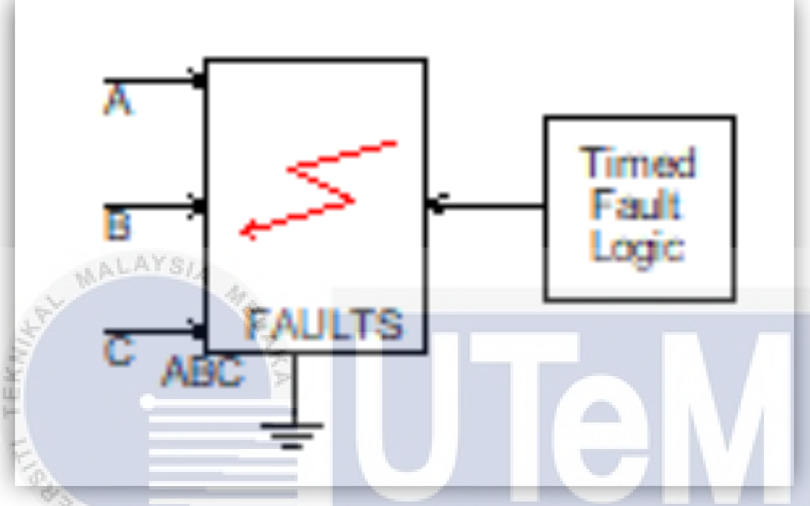
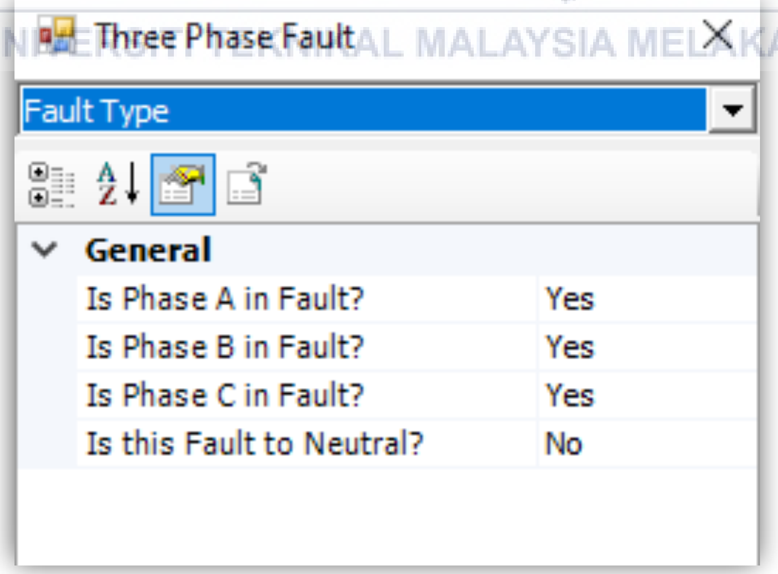


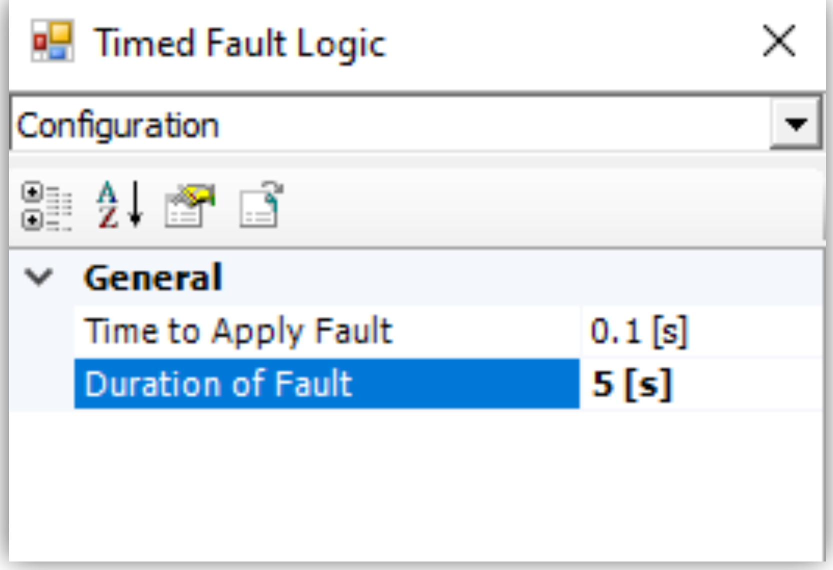
Figure 3.8 The fault block component



General

Is Phase A in Fault?	Yes
Is Phase B in Fault?	Yes
Is Phase C in Fault?	Yes
Is this Fault to Neutral?	No

Figure 3.9 The fault type setting



Time to Apply Fault 0.1 [s]

Duration of Fault 5 [s]

Figure 3.10 The fault time setting

3.6 Data Collection

Data gathering important information through simulations for analysis. The data collected will be in the form of signals, showing things like fault current and when the relay trips. These signals help to understand how the IDMT relay protection system behaves during different simulated faults. This data collection is crucial for a detailed analysis, allowing to study how the relay works in various situations and learn more about its performance.

3.7 Analyze and comparing data

The data collected from the simulation will be analysed and compare with the theoretical so we can prove the time grading of the simulation following the suppose time grading. The coordination time, or discrimination time margin, for electromechanical relays is specified to be within the range of 0.3s to 0.4s[17]. Historically, a normal grading margin was set at 0.5s[15]. However, in this thesis, a more nuanced approach is adopted, expanding the range to 0.3s - 0.5s for the margin, while allowing for an error margin of 7.5%[15]. The formula:

- Standard inverse

$$t_{OP} = TMS\left(\frac{0.14}{\left(\frac{I_{fault}}{I_{pickup}}\right)^{0.02} - 1}\right)$$

3.8 Progress BDP 1 and BDP 2

- Progress BDP 1 (Appendix F)
- Progress BDP 2 (Appendix G)

3.9 Summary

This chapter presented on the methodology for coordinating an IDMT relay in electrical power systems. The importance of a well-defined methodology cannot be overstated when it comes to achieving efficient and reliable protection. The project emphasizes the utilization of PSCAD, a powerful simulation software, to simulate fault conditions and assess the performance of the IDMT relay coordination strategy. PSCAD's capabilities enable accurate analysis and validation of the coordination approach, ensuring its effectiveness in various operating scenarios. At the core of the methodology lies the consideration of the pickup current as the main parameter for the IDMT relay. By carefully optimizing this parameter, the project aims to achieve optimal coordination among relays, reducing unnecessary tripping and enhancing the overall reliability of the protective system.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter delves into the analysis of results obtained from PSCAD simulations, aiming to understand the margin grading for overcurrent relay coordination. The simulations were conducted with a moderately inverse IDMT characteristic, aligning with the IEC 255-3 standard. This chapter scrutinizes the outcomes to uncover insights into the performance of the overcurrent relay coordination system. By evaluating the margin grading under these conditions, the discussion sheds light on the effectiveness and nuances of the relay's response, contributing to a deeper understanding of its coordination capabilities in adherence to industry standards.

The coordination time, or discrimination time margin, for electromechanical relays is specified to be within the range of 0.3s to 0.4s[17]. Historically, a normal grading margin was set at 0.5s[15]. However, in this thesis, a more nuanced approach is adopted, expanding the range to 0.3s - 0.5s for the margin, while allowing for an error margin of 7.5%[15].

4.2 Case of Study

The case study involves the examination of four distinct scenarios through PSCAD simulations, focusing on the margin grading for overcurrent relay coordination. Two Medium Voltage (MV) distribution networks were chosen for the case study, situated in different locations, one at the farthest load point from the main incoming substation and the other at the nearest. Each circuit carrying two cases of faults. These faults include faults between Red to Yellow to Blue and faults between Red to Blue to Yellow to Earth. The system is supplied by an incoming of 132kV, 50Hz generator based on information from the HT Schematic system provided from UTM (Appendix B).

4.3 Simulation in PSCAD

4.3.1 Current setting

In this study, the pickup current for the overcurrent relay is set to 150%. The calculation of the pickup current involves determining the percentage of the pickup current in relation to the rated current (Irms), calculated as the product of the current setting and Irms. The results are summarized in Table 4.1, presenting the measured values of the rated current, fault current and calculated pickup current obtained through PSCAD software for reference.

Table 4.1 Current Setting

Relay	Rated Current (A)	Pickup Current (A)	Line-Line Fault Current (A)	Line-Ground Fault Current (A)
A1	2.79618	4.19427	68.8703	54.4026
P1	12.0869	18.13035	377.208	311.428
P2	12.0869	18.13035	377.208	311.428
S1	12.0869	18.13035	377.208	311.428
S2	12.0869	18.13035	377.208	311.428
B1	12.0869	18.13035	377.208	311.428
B2	12.0869	18.13035	377.208	311.428
D1	1.50931	2.26397	371.991	302.804
D2	155.014	232.521	22014.3	17125.6
C1	1.50898	2.26347	372.036	302.839
C2	154.999	232.4985	22017	17126.8

4.4 Case 1A

The figure below (Figure 4.1) illustrates the operation in PSCAD at the farthest load point (Case 1A) from the main incoming substation. Initially, a three-phase line-to-line fault is applied downstream near relay D2. In this scenario, relay D2 is designated as the main protection device and is expected to respond swiftly to isolate the fault. Relay D1 is configured as a backup protection relay, ready to take action in the event of a malfunction in D2.

Additionally, other relays such as P1, P2, S1, S2, B1, and B2 are strategically positioned to act as backup protection in a cascading manner, starting from the nearest point to the fault. This coordinated setup ensures system protection if the fault magnitude or speed exceeds the capabilities of D2 or D1 or in case the fault is not promptly cleared by either of them. The system design incorporates a cascading protection scheme to address various fault scenarios effectively. The placement of backup relays ensures a layered response, enhancing the overall reliability and resilience of the protective system.

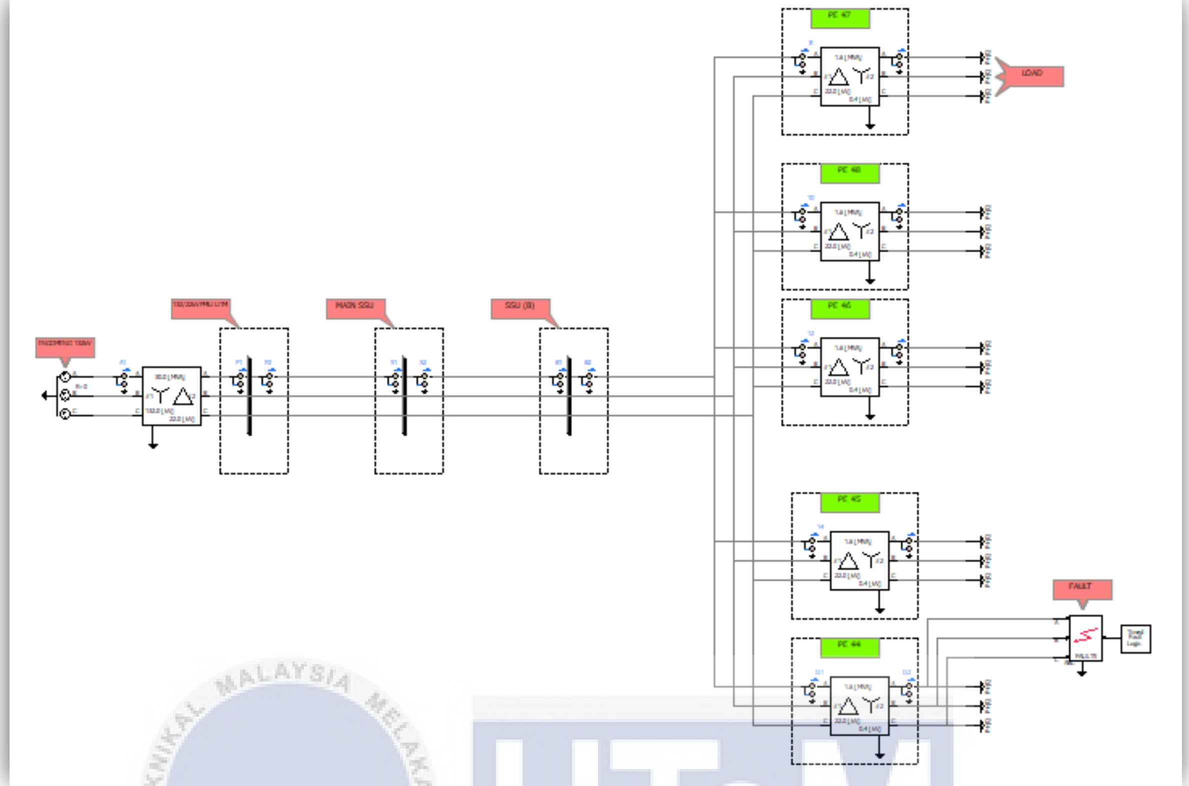


Figure 4.1 Operation of Relay for Case 1A

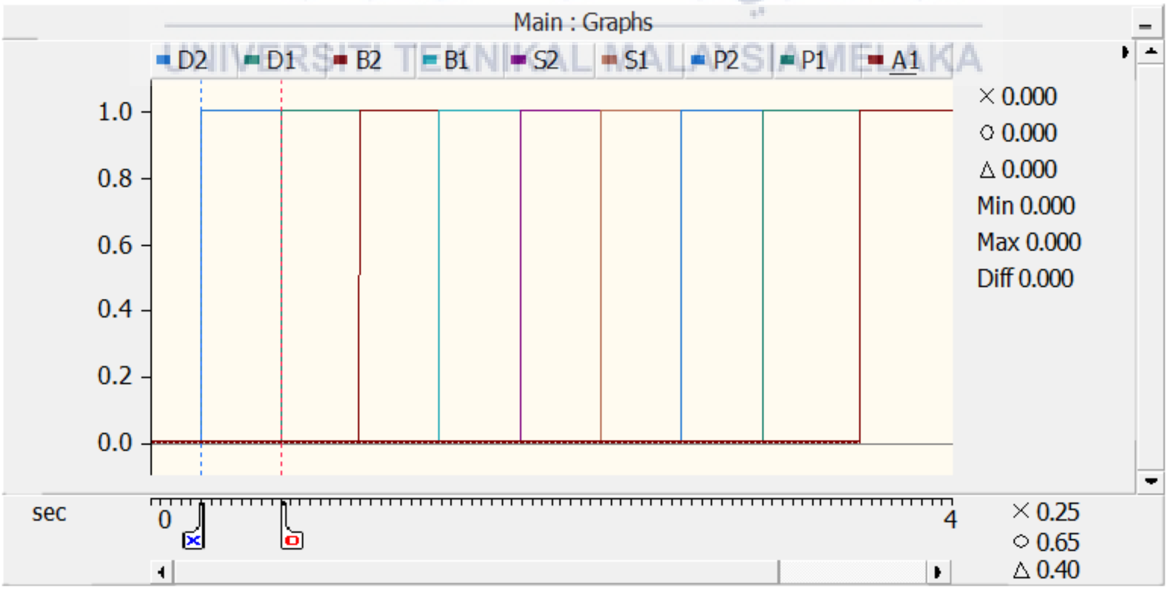


Figure 4.2.a Tripping Time for Relay D2 & D1 (Case 1A)

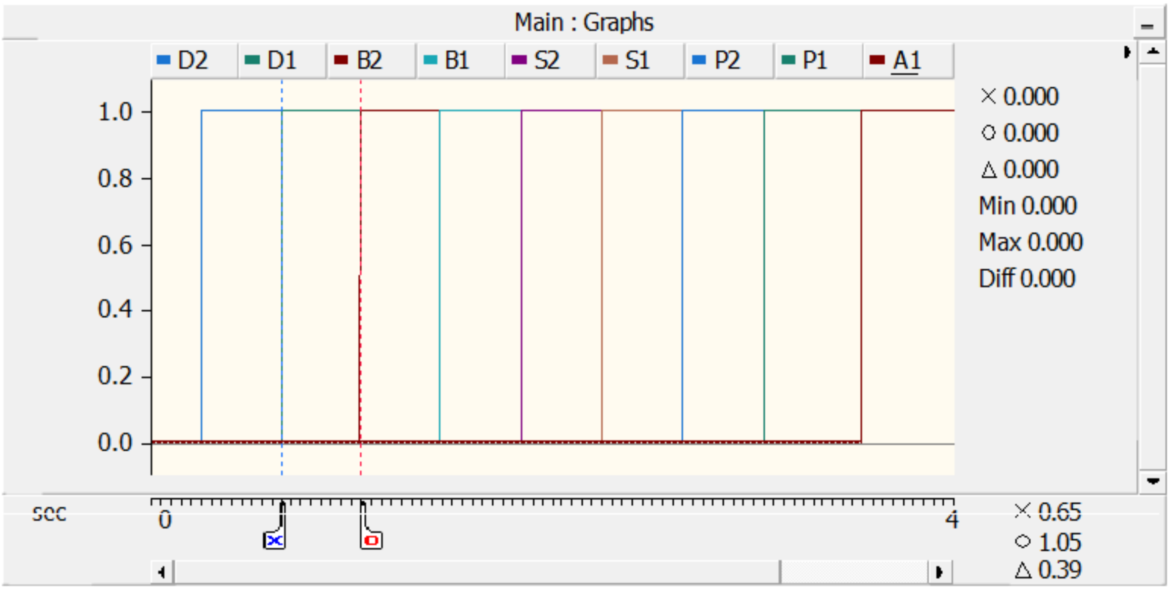


Figure 4.2.b Tripping Time for Relay D1 & B2 (Case 1A)

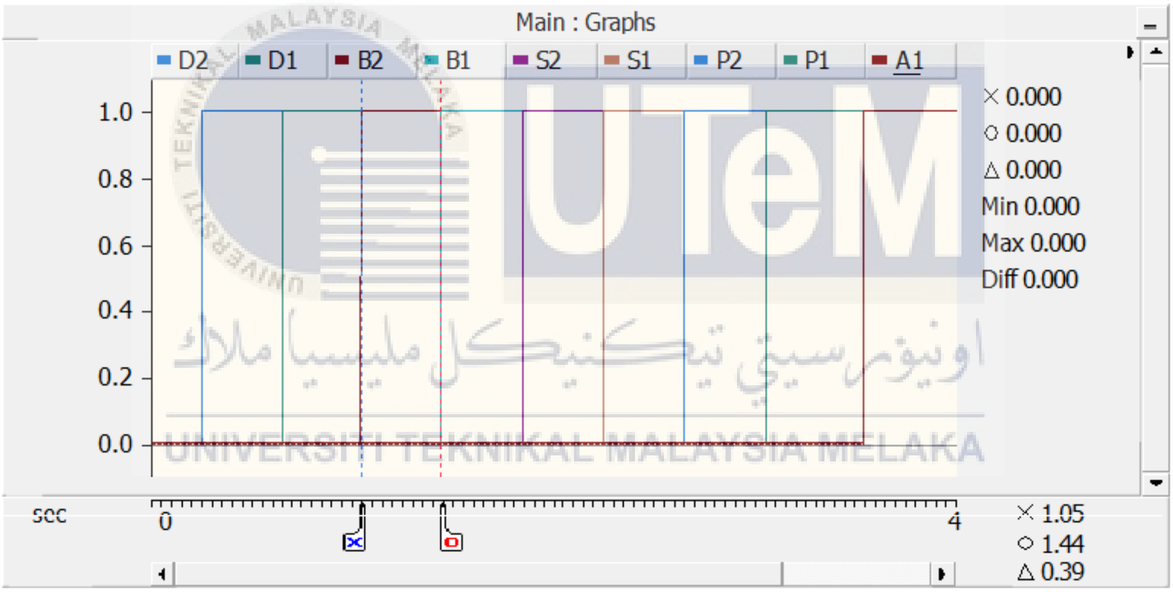


Figure 4.2.c Tripping Time for Relay B2 & B1 (Case 1A)

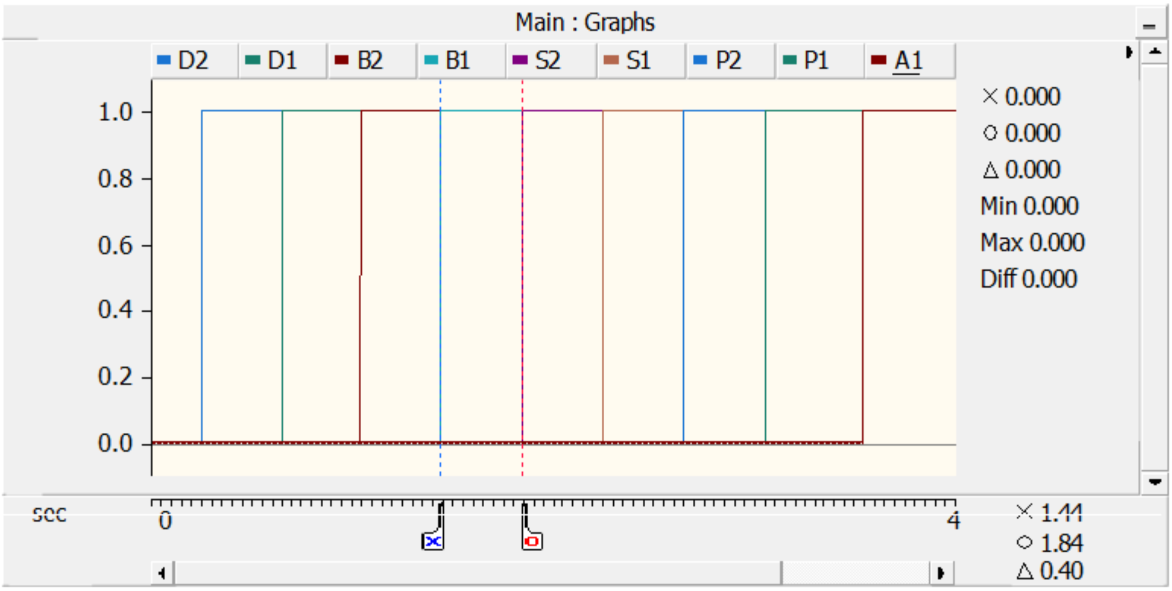


Figure 4.2.d Tripping Time for Relay B1 & S2 (Case 1A)

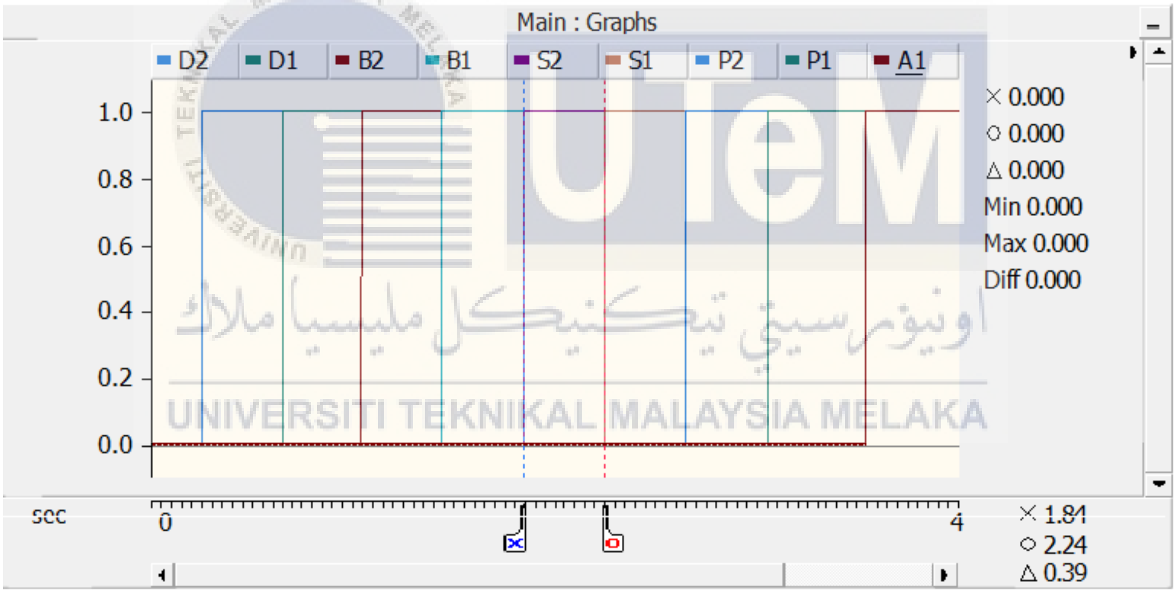


Figure 4.2.e Tripping Time for Relay S2 & S1 (Case 1A)

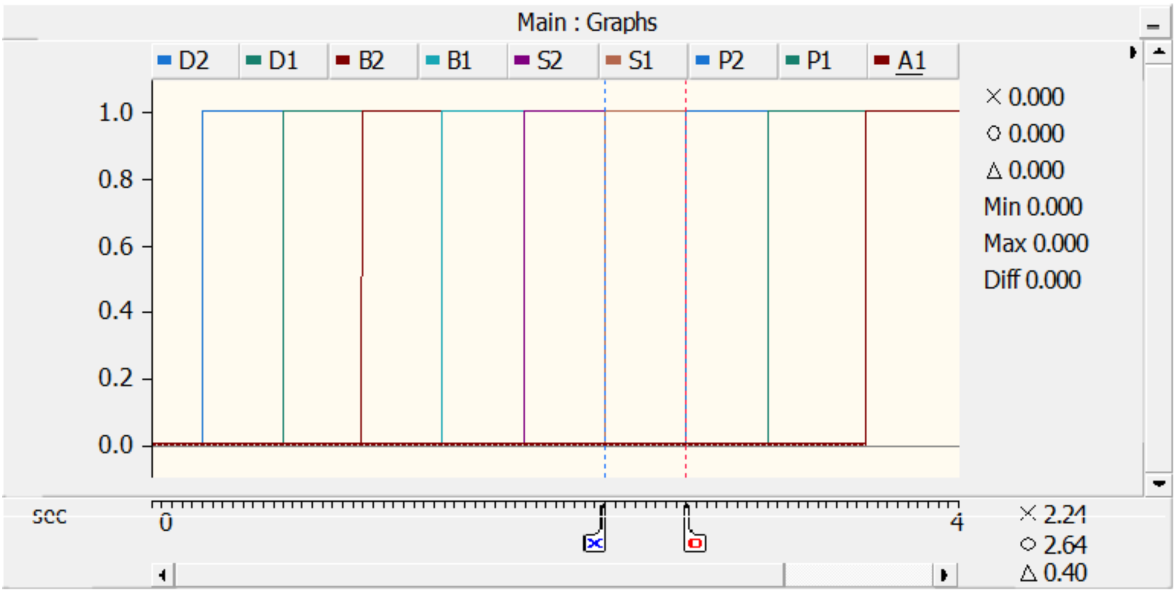


Figure 4.2.f Tripping Time for Relay S1 & P2 (Case 1A)

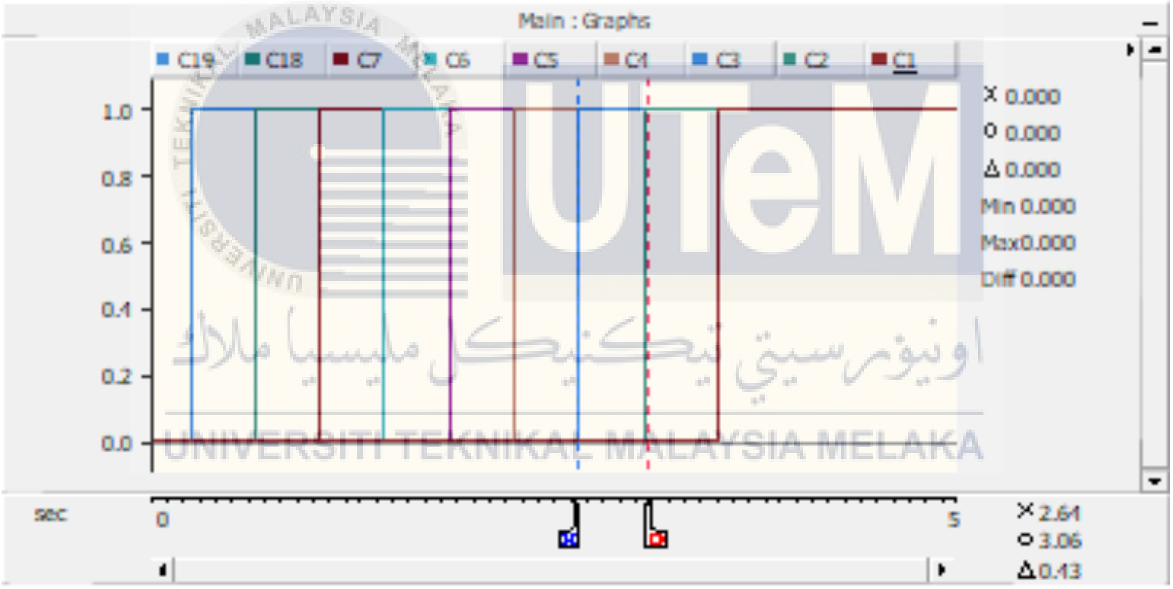


Figure 4.2.g Tripping Time for Relay P2 & P1 (Case 1A)

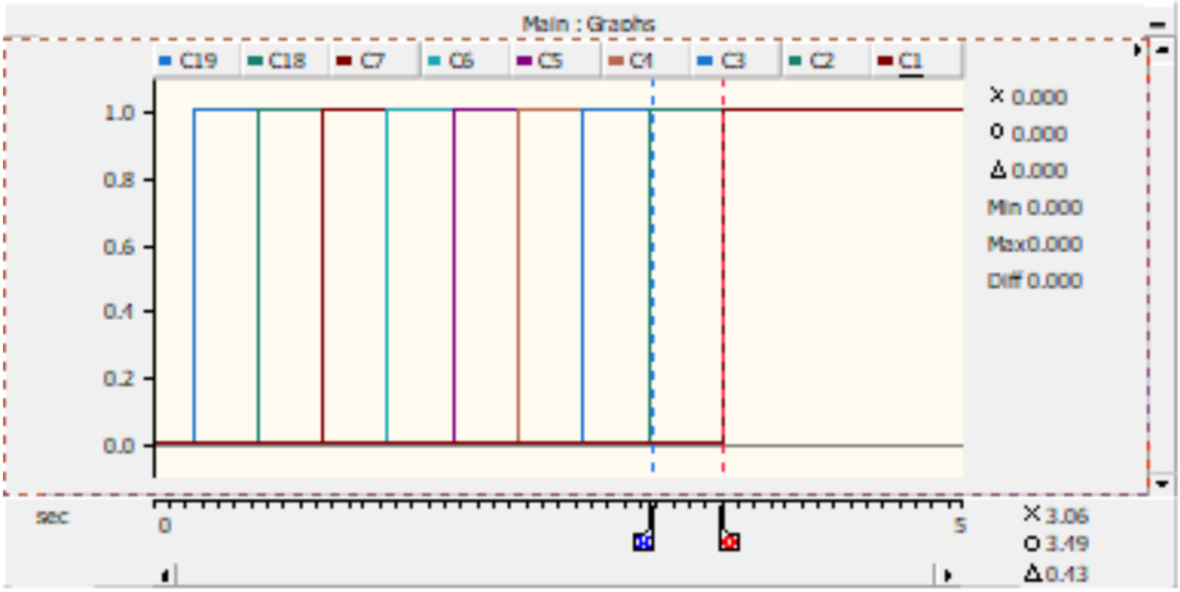


Figure 4.2.h Tripping Time for Relay P1 & A1 (Case 1A)

4.4.1 Calculation Value

The calculation values play a crucial role in comparing and validating the results obtained from simulations. Table 4.2 presents the pickup current and fault current values utilized for tripping calculations, serving as a reference for the analysis. In Table 4.3, the calculated values are showcased, derived using the formulas outlined in section 3.4. The time for the fault logic is set at 0.1 seconds, providing a standardized parameter for the time-to-fault application. These calculated values contribute to a comprehensive understanding of the relay's response and performance, enabling a thorough comparison with the simulation results and supporting the validation of the overall protective system design.

Table 4.2 Tripping Time and Time Fault Logic (Case 1A)

Relay	**TDS**	**Calculation Tripping Time, t(s)**	**Time Fault Logic (TFL) + t(s)**
A1	1.38	**3.35**	**3.45**
P1	1.32	**2.95**	**3.05**
P2	1.14	**2.55**	**2.65**
S1	0.96	**2.15**	**2.25**
S2	0.78	**1.75**	**1.85**
B1	0.6	**1.35**	**1.45**
B2	0.42	**0.95**	**1.05**
D1	0.42	**0.55**	**0.65**
D2	0.1	**0.15**	**0.25**

4.4.2 Comparison Between Calculation and Simulation

According to the relay tripping simulation (Table 4.3), fault occurr at load D2 in the power system network, the relay tripping sequence unfolds systematically. In this specific case, where the fault is identified at load end, the closest relay, D2, responds promptly, tripping at 0.25 seconds to swiftly isolate the fault. Subsequent simulations are conducted to evaluate the performance of relay D1. Upon detecting the fault current, D1 initiates a trip at 0.65 seconds, introducing a 0.40 seconds delay compared to D2, as illustrated in Table 4.2. The sequence proceeds with relay B2, which operates after a delay of 0.39 seconds, tripping at 1.05 seconds.

Moving along the relay chain, relay B1, positioned between SSU main and SSU B, detects the flowing fault current and introduces a delay of 0.39 seconds before tripping after the operation of relay B2. Subsequent relays, including S2 at 1.84 seconds (with a delay of 0.40 seconds after B1), S1 at 2.24 seconds (with a delay of 0.39 seconds after S2), P2 at 2.64 seconds (with a delay of 0.40 seconds after S1), P1 at 3.06 seconds (with a delay of 0.43 seconds after P2), and A1 at 3.49 seconds (with a delay of 0.43 seconds after P1), exhibit a sequential response.

In a notable observation, it becomes evident that the calculated values and the simulation values closely align throughout the relay tripping sequence. This alignment serves as a verification, demonstrating the consistency and reliability of both simulation and calculation values in the context of this study.

Table 4.3 Relay Time Margin (Case 1A)

Relay	Relay Tripping Time Calculation (s)	Time Margin (s)	Relay Tripping Time Simulation (s)	Time Margin (s)	% Error (Time Margin)	
					Cal	Simltn
A1	3.46	0.4	3.49	0.43	0	0
P1	3.06		3.06			
P1	3.06	0.4	3.06	0.42	0	0
P2	2.66		2.64			
P2	2.66	0.4	2.64	0.4	0	0
S1	2.26		2.24			
S1	2.26	0.4	2.24	0.39	0	0
S2	1.86		1.84			
S2	1.86	0.4	1.84	0.4	0	0
B1	1.46		1.44			
B1	1.46	0.4	1.44	0.39	0	0
B2	1.06		1.05			
B2	1.06	0.4	1.05	0.39	0	0
D1	0.66		0.65			
D1	0.66	0.4	0.65	0.4	0	0
D2	0.26		0.25			

4.5 Case 1B

In the PSCAD operation shown below (Figure 4.3), a fault occurred near the main incoming substation at the closest load point. This fault is a three-phase line-to-line fault downstream, close to relay C2. In this situation, it's crucial for relay C2 to act quickly as the primary protection, isolating the fault. If there's any issue with C2, relay C1 is ready to step in as a backup protection. Additionally, other relays like P1, P2, and A1 come into play, acting as backup protection based on their proximity to the fault. This coordinated response ensures the system is safeguarded against significant or fast faults, especially if C2 or C1 is unable to clear the fault promptly.

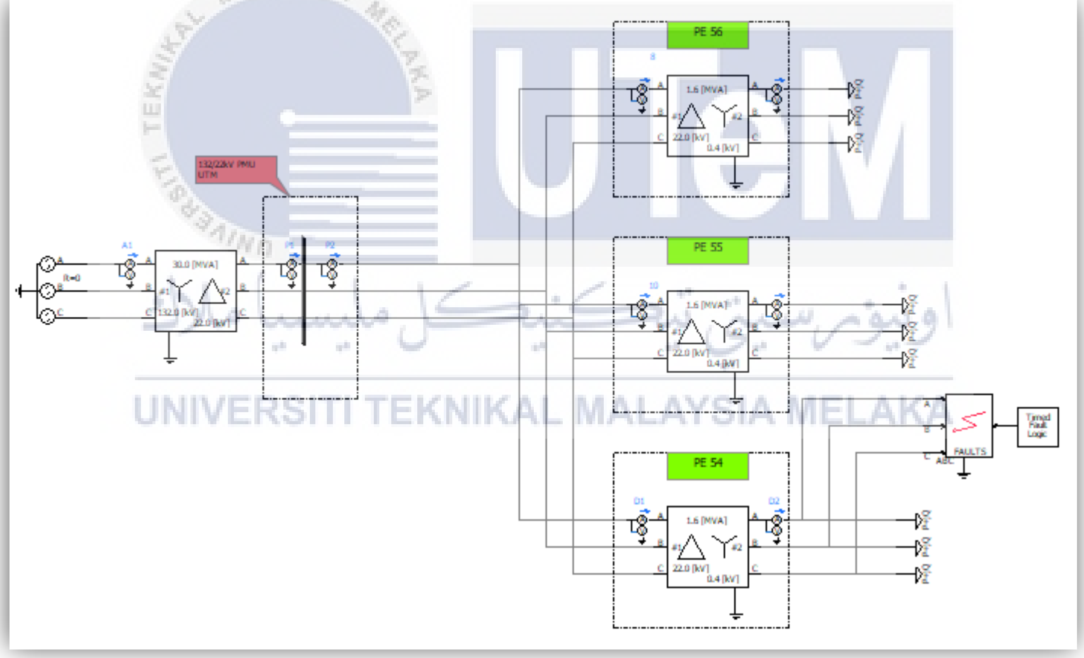


Figure 4.3 Operation of Relay for Case 1A

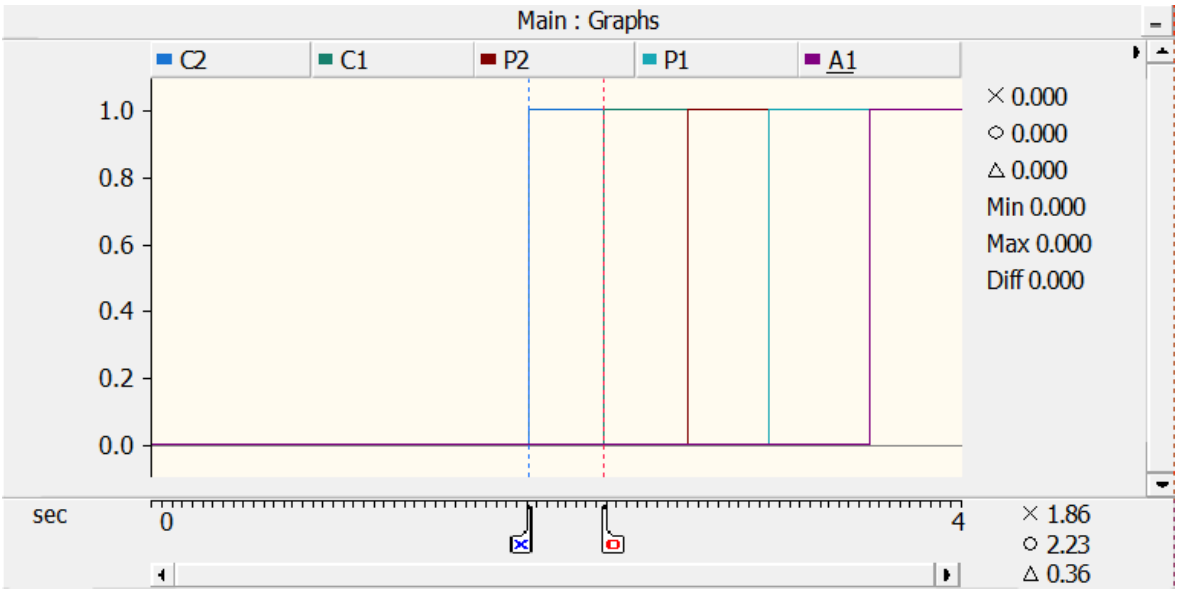


Figure 4.4.a Tripping Time for Relay C2 & C1 (Case 1B)

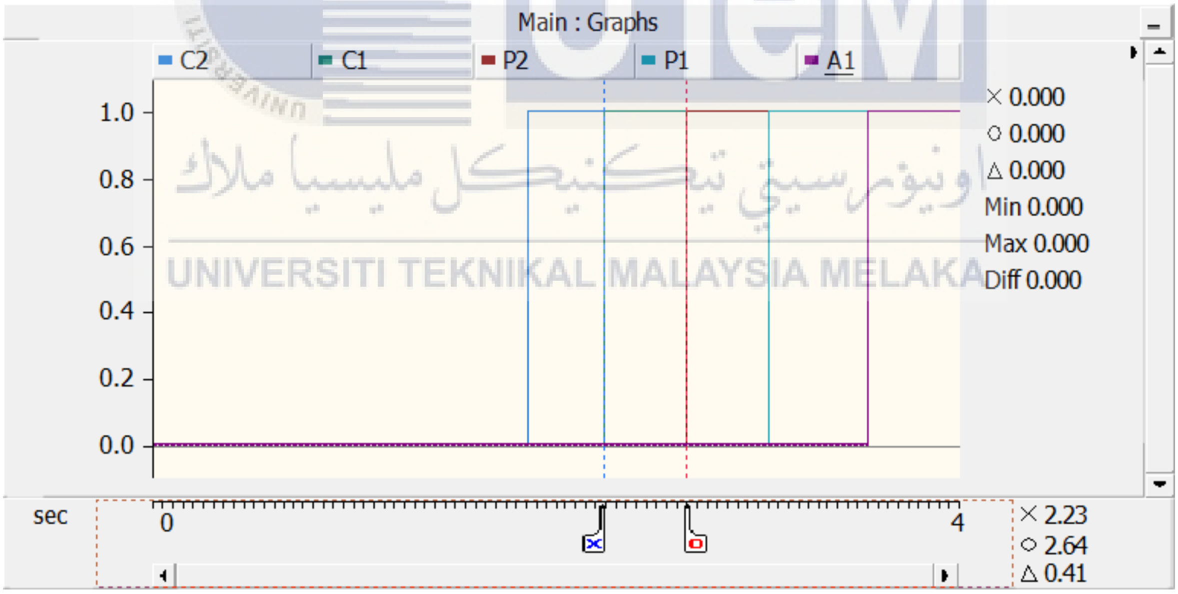


Figure 4.4.b Tripping Time for Relay C1 & P2 (Case 1B)

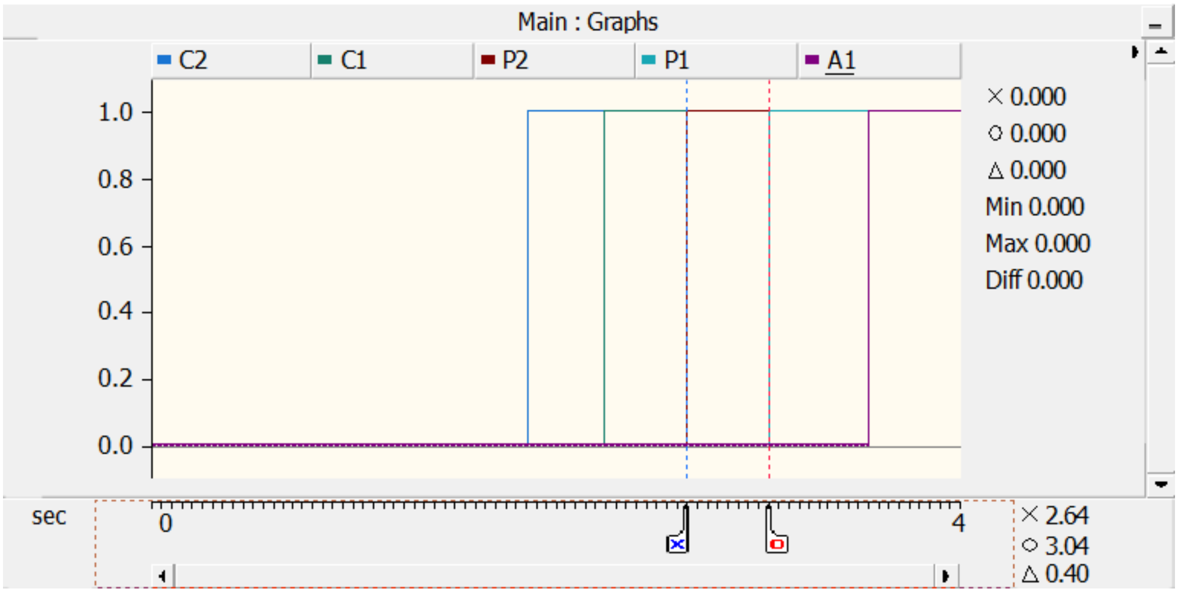


Figure 4.4.c Tripping Time for Relay P2 & P1 (Case 1B)

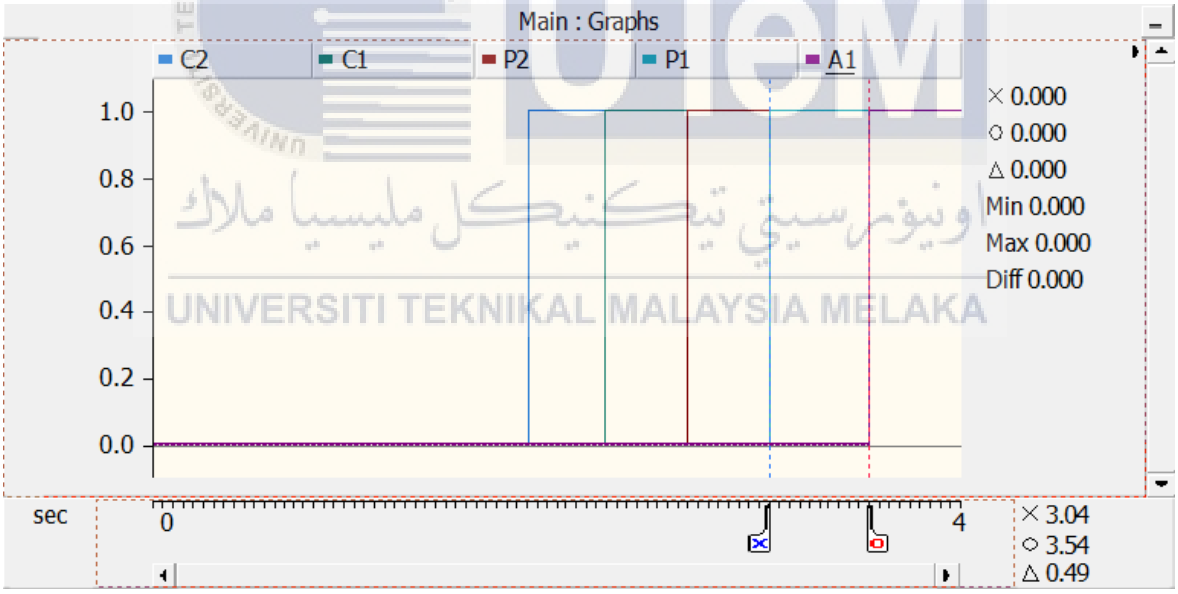


Figure 4.4.d Tripping Time for Relay P1 & A1 (Case 1B)

4.5.1 Calculation Value

The table below (Table 4.4) illustrates the calculation of tripping time and the time fault logic (set at 0.1 seconds) for Case 1B, involving a three-phase line-to-line fault. Additionally, the table provides information on the Time Dial Setting (TDS) utilized for this specific case, offering a comprehensive overview of the timing parameters involved in the protective system's response to the fault scenario.

Table 4.4 Tripping Time and Time Fault Logic (Case 1B)

Relay	**TDS**	**Calculation Tripping Time, t(s)**	**Time Fault Logic (TFL) + t(s)**
A1	1.38	**3.36**	**3.46**
P1	1.32	**2.96**	**3.06**
P2	1.14	**2.55**	**2.65**
C1	1.65	**2.15**	**2.25**
C2	1.19	**1.75**	**1.85**

4.5.2 Comparison Between Calculation and Simulation

According to the relay tripping simulation (Table 4.5), when a fault occurs at load C2, the relays in the network respond sequentially. Specifically, in this instance where the fault is at load, the closest relay, C2, trips at 1.86 seconds. Subsequently, the simulation is assessed for relay C1, which, upon detecting the fault current, trips at 2.23 seconds, representing a 0.36-second delay from C2.

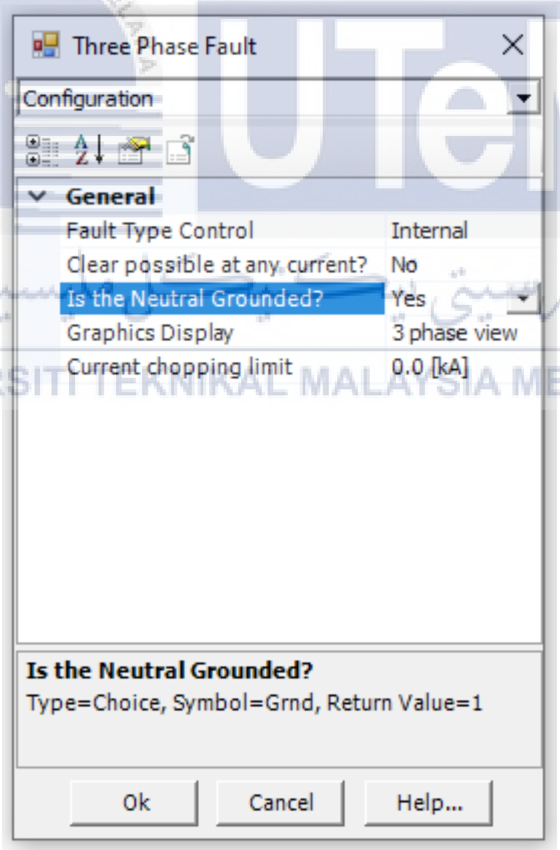
Following this, relay P2 comes into play, operating with a delay of 0.41 seconds and tripping at 2.64 seconds. Continuing the sequence, relay P1 trips at 3.04 seconds with a delay of 0.4 seconds after P2, and finally, relay A1 trips at 3.54 seconds, demonstrating a delay of 0.49 seconds after P1. This comparison between the calculated and simulated relay tripping times provides valuable insights into the performance and coordination of the relays in the system.

Table 4.5 Relay Time Margin (Case 1B)

Relay	Relay Tripping Time Calculation (s)	Time Margin (s)	Relay Tripping Time Simulation (s)	Time Margin (s)	% Error (Time Margin)	
					Cal	Simltn
A1	3.46	0.4	3.54	0.49	0	0
P1	3.06		3.04			
P1	3.06	0.41	3.04	0.4	0	0
P2	2.65		2.64			
P2	2.65	0.4	2.64	0.41	0	0
S1	2.25		2.23			
C1	2.25	0.4	2.23	0.36	0	0
C2	1.85		1.86			

4.6 Case 2A

In this case, the farthest load point (Case 1A) from the main incoming substation line is used, specifically a three-phase line-to-ground fault downstream near the load in proximity to relay D2. In this context, relay D2 assumes the role of the main protection device, requiring a rapid response to effectively isolate the fault. As a contingency measure, relay D1 is designated as a backup protection relay, ready to intervene should D2 malfunction. Additionally, other relays such as P1, P2, S1, S2, B1, and B2 are strategically positioned to act as backup protection, operating in sequence from the nearest point to the fault. This coordinated setup ensures comprehensive system protection in the event of a substantial or fast fault, or if the fault persists without being promptly cleared by either D2 or D1.



Three Phase Fault

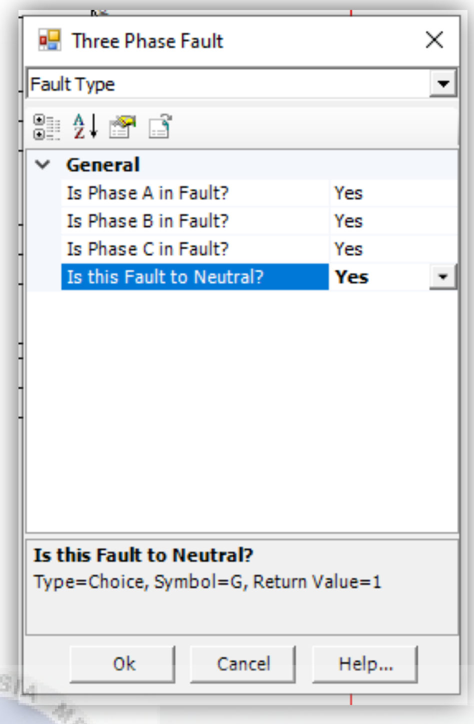
Configuration

General

Fault Type Control	Internal
Clear possible at any current?	No
Is the Neutral Grounded?	Yes
Graphics Display	3 phase view
Current chopping limit	0.0 [kA]

Is the Neutral Grounded?
Type=Choice, Symbol=Grnd, Return Value=1

Figure 4.5 Three Phase Fault to Ground Setting



Three Phase Fault

Fault Type

General

Is Phase A in Fault? Yes

Is Phase B in Fault? Yes

Is Phase C in Fault? Yes

Is this Fault to Neutral? **Yes**

Is this Fault to Neutral?

Type=Choice, Symbol=G, Return Value=1

Figure 4.6 Fault Type Setting (Grounded)

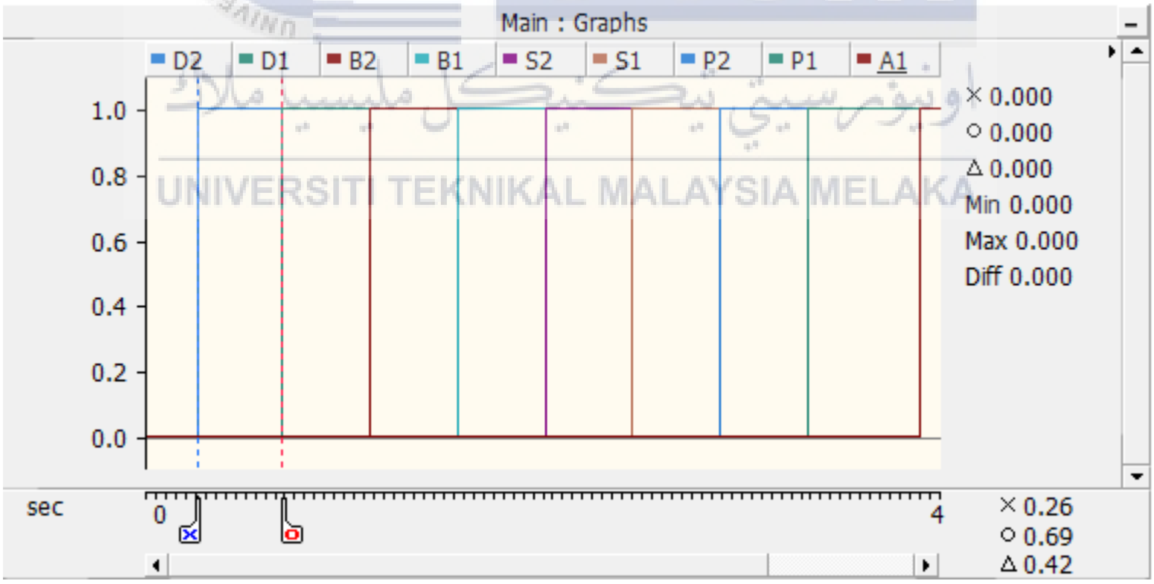


Figure 4.7.a Tripping Time for Relay D2 & D1 (Case 2A)

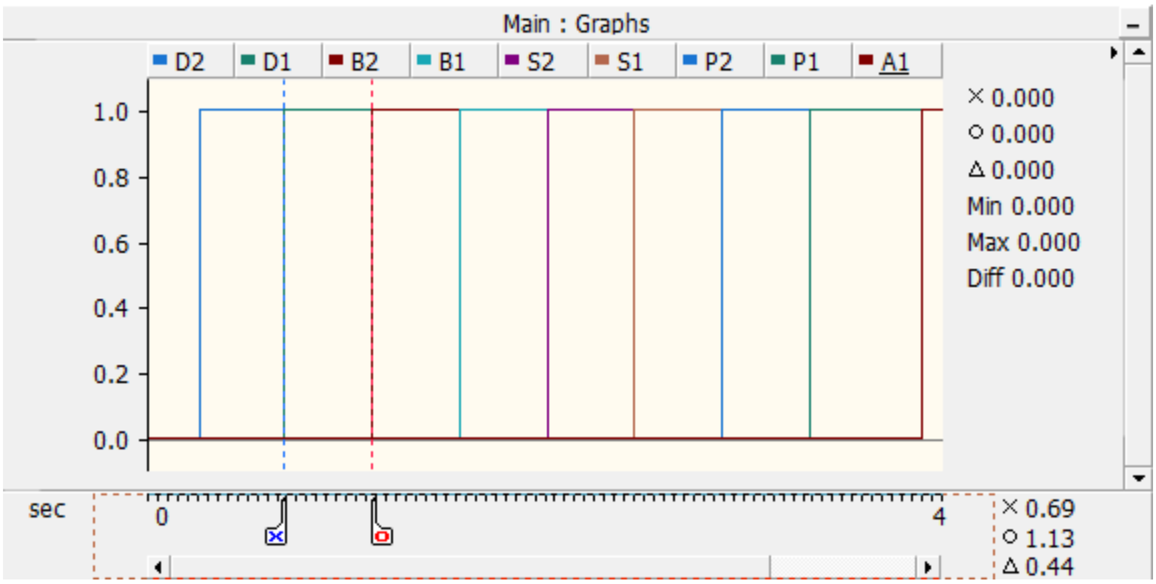


Figure 4.7.b Tripping Time for Relay D1 & B2 (Case 2A)

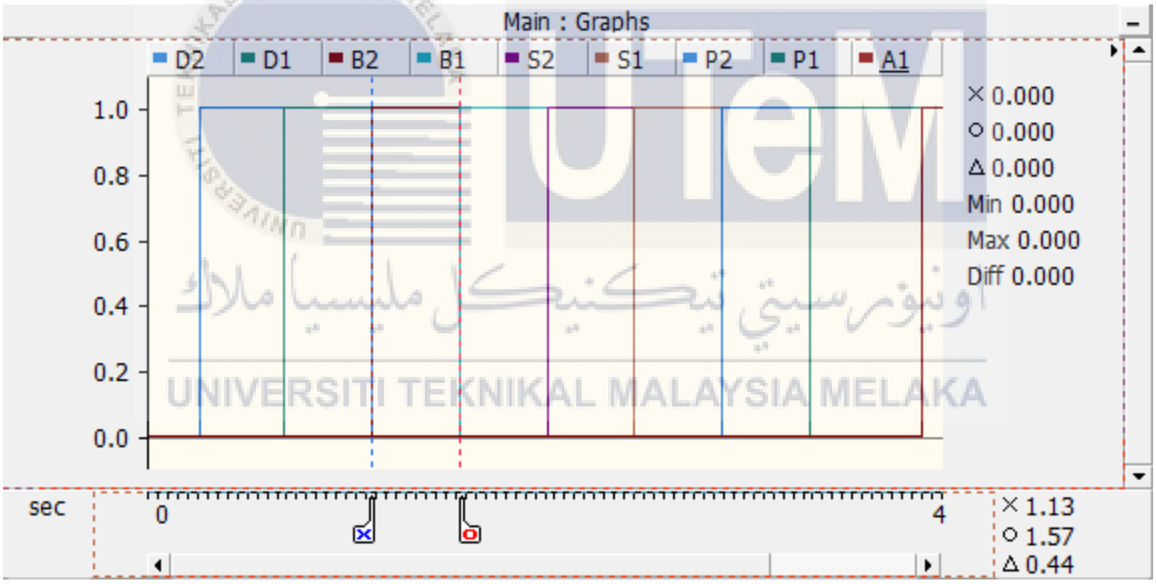


Figure 4.7.c Tripping Time for Relay B2 & B1 (Case 2A)

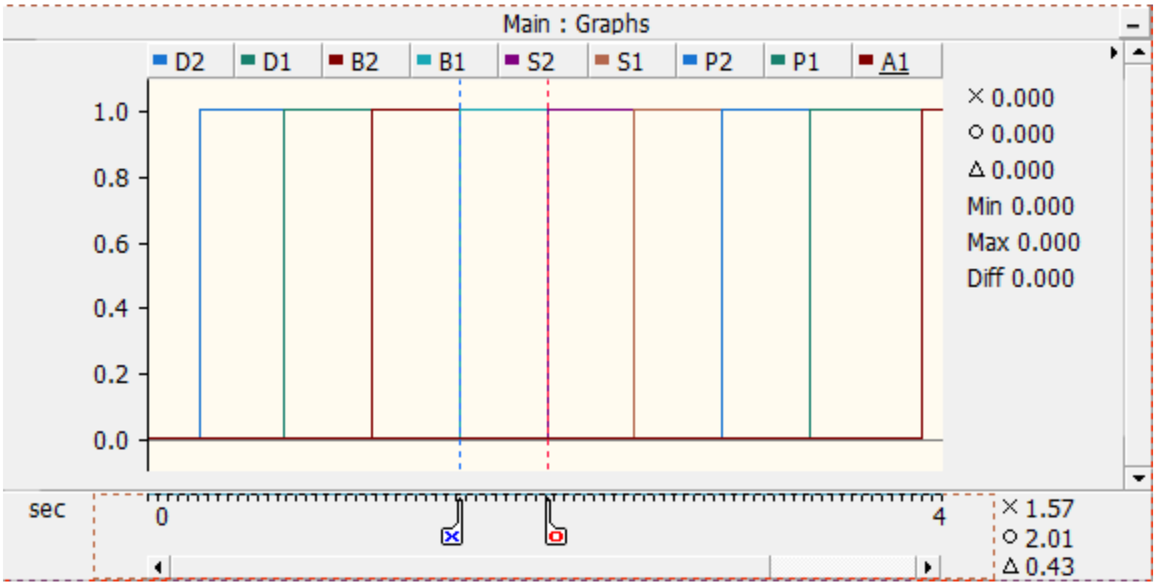


Figure 4.7.d Tripping Time for Relay B1 & S2 (Case 2A)

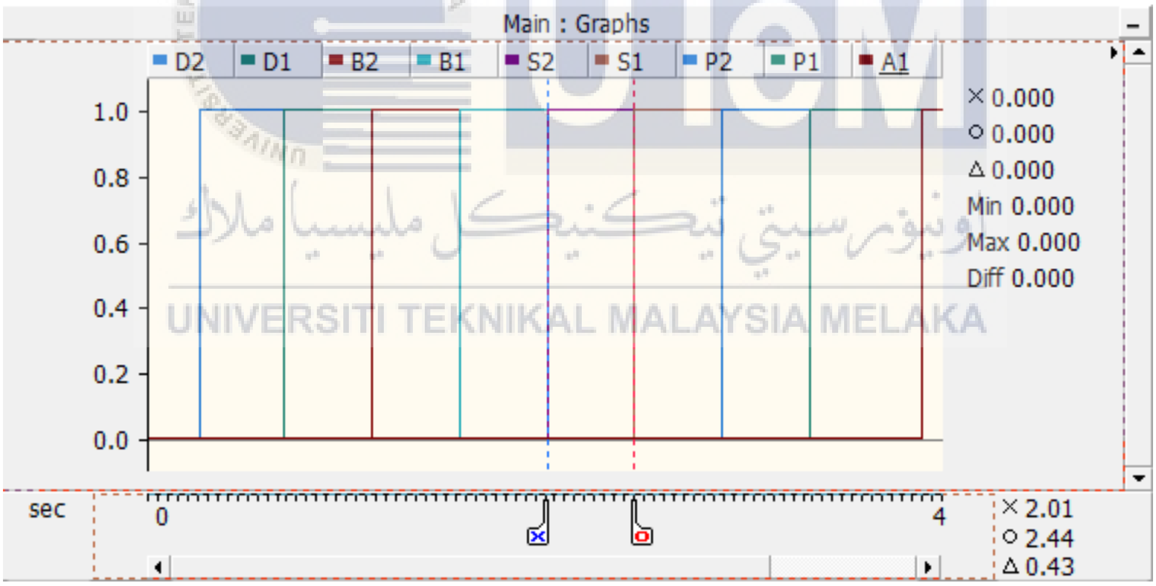


Figure 4.7.e Tripping Time for Relay S2 & S1 (Case 2A)

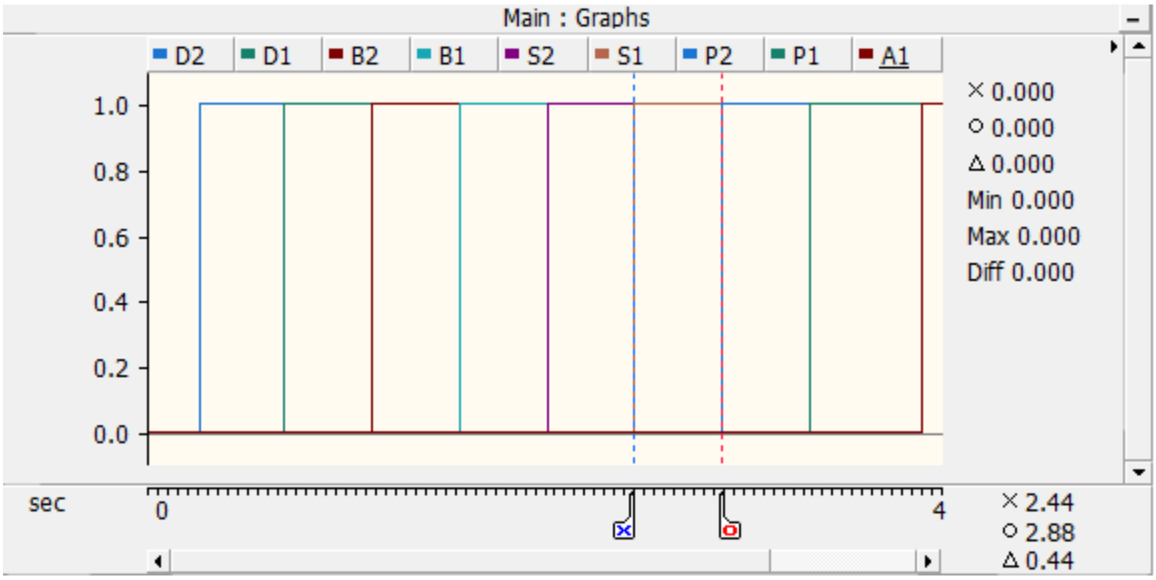


Figure 4.7.f Tripping Time for Relay S1 & P2 (Case 2A)

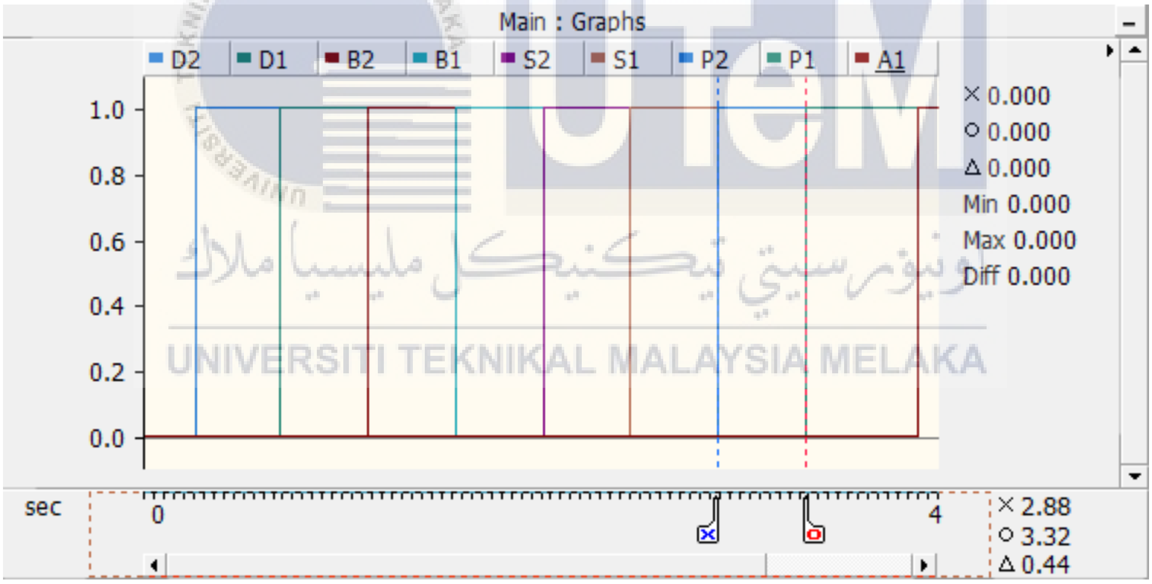


Figure 4.7.g Tripping Time for Relay P2 & P1 (Case 2A)

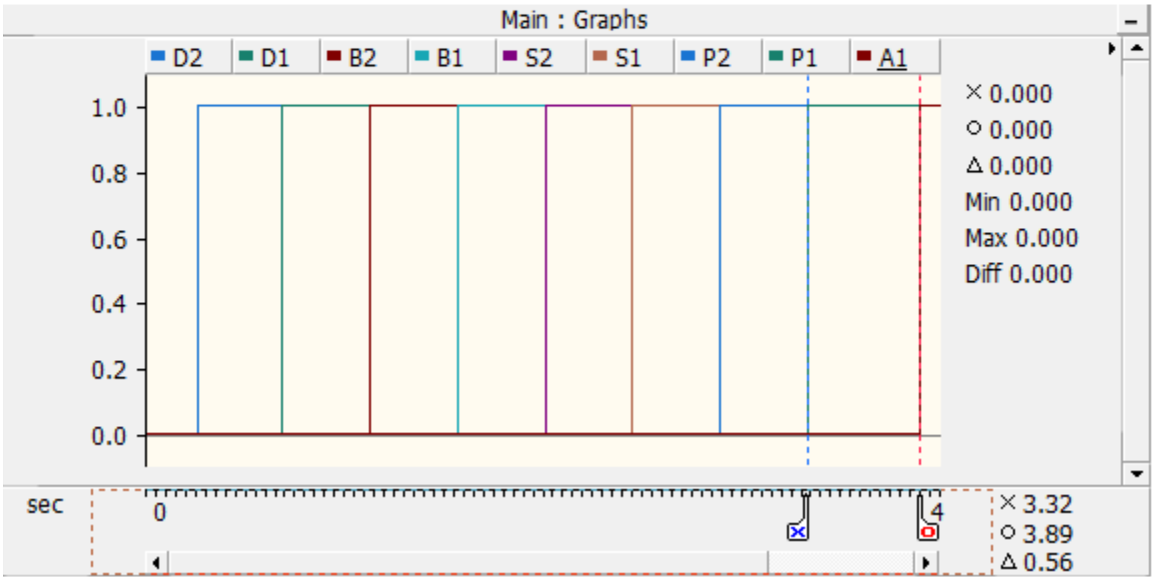


Figure 4.7.h Tripping Time for Relay P1 & A1 (Case 2A)

4.6.1 Calculation Value

The table below (Table 4.6) illustrates the calculation of tripping time and the time fault logic (set at 0.1 seconds) for Case 2A, involving a three-phase line-to-ground fault. Additionally, the table provides information on the Time Dial Setting (TDS) utilized for this specific case, offering a comprehensive overview of the timing parameters involved in the protective system's response to the fault scenario.

Table 4.6 Tripping Time and Time Fault Logic (Case 1B)

Relay	TDS	Calculation Tripping Time, t(s)	Time Fault Logic (TFL) + t(s)
A1	1.38	3.67	3.77
P1	1.32	3.16	3.26
P2	1.14	2.73	2.83
S1	0.96	2.30	2.40
S2	0.78	1.87	1.97
B1	0.6	1.44	1.54
B2	0.42	1.00	1.10
D1	0.42	0.57	0.67
D2	0.10	0.16	0.26

4.6.2 Comparison Between Calculation and Simulation

According to the relay tripping simulation (Table 4.7), the relay tripping sequence unfolds systematically. In this specific case, where the fault is identified at load end, the closest relay, D2, responds promptly, tripping at 0.26 seconds to swiftly isolate the fault. Subsequent simulations are conducted to evaluate the performance of relay D1. Upon detecting the fault current, D1 initiates a trip at 0.69 seconds, introducing a 0.42 seconds delay compared to D2. The sequence proceeds with relay B2, which operates after a delay of 0.44 seconds, tripping at 1.13 seconds.

Moving along the relay chain, relay B1, positioned between SSU main and SSU B, detects the flowing fault current and introduces a delay of 0.44 seconds before tripping after the operation of relay B2. Subsequent relays, including S2 at 2.01 seconds (with a delay of 0.43 seconds after B1), S1 at 2.44 seconds (with a delay of 0.43 seconds after S2), P2 at 2.88 seconds (with a delay of 0.44 seconds after S1), P1 at 3.32 seconds (with a delay of 0.44 seconds after P2), and A1 at 3.89 seconds (with a delay of 0.56 seconds after P1), exhibit a sequential response.

In a notable observation, it becomes evident that the calculated values and the simulation values are nearly identical throughout the relay tripping sequence. This alignment serves as a robust verification, demonstrating the consistency and reliability of both simulation and calculation values in the context of this study.

Table 4.7 Relay Time Margin (Case 2A)

Relay	Relay Tripping Time Calculation (s)	Time Margin (s)	Relay Tripping Time Simulation (s)	Time Margin (s)	% Error (Time Margin)	
					Cal	Simltn
A1	3.77	0.51	3.89	0.56	2	12
P1	3.26		3.32			
P1	3.26	0.43	3.32	0.44	0	0
P2	2.83		2.88			
P2	2.83	0.43	2.88	0.44	0	0
S1	2.4		2.44			
S1	2.4	0.43	2.44	0.43	0	0
S2	1.97		2.01			
S2	1.97	0.43	2.01	0.43	0	0
B1	1.54		1.57			
B1	1.54	0.44	1.57	0.44	0	0
B2	1.1		1.13			
B2	1.1	0.43	1.13	0.44	0	0
D1	0.67		0.69			
D1	0.67	0.41	0.69	0.42	0	0
D2	0.26		0.26			

4.7 Case 2B

In the PSCAD operation shown below, a fault occurred near the main incoming substation at the closest load point. This fault is a three-phase line-to-ground fault downstream, close to relay S2. In this situation, it's crucial for relay S2 to act quickly as the primary protection, isolating the fault. If there's any issue with S2, relay S1 is ready to step in as a backup protection. Additionally, other relays like P1, P2, and A1 come into play, acting as backup protection based on their proximity to the fault. This coordinated response ensures the system is safeguarded against significant or fast faults, especially if S2 or S1 is unable to clear the fault promptly.

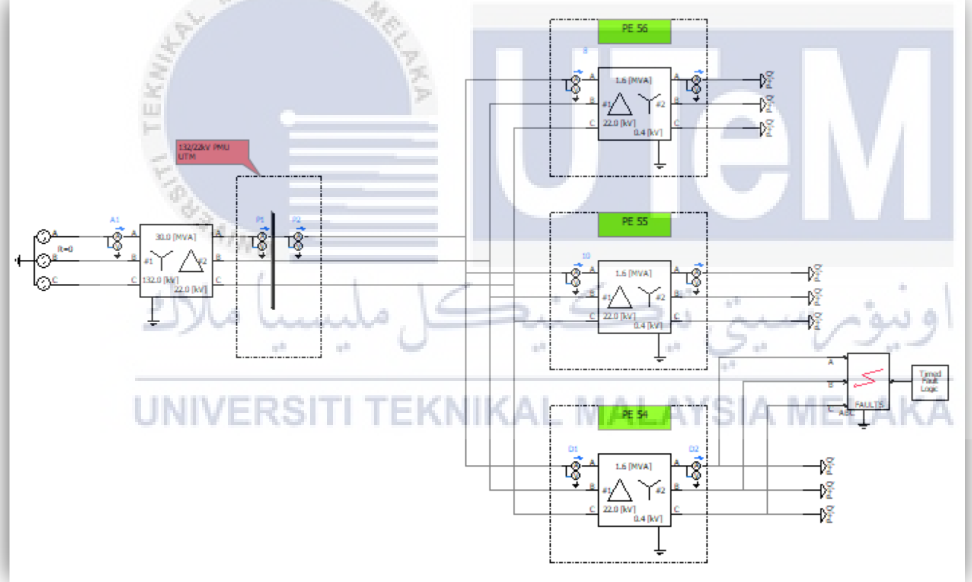


Figure 4.8 Operation of Relay for Case 2B

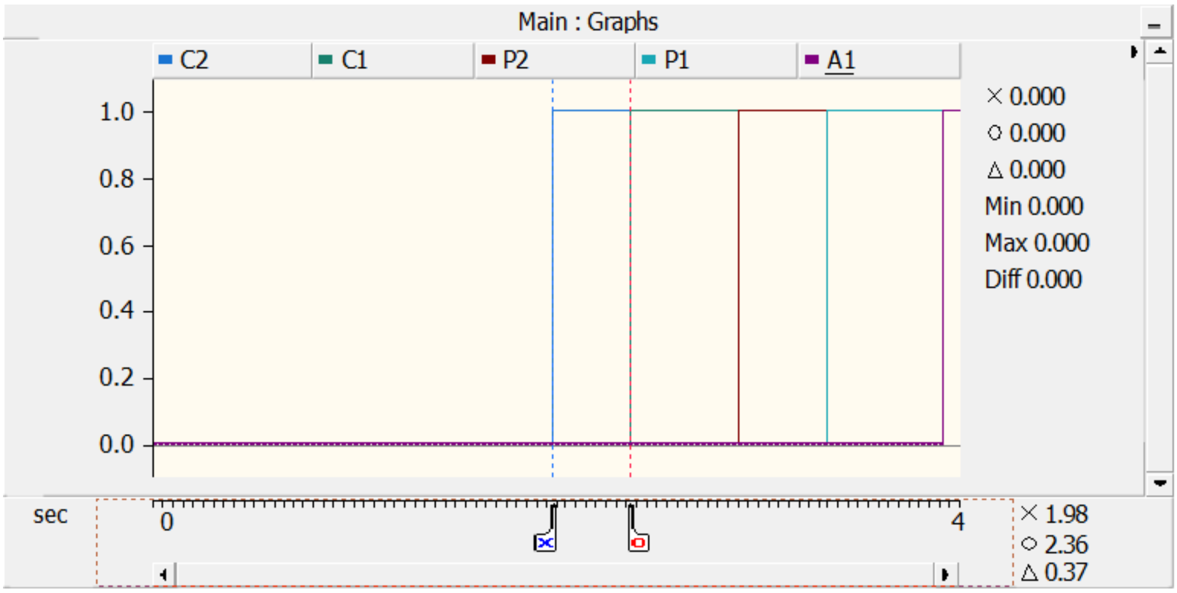


Figure 4.9.a Tripping Time for Relay C2 & C1 (Case 2B)

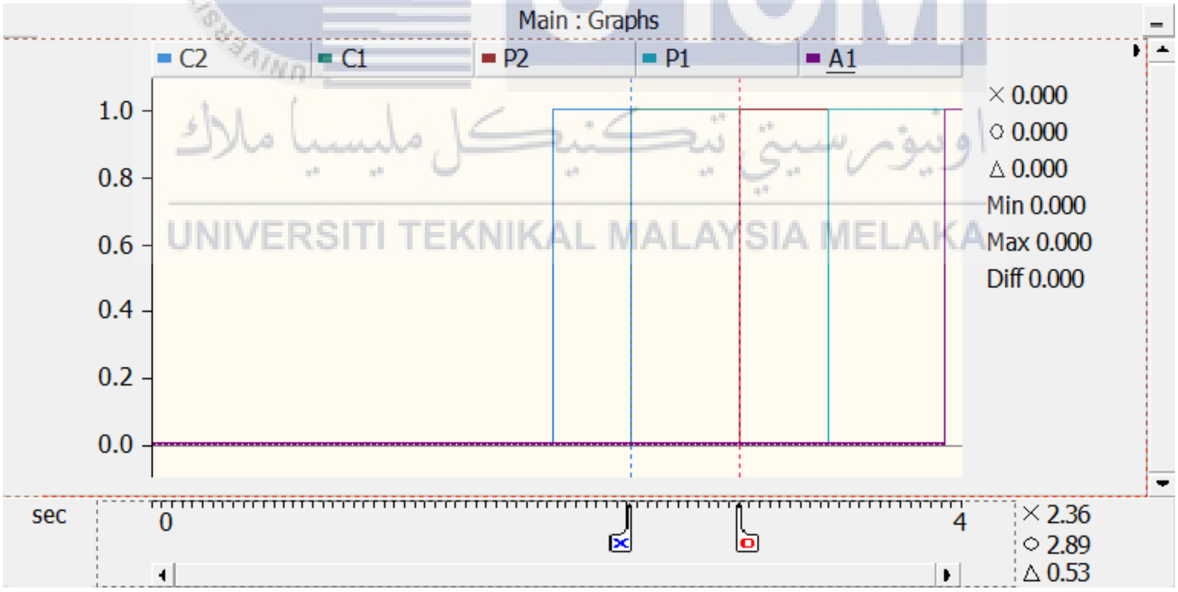


Figure 4.9.b Tripping Time for Relay C1 & P2 (Case 2B)

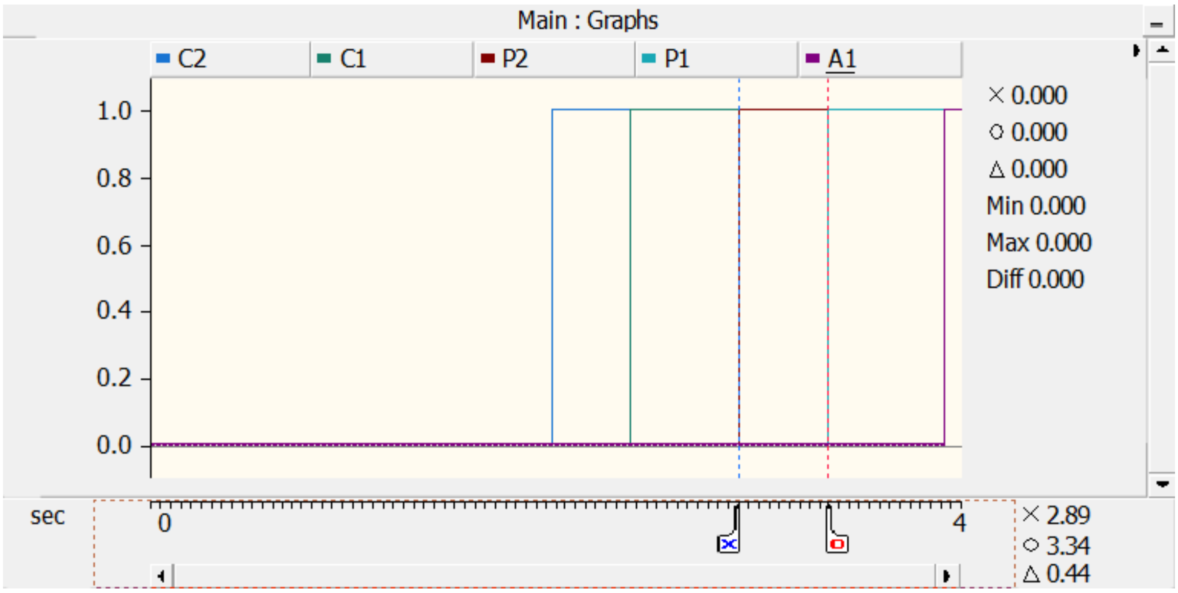


Figure 4.9.c Tripping Time for Relay P2 & P1 (Case 2B)

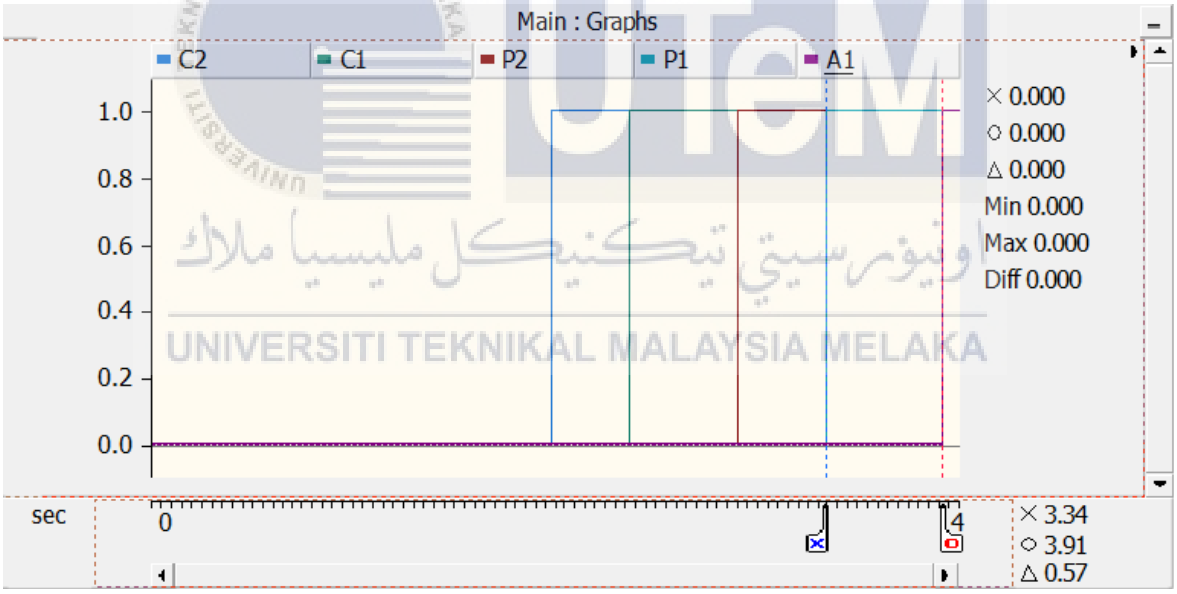


Figure 4.9.d Tripping Time for Relay P1 & A1 (Case 2B)

4.7.1 Calculation Value

The table below (Table 4.8) illustrates the calculation of tripping time and the time fault logic (set at 0.1 seconds) for Case 2B, involving a three-phase line-to-line fault. Additionally, the table provides information on the Time Dial Setting (TDS) utilized for this specific case, offering a comprehensive overview of the timing parameters involved in the protective system's response to the fault scenario.

Table 4.8 Tripping Time and Time Fault Logic (Case 2B)

Relay	TDS	Calculation Tripping Time, t(s)	Time Fault Logic (TFL) + t(s)
A1	1.38	**3.69**	**3.79**
P1	1.32	**3.17**	**3.27**
P2	1.14	**2.74**	**2.84**
C1	1.64	**2.23**	**2.33**
C2	1.12	**1.75**	**1.85**

4.7.2 Comparison Between Calculation and Simulation

According to the relay tripping simulation (Table 4.9), when a fault occurs at load C2, the relays in the network respond sequentially. Specifically, in this instance where the fault is at load, the closest relay, C2, trips at 1.98 seconds. Subsequently, the simulation is assessed for relay C1, which, upon detecting the fault current, trips at 2.36 seconds, representing a 0.37 second delay from C2.

Following this, relay P2 comes into play, operating with a delay of 0.53 seconds and tripping at 2.89 seconds. Continuing the sequence, relay P1 trips at 3.34 seconds with a delay of 0.44 seconds after P2, and finally, relay A1 trips at 3.91 seconds, demonstrating a delay of 0.57 seconds after P1. This comparison between the calculated and simulated relay tripping times provides valuable insights into the performance and coordination of the relays in the system.

Table 4.9 Relay Time Margin (Case 2B)

Relay	Relay Tripping Time Calculation (s)	Time Margin (s)	Relay Tripping Time Simulation (s)	Time Margin (s)	% Error (Time Margin)	
					Cal	Simltn
A1	3.79	0.52	3.91	0.57	4	14
P1	3.27		3.34			
P1	3.27	0.43	3.34	0.44	0	0
P2	2.84		2.89			
P2	2.84	0.51	2.89	0.53	2	6
S1	2.33		2.26			
C1	2.33	0.48	2.36	0.37	0	0
C2	1.85		1.98			

CHAPTER 5

CONCLUSION

5.1 Conclusion

In the culmination of this project, a comprehensive exploration was undertaken to scrutinize the intricacies of overcurrent relay settings within the radial distribution network. The primary focus was on comparing the setting parameters, namely pickup current values and relay operating times, through a meticulous blend of theoretical calculations and simulations performed using PSCAD software. The outcomes derived from this comparative analysis are noteworthy, revealing a remarkable convergence between the values obtained from the theoretical calculations and those generated through the PSCAD simulations.

This alignment of results not only underscores the accuracy of both methodologies but also stands as a testament to the robustness of the chosen simulation platform in mirroring real-world scenarios. The close correspondence between theoretical calculations and simulation outcomes establishes a solid foundation for the reliability of overcurrent relay settings in the radial distribution network. Beyond the immediate scope of this study, these findings contribute valuable insights to the broader field of power system protection, offering a nuanced understanding of the synergy between theoretical calculations and simulation-based approaches for optimizing relay settings in practical applications.

5.2 Recommendation

Based on the insights gained from this project, several additional recommendations can further enhance the application of overcurrent relays in radial distribution networks. Firstly, expanding the number of tested rings in future studies can provide more comprehensive validation and strengthen the generalizability of the findings. This would contribute to a more robust understanding of the relay settings' effectiveness across various network configurations.

Moreover, the fault scenarios applied in this project, covering single-phase faults, two-phase faults, three-phase faults, and single-phase to ground, two-phase to ground, and three-phase to ground faults, were deemed representative of a diverse range of real-world situations. This approach ensures the reliability of the findings in addressing different fault types and their impact on relay coordination.

Finally, considering newer relay technologies and adaptive settings is crucial, particularly concerning discrimination time margins between overcurrent relays. The study reveals that electromechanical relays exhibit coordination times of 0.3s to 0.4s, while microprocessor-based relays demonstrate faster coordination times ranging from 0.1s to 0.2s. Exploring these advanced technologies could potentially optimize coordination times, enhancing the overall efficiency of the protective system.

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APPENDICES

Appendix A (Formal Request Letter)

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Melaka, Malaysia.

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FAKULTI TEKNOLOGI DAN KEJURUTERAAN ELEKTRIK
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Rujukan Kami (Our Ref) : UTEM.600-3/9/9 (1)
Rujukan Tuan (Your Ref) :
Tarikh (Date) : 27 September 2023

Sr. ASLIZA BINTI BAKAR
Pengarah
Seksyen Projek dan Penyenggaraan
Bahagian Pengurusan Aset
Jabatan Timbalan Naib Canselor (Pembangunan)
Universiti Teknologi Malaysia

Assalamualaikum Wrt. Wbt. dan Salam Sejahtera,

Puan,

PERMOHONAN MENGAKSES "HIGH VOLTAGE SYSTEM SCHEMATIC" BAGI TUJUAN PROJEK SARJANA MUDA

Perkara di atas adalah dirujuk.

2. Adalah dimaklumkan, Dr. Nur Azura binti Noor Azhuan dari Fakulti Teknologi dan Kejuruteraan Elektrik (FTKE), Universiti Teknikal Malaysia Melaka (UTeM) merupakan penyelia kepada pelajar Projek Sarjana Muda (PSM), Muhammad Mirzan Bin Ruzi. Pelajar ini bakal menjalankan projek ini pada Oktober 2023. Beliau memerlukan kebenaran mengakses maklumat di atas bagi menyelesaikan projek PSM beliau dengan jayanya.

3. Sehubungan dengan itu, diharapkan pihak Puan dapat memberikan kebenaran kepada pelajar ini. Kerjasama dan perhatian pihak Puan berhubung perkara ini amat dihargai dan diucapkan ribuan terima kasih.

Sekian, wassalam.

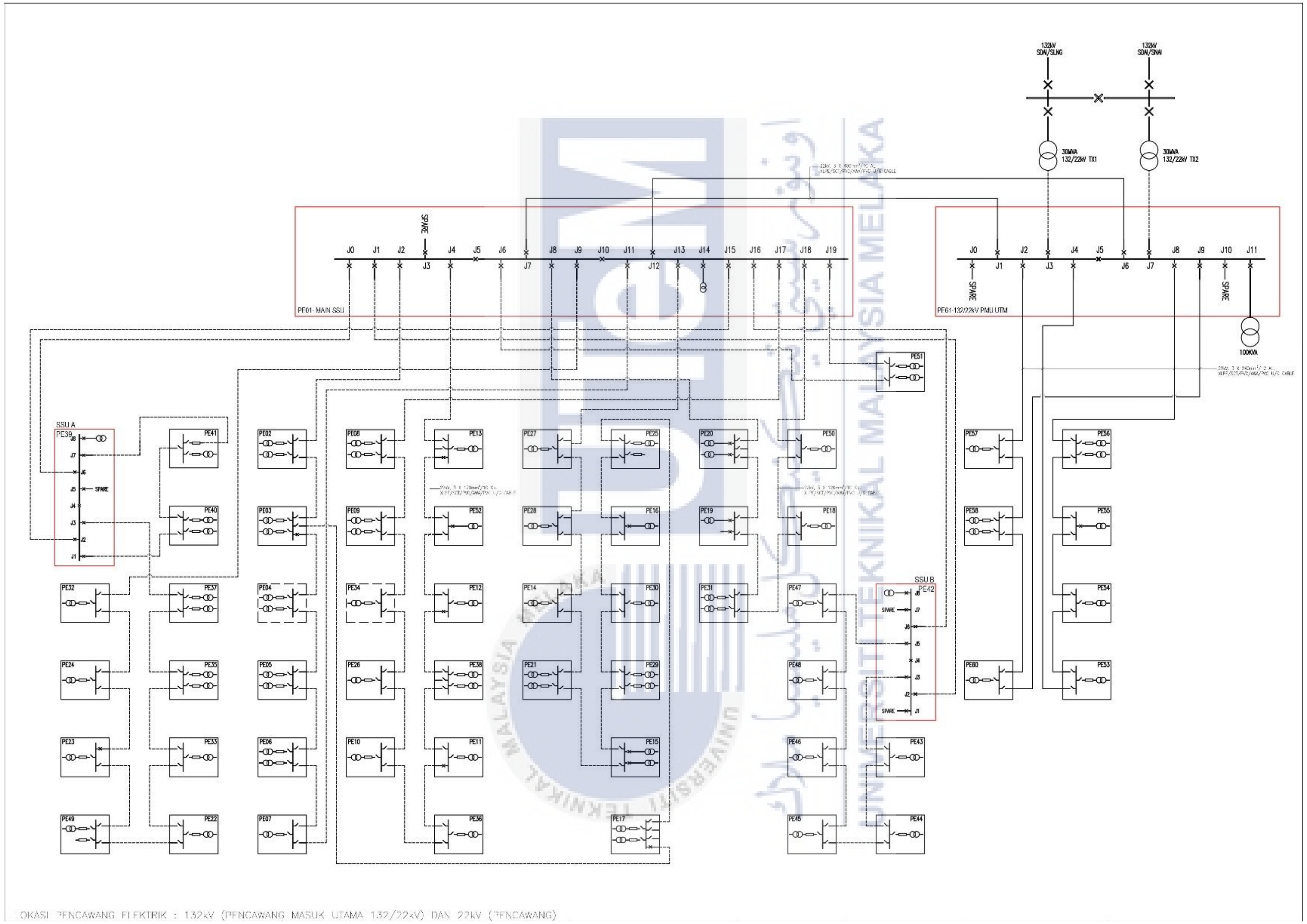
"MALAYSIA MADANI"
"BERKHIDMAT UNTUK NEGARA"
"KOMPETENSI TERAS KEGEMILANGAN"

Saya yang menjalankan amanah,

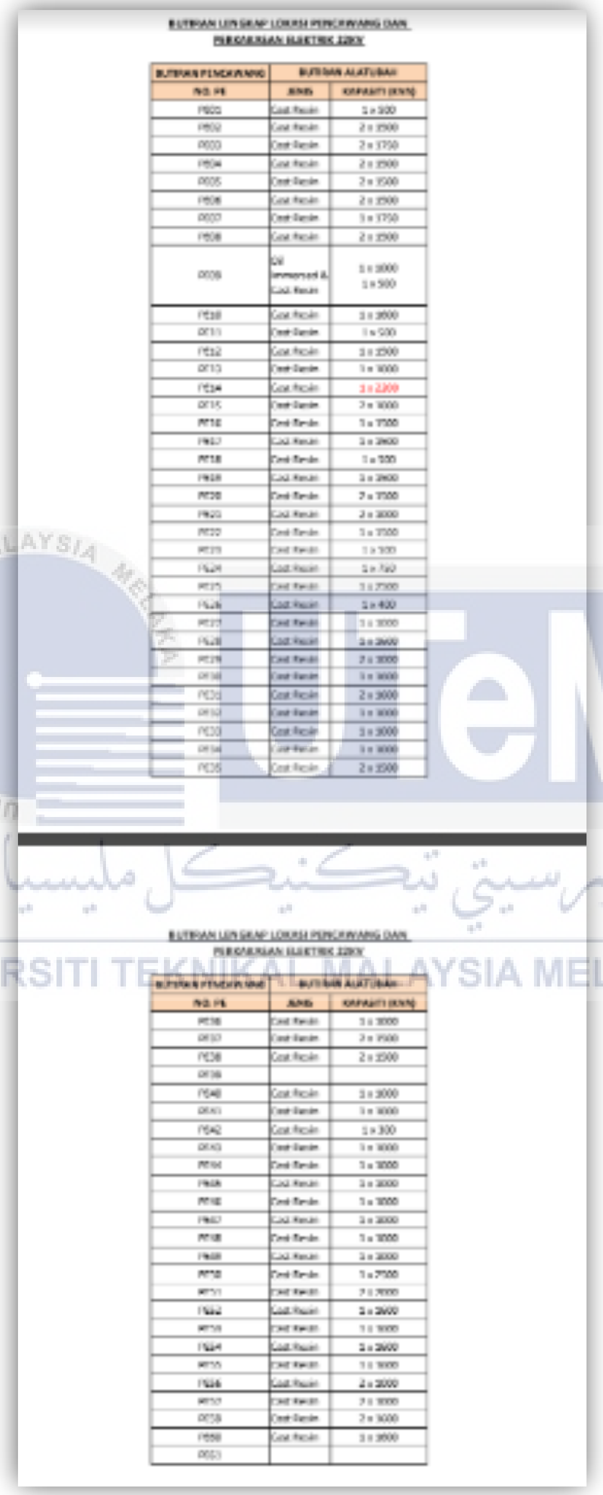
PROFESOR MADYA DR. HIDAYAT BIN ZAINUDDIN
Dekan
Fakulti Teknologi Dan Kejuruteraan Elektrik
Universiti Teknikal Malaysia Melaka

SEBUAH UNIVERSITI TEKNIKAL AWAM

Appendix B (UTM HT Schematic system)



Appendix C (UTM Transformer Rating)



Appendix D (Current Rating & Grounding Sytem)

Appendix E (SPP UTM and Distribution Room)

Appendix F (Progress BDP 1)

BDP	**WEE**													
PROGRES	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**1**	**1**	**1**	**1**
BDP 1 briefing by JK PSM,	🟩													
Discussion and verification the project	🟩	🟩												
Submit the selected topic to		🟩												
Identify the problem statement and objective with			🟩											
Report Writing: Chapter 1 (introduction, Problem statement, Objective,			🟩	🟩	🟩									
Finding journals and articles that related to the				🟩	🟩	🟩								
PSM 1 Progress 1							🟩							
Report Writing: Chapter 2(Literature							🟩	🟩	🟩	🟩				
Report Writing: Chapter 3										🟩	🟩	🟩		
Design Circuit in PSCAD										🟩	🟩	🟩		
Identify the related										🟩	🟩	🟩		
PSM 1 Progress 2												🟩		
Correction for Chapter 1, 2 and													🟩	
Finalize the PSM 1													🟩	
Construct PSM 1 Presentation													🟩	
BDP 1 PRESENTATION AND														🟩

Appendix G (Progress BDP 2)

BDP 2	**Week**													
Progress	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Meeting With SV														
Make an appointment with SPP UTM	🟩													
Meeting with Electrical Engineer at UTM Skudai		🟩	🟩											
Site Visit				🟩										
Analyse Collected Data					🟩		🟩							
Contruct a Simplify Power Sytem					🟩		🟩							
Making Simulation in PSCAD							🟩							
Making measurement in PSCAD							🟩	🟩						
Calculation							🟩	🟩	🟩					
Simulate Calculation Value									🟩	🟩				
Comparing Data										🟩	🟩			
Poster												🟩	🟩	
Update Report		🟩	🟩	🟩	🟩		🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Presentation														🟩