Faculty of Electrical Engineering and Technology

The Development Of Electrical Fault Troubleshooting Trainer Using Small Scale Single Phase Electrical Wiring Circuit

AMIRUL AIMAN BIN TUPIN

Bachelor of Electrical Engineering Technology with Honours

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A project report submitted
in partial fulfillment of the requirements for the degree of
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Tarikh: 17 JANUARY 2024

DR. MOHD BADRIL BIN NOR SHAH
KETUA JABATAN TEKNOLOGI KEJURUTERAN
Fakulti Teknologi dan Kejuruteraan Elektrik
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DEDICATION

The Development Of Electrical Fault Troubleshooting Trainer Using Small Scale Electrical Wiring Circuit project is a project that is purposely to help anyone who wants to learn how to troubleshoot an electrical wiring circuit. This project is dedicated to my family, especially my parents who endlessly support me through my bachelor's degree journey. I also want to thank my supervisor Dr. Badril, who always helped me in completing this BDP. To Sir Adli and Sir Addy, I will ever be grateful for your invaluable guidance and expertise in this line of work. To my housemate who helped me in completing this report, thank you so much.

ABSTRACT

Every wireman or electrician should establish a safe and effective electrical infrastructure that complies with safety regulations and serves the electrical requirements of building occupants. Many wiremen can perform the electrical installation but still lack the skill to troubleshoot when a fault occurs. This study can be one of the efforts to resolve the problem by developing a trainer to troubleshoot the electrical installation fault. Electrical faults can be taught theoretically but to master the skills to perform troubleshooting to identify the location and the root cause of the faults, it requires a good understanding of electrical circuits and some hands-on experience. This troubleshooting trainer emulates the fault by using Arduino as a controller. The Arduino will trigger the relays in the circuit and protection devices such as MCB and RCCB will trip according to the fault that occurs in the circuit. Then, troubleshooting must be done to identify the fault location while following the right safety guidelines in troubleshooting.

ABSTRAK

Setiap pendawai atau juruelektrik harus mewujudkan infrastruktur elektrik yang selamat dan berkesan yang mematuhi peraturan keselamatan dan memenuhi keperluan elektrik penghuni bangunan. Ramai pendawai boleh melakukan pemasangan elektrik tetapi masih kurang kemahiran untuk menyelesaikan masalah apabila berlaku kerosakan. Kajian ini boleh menjadi salah satu usaha untuk menyelesaikan masalah dengan membangunkan sebuah sistem untuk menyelesaikan masalah kerosakan pemasangan elektrik. Kerosakan elektrik boleh diajar secara teori tetapi untuk menguasai kemahiran melakukan penyelesaian masalah bagi mengenal pasti lokasi dan punca kerosakan, ia memerlukan pemahaman yang baik tentang litar elektrik dan beberapa pengalaman amali. Pengendali penyelesaian masalah ini menghasilkan semula gangguan dengan menggunakan Arduino sebagai pengawal. Arduino akan mencetuskan geganti dalam litar dan peranti perlindungan seperti MCB dan RCCB akan teraktif mengikut kerosakan yang berlaku dalam litar. Kemudian, penyelesaian masalah mesti dibuat untuk mengenal pasti lokasi kerosakan sambil mengikut garis panduan keselamatan yang betul dalam proses penyelesaian masalah tersebut.

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V	-	Voltage
A	-	Ampere
$	-	Dollar USA
m^2	-	Square Meter
mm^2	-	Square Millimeter

LIST OF ABBREVIATIONS

Volt	-	Voltage
Amp	-	Ampere
FYP	-	Final Year Project
PSM	-	Projek Sarjana Muda
MCB	-	Miniature Circuit Breaker
RCCB	-	Residual Current Circuit Breker
LCD	-	Liquid Crystal Display
SMS	-	Short Message Service
SSO	-	Switch Socket Outlet
UPS	-	Uninterrupted Power Supply
DB	-	Distribution Box
LED	-	Light Emitting Diode

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CHAPTER 1

INTRODUCTION

1.1 Background

Electrical installation is divided into two sectors. Which are the domestic sector and the industries sector. Usually, the domestic sector uses a single-phase wiring system and industries commonly use three-phase wiring systems. Particularly wiring in both sectors must adhere to safety regulations for design and installation. When installing related control, circuit protection, and distribution equipment in a building, voltage, current, and functional requirements must be observed. Regulations regarding cable safety at the local, state, and local levels may vary from one another.

Electrical faults commonly occur either during the installation phase or after the installation phase. There are several types of faults in electrical wiring which are line-earth faults, neutral-earth faults, line-neutral faults, line break faults, and neutral break faults. These faults may be caused by improper installation, damaged cables and equipment fault, overcurrent or overvoltage of the circuit, moisture existence.

In a basic structure of wiring in domestic electrical installation, there is a safety device that involves in the circuit i.e., RCCB, MCB, and fuses. These devices is required to react to faults that might happen to avoid accidents. Besides, there are two types of circuit connection which are ring type and radial type. Both types have their own current carrying capacity based on the projection load.

Troubleshooting is the process of finding a solution, but when it comes to electricity, troubleshooting is only carried out when there is an electrical failure. Electrical troubleshooting is the process of identifying electrical circuit faults by examining the functioning and behavior of the problematic circuit by using an appropriate instrument. Once the root cause of fault is identified, suitable rectification work can be performed accordingly.

1.2 Problem Statement

Most wiremen have the skill to make electrical installation but do not have skill to perform troubleshooting to find the fault that occurs in the wiring circuit. This problem has become a cultural issue in domestic and commercial wiring installation industry. This is because they do not have experience of all the faults that occur in electrical installation. Electrical faults can be taught during theoretically, but to obtain the skills to perform troubleshooting to identify the location and the root cause of the faults, it requires a good understanding of electrical circuit, skill to use appropriate instruments and some hands-on experience.

1.3 Project Objective

The main aim of this project is to develop a training system that is efficient enough for learning purposes that can be used in education. This project may solve the main problem which is the wiremen does not possess skills to troubleshoot the electrical installation. Specifically, the objectives are as follows:

a) To design an electrical fault troubleshooting trainer using a small-scale single-phase electrical wiring circuit.
b) To develop a prototype hardware of the designed electrical fault troubleshooting trainer

c) To verify the efficacy of the developed prototype through questionnaires to lectures or instructors.

1.4 Scope of Project

The scope of this project is as follows:

a) Single-phase wiring circuit.

- The system will be designed by using a single-phase wiring circuit that consists of a switch to turn on the light, and several socket switch outlets in the ring or radial connection.

b) Fault in basic electrical wiring.

- The trainer will emulate five types of fault, which are line-earth fault, neutral-earth fault, line-neutral fault, line break fault, and neutral brake fault.

c) Fault emulation using microcontroller-based circuits.

- The system will be using an Arduino microcontroller as the controller to trigger the electrical fault in the circuit.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review is a summary and evaluation of previous research on a particular subject. It is a crucial feature of research that assists in determining the current level of knowledge and comprehension regarding a certain subject. An effective literature review may serve as a solid base for research efforts by guiding the questions, assumptions, and methods. Additionally, it allows the researcher to establish new approaches or gain an improved understanding of the subject.

2.2 Electrical Installation Circuit

An electrical installation circuit is a system of interconnected electrical components that are designed to provide electrical power to a building or facility without causing any harm or property damage. The components like wires, cables, smart controllers (circuit breakers), and outlets among others located in buildings or facilities with an essential role in supplying power sourced mainly from utility companies through proper distribution channels within structures. These circuits must adhere to established code requirements while safely delivering predictable amounts of energy wherever it's needed. Domestic electrical installations in Malaysia typically consist of a main distribution board (MDB) that is connected to the main power supply from the utility company. The MDB is in control of supplying energy to different circuits, including lighting, outlets, and electrical appliances, throughout the home. The types of circuit arrangements for socket outlets and lighting circuits that are usually used in domestic usage can be divided into two arrangements which are ring circuit and radial circuit.

2.2.1 Ring Circuit

The purpose of distribution feeder (cable or line) is to provide path for energy flow from GSS all the way to the distribution customer. Traditional distribution feeders (without DER) are usually operated in radial configurations - the energy flows uni-directionally from the GSS to the load. The feeders are typically categorized by its: (i) voltage level, (ii) conductor material, (iii) conductor size (cross sectional area), (iv) insulation type and (v) no of phases. These feeders scattered all over different supply zones. Hence, they are extensive and large in numbers.

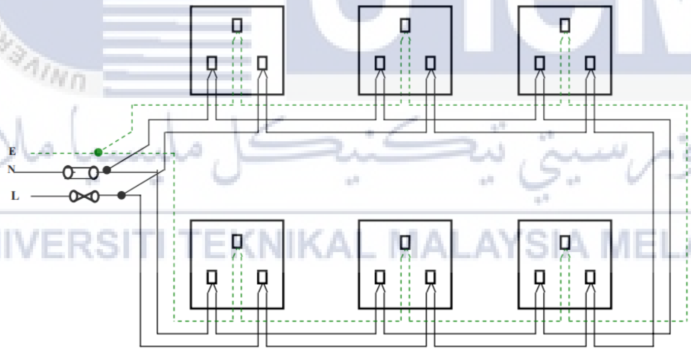


Figure 2-1 Ring Circuit [2]

2.2.2 Radial Circuit

In In contrast to a ring circuit, a radial circuit does not bring a wire from the farthest socket outlet back to the consumer unit [1]. The advantage of using this circuit is when it is in a big building where a cable must be brought from the farthest socket outlet back to the consumer unit or distribution board, radial circuits are sometimes thought to be more cost-effective to establish than ring circuits. By referring to Table 2-1 indicates that two types of radial circuits are permitted when using socket outlets.

Table 2-1 Type of radial circuit requirement [2]

Circuit Type	Over Current Protection Rating (Fuse or MCB) (Ampere)	Minimum Size of Copper Conductor in PVC or Rubber Insulaltion (mm^2)	Maximum Floor Area (m^2)
Ring	30 or 32	2.5	100
Radial	30 or 32	4.0	50
Radial	20	2.5	20

- Those with a 20 Amp overcurrent device rating and 2.5 mm^2 cable wiring (these can provide an infinite number of socket outlets up to a maximum floor area of 20 m^2).
- those protected by a 30Amp or 32Amp overcurrent device rating and wired in 4 mm^2 cable (these may provide an infinite number of socket outlets up to a maximum floor area of 50 m^2).

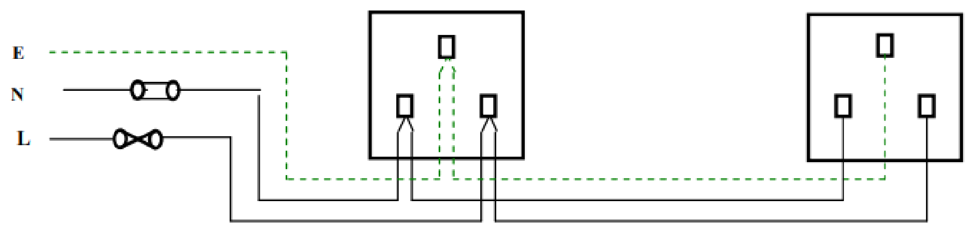


Figure 2-2 Radial Circuit [2]

2.3 Protection Device

For each circuit there is a maximum voltage or current. If this value is exceeded, the cable overheats, the insulation of the cable melts, and a fire starts. Electrical protection devices are critical because they protect against the damage that electrical mishaps can cause to people, property, and infrastructure. Unintentional electrical incidents such as overloads, short circuits, and ground faults can occur suddenly and without warning. Electrical protection devices must be present in every home, business, facility, and industry. There are several protection devices related to the topic which are miniature circuit breaker (MCB) and Residual Current Circuit Breaker (RCCB).

2.3.1 Miniature Circuit Breaker (MCB)

A circuit breaker (MCB) is an electrical switch that automatically shuts down the circuit in the event of an abnormal condition of the power system, i.e., both an overload and a faulty condition [3]. The days of relying on fuses in low voltage electrical networks are largely over as miniature circuit breakers (MCBs) offer greater sensitivity and reliability in detecting overcurrent. Unlike rewireable or replaceable fuses that require significant effort to restore supply after tripping, turning an MCB back on is all it’s needed to quickly resume normal operations. Understanding how these devices function on a deeper level helps improve their functionality and security.

Figure 2-3 Miniature Circuit Breaker (MCB) [3]

2.3.2 Residual Current Circuit Breaker (RCCB)

The RCCB operates on the principle of Kirchhoff's law, which requires that the incoming and outgoing currents of a circuit be equal. Consequently, the RCCB compares the different current strengths between current-carrying and neutral conductors [4]. Maintaining the balance between current flow from both live and neutral wires is crucial. In cases of faults, when the neutral wire's flow decreases, it results in Residual Current. Such a discrepancy should be detected by a residual current device, which then quickly disconnect the circuit.

Figure 2-4 Residual Current Circuit Breaker (RCCB) [5]

2.4 Software

This project involves significant use of software, which is essential for simplifying and improving the process of achieving the objective of this project. The ideal software may make all the difference in reaching efficiency and effectiveness, whether it's managing complicated projects, analyzing large data sets, or automating repetitive operations. The goal of this report is to give a thorough analysis of the project by utilizing software and completing the hardware in the context of an electrical wiring circuit troubleshooting trainer which highlights its features, advantages, and effects. We may learn a lot about the modern tools that help us do work more efficiently and accurately by perusing some types of software used in this industry. Table 2-2 list some of the software related to this project.

Table 2-2 Software Related To Project

Software	Capabilities	Price
AutoCAD	AutoCAD is a computer-aided design software developed by the company Autodesk (hence the name AutoCAD) [11]. Users can create and alter digital 2D and 3D designs more quickly and simply than designed by hand. In this project, AutoCAD software is used to draw a single line diagram for electrical wiring circuit.	Free for student
ETAP (Electrical Transient and Analysis Program)	A software programme for analytical engineering called ETAP provides a range of completely integrated	$700 per license

	software solutions for electrical engineering, including those for arc flash, load flow, short circuit, transient stability, relay coordination, cable ampacity, optimum power flow, and more [12].	
SOLIDWORKS ELECTRICAL	Solidwork electrical capable of designing single-line and multi-line schematic tools, which facilitate rapid planning of your embedded electrical system and incorporate a library of hundreds of symbols and components [13].SOLIDWORKS Electrical schematics may be integrated with the 3D model, and you can then add 3D replicas of all electrical components to the model while establishing routes and connections using wires, cables, and harnesses.	$4,195

2.5 Related Previous Works

The foundation for the current understanding of electrical installation issues, from technological developments to social challenges, has been established through previous research and studies. These pieces of literature contributed to the growth of ideas, models, and frameworks while also offering practical solutions to several kinds of issues. In the context of this debate, previous research related to electrical installation topics or issues might serve as a basis for additional analysis, assist the course of study, and reveal knowledge gaps that need to be filled. There are several previous research that related to the electrical fault troubleshooting trainer using small scale single phase electrical wiring circuits which are:

2.5.1 Lighting and Appliance Circuits Training Project Using InsTrain

According to [6], The “Lighting and appliance circuits” training system illustrates the planning, installation and testing of common circuits in a complete building. This involves simulating the wiring for the entire structure and fault emulation using given software. The program can trigger real faults that are common in practice, including short circuits, wiring faults including short circuits, damaged ground wires, insulation faults, and faulty equipment. These faults must all be found and fixed by the students.

Figure 2-5 EGT 2 equipment set Lucas-Nülle [6]

2.5.2 Development Of An Electrical Wiring Installation Trainer

According to [7], the authors present that the instructor will be able to install, troubleshoot, and commission electrical wiring in residential, commercial, and industrial buildings. It is designed to allow students to experience the actual wiring of a circuit for a specific task and to enhance the learning experience and understanding of the subject. The trainer uses 220 V AC as the power supply for the circuit and is connected to a low voltage supply to protect the circuit. It also includes a circuit breaker, distribution boxes, power supply boxes, U terminals, base plates, switches, outlets, and LED light bulbs.

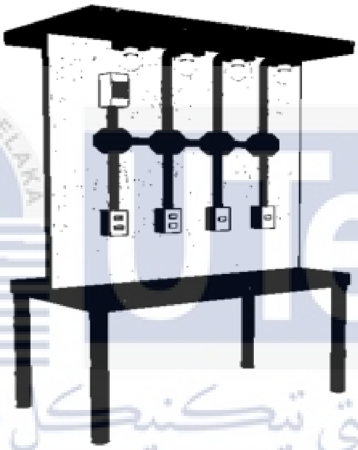


Figure 2-6 Electrical Wiring Installation Trainer [7]

2.5.3 Automatic System for Utility Electrical Fault

The work done by [8] is about developing an automatic system to detect the location of the continuous electrical fault and isolate the continuous fault from the system. Then, the breaker can be designed to automatically turn on the ground fault circuit interrupter (RCCB) to restore power to the supply. This project is using LabVIEW software in designing the program to detect faults.

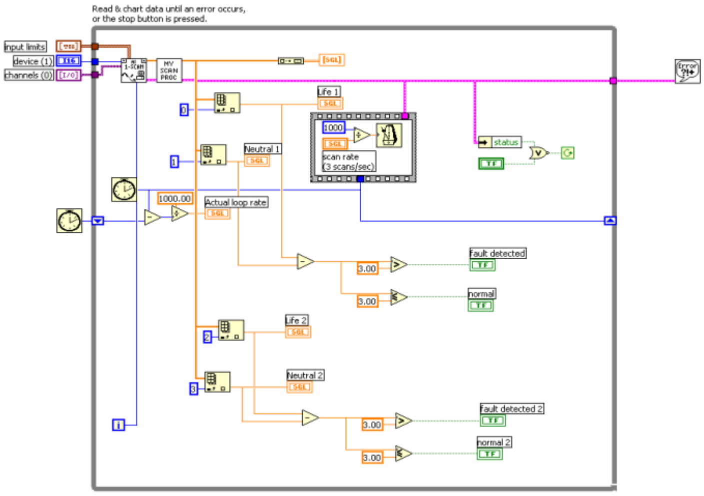


Figure 2-7 Program Block Diagram in LabVIEW [8]

2.5.4 Simulation of Underground Cable Fault Detector Using Arduino

According to [9], the author designed a system to identify issues in the underground link line from the base station to fix the areas within km. This framework takes advantage of upgraded power supplies and Arduino control modules. Here, an error made with the switch arrangement that creates a network of resistor-based detectors is linked to an Arduino controller to aid the inbuilt ADC tool in the microcontroller, which communicates with the connection length in kilometers.

Figure 2-8 Model of Underground Cable Fault Detector [9]

2.5.5 Design and Implementation of Electricity Fault Detection System Using Arduino UNO

The work done by [10] states that the focus of this work is on developing a prototype electrical installation that uses a manual simulation approach to identify faults that are both emergency and maintenance related. The lamp serves as the load in the prototype, which also has an Arduino UNO microprocessor, GSM module, and buzzer. The microcontroller will identify and verify the type of installation fault that occurred before sending the data of the fault via the GSM module. The GSM module then sends the information to the mobile phone and notifies the user of the error. Additionally, a buzzer will serve as a warning system by making a loud noise to indicate a problem that has to be fixed right away or an emergency. The customer will receive the data for both problems via Short Message Service (SMS). The SMS will inform the user of the sort of installation faults, such as an emergency or the need for maintenance.

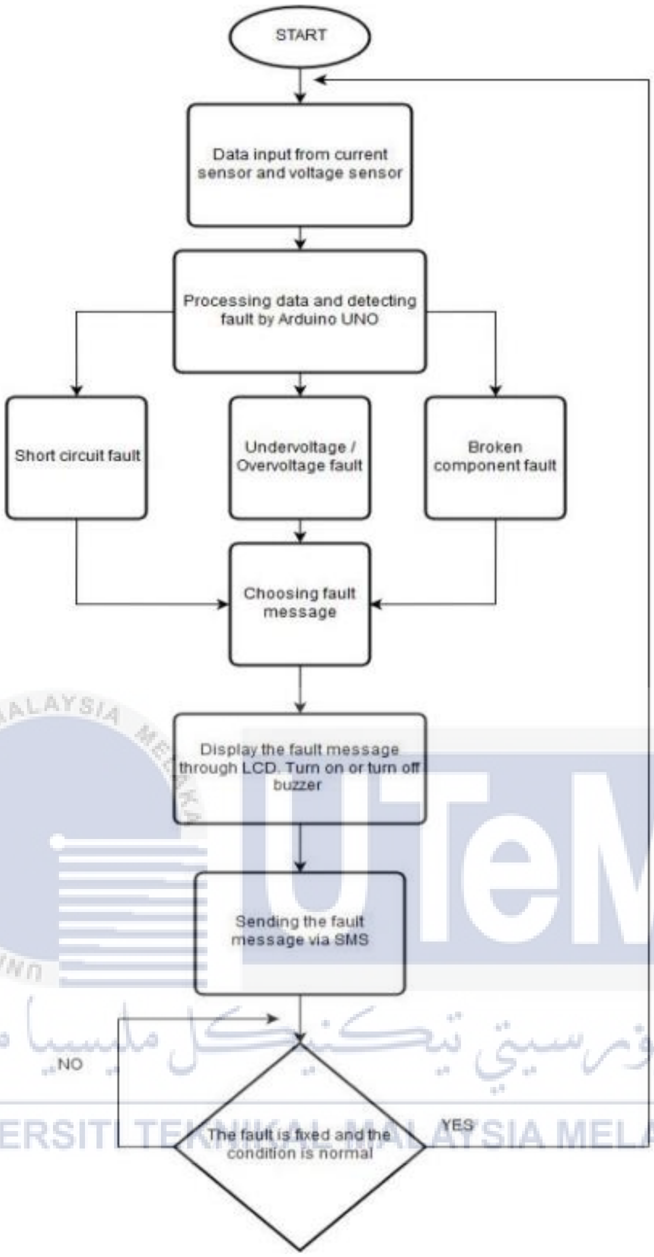


Figure 2-9 Flow Chart of Electricity Fault Detection System [10]

Table 2-3 Comparison of Previous Work

NO	AUTHOR (S)	TITLE	FUNCTIONAL	REMARKS
1	Lucas-Nülle	Lighting and Appliance Circuits Training Project Using InsTrain	Design to simulate the wiring for the entire structure and fault emulation using the given software	The program can trigger real faults that are common in practice, such as short circuits, wiring faults including short circuits, damaged grounding wires, faults in insulation, and malfunctioning equipment.
2	J. G. Pereyras	Development Of An Electrical Wiring Installation Trainer	Designed to allow students to experience the actual wiring of the electrical circuit of a given task, and to enhance the student learning experience in this area	It included a circuit breaker, power supply boxes, junction boxes, single switches, three-way switches, outlets, base plates, sockets, LED light bulbs, flexi hoses, and U-clamps

3	P. Darul Ridzuan	Automatic System for Utility Electrical Fault	Detect the location of the electrical fault then isolate the fault from the system and automatically turn on the ELCB to restore the supply	Using the LabVIEW program to detect the location of faults in the system.
4	M. Azmir, M. Salimi, and A. Hashim	Simulation of Underground Cable Fault Detector Using Arduino	Design a system to identify issues in the underground link line from the base station to fix the areas within Km	Contain Arduino UNO R3, different rated resistors, DC relay and relay drivers, switches, and LCD.
5	C. Adrian and M. Galina	Design and Implementation of an Electricity Fault Detection System Using Arduino UNO	Developing a prototype of electrical installation to identify faults and send the information to GSM module before sending it to the mobile phone and notifying the user of the error	Contain Arduino UNO R3, ACS-712 current sensor module, Voltage sensor module, GSM module SLM800L, Buzzer 5 Volt

2.6 Safety Issue About Electrical Installation Safety

Electrical installation troubleshooting includes identifying and repairing problems with electrical systems while prioritizing safety. Lack of knowledge and overconfidence are the most frequent reasons for electrical accidents and injury [21]. There are many individuals who mistakenly assume that installing electrical wiring and cabling using DIY techniques is as simple as nailing something to the wall. If you attempt to repair electrical equipment without any training, you run the considerable danger of receiving an electric shock and, if the problem gets ignored, it can have even worse consequences. According to [22], a study found that 255 electrical deaths in Taiwan are cause by failure to improper use of personal protective equipment (PPE), accidental contact with exposed electrical parts, poor work practice, maintain safe distances, lack of effective safety devices or unsafe environment), defective tools and equipment, and prevention measures (safe work practices, guarding, insulation, grounding, and electrical protective devices) were established based on the given typical circumstances.

Electrical installation refers to the process of installing electrical systems in residential, commercial, and industrial facilities. The main objective of electrical installation is to establish a safe and effective electrical infrastructure that complies with safety regulations and serves the electrical requirements of building occupants. To avoid electrical risks including electrical shocks, fires, and equipment damage, proper electrical installation is essential. However, electrical faults in electrical installation cannot be avoided. In order to have a right and safe troubleshooting technique, a safe practice of troubleshooting must be experience for technician or electrician. One of the safest practices that can be applied is by using an electrical fault troubleshooting trainer. To make a trainer safe from nonsense tripping of RCCB of the building and electrocution to the students, an isolation transformer be used. Isolation transformer will isolate between building power supply and the electrical load, thus removing any potential voltage between a human to earth, therefore the live current unable to flow through the human body [23]. Overall, electrical fault troubleshoots trainer and proper installation guidance can be one of the efforts to have a safe work practice to avoid electrical risk in electrical installations.

2.7 Summary

In summary, not many studies carried out the design of a trainer that function to simulate the wiring for the entire structure and can-do fault emulation test. The project design by Lucas-Nülle is slightly similar to the current project idea but the difference is Lucas-Nülle project uses its own software to emulate the fault in the system. But the idea of designing the project using an Arduino microcontroller is feasible. Using Arduino to emulate faults in the system is easier and does not require much apparatus and equipment to deliver the same output. The work on developing a prototype of electrical installation can be extracted from the related previous research.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The method used when conducting a research study is extremely important in determining the overall validity and dependability of the results. This chapter gives a thorough breakdown of the methodology used in this study, describing the steps and methods used to gather and analyze data. Readers will have a solid understanding of the research design, the participants, the data collecting tools used, and the analytical methodologies used after reading about the methodology. This chapter acts as a plan of action for carrying out the study, providing accuracy, authenticity, and reliability.

3.2 Methodology

In conducting research, there will undoubtedly be difficulties and challenges, such as the use of specific techniques or methods, analysis of data, etc. Methodology is a family of logics used for research considerations or as a process to perform an action. This troubleshooting trainer is to fulfill the objective of developing a hardware prototype for the designed electrical troubleshooting trainer and also to collect information from the respondents regarding their perspectives, experiences, and views based on the survey.

3.3 Project Architecture

Figure 3-1 below shows the flowchart of the final year project. It was divided into two which are Final Year Project (FYP) 1 and Final Year Project (FYP) 2. The first step in doing this project is finding the supervisor for this FYP. After that, there is a discussion session between the supervisor and student to select the project title. The main objective and problem statement are the points that have been discussed and identified. The scope of this project also needs to recognize the limitation of this project. Next, to analyze the project implementation and requirements, a literature review on some articles about past studies needs to be reviewed in order to gain more understanding about the project that wants to develop. Furthermore, before planning and designing the project, research, and selection of the hardware need to be done. Moreover, after the project has been designed some minor simulations need to be tested. Last but not least, for the analysis of the project, a survey to examine the effectiveness of the electrical fault troubleshooting trainer and student knowledge about electrical wiring installation needs to be prepared. All that had been state above have been done in the FYP1.

FYP 2 starts with development of hardware for single-phase wiring circuit which involve of equipment purchasing, hardware construction, wiring connection, and testing functionallity of the circuit. The circuit's functionality needs to be tested before proceeding to the next step to ensure it is working correctly. Next step is the development of hardware for the fault emulate system using Arduino which include equipment purchasing, coding-hardware testing, circuit soldering, system functionallity test. The system's functionality needs to be tested before proceeding to the next step to ensure it is working perfectly. Next step is combination hardware of single-phase wiring circuit and the fault emulate system using Arduino. Upon completion of the development process, the project will be subjected to several testing session to ensure its functional accuracy. Any errors encountered trigger immediate software and hardware troubleshooting to guarantee optimal performance. Following completion, the project will be explained to the student and lecturer, highlighting its key outcomes. An in-depth analysis of the project data will then be conducted to evaluate its success, with the findings used to finalize the report.

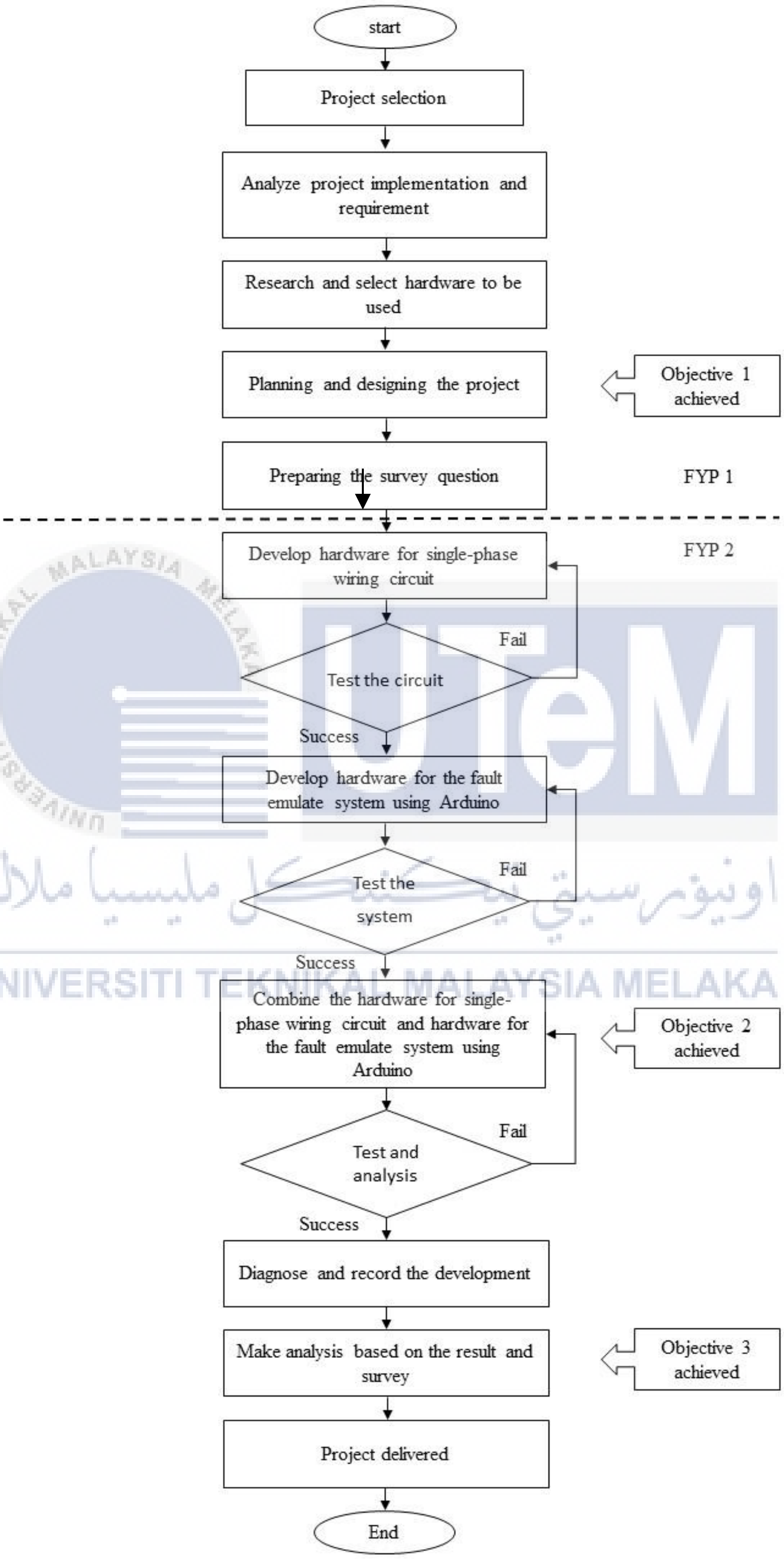


Figure 3-1 Flowchart of the final year project (FYP 1 & FYP 2)

3.4 Hardware Component

In completing the project, some of the equipment hardware needs to be determined to know its specification that matches the requirement of the project. This is important because the wrong hardware chosen to be used in the project might cause a malfunction in the project system.

3.4.1 Uninterrupted Power Supply (UPS)

When power failures like power outages happen, computer equipment like servers and workstations may malfunction, resulting in a number of issues like the loss of crucial data and program malfunction. Uninterruptible Power Supply is a device that continues to provide power to devices for a certain period of time despite issues with utility power and other power sources [14]. But for this project, UPS is used as the main supply to the system since there is no connection to the utility power for safety purposes. If the developed system is connected directly to the building power system, it can induce nuisance tripping of RCCB of the building.

Figure 3-2 Uninterruptible Power Supply (UPS) [15]

3.4.2 Arduino UNO

Arduino is a programmed circuit board that is open source and may be used in a broad range of production facility projects, both basic and complicated. This circuit board has a microcontroller that may be configured to detect and manage physical items [16]. Arduino in this project is used as the controller for the overall system to emulate the fault in the circuit. Figure 3.8 show Arduino UNO consists of a total of 14 digital I/O pins labeled as D0 to D13, 6 analog input pins labeled as A0 to A5, a Power Connector, a USB Connector, a build in voltage Regulator, a Reset Button, an ICSP Header, etc.

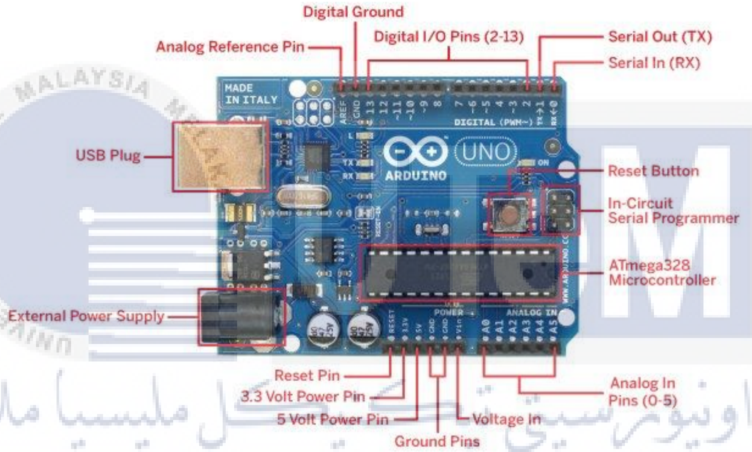


Figure 3-3 Arduino UNO [17]

3.4.3 Power Relay

Relays function as electrically controlled switches that switch one or more contacts using an electromagnet to move a switching mechanism. [18]. They are used when one or more load circuits must be switched on or off by a control signal. Power relays are widely utilized in many different applications, such as telecommunications, power distribution, control systems, industrial automation, and more. Figure 3-4 shows the high-power relay design and Table 3-1 shows its specification.

Figure 3-4 Power relay

Table 3-1 Feature And Specification of Power Relay

Features	Specification
Contact rating	7A/250VAC 10A/250VAC 15A/250VAC
Max switching voltage	250VAC
Max switching current	15A
Coil voltage range	5Vdc - 48Vdc
Coil current range	89.3mA - 10mA

3.4.4 Buck Converter

The buck converter, sometimes referred to as a step-down converter, is a significant design in power electronics that converts a greater input voltage to a lower output voltage [24]. This project uses a buck converter to step down the voltage from a 12-volt rechargeable battery to 5 volts. This 5-volt supply powers the Arduino, the power relays, and the entire circuit of the fault emulation system.

Figure 3-5 Buck converter

3.5 Software Development

This software is crucial to the operation of the overall project system. Without this application, it is impossible to build a wiring circuit for the system and verify the circuit's operation on a working system.

3.5.1 PQ ONE

Hioki created PQ ONE, a potent freeware programme, especially for analysing data from their line of Power Quality Analyzers [25]. These advanced analyzers, such as the Hioki 3100 series, are used to test and record several electrical characteristics inside a power system. After then, PQ ONE intervenes to assist in interpreting all of the data.

3.5.2 Proteus 8

The Proteus Design Suite is a set of specific software tools used mostly for automating electrical design [20]. Electronics designers, students, and technicians often use this programme to simulate a schematic circuit and accurately reproduce a circuit function..

3.5.3 Arduino IDE

For creating electrical projects, there is an open-source platform called Arduino. Arduino system comprises a software program called the IDE (Integrated Development Environment) that runs on your computer which allows users to construct coding according to the project function. To upload programmes and communicate with it, it can also be connected to the Arduino hardware. [19].

3.6 Fault Emulation System Using Arduino

Figure 3-6 shows the flow diagram of the fault emulates system using Arduino. The system consists of 5 switch buttons to signal the Arduino about the type of fault to be emulated. Each of the buttons will trigger different types of faults. A reset switch will reset all the faults that have been triggered.

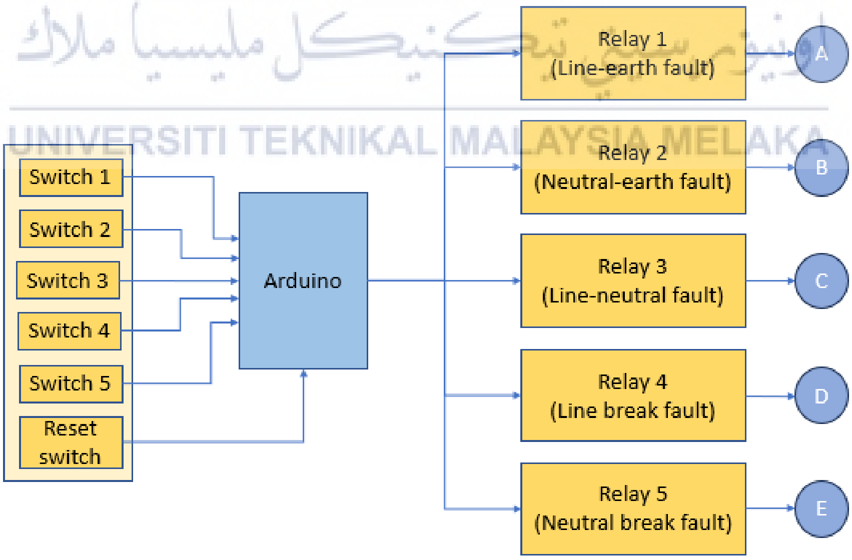


Figure 3-6 Flow Diagram Of The Fault Emulate System Using Arduino

Each of the faults that have been triggered is located at different points in the single-phase electrical wiring circuit. The location of the fault can be flexibly placed at different points in the circuit. Figure 3-7 shows the faults placement point at the single-phase electrical wiring circuit.

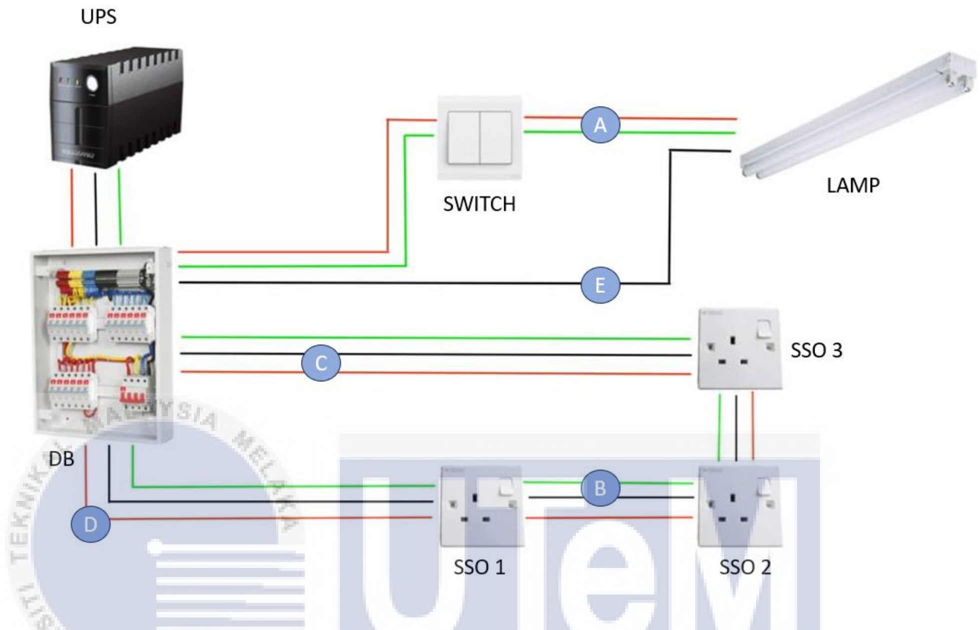


Figure 3-7 Faults Placement Point At The Single-Phase Electrical Wiring Circuit

3.6.1 Simulation of the Fault Emulate System Using Arduino Circuit

Figure 3-8 shows the Fault Emulate System Using Arduino Circuit design using Proteus 8 software. The output of this simulation will be shown as the LED will light up as a sign the relays are reacting to the signal from the switch.

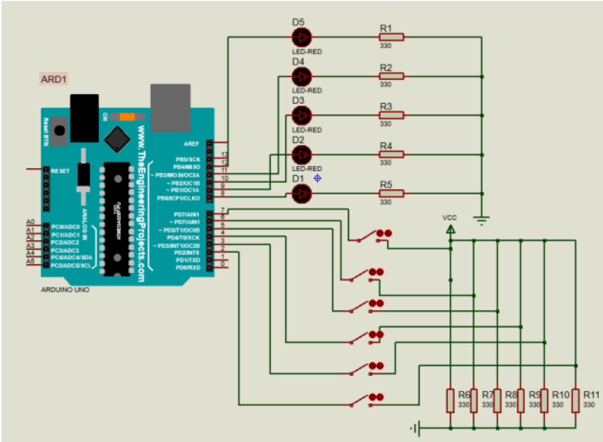
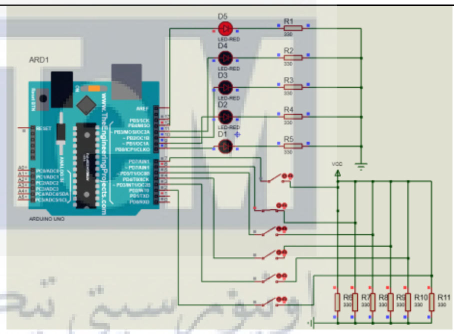
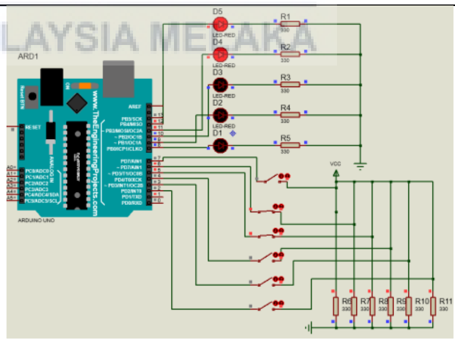
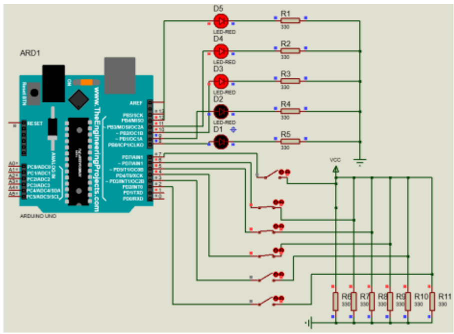
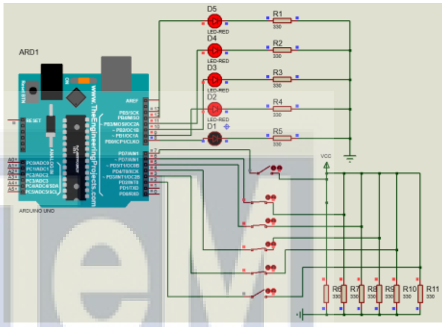
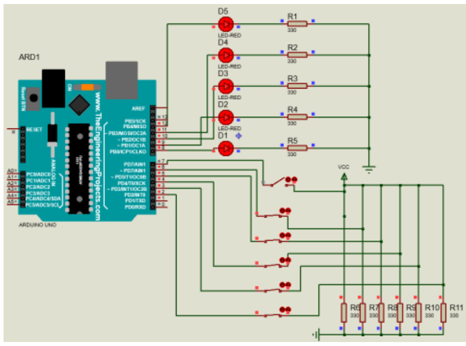


Figure 3-8 The Fault Emulate System Using Arduino Circuit

Table 3-2 Result of Simulation

Case	Result	Circuit
S1 turn on	• Relay 1 on (line-earth fault)	
S1 & S2 turn on	• Relay 1 on (line-earth fault) • Relay 2 on (neutral-earth fault)	

S1, S2 & S3 turn on	• Relay 1 on (line-earth fault) • Relay 2 on (neutral-earth fault) • Relay 3 on (line-neutral fault)	
S1, S2, S3 & S4 turn on	• Relay 1 on (line-earth fault) • Relay 2 on (neutral-earth fault) • Relay 3 on (line-neutral fault) • Relay 4 on (line break fault)	
S1, S2, S3, S4 & S5 turn on	• Relay 1 on (line-earth fault) • Relay 2 on (neutral-earth fault) • Relay 3 on (line-neutral fault) • Relay 4 on (line break fault)	

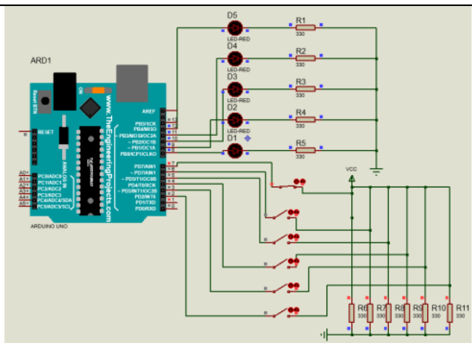
	• Relay 5 on (neutral brake fault)	
Reset Switch turn on	• All relays turn off	

Table 3-2 shows the result of the simulation using proteus 8 which the LED will light up indicating the function of relays in the circuit. The number of faults in the circuit will reflect how many switches are turned on. The coding of this system can be referred to in **Appendix A**.

3.6.2 Hardware Of Fault Emulate System Using Arduino Circuit

Figure 3-9 shows the hardware of fault emulate system using arduino. This system is the controller to emulate fault in the single-phase wiring circuit. It is necessary to test the circuit on a breadboard before completing the hardware to ensure the system functions as intended. This system utilizes a 12-volt rechargable battery and a 5-volt buck converter as its primary power source.

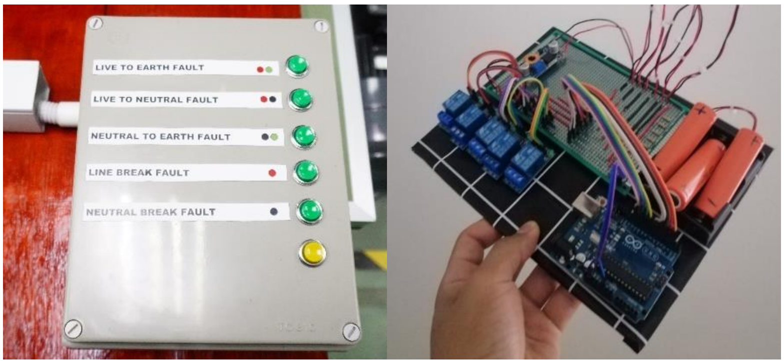


Figure 3-9 Hardware Of The Fault Emulate System Using Arduino

3.7 Single-Phase Electrical Wiring Circuit

Figure 3-10 shows a single-line diagram of the single-phase electrical wiring circuit that has been used in this project. The circuit consists of main equipment, which is a 63Amp main switch, two 63Amp RCCBs, 6Amp MCB, 1Amp MCB, a fluorescent lamp output, and three switch socket outlets that are connected in a ring connection. Figure 3-11 shows the complete single-phase electrical wiring circuit hardware. The circuit's functionality needs to be tested after the equipment have been fully installed.

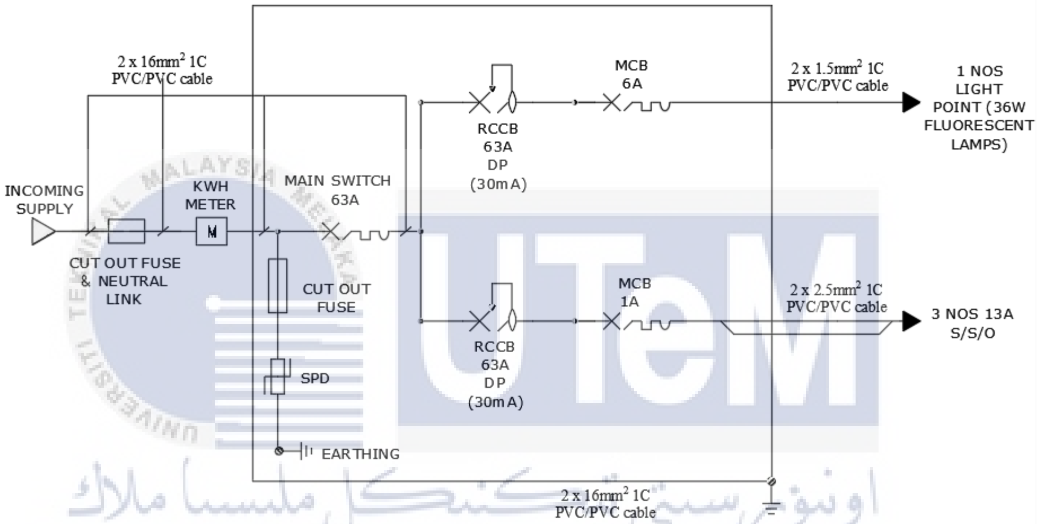


Figure 3-10 Single-Line Diagram of The Single-Phase Electrical Wiring Circuit

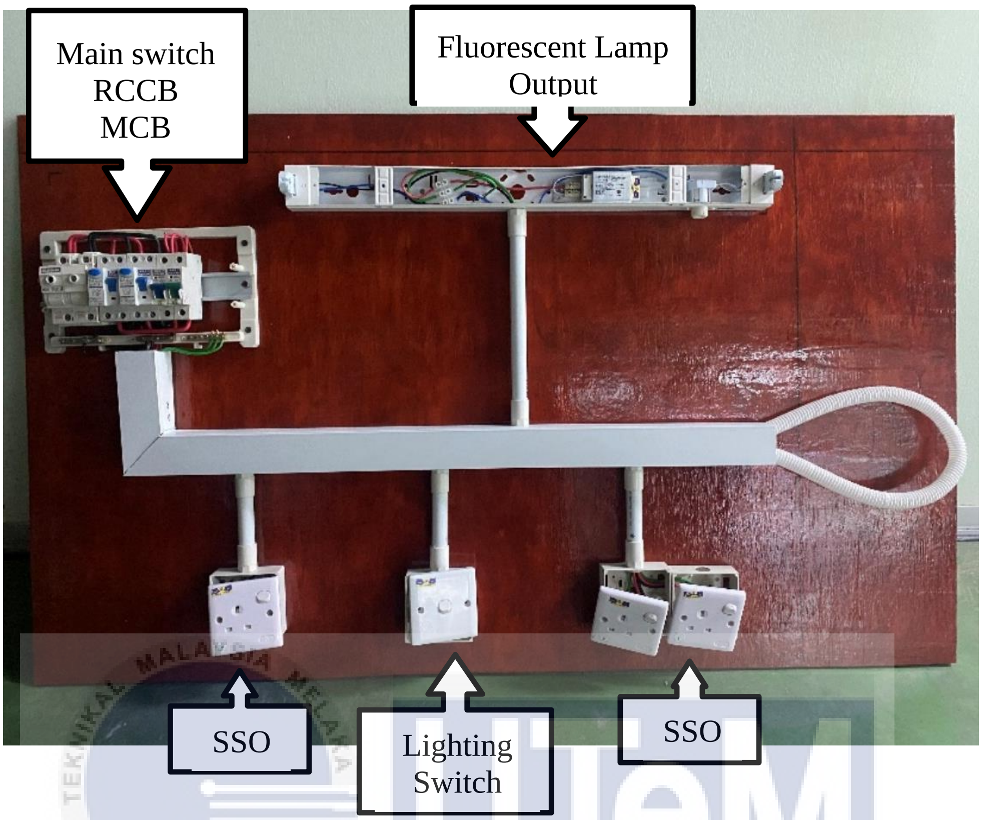


Figure 3-11 The Single-Phase Electrical Wiring Circuit Hardware

3.8 Electrical Fault Troubleshooting Trainer

Figure 3-12 show the overall hardware of electrical fault troubleshooting trainer. This trainer is a combination of two different systems that integrated together which is the single-phase electrical wiring circuit and the fault emulate system using arduino. The trainer operates as a standard single-phase wiring circuit until a switch activates the fault emulation system. Once triggered, the system emulates the desired fault type.

Figure 3-12 Electrical Fault Troubleshooting Trainer

3.9 Testing Method

All electrical projects, regardless of complexity, require thorough testing to ensure their functionality. Similarly, this specific project also needs meticulous testing to verify its intended operation. There are several testing methods used in this project.

3.9.1 Uninterruptible Power Supply (UPS) As Main Supply

Based on Figure 3-13 , it show connection uninterruptible power supply (UPS) used as main supply through the circuit. This project utilizes an uninterruptible power supply (UPS) to prevent power outages and disruptions, commonly referred to as "nuisance trips," within the building.The system will be tested to know either all type of fault can be emulate by using UPS. The result of the testing will be recorded and analyzed.

Figure 3-13 Uninterruptible Power Supply (UPS) As Main Supply

3.9.2 Direct Supply As Main Supply

Figure 3-14 shows the connection direct supply from the building used as main supply through the circuit. The direct supply used in this project is to assess both the behavior of safety equipmentt and the actual current that might trip the safety equipment. The result of the testing will be recorded and analyzed.

Figure 3-14 Direct Supply As Main Supply

3.9.3 Power Quality Analyzer To Analyze Current And Voltage

Figure 3-15 shows power quality analyzer used in the project. In order to identify the real current and voltage that passes through the circuit when the electrical fault is emulated, the power quality analyzer is used in the project.

Figure 3-15 Power Quality Analyzer Used In The Project

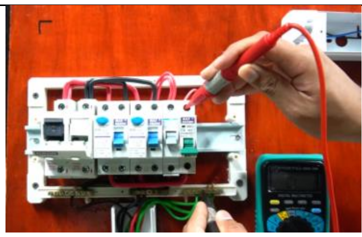
3.10 Procedure

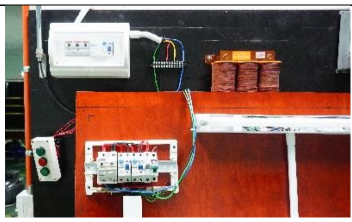
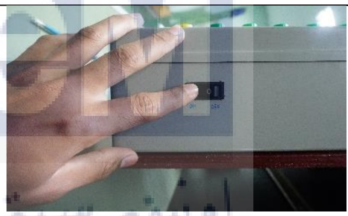
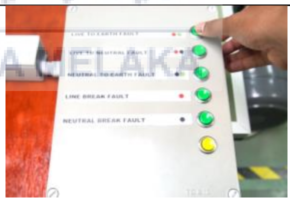
Each project has its own goals, tasks, and challenges. Standardized procedures must be followed to make sure the project produces optimal performance and to ensure safety. These troubleshoot trainers also have procedures to be followed.

3.10.1 Procedure To Use The Trainer

Table 3-3 outlines the comprehensive steps for utilizing the electrical fault troubleshoot trainer. These procedures serve as essential guidelines that everyone must adhere to in order to prevent any potential issues or complications.

Table 3-3 Procedure To Use The Trainer

Steps	Description	Example Picture
Step 1	Do contiunity test between cable live, neutral and earth. Make sure there is no contact.	

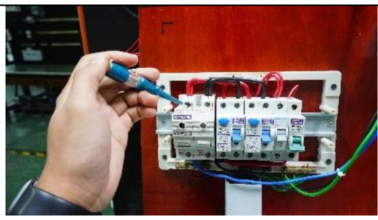
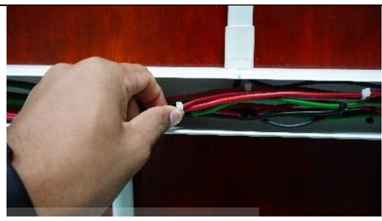
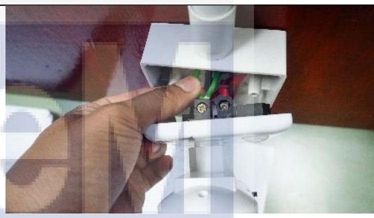
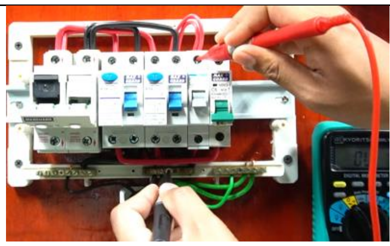
Step 2	Connect incoming supply cable to the Main Switch at DB box.	
Step 3	Turn on the incoming supply and use test pen to make sure there is supply before turn on all the RCCBs and MCB accordingly.	
Step 4	Turn on switch for SSO and Lighting Circuit. Make sure in normal condition, every load can be turned on.	
Step 5	Turn on the switch at The Fault Emulate System.	
Step 6	Press the switch button at The Fault Emulate System to emulate fault.	
Step 7	Press Reset button to reset the system.	

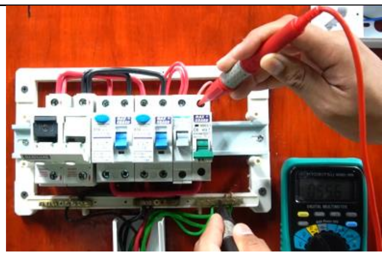
3.10.2 Procedure To Troubleshoot The Fault

Table 3-4 outlines the process needed to diagnose a simulated fault. Anyone wishing to lower risk of and improve safety should adhere to these steps.

Table 3-4 Procedure To Troubleshoot The Fault

Line Break & Neutral Break Fault		
Steps	Description	Example Picture
Step 1	Make sure the supply is turned off.	
Step 2	Use a test pen or multimeter to make sure there is no residual voltage in the circuit.	
Step 3	Do a continuity test on the circuit.	
Step 4	Check loose connections.	
Step 5	Determine the root cause of the fault.	
Live To Neutral Fault, Live To Earth Fault, Neutral To Earth Fault		

Step 1	Make sure the supply is turned off.	
Step 2	Use a test pen or multimeter to make sure there is no residual voltage.	
Step 3	Identify if there is an abnormal condition at the circuit such as burn/melt insulation cable.	
Step 4	Identify if there is a loose connection that might cause a shortage.	
Step 5	Identify if there is an insect inside the trainer that might cause a shortage in the circuit.	
Step 6	Depending to type of fault, check continuity between: • live and neutral cable • Live and earth cable • Neutral and earth cable	 (live to neutral continuity test)

		 (live to earth continuity test)  (Neutral to earth continuity test)
Step 7	Determine the root cause of the fault.	

3.11 Survey Questions

For analysis in this project, a survey in the form of a questionnaire can be carried out. The survey consists of 15 questions and the survey is suitable as it is not too many and convenient for respondents to answer as it also can gather all the information needed to be extracted. The questionnaire form can be referred to in **Appendix B**.

3.12 Summary

In this chapter, the proposed methodology is presented to develop a new, effective, and integrated approach to develop a trainer for troubleshooting electrical systems, using a small single-phase circuit. Besides, it also explain on testing method used to power up the circuit and measure current and voltage for each type of fault. This chapter also provide the procedure to operate the trainer and procedure of troubleshoot once the fault is emulated. Last but not least, a survey to get the analysis is made and the data is collected.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter builds upon the testing method mentioned in Chapter 3 to explain the results and discuss their broader implications. The analysis focuses on behavioral changes, equipment condition, and data related to current spikes during fault emulation. Besides, the result from data survey to verify the efficacy of the developed prototype will be analyzed.

4.2 Results and Analysis Used Uninterruptible Power Supply (UPS) As Main Supply

The system will be tested to know either all type of fault can be emulate by using UPS. The result of the testing can be analyzed as follow:

4.2.1 Grounding system isolated from building grounding

Table 4-1 shows how the trainer performed in the test, including changes in behavior and the condition of the equipment. This testing method utilised method of testing using uninterrupt power supply as main supply using isolated grounding. The result is as follow:

Table 4-1 Result using UPS as main supply with isolated grounding

Type of fault	Safety Equipment used	Behavior of safety equipment	UPS & Relay condition
Line Break	NA	Open circuit	UPS: Normal Relay: Normal

Neutral Break	NA	Open circuit	UPS: Normal Relay: Normal
Neutral to Earth	RCCB 63A (0.03A)	No Trip	UPS: Normal Relay: Normal
	RCCB 63A (0.1A)	No Trip	UPS: Normal Relay: Normal
Live to Earth	RCCB 63A (0.03A)	No Trip	UPS: Normal Relay: Normal
Live to Neutral	MCB 6A	No Trip	UPS: Shutdown Relay: Normal
	MCB 20A	No Trip	UPS: Shutdown Relay: Normal
	MCB 32A	No Trip	UPS: Shutdown Relay: Normal

Result from the table 4-1 shows line break and neutral break have no issue to perform fault emulated. However, the behavior of safety equipment no trip for the rest of the fault emulated. Live to Neutral fault emulated will cause the UPS to shutdown. From the result and observation, using UPS as main supply would not cause the system run to emulated the fault because the current when the fault occur is below triggering value for the MCB and RCCB and there is no proper grounding system.

4.2.2 Grounding system use grounding from building

Table 4-2 shows how the trainer performed in the test, including changes in behavior and the condition of the equipment. This testing method utilised method of testing using uninterrupt power supply as main supply and using grounding from the building. The result is as follow:

Table 4-2 Result using UPS as main supply with grounding from building

Type of fault	Safety Equipment used	Behavior of safety equipment	UPS & Relay condition
Line Break	NA	Open circuit	UPS: Normal Relay: Normal
Neutral Break	NA	Open circuit	UPS: Normal Relay: Normal
Neutral to Earth	RCCB 63A (0.03A)	Trip	UPS: Normal Relay: Normal
Live to Earth	RCCB 63A (0.03A)	Trip at trainer's RCCB and trip at building RCCB.	UPS: Normal Relay: Blow
Live to Neutral	MCB 1A	No Trip	UPS: Shutdown Relay: Normal
	MCB 32A	No Trip	UPS: Shutdown Relay: Normal

Result from the table 4-2 shows line break and neutral break have no issue to perform fault emulated. The behavior of RCCB will trip but will cause nuisanse tripping of building electrical circuit when Live to Earth fault is emulated. Live to Neutral fault emulated will cause the UPS to shutdown but the MCB did not trip. From the result and observation, using UPS as main supply and using proper grounding will cause the fault can be emulated but not for Live to Neutral fault because the current when the fault occur is below triggering value for the MCB.

4.3 Results and Analysis Used Direct Supply as Main Supply

Table 4-3 shows how the trainer performed in the test, including changes in behavior and the condition of the equipment. This method of testing using direct supply as the main supply to the circuit. The result is as follows:

Table 4-3 Result using Direct Supply as main supply

Type of fault	Safety Equipment used	Behavior of safety equipment	Relay condition
Line Break	NA	Open circuit	Normal
Neutral Break	NA	Open circuit	Normal
Neutral to Earth	RCCB 63A (0.03A)	Trip	Normal
Live to Earth	RCCB 63A (0.03A)	Trip at trainer's RCCB and trip at building RCCB.	Blow
Live to Neutral	MCB 1A	Trip	Normal
	MCB 32A	Trip	Blow

Result from the table 4-3 shows line break and neutral break have no issue to perform fault emulated. The behavior of RCCB will trip when neutral to earth fault emulated, but will cause nuisanse tripping of building electrical circuit and the relay to blow when Live to Earth fault is emulated. Live to neutral fault emulated will cause MCB to trip but will cause relay to blow when using higher MCB current such as 32A. It is because the relay can only sustain when the current below 10A. So, for protection, a resister load need to be install before the relay to reduce possibility relay to blow.

4.4 Result Difference Between Using UPS As Main Supply and Direct Supply As Main Supply

Table 4-4 show the difference result when using different type of supply as the main supply to the circuit. To make sure this troubleshoot trainer can emulate all types of fault, the use of direct supply as main supply is necessary.

Table 4-4 Result Difference Between Using UPS As Main Supply and Direct Supply As Main Supply

Type of fault	UPS (ground connect to building)	Direct Supply
Line Break	Open circuit	Open circuit
Neutral Break	Open circuit	Open circuit
Neutral to Earth	RCCB trip and relay is normal.	RCCB trip and relay is normal.
Live to Earth	Trip at trainer's RCCB and trip at building RCCB. Relay blow.	Trip at trainer's RCCB and trip at building RCCB. Relay blow.
Live to Neutral	MCB not trip and Relay is normal. However, UPS will shut down.	MCB trip and Relay is normal.

4.5 Analyze Current And Voltage using Power Quality Analyzer

In order to identify the real current and voltage that passes through the circuit when the electrical fault is emulated, the power quality analyzer is used in the project. The first fault to be identify its current and voltage is Neutal to Earth fault. Figure 4-1 show the result of the test. The different current between the live and neutral current will cause RCCB triggered and trip.

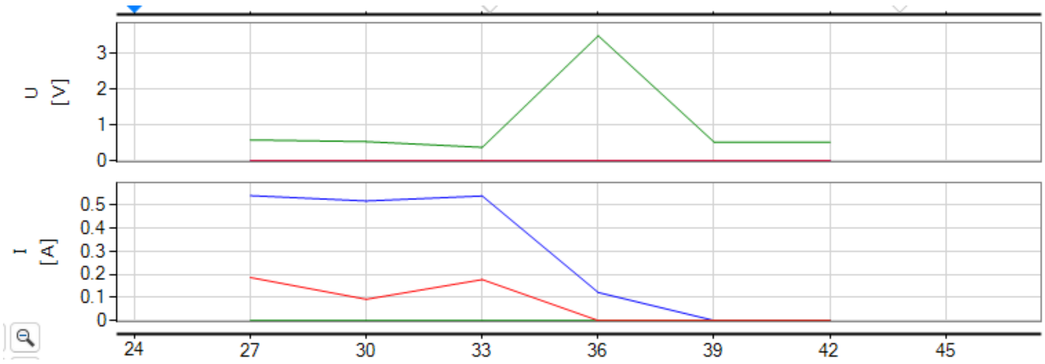


Figure 4-1 Result Actual Current And Voltage For Neutal To Earth Fault

Next, the fault to be identified is its current and voltage is live to earth fault. Figure 4-2 show the result of the test. The different current between the live and neutral current will cause RCCB triggered and trip.

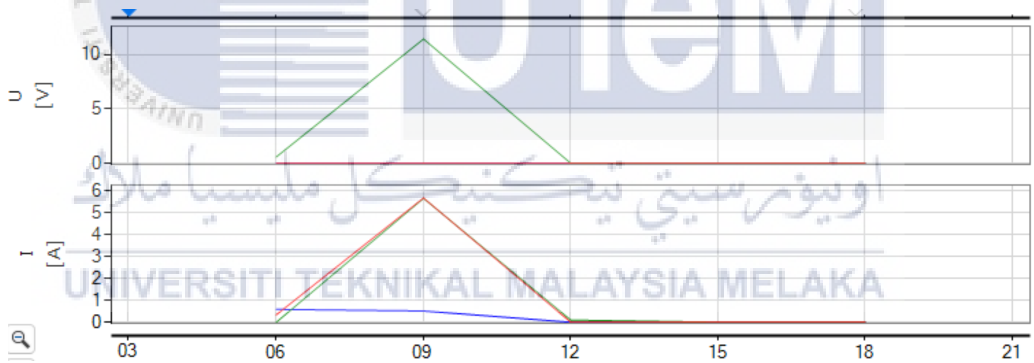


Figure 4-2 Result Actual Current And Voltage For Live To Earth Fault

Finally, the fault to be identified is its actual current when fault emulated is Live to Neutral fault. Figure 4-3 show the result of the test. The result shows that the current will exceed the MCB rating which is 1A. So it will cause MCB to trip.

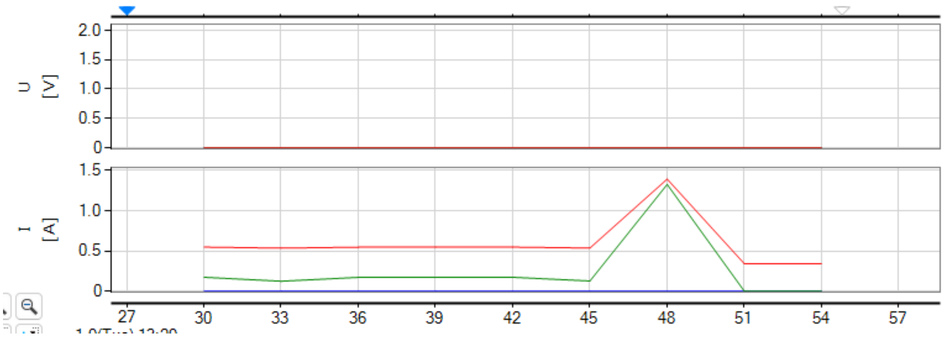


Figure 4-3 Result Actual Current For Live To Neutral Fault

4.6 Result Analysis and Survey Question

The survey is carried out for about 8 recipients which includes lecturer and student at Campus technology. This survey is carried out to obtain the feedback and to examine the effectiveness of the troubleshoot trainer. The demonstration of the trainer were shown by using video to every recipients. The duration for demonstration and explanation approximately 4 to 5 minutes.

Question 1: Electrical wiring Circuit troubleshooting is an interesting subject?

Figure 4-4 shows that 37% of the recipients agree and 63% of them strongly agree that this subject is very interesting. Since most of them are electrical engineering students and lecturers, this explains why it is an interesting subject to them.

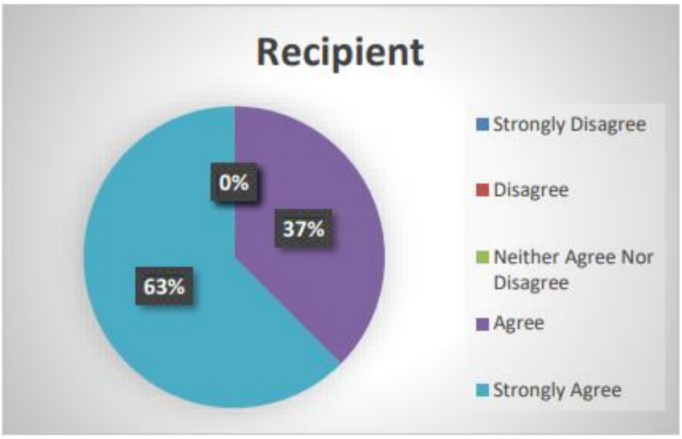


Figure 4-4 Survey Question 1

Question 2: Most of the wiremen are not able to conduct electrical wiring troubleshooting.

Figure 4-5 shows that most of the recipients strongly agree that most of the wiremen and electrician still not be able to conduct electrical wiring troubleshooting.

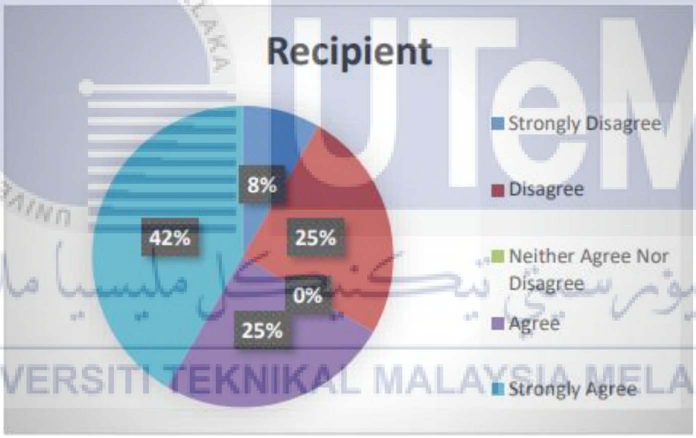


Figure 4-5 Survey Question 2

Question 3: The trainer functions as a real situation condition.

Figure 4-6 shows that all of the recipients agree that the trainer function as a real situation condition this trainer can trip according to emulated fault.

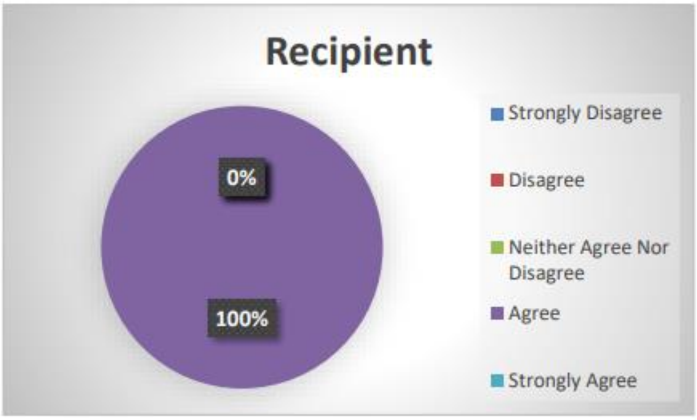


Figure 4-6 Survey Question 3

Question 4: This trainer is according to the student's knowledge level.

Figure 4-7 shows that 38% of the recipients agree and 62% of them strongly agree that this trainer is suitable to student knowledge levels. It is because this trainer only utilized single-phase electrical wiring circuit as it only basic knowledge of electrical wiring.

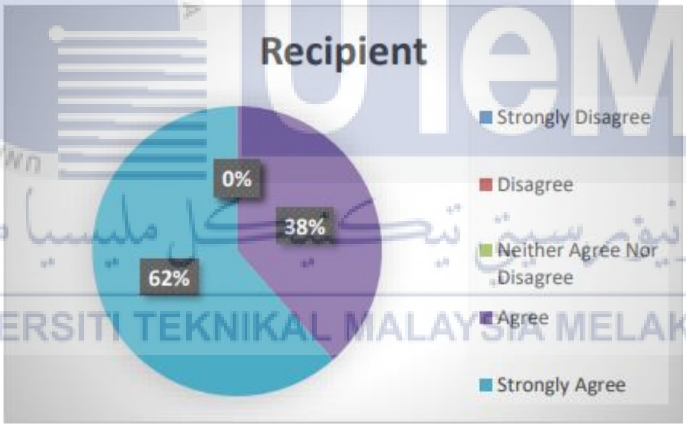


Figure 4-7 Survey Question 4

Question 5: Teachers/demonstrators are experts to use this trainer.

Figure 4-8 shows the majority of the recipient agree and strongly agree that any teacher/demonstrator are expert to use this trainer. However, 25% of them still didn't know to agree or to disagree with the statement.

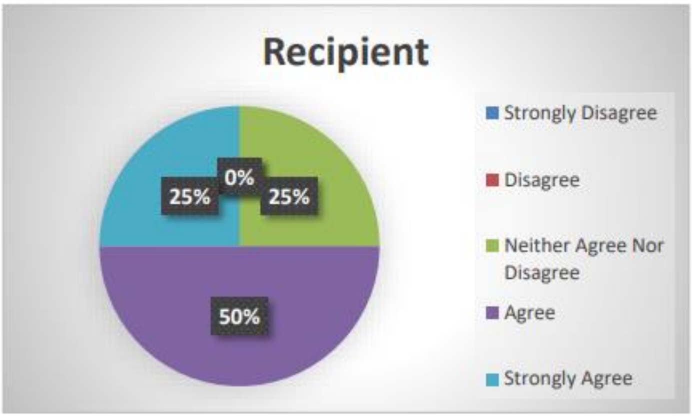


Figure 4-8 Survey Question 5

Question 6: The trainer saves students' hands-on learning time.

Figure 4-9 shows most recipients agree that the trainer can save student's hands on learning time. It is because this trainer has a fault emulate system that is easy to reset the trainer to normal condition. So that the student doesn't have to reconstruct the whole wiring.

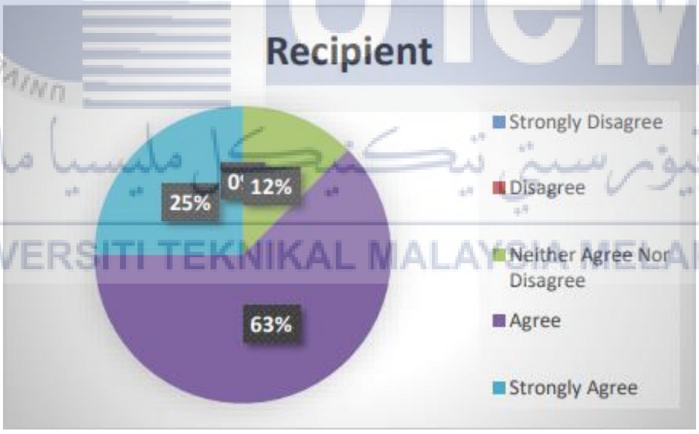


Figure 4-9 Survey Question 6

Question 7: The trainer can be highly interactive during practical sessions.

Figure 4-10 shows that the majority of the recipients agree that this trainer is very interactive during practical session as it is easy to operate and emulate the fault. So they find it easy to interact with the trainer.

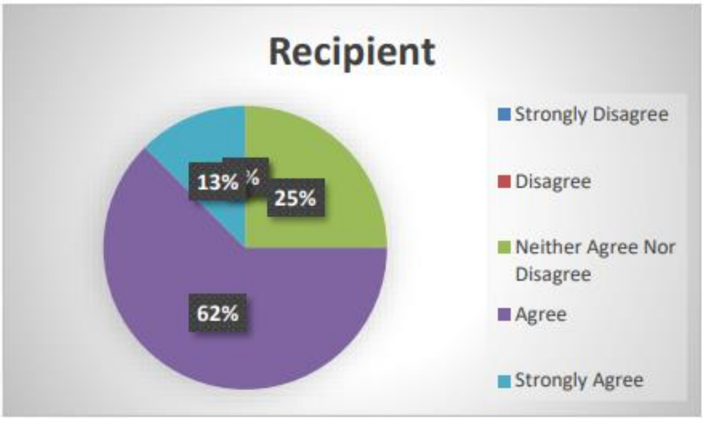


Figure 4-10 Survey Question 7

Question 8: The trainer helps the students to improve their hands-on skills.

Figure 4-11 shows that 50% of the recipients agree this trainer can help to improve their hands-on skills as it promotes educational opportunities for them to easy access to the trainer and learn troubleshooting.

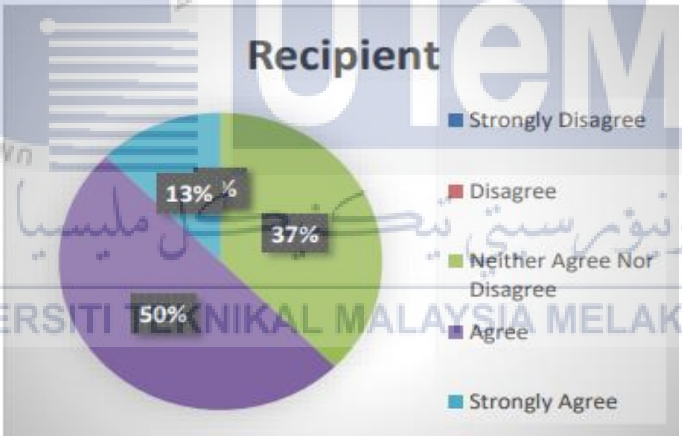


Figure 4-11 Survey Question 8

Question 9: The trainer needs improvement in its design to make it more user-friendly.

Figure 4-12 shows that 63% of the recipient agree that the trainer needs improvement in its design to make the trainer more efficient and user friendly.

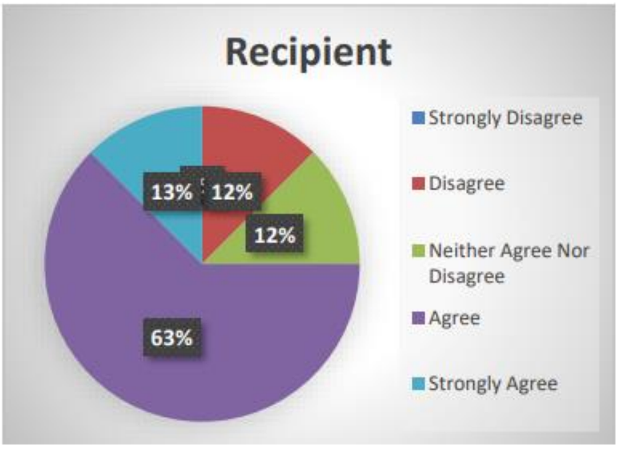


Figure 4-12 Survey Question 9

Question 10: The teacher/demonstrator can clarify the actual concept of the system easily to the student by using this trainer.

Based on figure 4-13, the majority of recipients, with 73% percentage agree that the teacher and demonstrator can easily use this trainer to clarify to the student the actual concept of the electrical wiring circuit system.

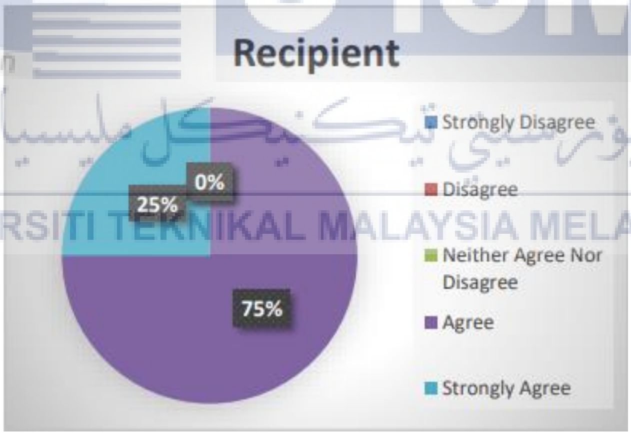


Figure 4-13 Survey Question 10

Question 11: Students can have a better understanding of electrical wiring troubleshooting after using trainer.

Figure 4-14 shows that most of the recipient agree that student can have better understanding of electrical wiring troubleshooting after try to use this trainer because the teachers can show the write way of troubleshooting and hands on session to troubleshoot the trainer.

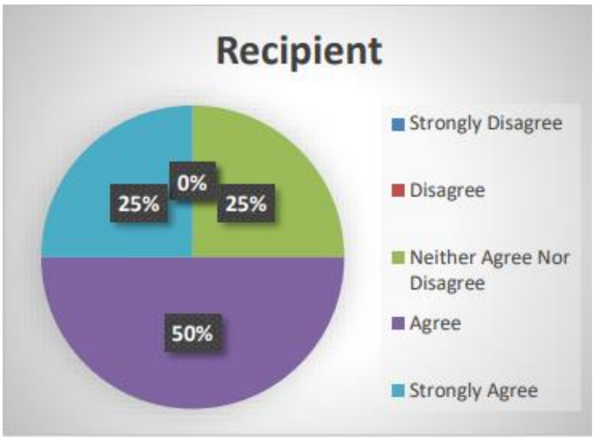


Figure 4-14 Survey Question 11

Question 12: Students can operate this trainer without the guidance of an educator/ teacher.

Figure 4-15 shows most of the recipient disagree that student can operate this trainer without the guidance of teacher. This is because, even there are explanation on procedures this trainer should have someone to observe student behavior when using the trainer.

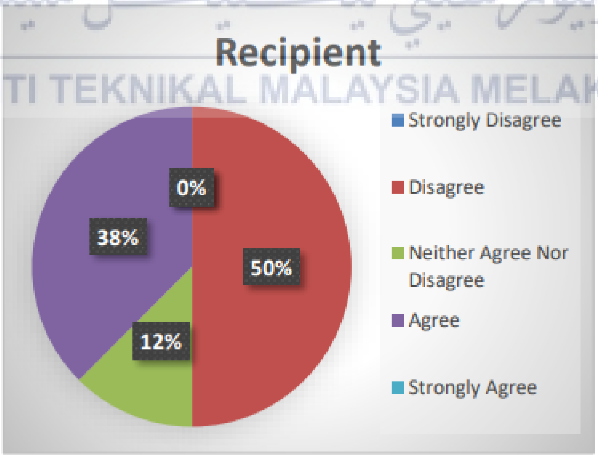


Figure 4-15 Survey Question 12

Question 13: This trainer used a suitable design and interface for the learning proposed.

Figure 4-16 shows 50% of the recipient is which is 4 people neither agree nor disagree that this trainer used a suitable design and interface for learning proposed. The rest are agreed and strongly agree to the statement.

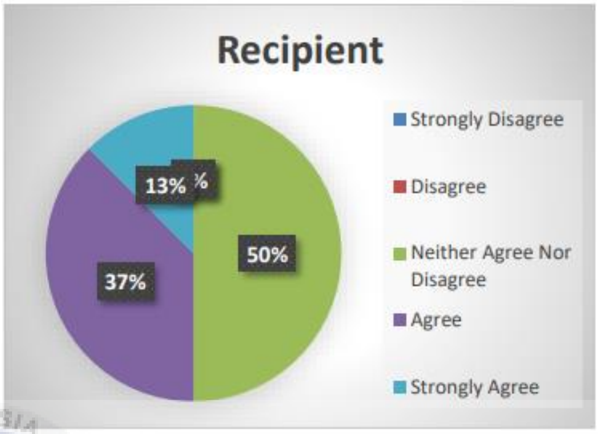


Figure 4-16 Survey Question 13

Question 14: This trainer motivates the students to learn the proper troubleshooting technique.

Based on figure 4-17 most of the recipients agree and some of them strongly agree that this trainer motivates the student to learn the proper troubleshooting technique. Because the trainer is easy to use.

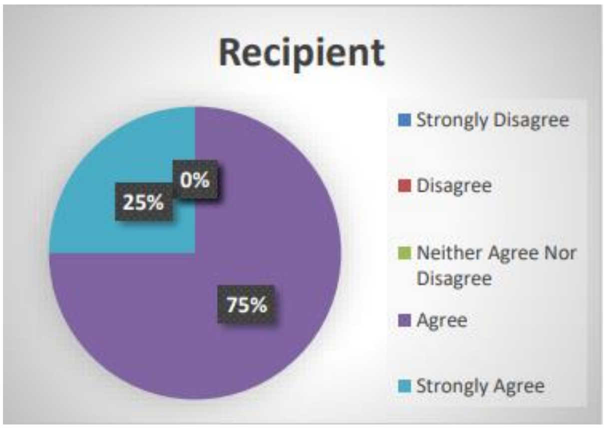


Figure 4-17 Survey Question 14

Question 15: This trainer plays an important role in students' learning.

Figure 4-18 shows that most of the recipients are strongly agree and agree this trainer play an important role in student's learning about electrical wiring troubleshoot.

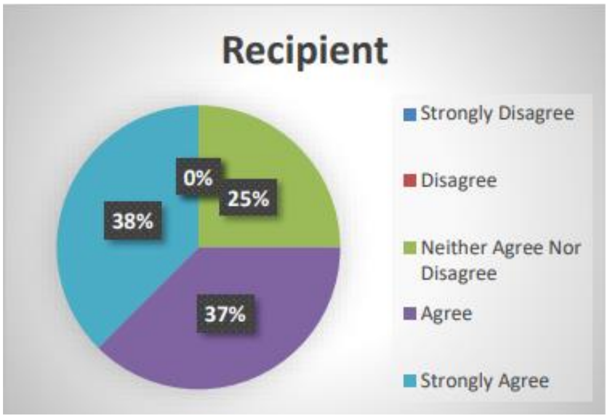


Figure 4-18 Survey Question 15

4.7 Summary

This chapter presents the findings of the testing method employed to develop an electrical fault troubleshooting trainer. The analysis of these findings will assess the trainer's functionality, efficiency, and suitability for educational purposes. Additionally, a survey was conducted to gauge the trainer's perceived effectiveness amongst users. The survey results revealed that a majority of respondents endorsed the trainer's efficacy for classroom education.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

To sum up, this project have achieved all three objective which is to design an electrical fault troubleshooting trainer, to develop a prototype hardware and to verify the efficacy of the developed prototype through questionnaires. The method of achiving these objective have been clarified in chapter 3.

The first objective, to design an electrical fault troubleshooting trainer, was accomplished during PSM 1. This required an understanding of using software to design a fault simulation system using an Arduino and a single-phase electrical wiring circuit. The design adhered to both regulations and theoretical knowledge. However, in PSM 2, the hardware presented a design challenge, as the troubleshooting trainer did not function as planned. Certain equipment replacements may be necessary to ensure full system functionality.

The second phase the project, PSM 2, focused on building a physical prototype for the electrical fault troubleshooting trainer. This required a hands on skills to perform hardware fabrication and assembly. While the prototype construction went smoothly, the testing stage threw some curveballs. Using a UPS as the main power source resulted in insufficient current, hindering proper fault emulation. Conversely, connecting to the building's direct supply triggered nuisance tripping of the RCCB on the building. However, the actual behavior of the equipment have been recorded and analyze in chapter 4.

The third project phase is in PSM 2, which focused on evaluating its effectiveness through questionnaires. The majority of respondents expressed positive support for using this trainer to educate individuals interested in electrical circuit troubleshooting. However, the feedback also highlighted areas for improvement to enhance its reliability and efficiency.

5.2 Potential for Commercialization

The "Electrical Fault Troubleshooting Trainer using a small-scale single-phase electrical wiring circuit" project has strong commercialization potential. Given its focus on training and education, it could be suitable for commercialization to:

i. Universities and colleges as it suitable for engineering departments and related programs that could use this project for practical learning in electrical engineering and power systems courses.

ii. Corporate training programs such as companies in construction, maintenance, and facilities management could utilize this project to train their employees on basic electrical troubleshooting for building systems and equipment.

iii. DIY and hobbyist communities such as makerspaces, online communities, and individuals interested in DIY projects could benefit from this project interactive learning approach to understand and troubleshoot basic electrical systems.

5.3 Future Works

Building upon the successes of this project, we can identify exciting opportunities for further development, such as:

i. Consider using high-quality Residual Current Circuit Breakers (RCCBs) and Miniature Circuit Breakers (MCBs) equipped with advanced tripping mechanisms and reliable materials for optimized circuit protection.

ii. Consider implementing a visual indicator system to monitor the health and operational readiness of safety equipment like RCCBs and MCBs.

iii. Consider implementing a data acquisition system (DAQ) equipped with sensors to monitor, record, and analyze spike current and voltage during emulated faults.

iv. Consider to use isolation transformer to isolate the trainer circuit and electrical building circuit. This is to prevent nuisanse tripping of building electrical circuit due to the fault at the trainer.

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APPENDICES

Appendix A Fault Emulate System Coding

```
int switch1=0;
int switch2=0;
int switch3=0;
int switch4=0;
int switch5=0;
int reset=0;

void setup() {

pinMode(2, INPUT);
pinMode(3, INPUT);
pinMode(4, INPUT);
pinMode(5, INPUT);
pinMode(6, INPUT);
pinMode(7, INPUT);


pinMode(8, OUTPUT);
pinMode(9, OUTPUT);
pinMode(10, OUTPUT);
pinMode(11, OUTPUT);
pinMode(12, OUTPUT);

digitalWrite(8, HIGH);
digitalWrite(9, HIGH);
digitalWrite(10, HIGH);
digitalWrite(11, HIGH);
digitalWrite(12, HIGH);


Serial.begin(9600);
}

void loop() {


 reset = digitalRead (7);
 switch1 = digitalRead (2);
 switch2 = digitalRead (3);
 switch3 = digitalRead (4);
 switch4 = digitalRead (5);
 switch5 = digitalRead (6);


if (switch1 == HIGH )
{ digitalWrite (8, LOW);}

if (switch2 == HIGH )
{ digitalWrite (9, LOW);}
```

```
if (switch3 == HIGH )
{ digitalWrite (10, LOW);}

if (switch4 == HIGH )
{ digitalWrite (11, LOW);}

if (switch5 == HIGH )
{ digitalWrite (12, LOW);}

else if (reset == HIGH){
digitalWrite (8, HIGH);
digitalWrite (9, HIGH);
digitalWrite (10, HIGH);
digitalWrite (11, HIGH);
digitalWrite (12, HIGH);

}
  Serial.println ("switch : " );
  Serial.println(digitalRead (3));
  delay (1000);
}
```

Appendix B Questionnaire Form (Survey)

Development of electrical fault troubleshooting trainer using small scale single phase electrical wiring circuit

Satisfaction Survey

Name: ____ Date: ___________

Title Please (√): Educator/ Lecturer ( ) Learner/ Student: ( )
Directions: The purpose of this survey is to examine the effectiveness of the electrical fault troubleshooting trainer and student knowledge about electrical wiring installation. Please rate the following items by (√) one number for each question.

No	Question	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
1	Electrical wiring Circuit troubleshooting is an interesting subject.	1	2	3	4	5
2	Most of the wiremen are not able to conduct electrical wiring troubleshooting.	1	2	3	4	5
3	The trainer function as a real situation condition.	1	2	3	4	5
4	This trainer is developed according to the current student's knowledge level.	1	2	3	4	5
5	The trainer is easy to be understood and used by teachers,	1	2	3	4	5
6	The trainer can saves students' hands-on learning time.	1	2	3	4	5
7	The trainer can be highly interactive during practical sessions.	1	2	3	4	5
8	The trainer helps the student to improve their hands-on skill.	1	2	3	4	5

9	The trainer needs improvement in its design to make it more user-friendly.	1	2	3	4	5
10	The teacher/demonstrator can clarify the actual concept of the system easily to the student by using this trainer.	1	2	3	4	5
11	Students can have a better understanding of electrical wiring troubleshooting after using trainer.	1	2	3	4	5
12	Students can operate this trainer without the guidance of an educator/ teacher.	1	2	3	4	5
13	This trainer used a suitable design and interface for the proposed learning.	1	2	3	4	5
14	This trainer motivates the students to learn the proper troubleshooting technique.	1	2	3	4	5
15	This trainer plays an important role in students' learning.	1	2	3	4	5