AUTOMATED ELECTRICAL PROTECTION SYSTEM
(Auto-EProS)

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
for the Degree
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved:

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Project Supervisor

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Ahmad Zakwan Hariz Bin Abd Azzis

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ABSTRACT

Power outage is a common problem happened when there are electrical faults occurred, which would lead to discontinuity of electric supply to domestic building. For domestic consumers, power continuity is very important since some of their appliances such as refrigerator, aquarium and alarm system need a continuous electric supply. However, fault occurred in the system will trip the earth leakage circuit breaker (ELCB) and disrupt the supply to all the appliances. Fault may occur due to short circuit, ground fault or overloading. Therefore, fault location detection is essential to ensure power continuity and reliability in which the fault may be isolated from the system once detected. An automatic system for fault detection and ELCB reset setting crucial to be developed to encounter the problem.

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LIST OF ABBREVIATIONS

AC	Alternating Current
CT	Current Transformer
DC	Direct Current
ELCB	Earth Leakage Circuit Breaker
MCB	Miniature Circuit Breaker
RCBO	Residual Current Circuit Breaker with Overload
RCCB	Residual Current Circuit Breaker
RCD	Residual Circuit Device
SP	Solenoid Plunger

CHAPTER 1

PROJECT BACKGROUND

1.1 Background of Study

Power reliability and continuity is very important and critical to a domestic building. There are electrical equipments and appliances which need to be continuously turned on even when the occupants leave the building for a period of time such as alarm system, refrigerator and aquarium ventilation system. However electrical fault may occur in a system that leads to unexpected power outages. Automatic fault location detection needs to be designed to isolate the permanent fault from the system and prevent from greater problem. Therefore, a mechanism and program can be designed to automatically detect fault location at Miniature Circuit Breaker (MCB), isolate it and reset the Earth Leakage Circuit Breaker (ELCB) in order to restore the supply. A project done in one of university regarding the automatic ELCB, but the fault location detection is not yet being developed. This project will merge the automatic ELCB and automatic fault location together in a single system and prototype.

1.2 Problem Statement

Tripping of ELCB when there is no occupant inside may lead to undesired circumstances. The critical appliances such as aquarium, refrigerator and alarm system need a continuous supply of electricity to operate. The problem comes when the ELCB trips when no occupants in the house for a period of time. If the power supply is blackout, operation of critical equipment such as alarm system will be instantaneously terminated. Loss of electricity supply may also contribute to property loss due to equipment failure such as dying of exotic fish and food damage.

ELCB may also trip when fault occurs in the internal wiring. When electrical tripping is occurring, ELCB will break the supply to all feeders (appliances). An automatic system to restore the supply by turning back on the ELCB is required. But when there is a permanent fault exist is the system, the ELCB would not be able to be turned back on as it will trip again due to the permanent fault.

1.3 Project Objectives

The objectives of this project are:

- To improvise previous project in which the function is limited to only reset the ELCB automatically without isolating the fault.
- To develop a mechanism and program to detect the fault location, isolate it and automatically reset the ELCB.
- To produce a more efficient and reliable functioning prototype.

1.4 Scope of study

This project requires deep understanding in the power system basic theory and domestic electrical wiring configuration. The main focus is determining the location of fault in a wiring system where it is important in designing an automatic breaker which can handle permanent fault and able to isolate the fault.

Major scopes of work for this project are:

- Design system for fault location detection
- Improvising ELCB auto-reset mechanism
- Develop a working prototype to simulate real application and situation

CHAPTER 2

LITERATURE REVIEW

2.1 Domestic Electrical System

Domestic electrical system refers to electrical system developed for home and residential, which mostly utilizes single-phase type of power system. In electrical engineering, the term single phase electric power system refers to the distribution of alternating current (AC) electric power using a system in which all the voltages of the supply vary in unison [1].

A single phase load may be powered from a three-phase distribution system either by connection between a phase and neutral (120 V or 230 V). Generally in Malaysia, Tenaga Nasional Berhad (TNB) supplies single-phase 2-wires with rating of 240 V to domestic premises [2]. On higher voltage system, a single phase transformer is use to supply a low voltage system especially in rural area, where the cost of three phase distribution network is high [3].

Although single phase system has safety (earth conductor) but this can't ensure perfect protection to the electrical circuit, electrical equipment and also human life from high voltage. In Malaysia, according to *Utusan Malaysia* (2011), it is about 191 people died out of 405 electrical accidents due to electrical faults occurred recorded for year of 2005 until 2011 [4]. Therefore, as part of increasing electrical protection and reducing accidents due to electrical faults, installation of protection device such as circuit breaker is required besides exposure on electrical safety and hazard towards the public.

This project requires clear understanding on the common fault and the basic protection system of domestic or home electrical system. Both entities are important to be understood as to overview the effects of electrical faults and poor electrical protection system, which commonly lead to injury or death due to electrical shock besides technical and economical losses due to equipment failure.

2.2 Common Domestic Electrical Fault

In domestic premises, there are three common factors that cause electrical problems at home that might lead to fatality or equipment failure [5], which are:

- Faulty wiring in the house
- Improper flexible cords
- Faulty appliance

Technically, the above factors cause current/earth leakage fault and overcurrent fault. Earth leakage fault exist when unintended path is established between the normal current carrying conductors which has contact directly or indirectly with earth [6]. Direct contact refers to contact with parts that will result an electric shock in normal operation while indirect contact refers to contact with exposed conductive parts which result in an electric shock in case of fault [7]. Both conditions are illustrated in Figure 1.

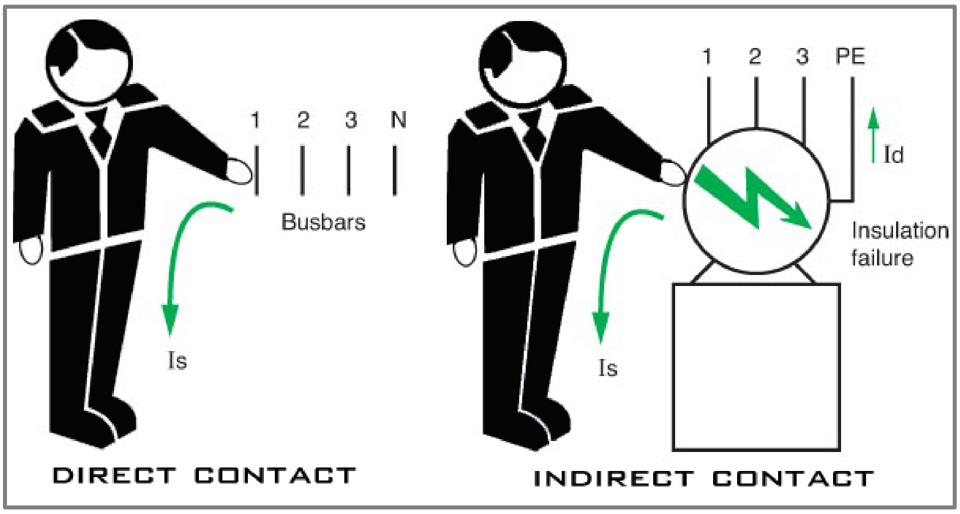

Figure 1: Illustration of Earth Fault Conditions [7]

Ovecurrent fault occurred when the current exceeds the rated current carrying capacity of the conductor [8] and can be divided into two types: overload and short circuit. Overload faults are caused by excessive loads where a larger than intended electric current exists throughout a conductor, leading to an excessive heat generation, and the risk of fire or equipment damage [8, 9]. While a short circuit in an electrical circuit that allows a current to travel along an unintended path, often where essentially no (or very low) electrical impedance is encountered [10].

2.3 Domestic Electrical Protection

In general, for domestic electrical protection which utilizes single-phase power system will concentrate on protecting electrical circuits from overcurrent and ground faults. Circuit breaker such as Miniature Circuit Breaker (MCB) is preferred for overcurrent fault and earth leakage circuit breaker (ELCB) or residual current circuit breaker (RCCB) used to protect from ground fault.

Most houses nowadays are protected by circuit breakers rather than fuses [10], since fuses have to be replaced when it blows and sometimes fuses could create overheat in a circuit [11]. A circuit breaker that “tripped” can be mechanically reset or switched on to resume operations once the problem occurred has been resolved. Circuit breakers also protect branch circuits with size range of 120 Volts or 230 Volts [12].

ELCB or Earth Leakage Circuit Breaker is designed to detect electric current leakage in a house wiring and protect from earthing problems. When amount of leaked current exceeds the value set by ELCB for instance 30 mA, the ELCB will then isolate supply from internal circuits [13]. This is done automatically within a fraction of a second of the leakage being detected, before the magnitude of the leakage current reaches a level that can cause serious injuries or electrocution. With a proper use of ELCB, the possibility of serious injuries due to electric shock to a person who accidentally come into contact with energized metal casing of an appliance is minimized.

2.4 Earth Leakage Circuit Breaker

As briefly explained in Chapter 2.3, an Earth Leakage Circuit Breaker or acronym as ELCB is a safety device which used in electrical installations with high earth impedance to prevent shock. An ELCB provides a safer electrical installation since it shut the power off when dangerous conditions occur [14]. For instance, if a person touches something, typically a metal part on faulty electrical equipment, which is at a significant voltage relative to the earth, electrical current will flow through that person to the earth. The current that flows are too small to blow an electrical fuse but still very harmful and could cause death. An ELCB has the ability to detect even a small current flow to earth (earth leakage) and disconnects the breaker.
There are two types of ELCB which are:

- Voltage operand
- Current operand

Voltage operated ELCB operates at a detected potential of around 50 V to open a main breaker and isolate the supply from the protected premises [15]. But since it operates at 50 V, it is not been used in newer domestic wiring as the 50 V is still considered as safe voltage for alternating current [16]. For newer domestic wiring, current operated ELCB is more preferable to be installed in premises due to reliability. Current-operated ELCB is generally known as Residual Current Device (RCD). The function is similar, which protect against earth leakage, though the details and method of operation are different [14].

2.5 Residual Current Device

Residual Current Device or simply RCD, as in Figure 2, is nowadays firmly established worldwide as primary means of providing protection against electrocution and fires that caused by electrical faults. Less than one quarter of an amp (250 mA) leaking from a faulty installation can generate sufficient heat to start a fire (the heating effect is proportional to the current squared), or if leaking through a human body for only 200 mS can cause heart fibrillation and subsequent death [17]. In short, RCD is a protection device used to disconnect circuit when residual current reaches or exceed device rated residual current.

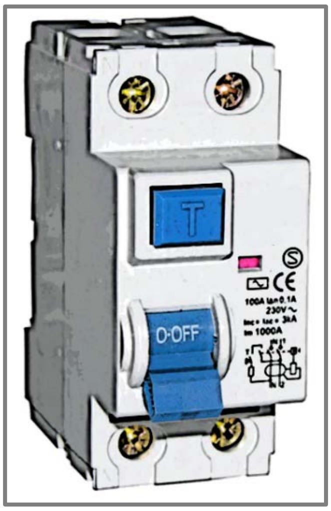

Figure 2: Residual Current Circuit Breaker [18]

The RCD operates by measuring the current balance between two conductors using a differential current transformer, as illustrated in Figure 3. Difference between the current flowing out the live wire (to the load) and the returning current (from the load) through the neutral wire, also known as residual current, is measured. Current leakage said to be exist when the difference sum measured is not equal to zero and the device will open it contacts [18]. As according to the IEC, RCD in buildings must be installed with residual current rating of 30 mA for protection against shock [19]. The RCD will trip if the residual current or the difference between current flowing in an out exceeds 30 mA.

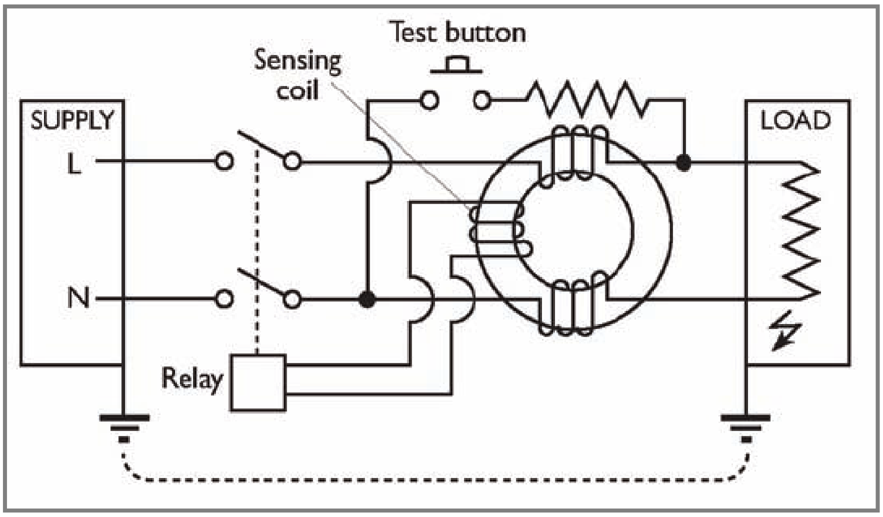

Figure 3: RCD Basic Operation Diagram [17]

2.6 Miniature Circuit Breaker

Miniature circuit breakers or MCB, as in Figure 4, are commonly used in the electrical consumer units of domestic dwellings and small industrial premises to protect and control the electrical supply to respective electrical circuits of the building. This resettable protective device also designed to isolate a circuit during an overcurrent (both overload and short circuit) event without using fuse [20]. MCB is preferable for building protection rather than using fuse because of its resettable capability [11].

Figure 4: Miniature Circuit Breaker [20]

MCB typically comprises an electrical contact mounted on a movable contact carrier which rotates away from a stationary contact in order to interrupt the current path. The mechanism of operation includes a movable handle that extends at the outside of the housing. The handle has basically three stable positions: on, off, and tripped. These three positions are to indicate the condition of the contacts when the handle is viewed. The trip mechanism is automatically releasable to effect tripping operations and is manually resettable following tripping operations. The mechanism will respond to instantaneous high current to open the contact and therefore interrupts the current flow [20].

2.7 Current Sensor

Current sensor is basically a device that functions to detect electrical current either AC or DC in a wire, and generates a signal proportional to it [21]. There are two common types of current sensor, which are current switches and current transducer [22]. For this project, it is preferably to use current transformer, a type of current switches, since the range of sensing current value is higher.

It is crucial in this project to have suitable current sensor with the correct rating and sensitivity as to accurately measure and obtain current value. Inaccurate measurement may lead to wrong calculation, which is important in detecting fault location and fault isolation from main line. There are many different types of current sensor available in the market, one of them is as shown in Figure 5. It is preferable to have current sensor that able to detect up to 40 A for domestic usage.

Figure 5: Current Sensor [23]

2.8 Solenoid Plunger

A solenoid is a coil wound into a tightly packed helix which able to converts electrical power into linear mechanical power [24]. A solenoid plunger, as in Figure 6, is an electromechanical plunger with ability of pulling in or pushing out an iron plunger out of coil when it is electromagnetically energized.

An application example of solenoid plunger is the electric doorbell, where a chime unit consisting of two flat metal bar resonators, which are struck by plungers operated by two solenoids. The flat bars are tuned to two pleasing notes. When the doorbell button is pressed, the first solenoid plunger will strikes one bar, and when the button is released, a spring on the plunger pushes the plunger up, causing it to strike the other bar, creating a "*ding-dong*" sound [25].

The application of the solenoid plunger will be applied in this project as an external switching mechanism for breakers. When a breaker is tripped, one of the solenoid plungers will be electromagnetically energized by a pulse sent by the microprocessor and the plunger will push the breaker switch into "on" position.

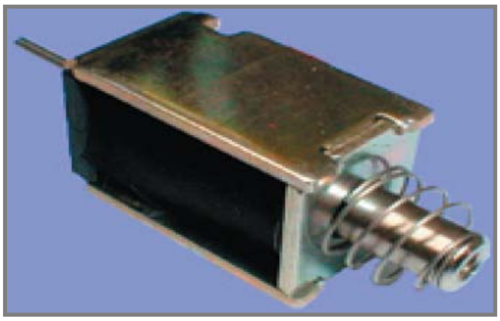

Figure 6: Solenoid Plunger (from Appendix D)

CHAPTER 3

METHODOLOGY

3.1 Project Flow

A good project planning will initiate a good project framework, which would lead to a success of a project. As illustrated in Figure 7, the project is systematically planned to meet with the specific timeline.

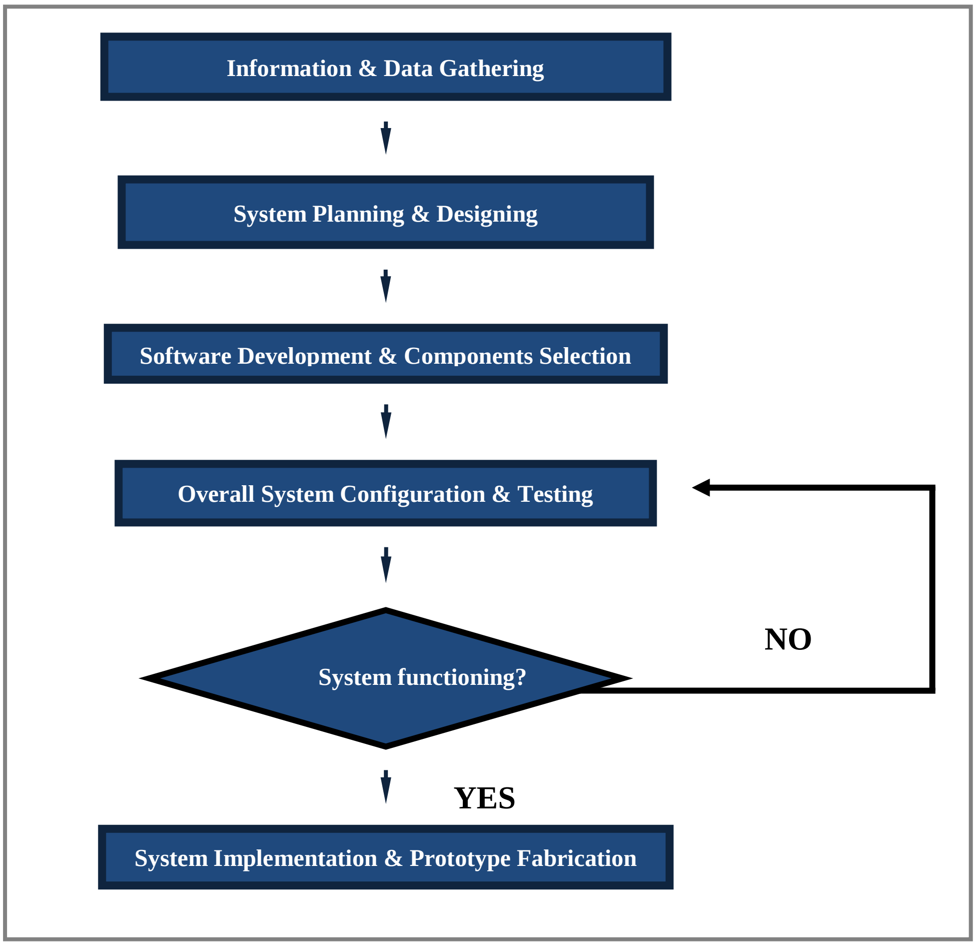

Figure 7: Project Flowchart

For this project, the sequence begins with *Information and Data Gathering* of problem stated as well as getting clear view and understanding on the domestic electrical wiring, which includes information regarding types of breakers used and hardware selected. The, proceed with *System Plan and Design* phase. This is where the overall system is being drafted, the software and hardware of the system and the overall system operation.

In *Software Development and Components Selection* phase includes programming development to control the whole protection system and components that needed in designing and developing the prototype. Once the system is completely configured and the hardware and software is synchronized, the system functionality will be tested. If passed, system is ready to be implemented and fully developed as a functional prototype. Vice versa, the system will be reconfigured back and troubleshoot.

3.2 System Plan of Operation

In the System Plan & Design stage, an automatic system is designed for domestic electrical system to auto-reset ELCB and auto-detection if any permanent fault occurred. The system operation is divided into two parts: power recovery and fault location detection. In *Power Recovery* part, it covers about the automatic reset of ELCB, which restore the supply and the *Fault Location Detection* part will covers how the permanent fault is being detected and finally isolate it from the main system.

3.2.1 Power Recovery

Power recovery is a process of turning back the power on after the power is out or shut down for a period of time as result of tripping or faulty. Quick power recovery is important when there are equipments or electrical appliances which require continuous power supply such as refrigerator, water pump for aquarium, alarm system and few others. Currently, as for home electrical system, power recovery is manually done. In other words, a person has to switch on the main switch in distribution board to turn the power back on after tripping occurred. It becomes a problem when the residents or owner of the house is out for a period of time and no one is there to turn the power back on.

When electrical tripping is occurring, Earth Leakage Circuit Breaker (ELCB) will break the supply to all feeders (appliances). An automatic system to restore the supply by turning back on the ELCB is required. But when there is a permanent fault exist is the system, the ELCB won't be able to be turned back on as it will trip again due to the permanent fault. Therefore, to be able to restore the power supply, a system with ability of detecting fault location need to be developed and fault need to be isolated. Once fault detected and isolated, ELCB will be switched on and supply is restored. The process of power recovery is summarized as in Figure 8.

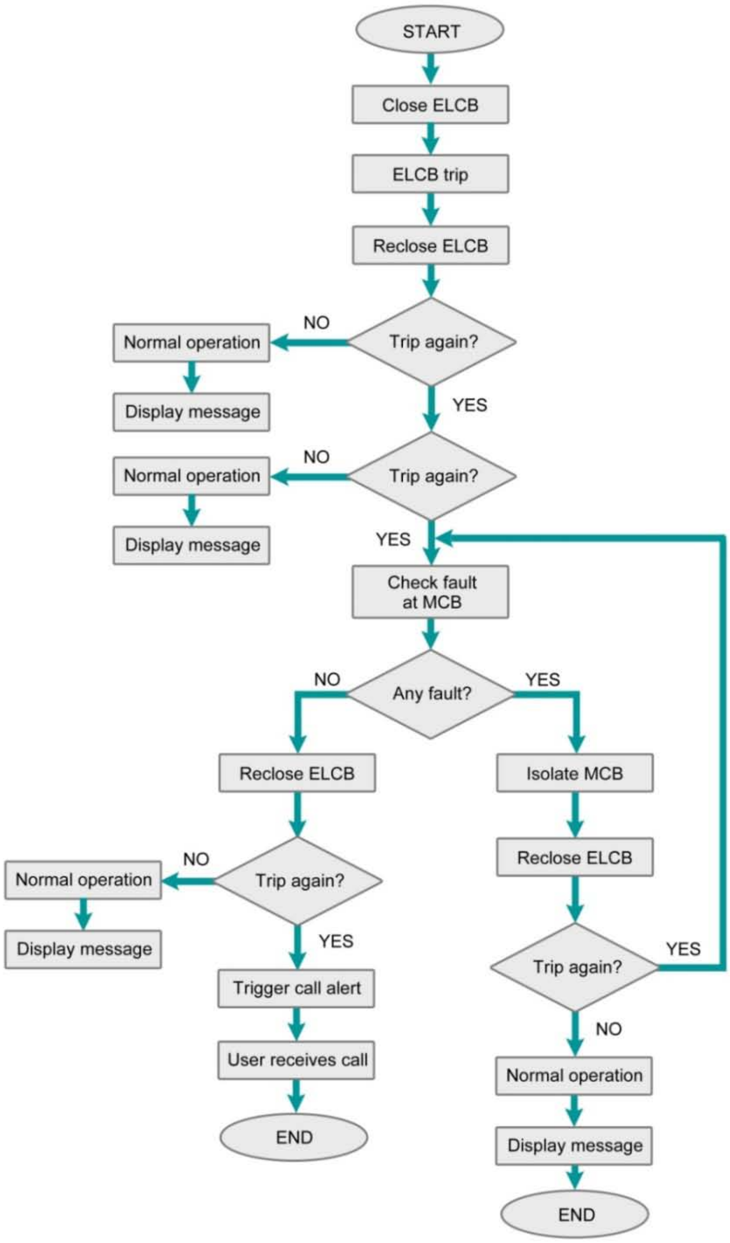

Figure 8: System Flowchart

3.2.2 Fault Location Detection

Domestic electrical fault would normally occur at individual circuit, either switches or sockets. Fault may occur as result of overcurrent condition, such as overload or high level short circuit and may occur at any point in the domestic electric system. Fault detection may prevent from unexpected power outage.

To isolate fault from main line, the location of the fault must be identified first. This can be done through current comparison, where the amount of current travelling into the load is not equal to the current travelling out of the load. As in Figure 9, which illustrated simple domestic electrical wiring diagram, the current in live wire (red line) is travelling through ELCB and MCB and end at the load. The current is then travel out from the load to neutral bar and travels back to ELCB. The amount of current travel in and out is measured and compared.

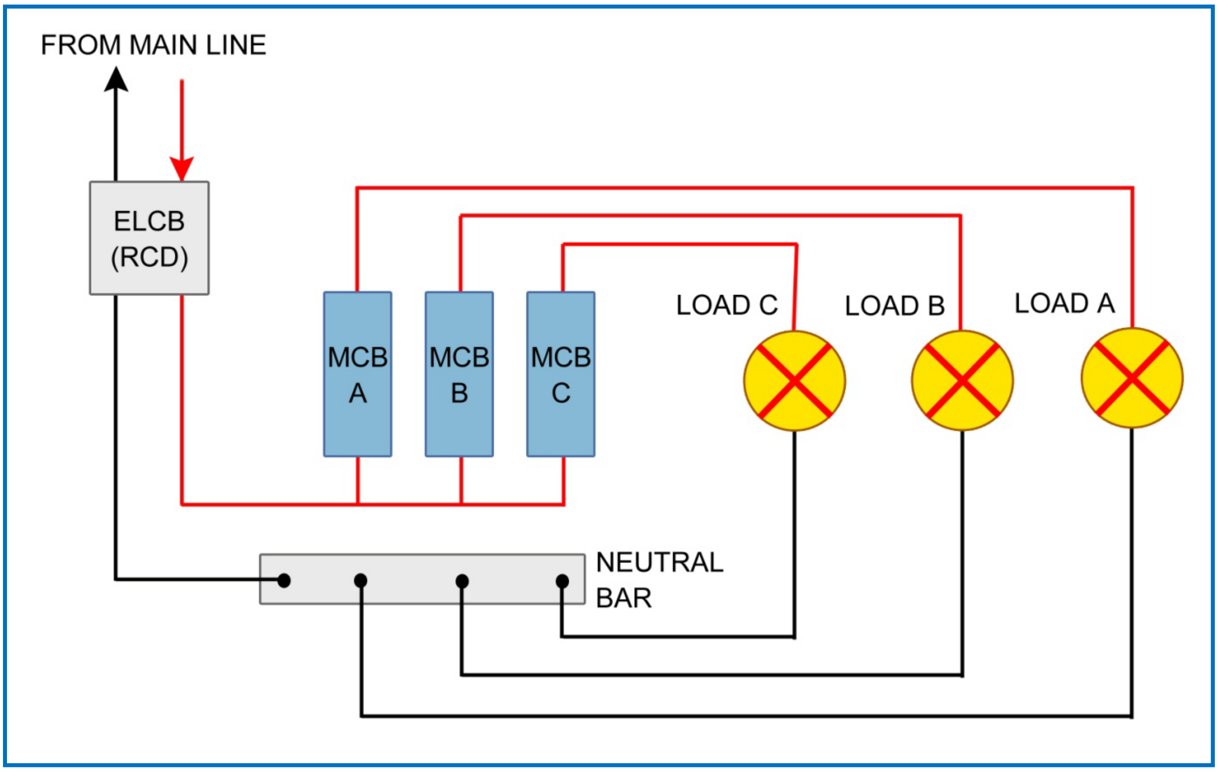

Figure 9: Simple Domestic Electrical Wiring Diagram

To be able for the MCB of the fault location to be tripped off, a level of current difference is set up. For instance, difference between current level at live wire and current level at neutral wire is set to 30 mA. If the difference exceeds 30 mA, then that particular MCB is turned off and ELCB will be reclosed and power turned back on. The level of current will be detected by using either current transducer or current clamp.

The overall process an operation of fault location detection is summarized is form of flowchart as Figure 10.

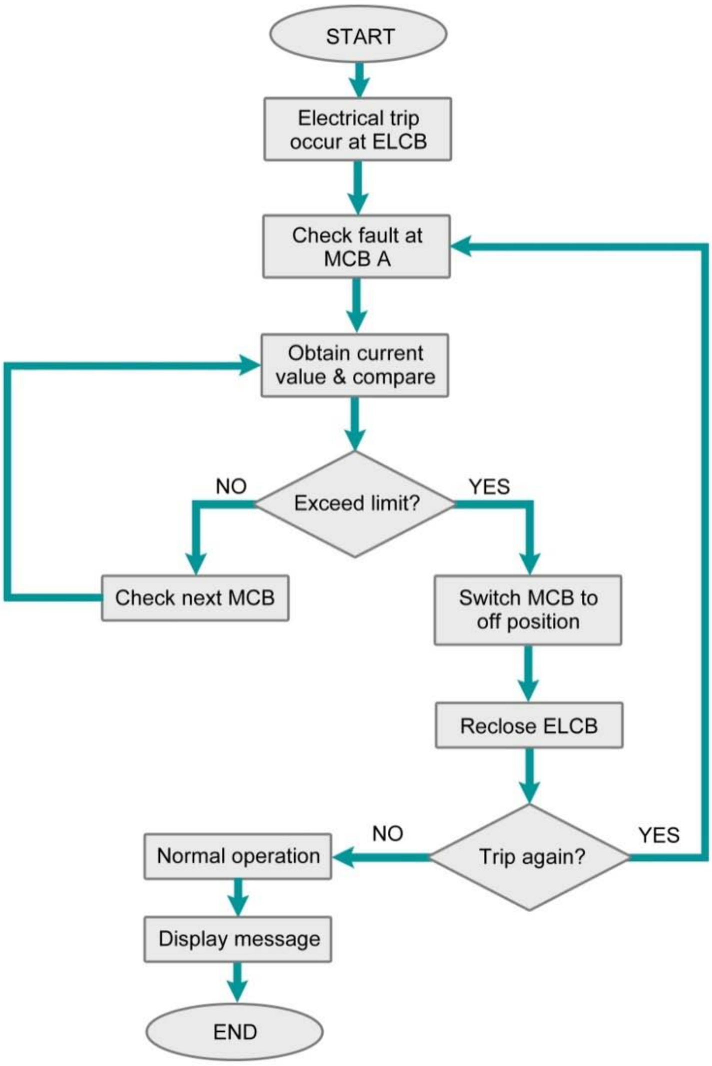

Figure 10: Fault Location Detection Process Flowchart

3.3 Tools and Equipments Required

- Hardware required for the project:-

Table 1: Hardware Required and Its Functionality

Components/Hardware	Functions
ELCB	Safety device to prevent electrical shock. One of main components of the project.
MCB	To control electric supply to respective electrical circuits in a building. One of main components of the project.
Current Transducer / Clamp	To measure and obtain current value
Relay	Required for circuit switching
DC Motor	To switch ELCB & MCB on/off
Arduino UNO Board	For software and programming of the system
LCD Display	To display message during normal operation and when trip occur

- Software required for the project:-

Table 2: Software Required and Its Functionality

Functionality	Software Used
Documentation	Microsoft Word
Programming	Arduino Development Environment
Simulation and Design	Fritzing, AutoCAD

3.5 Components Selection

Components are very important features in this project. Selection of components is made through literature review done earlier to ensure correct rating of component that going to be used for the project. Listed below are the main components required for this project:

- Residual Current Circuit Breaker (see Appendix C)
- Miniature Circuit Breaker (see Appendix D)
- Split Core Current Sensor (see Appendix E)
- 12V DC Motor

3.6 Prototype Layout Design

Once done with the selection of components, prototype layout is planned and designed as in Figure 11. This prototype will basically consist of two main compartments: the main board and the external enclosure. The main components which comprises of RCCB, MCB, CT and SP will be placed in the main compartment. The RCCB and MCB are positioned according to the real arrangement of breakers in the distribution board.

The microcontroller Arduino UNO, LCD display, adapter and battery pack will be placed in the external compartment. The reason of separating the compartments is to make easier for the user to change battery and to view the LCD display. The position of the external component is suggested to be placed beside the main compartment for shorter wiring and easier installation.

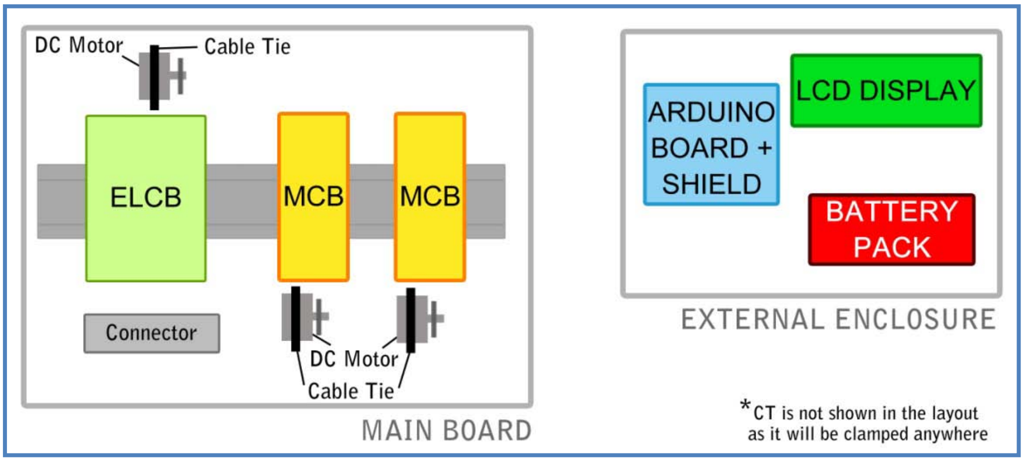

Figure 11: Prototype Layout Design

3.7 Circuit Diagram

Wiring is an important process of developing a prototype. The wiring diagram for this project is illustrated in Figure 12, where it shows the wiring diagram of both compartments and how both compartments are interconnected. ECLB and MCB connection in the main compartment is fixed as to imitate the real distribution board wiring. Most wiring modification will be made only in the external compartment and the connection between both compartments since some of components will be placed in the main compartments.

For this prototype, it is preferable to use battery pack as the source instead of tapping from the main line (from power supplier) for easier installation and portability. It is also expected that this prototype will be more like "plug and play" hardware characteristics. The components chosen are also should be able to accommodate with the expectation, for example using split core current transformer, which can be clamp at any wire without interruption or disconnection of wiring.

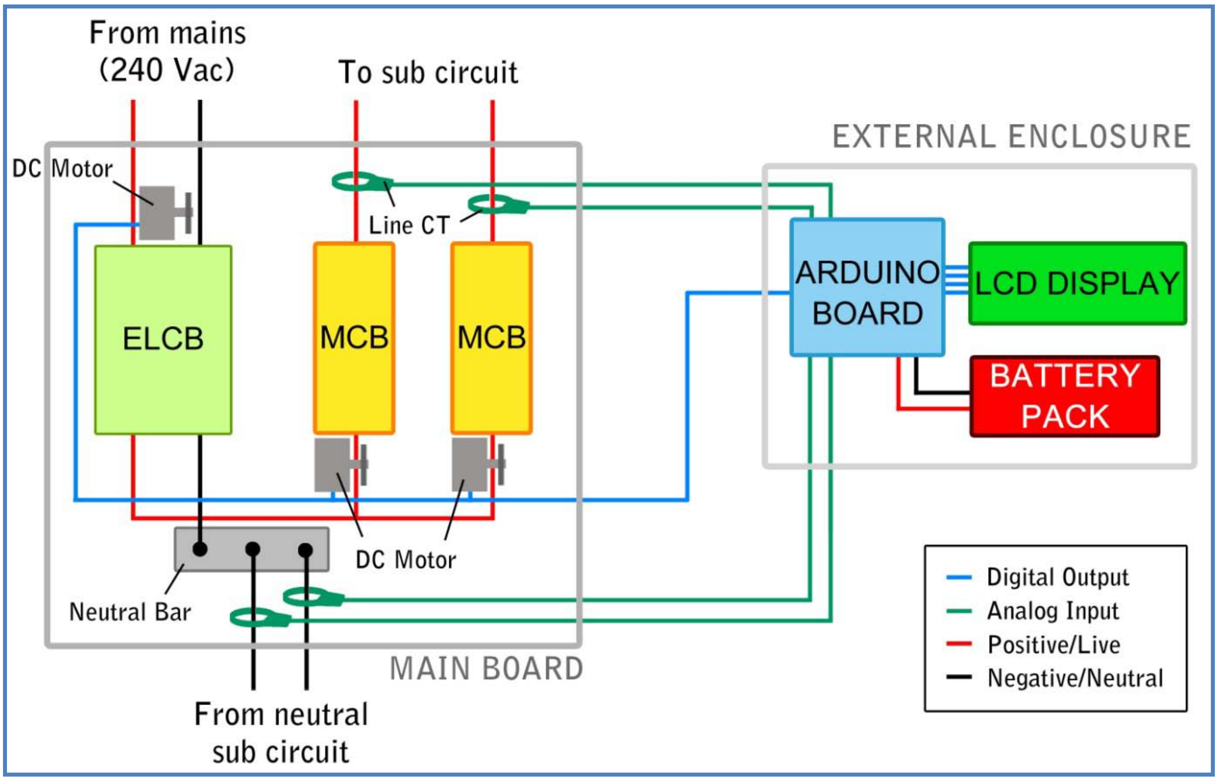

Figure 12: Circuit Diagram of the Prototype

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Current Sensor Functionality Test

To verify the functionality of the current sensor, a test had been carried out. The test is done with several domestic devices and appliances that commonly used in human daily life for example lamp, kettle, iron and rice cooker. The current measurement is taken by using current sensor and current value can be read through the serial display of the microcontroller as sample reading in Figure 13. According to the datasheet, accuracy of the current sensor is about ±1%. The result of the test is summarized in Table 3.

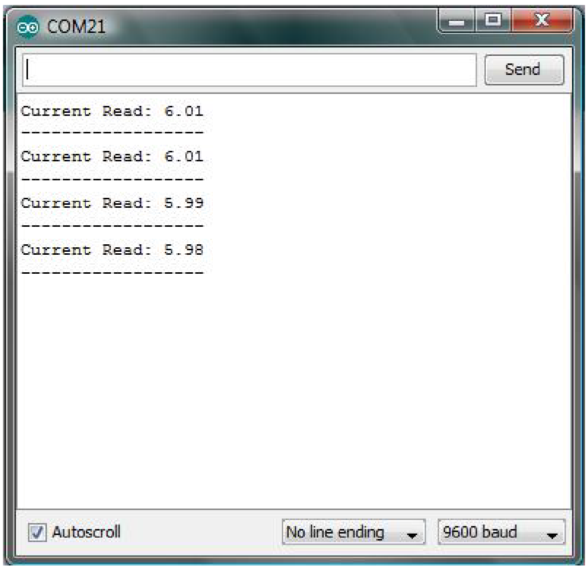

Figure 13: Sample Current Reading

Table 3: Current Sensor Test Result

Device	Power (Watt)	Calculated Current (Amp)	Current Reading (Amp)
Lamp	70	0.292	0.350
Rice Cooker	450	1.875	1.887
Iron	1000	4.167	4.204
Kettle	1500	6.250	6.265

From the result in Table 2, the reading of the current sensor is in range of accuracy as in datasheet. The current sensor is valid to be used as measurement device in this project.

4.2 Simulation Test

The simulation test is done to test both functions in the system created: the power recovery function and fault location detection function. The test is done before it can be implemented in real prototype. There are three tests that will be carried out in this simulation test: normal condition, auto-reset ELCB, and MCB check operation. To carry out the simulation test, a simulation circuit connected with current sensor had been setup as in Figure 14 and the programme had been successfully written and downloaded to the Arduino board.

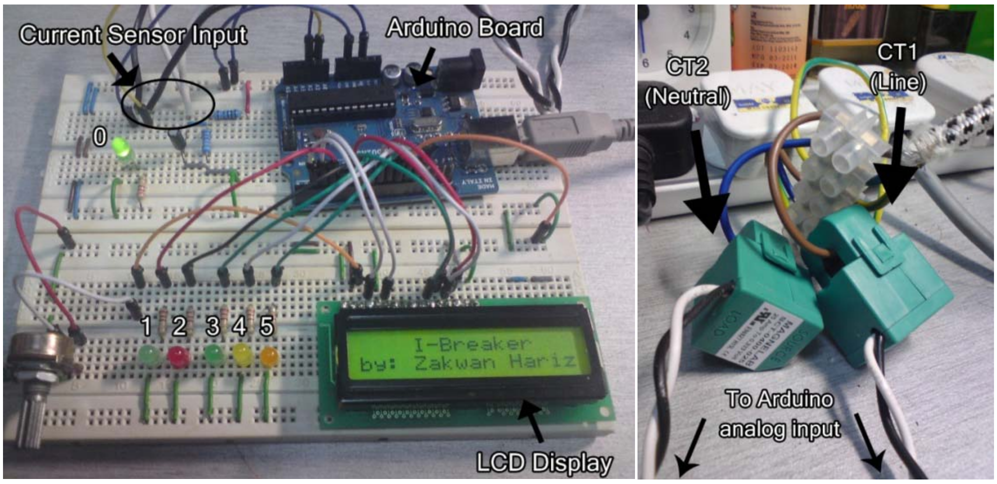

Figure 14: Test Circuit and CT Connection

In the test circuit designed, the desired hardware (motor, solenoid and hand phone) that should be used in real prototype is currently represented by LED, for testing purpose. The function of each LED is summarized as in Table 4.

Table 4: LED Function

LED Number	Function
0	Indicator for power supply
1	Indicator for normal condition
2	Indicator for fault condition
3	Represent DC motor, for ELCB auto-reset
4	Represent DC motor, for triggering MCB off
5	Represent hand phone, to make able for call alert

4.2.1 Normal Condition Test

This test is to verify that the system designed is able to detect normal condition, at which power is ON (or "1"). When the system detects a normal condition, LED 1 will light up and the LCD will display "Normal Condition" as in Figure 15. Normal condition means that the circuit is working as usual without fault, or no fault yet had occurred.

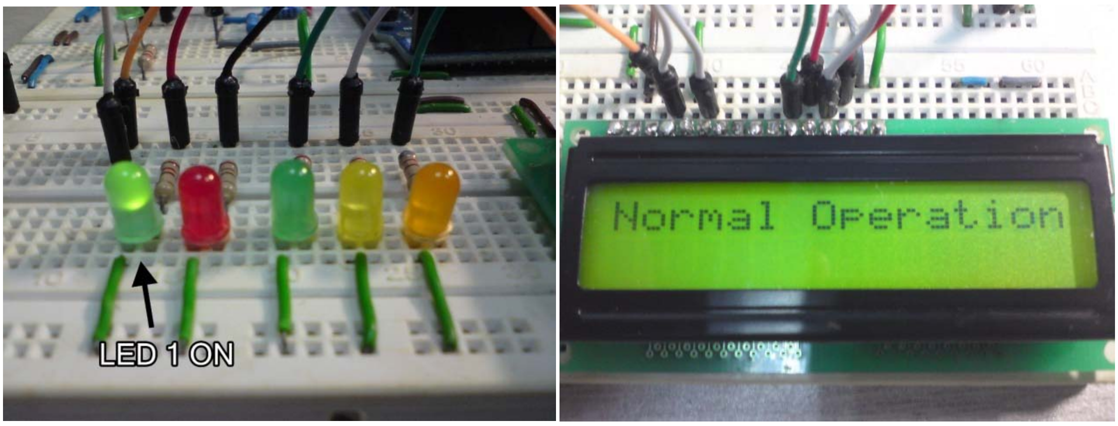

Figure 15: Normal Condition Testing

4.2.2 Auto-Reset ELCB Test

This part is to test the functionality of automatic ELCB reset operation. During power outage, at which power is OFF (or “0”), LED 2 will light up to indicate that the ELCB is tripped or fault condition is occurred. ELCB will undergo maximum of three times reset testing. To represent the motor that will reset the ELCB, LED 3 is set to be ON for 3 seconds and OFF for 3 seconds as delay. The 3 seconds delay is to make able for the microprocessor to check if the power is “1” or “0” and to switch off the motor. If “1”, the system will be back to normal operation. If “0”, the system will reset ELCB up to three times. During the reset operation, the LCD will display “ELCB Tripped, Reset Test: (Test Sequence Number)”. The result of the test is as in Figure 16.

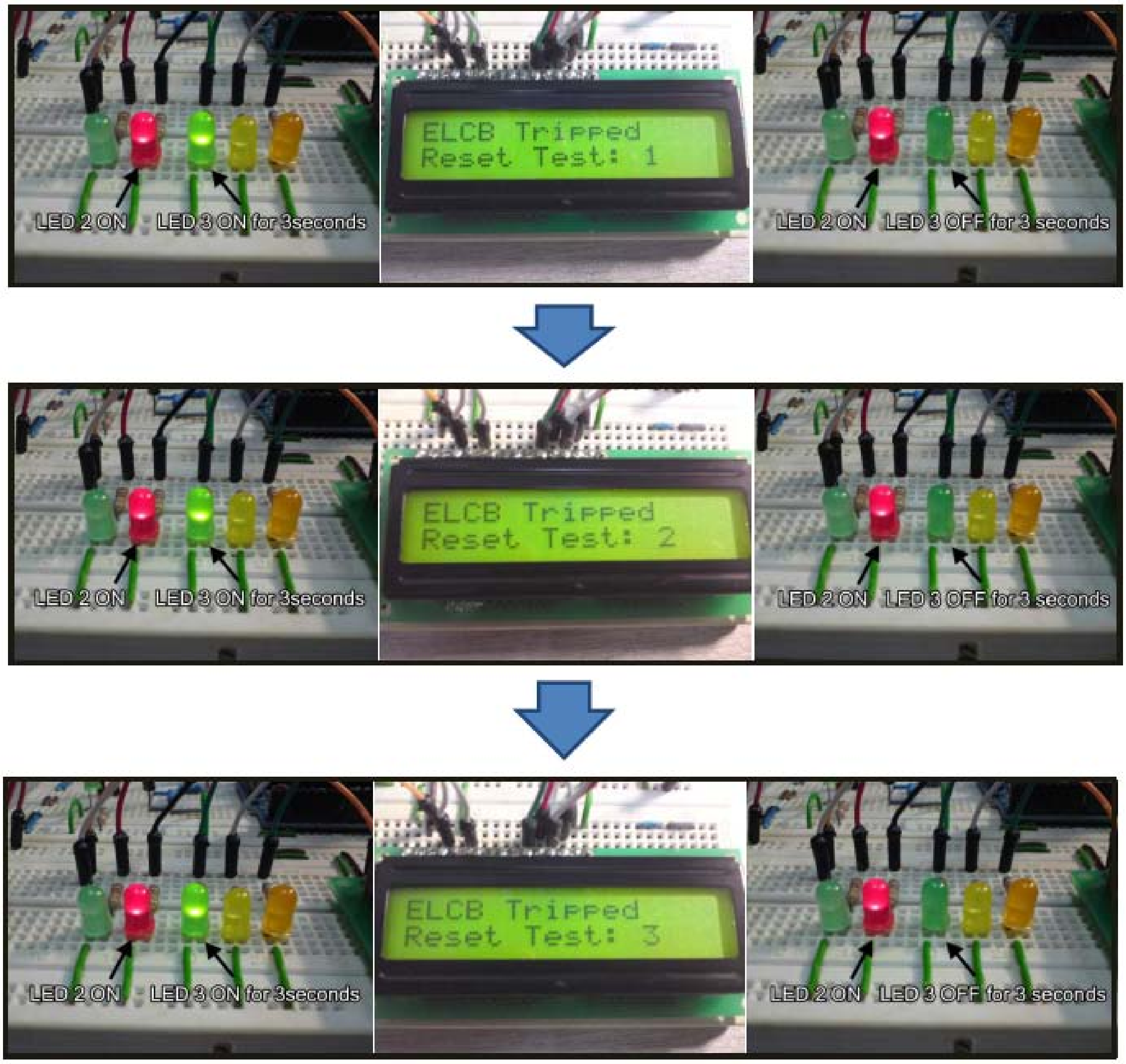

Figure 16: Auto-Reset ELCB Simulation Test

4.2.3 MCB Check Operation Test

Once the ELCB reset operation reached "Reset Test: 3", and the power is still "0", the system will check each MCB since MCB is installed at individual circuit. The system will check if the difference between line current and neutral current exceeds the limit current allocated. In this project, the limit current is set to 30 mA, as according to ELCB trip rating. When entering the MCB check operation, LED 3 will turn OFF and LED 4 will turn ON for 3 seconds while the LCD is displaying "MCB Checking..." as in Figure 17. LED 4 then will turn OFF, and LED 3will turn ON again for 3 seconds to reset the ELCB. Assume that once the LED 4 is OFF, the MCB is OFF position.

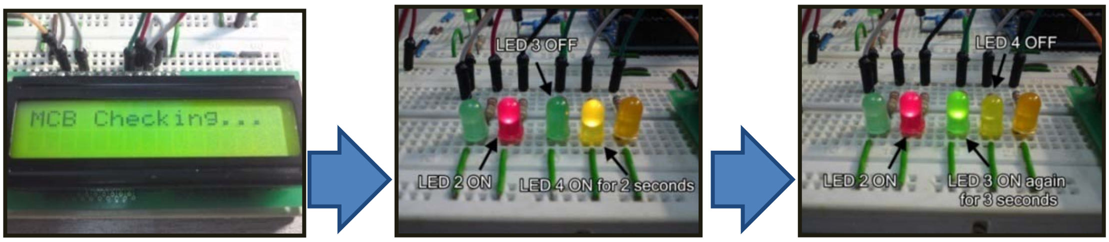

Figure 17: MCB Check Operation

The process is a representation where when the MCB is switched OFF, the ELCB will try to reset again. Once reset, the program then will check the power. If the power is still "0", the system will trigger call alert to inform the user that a fault has occurred at her/his house. Phone alert is represented by LED 5. LED 5 will turn ON for 4 seconds to trigger call alert and LCD will display "Unknown Fault; MCB Off" as in Figure 18 since the cause of fault is unknown.

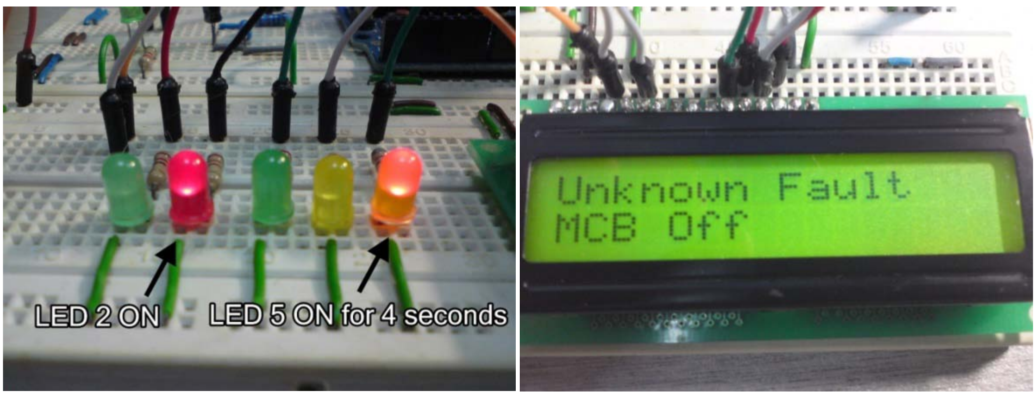

Figure 18: Unknown Fault with MCB Off

But if power return “1”, or ON, call alert will also be triggered but the LCD will display “Fault Detected @; MCB 1” as in Figure 19 since the fault is known occurred at MCB 1. For testing purpose, only one MCB is being used and labelled by “MCB 1”. More MCB will be added in real prototype.

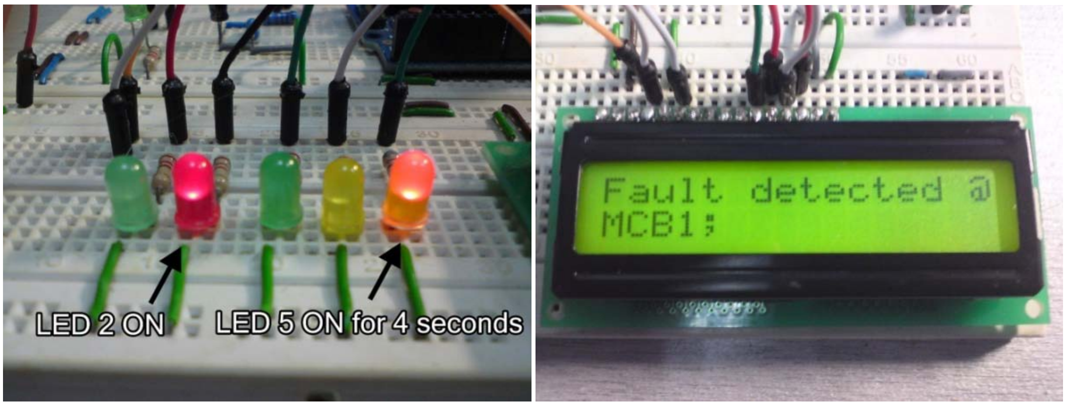

Figure 19: Fault at MCB 1

The previous testing condition only when there is fault occurred at MCB, where the difference between line current and neutral current exceeds 30 mA. But if the difference does not exceeds 30 mA, but the power is still OFF or “0”, the LCD will display “Unknown Fault; MCB On” and call alert will be triggered as in Figure 20. This is due to unknown fault had occurred but no fault is detected at any MCB checked. Since there is no fault detected, therefore no MCB will be turned OFF.

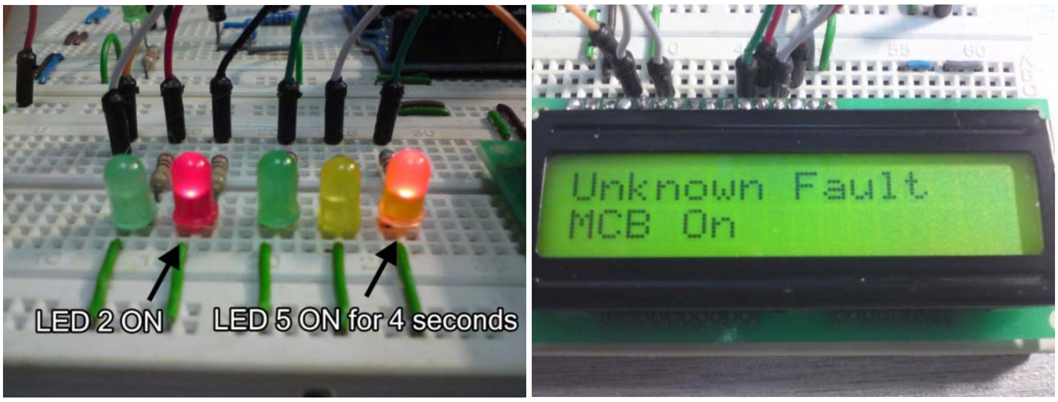

Figure 20: Unknown Fault with MCB ON

4.3 Prototype Development

Results from the simulation test had verified that the system developed is well-functioning. The system developed will then be implemented in real prototype and hardware. Figure 21 shows the overall view of the prototype designed.

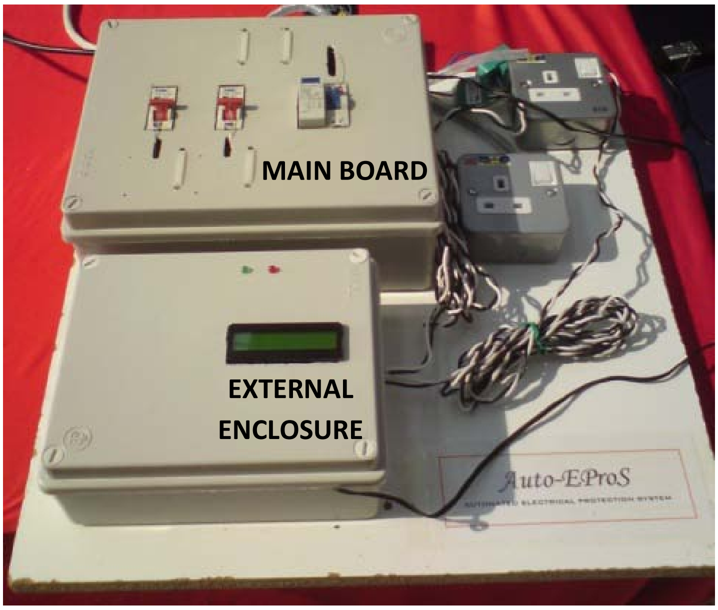

Figure 21: Overall View of the Prototype

The prototype is designed with one ELCB and two MCBs to represent the home distribution board. There are two main compartments in the prototype, the main board and the external enclosure. The main board is where the ELCB, MCBs and DC motors are placed, while the external enclosure contains batteries, Arduino board, LCD display and other electronic components. Figure 22 shows the DC motors that are being used for triggering mechanism. Solenoid plungers are replaced by DC motor due to several circumstances.

A nylon cable is attached between each DC motors with the ELCB and MCBs for the triggering mechanism. Each DC motor will be driven by a motor drive, comprises of N-channel power MOSFET, diode, resistor and connector.

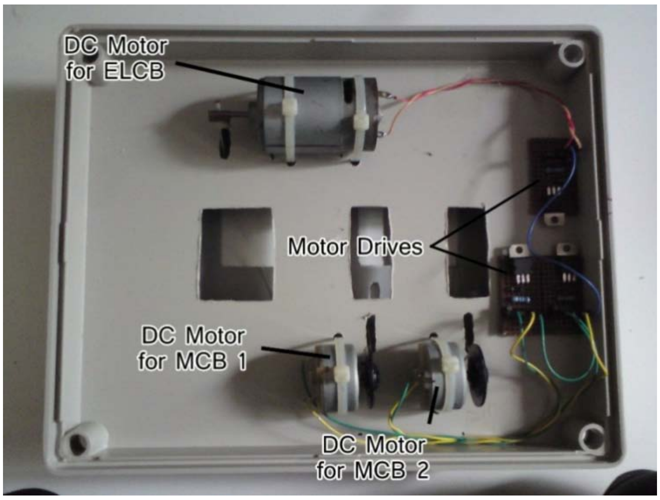

Figure 22: DC Motors Configuration

4.4 Prototype Test

The designed prototype is ready to be tested to observe its actual functionality. The tests done are similar with the simulation test and results are as in the following sections.

4.4.1 Prototype Test 1: Normal Condition

The prototype designed is first test in its normal condition. It is a condition where everything is working as usual, no fault during this period. Figure 23 shows the result of the test. In this test, both MCBs and ELCB is in ‘ON’ position and LCD display will display “Normal Condition”. An indicator, the green LED, will light up to indicate the system is in normal condition.

Figure 23: Normal Condition of the Prototype

4.4.2 Prototype Test 2: Auto-Reset ELCB

This is an actual test of auto-reset ELCB function by using the prototype designed. The operation and reset sequence is similar to the simulation test in Section V.C, but the LEDs are replaced by the real hardware, DC motor. The ELCB reset sequence is shown in Figure 24. During trip, ELCB will be in 'OFF' position and 'ON' position after reset operation. The LCD will display the reset sequence to indicate the number of reset test done. The system developed for the auto-reset ELCB will check for power after each reset sequence completed. For instance, after ELCB had completed reset test sequence 1, the system will check for the electrical power supply. If there is no power supplied, then the system will go for next reset sequence. But if power is restored after the first or second sequence, then the system will indicate "Normal Operation".

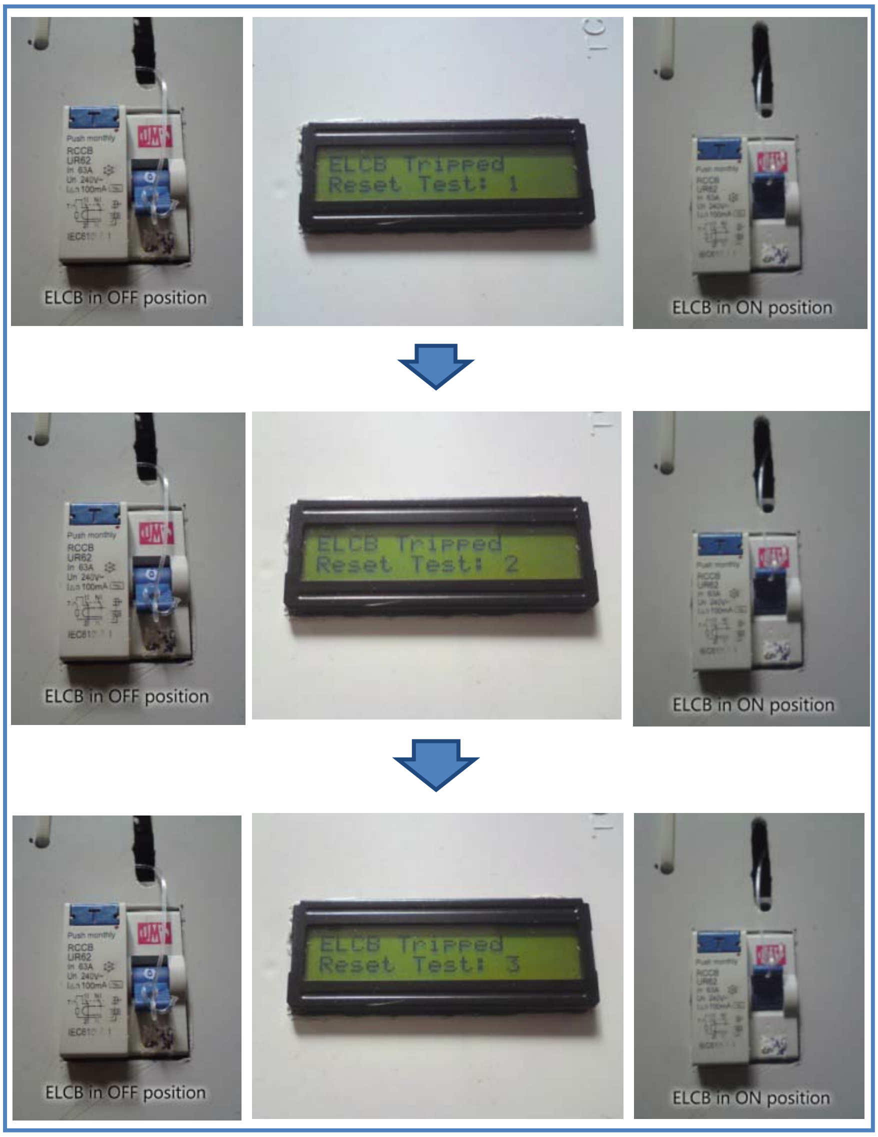

Figure 24: Actual Auto-Reset ELCB Test

4.4.3 Prototype Test 3: Fault Location Detection

Once the auto-reset ELCB operation reached reset test number 3, the system will check for fault at MCB. For testing purpose and real situation demonstration, electrical fault is intentionally created at MCB 1. Figure 25 shows the flow of MCB checking operation. Once the system enters the MCB checking stage, it will read current value obtained the current sensors and check for the current difference at MCB 1.

If difference exceeds the limit set, MCB 1 is considered as faulted. Therefore, MCB 1 will be switched off and ELCB will be reset again. Once the process of switching off and on MCB and ELCB is completed, the LCD will display "Fault Detected @ (Fault Location)". In this test, it displays "Fault Detected @ MCB 1", indicating that an electrical fault had occurred at MCB 1. Then, the system will trigger call alert to notify the user.

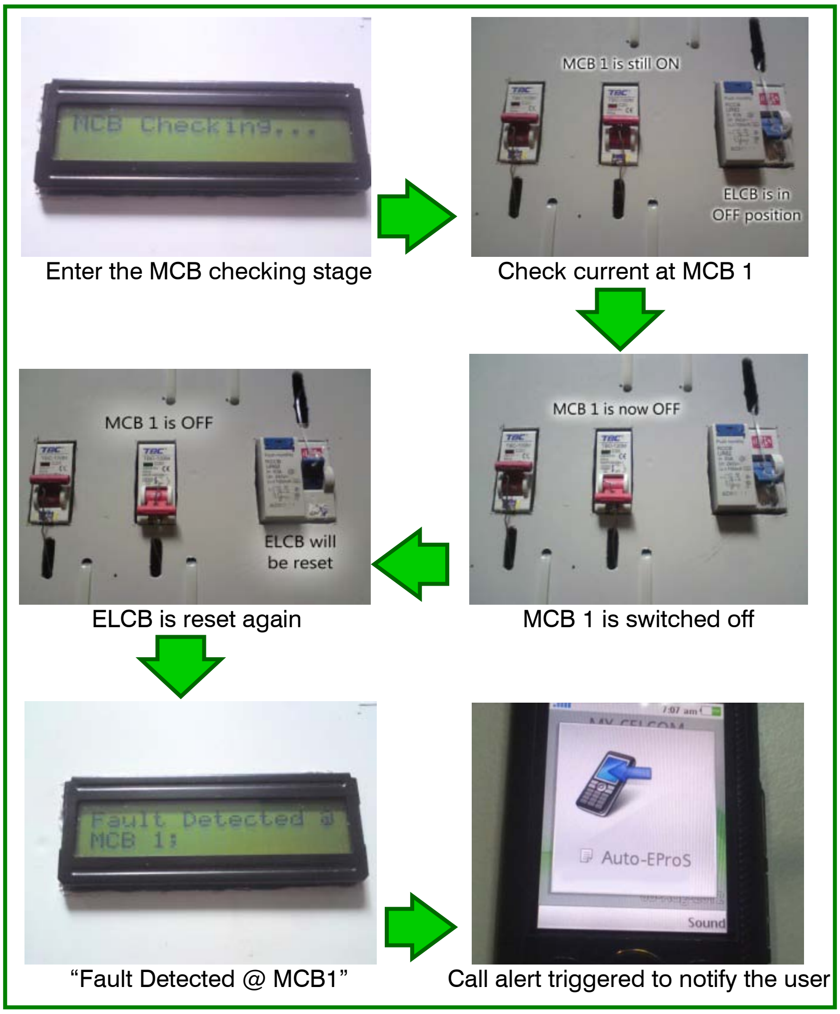

Figure 25: Fault Location Detection Test

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project, Automated Electrical Protection System or Auto-EProS can be considered as a new invention in electrical protection field. Since the progress can be said is on schedule and the tests are done successfully, the project seems going to be a successful project. Lots of improvements had been made from previous project as according to methodology suggested and studies done. This project requires high understanding in power system as well as vast knowledge in electronic to accurately measure the parameters and make it able to communicate with electronic components. Towards the end of this project, it is expected that this project will be significant in terms of technical and economical besides commercially valued.

5.2 Recommendations

Towards the end of this project, a few recommendations are to be made as followings in order to improve the efficiency and effectiveness of the system developed:

- Use different type of triggering mechanism, e.g. use solenoid instead of dc motor
- Develop the system to cater the plug-and-play characteristics
- If possible, use differential current transformer instead of split core current transformer to directly obtain the current difference value
- The system may be developed for three phase system, for industrial purposes

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APPENDIX A

No	Detail/Week – FYP I	1	2	3	4	5	6	Mid-Semester Break	7	8	9	10	11	12	13	14
1	Selection of Project Topic															
2	Literature Review and Research on Topic Selected															
3	Scope and Methodology Analysis															
4	Submission of Extended Proposal															
5	Prototype Plan & Design: Drafting Stage															
6	Proposal Defence															
7	Prototype Drafting Continue															
8	Interim Report Submission															

No	Detail/Week – FYP II	1	2	3	4	5	6	Mid-Semester Break	7	8	9	10	11	12	13	14
1	Software & Hardware Development															
2	System Functionality Test															
3	System Troubleshooting															
4	System Implementation & Prototype Fabrication															
5	Draft Report															
6	Submission & Completion of Project															

APPENDIX B

```
LiquidCrystal lcd(2, 3, 5, 6, 9, 10);
const int normal = 1;
const int trip = 4;
const int sp_main = 7;
const int sp_1 = 8;
const int sp_2 = 11;
const int hp = 13;
const int power = 12;
int count_elcb;
int count_reset;
int powerValue;
int memLoc1 = 188;
int memLoc2 = 200;

void setup()
{
  lcd.begin(16,2);
  lcd.print(" = Auto-EProS = ");
  lcd.setCursor(0,1);
  lcd.print("by: Zakwan Hariz");
  delay(3000);
  pinMode(1,OUTPUT);
  pinMode(4,OUTPUT);
  pinMode(7,OUTPUT);
  pinMode(8,OUTPUT);
  pinMode(11,OUTPUT);
  pinMode(13,OUTPUT);
  pinMode(12,INPUT);
  emon1.current(1, 111.1);
  emon2.current(2, 111.1);
  emon1.current(3, 111.1);
  emon2.current(4, 111.1);
}

void loop()
{
  int powerValue_int = digitalRead(power);          // Checking power
condition
  if (count_elcb == 4 && powerValue_int == 0)
  {
    digitalWrite(trip,HIGH);
    digitalWrite(normal,LOW);
    int powerValue_fault = digitalRead(power);
    if(powerValue_fault == 1)
    {
      count_elcb = 0;
    }
  }
    /* During trip, power reading is zero, or LOW condition */
```

```
else if(count_elcb != 4 && powerValue_int == 1)
  {
    normal_display();
    digitalWrite(normal,HIGH);              // At normal condition
    digitalWrite(trip,LOW);

    //Current Sensor at MCB 1
    double Irms_L1 = emon1.calcIrms(1480);  // Calculate Irms only
    double Irms_N1 = emon2.calcIrms(1480);
    long lineCurrent1 = Irms_L*100;
    long neutCurrent1 = Irms_N*100;
    long diff1 = lineCurrent - neutCurrent;
    EEPROMWriteInt(memLoc1,diff1);

    //Current Sensor at MCB 1
    double Irms_L2 = emon3.calcIrms(1480);  // Calculate Irms only
    double Irms_N2 = emon4.calcIrms(1480);
    long lineCurrent2 = Irms_L*100;
    long neutCurrent2 = Irms_N*100;
    long diff2 = lineCurrent - neutCurrent;
    EEPROMWriteInt(memLoc2,diff2);

    count_elcb = 0;
    int powerValue_0 = digitalRead(power);
    if (powerValue_0 == 0 && count_elcb == 0)  // First trial
    {
      lcd.clear();
      lcd.print("ELCB Tripped");
      lcd.setCursor(0,1);
      lcd.print("Reset Test: 1");
      trip_reset();
      delay(2500);
    }

    count_elcb = 1;
    int powerValue_1 = digitalRead(power);
    if(powerValue_1 == 0 && count_elcb == 1)  // Second trial
    {
      lcd.clear();
      lcd.print("ELCB Tripped");
      lcd.setCursor(0,1);
      lcd.print("Reset Test: 2");
      trip_reset();
      delay(2500);
    }

    count_elcb = 2;
    int powerValue_2 = digitalRead(power);
    if(powerValue_2 == 0 && count_elcb == 2) // Third trial
    {
      lcd.clear();
      lcd.print("ELCB Tripped");
      lcd.setCursor(0,1);
      lcd.print("Reset Test: 3");
```

```
      trip_reset();
      delay(2500);
    }

    count_elcb = 3;
    int powerValue_3 = digitalRead(power);
    if(powerValue_3 == 0 && count_elcb == 3)
    {
      lcd.clear();
      lcd.print("MCB Checking...");
      delay(2000);
      currentDiff1 = EEPROMReadInt(memLoc1); //read memory from CT 1
      currentDiff2 = EEPROMReadInt(memLoc2); //read memory from CT 2

      if(currentDiff1 < 300 && currentDiff1 > -300 || currentDiff2 <
300 && currentDiff2 > -300)
      {
        lcd.clear();
        lcd.print("Unknown Fault");
        lcd.setCursor(0,1);
        lcd.print("MCB On");
        phone_alert();
        count_elcb = 4;
      }//no difference

      if(currentDiff1 >= 300 || currentDiff1 <= -300 )
      // Compare current value
      {
        mcb1();
        trip_reset();
        int powerTest_MCB = digitalRead(power);
        if(powerTest_MCB == 0)
        {
          lcd.clear();
          lcd.print("Unknown Fault");
          lcd.setCursor(0,1);
          lcd.print("MCB Off");
          phone_alert();
          count_elcb = 4;
        }//difference with power 0

        if(powerTest_MCB == 1)
        {
          lcd.clear();
          lcd.print("Fault Detected @");
          lcd.setCursor(0,1);
          lcd.print("MCB 1; ");
          phone_alert();
          count_elcb = 4;
        }//difference with power 1

      if(currentDiff2 >= 300 || currentDiff2 <= -300 )
      // Compare current value
```

```
      {
        mcb2();
        trip_reset();
        int powerTest_MCB = digitalRead(power);
        if(powerTest_MCB == 0)
        {
          lcd.clear();
          lcd.print("Unknown Fault");
          lcd.setCursor(0,1);
          lcd.print("MCB Off");
          phone_alert();
          EEPROMWriteInt(memLoc,0);
          count_elcb = 4;
        }//difference with power 0

        if(powerTest_MCB == 1)
        {
          lcd.clear();
          lcd.print("Fault Detected @");
          lcd.setCursor(0,1);
          lcd.print("MCB 2; ");
          phone_alert();
          EEPROMWriteInt(memLoc,0);
          count_elcb = 4;
        }//difference with power 2
      }// difference during fault loop
    }// MCB test loop
  }//count!=4
}//void loop

void normal_display()
{
  lcd.clear();
  lcd.print("Normal Operation");
  delay(800);
}

void trip_reset()                     // ELCB reset function
{
  digitalWrite(normal,LOW);
  digitalWrite(trip,HIGH);
  delay(1500);
  digitalWrite(sp_main,HIGH);
  delay(1500);
  digitalWrite(sp_main,LOW);
}

void mcb1()                             //Motor at MCB1
{
  delay(1500);
  digitalWrite(sp_1,HIGH);              // trigger plunger at MCB 1
  delay(1000);
  digitalWrite(sp_1,LOW);               // plunger turns off
}
```

```
void mcb2()                               //Motor at MCB2
{
  delay(1500);
  digitalWrite(sp_2,HIGH);                // trigger plunger at MCB 1
  delay(1000);
  digitalWrite(sp_2,LOW);                 // plunger turns off
}

void phone_alert()                        //Call Alert Function
{
  delay(800);
  digitalWrite(hp,HIGH);                  // phone ON
  delay(1500);                            // 3 seconds delay
  digitalWrite(hp,LOW);                   // phone OFF
}

//Write Function
void EEPROMWriteInt(int p_address, long p_value)
{
  byte Byte1 = ((p_value >> 0) & 0xFF);
  byte Byte2 = ((p_value >> 8) & 0xFF);
  byte Byte3 = ((p_value >> 16) & 0xFF);
  byte Byte4 = ((p_value >> 24) & 0xFF);

  EEPROM.write(p_address, Byte1);
  EEPROM.write(p_address + 1, Byte2);
  EEPROM.write(p_address + 2, Byte3);
  EEPROM.write(p_address + 3, Byte4);
}

//Read Function
unsigned long EEPROMReadInt(int p_address)
{
  byte Byte1 = EEPROM.read(p_address);
  byte Byte2 = EEPROM.read(p_address + 1);
  byte Byte3 = EEPROM.read(p_address + 2);
  byte Byte4 = EEPROM.read(p_address + 3);

  long firstTwoBytes = ((Byte1 << 0) & 0xFF) + ((Byte2 << 8) &
0xFF00);
  long secondTwoBytes = (((Byte3 << 0) & 0xFF) + ((Byte4 << 8) &
0xFF00));
  secondTwoBytes *= 65536;

  return (firstTwoBytes + secondTwoBytes);
}
```

APPENDIX C

System
pro *M* compact®

Selection tables
RCD-blocks DDA 200 series
A y type

DDA 200 A

A

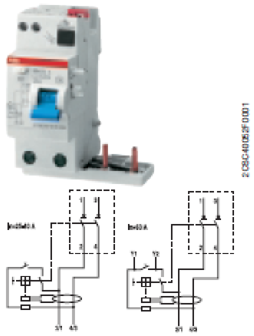
DDA 200 A type

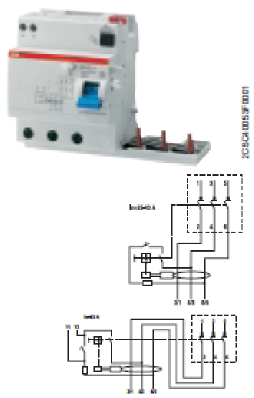
Function: RCD-block for assembly on site with MCBs S 200 series. Protection against the effects of sinusoidal alternating and direct pulsating earth fault currents; protection against indirect contacts and additional protection against direct (with IΔn=30 mA) contacts.

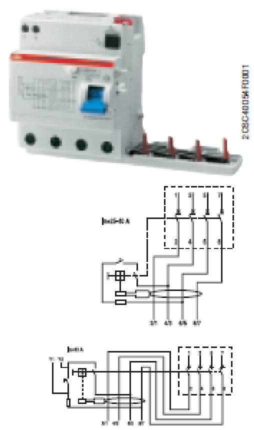
Application: residential, commercial, industrial.

Standard: IEC/EN 61009 Ann. G

3







Number of poles	Nominal fault current IΔn mA	Nominal current In A	Order details Type code	Order code	Bbn 8012542 EAN	Price 1 piece	Price group	Weight 1 piece kg	Pack unit pc.
2	10	25	DDA202 A-25/0.01	2CSB202101R0250	795308			0.200	1
	30	25	DDA202 A-25/0.03	2CSB202101R1250	795407			0.200	1
		40	DDA202 A-40/0.03	2CSB202101R1400	795506			0.200	1
		63 ③	DDA202 A-63/0.03	2CSB202101R1630	795605			0.200	1
	100	25	DDA202 A-25/0.1	2CSB202101R2250	795704			0.200	1
		40	DDA202 A-40/0.1	2CSB202101R2400	795803			0.200	1
		63 ③	DDA202 A-63/0.1	2CSB202101R2630	795902			0.200	1
	300	25	DDA202 A-25/0.3	2CSB202101R3250	796008			0.200	1
		40	DDA202 A-40/0.3	2CSB202101R3400	796107			0.200	1
		63 ③	DDA202 A-63/0.3	2CSB202101R3630	796206			0.200	1
	500	25	DDA202 A-25/0.5	2CSB202101R4250	796305			0.200	1
		40	DDA202 A-40/0.5	2CSB202101R4400	796404			0.200	1
		63 ③	DDA202 A-63/0.5	2CSB202101R4630	796503			0.200	1
	1000	25	DDA202 A-25/1	2CSB202101R5250	808909			0.200	1
		40	DDA202 A-40/1	2CSB202101R5400	809005			0.200	1
		63 ③	DDA202 A-63/1	2CSB202101R5630	796602			0.200	1
3	30	25 ①	DDA203 A-25/0.03	2CSB203101R1250	796701			0.200	1
		40 ①	DDA203 A-40/0.03	2CSB203101R1400	796800			0.200	1
		63 ③	DDA203 A-63/0.03	2CSB203101R1630	796909			0.350	1
	100	25	DDA203 A-25/0.1	2CSB203101R2250	797005			0.200	1
		40	DDA203 A-40/0.1	2CSB203101R2400	797104			0.200	1
		63 ③	DDA203 A-63/0.1	2CSB203101R2630	797203			0.350	1
	300	25 ①	DDA203 A-25/0.3	2CSB203101R3250	797302			0.200	1
		40 ①	DDA203 A-40/0.3	2CSB203101R3400	797401			0.200	1
		63 ③	DDA203 A-63/0.3	2CSB203101R3630	797500			0.350	1
	500	25	DDA203 A-25/0.5	2CSB203101R4250	797609			0.200	1
		40	DDA203 A-40/0.5	2CSB203101R4400	797708			0.200	1
		63 ③	DDA203 A-63/0.5	2CSB203101R4630	797807			0.350	1
	1000	25	DDA203 A-25/1	2CSB203101R5250	809104			0.200	1
		40	DDA203 A-40/1	2CSB203101R5400	809203			0.200	1
		63 ③	DDA203 A-63/1	2CSB203101R5630	797906			0.350	1
4	30	25 ①	DDA204 A-25/0.03	2CSB204101R1250	798002			0.200	1
		40 ①	DDA204 A-40/0.03	2CSB204101R1400	798101			0.200	1
		63 ② ③	DDA204 A-63/0.03	2CSB204101R1630	798200			0.350	1
	100	25	DDA204 A-25/0.1	2CSB204101R2250	798309			0.200	1
		40	DDA204 A-40/0.1	2CSB204101R2400	798408			0.200	1
		63 ③	DDA204 A-63/0.1	2CSB204101R2630	798507			0.350	1
	300	25 ①	DDA204 A-25/0.3	2CSB204101R3250	798606			0.200	1
		40 ①	DDA204 A-40/0.3	2CSB204101R3400	798705			0.200	1
		63 ③	DDA204 A-63/0.3	2CSB204101R3630	798804			0.350	1
	500	25	DDA204 A-25/0.5	2CSB204101R4250	798903			0.200	1
		40	DDA204 A-40/0.5	2CSB204101R4400	799009			0.200	1
		63 ③	DDA204 A-63/0.5	2CSB204101R4630	799108			0.350	1
	1000	25	DDA204 A-25/1	2CSB204101R5250	809302			0.200	1
		40	DDA204 A-40/1	2CSB204101R5400	809401			0.200	1
		63 ③	DDA204 A-63/1	2CSB204101R5630	799207			0.350	1

① available in the version fitting in 4 modules
② version with test button working at 115 VAC-127 VAC is available on request
③ provided with additional terminals for remote tripping

APPENDIX D

protection
circuit-breakers up to 63 A

12498

C60a circuit-breakers
4.5 kA, C curve
AS/NZS 4898

Approval No: N13634

functions

The circuit-breakers combine the following functions:
- protection of circuits against short-circuit currents,
- protection of circuits against overload currents,
- control,
- isolation,
- protection of persons against indirect contact.

- C60a circuit-breakers are used in the domestic sectors where single phase fault levels are less than or equal to 4.5kA.

description

technical data
C60a circuit-breakers

■ power circuit
□ voltage rating: 240 V AC
□ number of cycles (O-C): 10 000
□ foolproof terminal design
- moving barrier prevents incorrect cable insertion
- cable strand centering guides ensure correct cable positions and strand grouping
□ isolation with positive contact indication
□ bistable din clip, simplifies disassembly

■ environment
□ tropicalisation: treatment 2
(relative humidity: 95 % at 55 °C)
□ connection: tunnel terminals for the following cables:
- up to 25A : 25mm^2 stranded
- 32 to 63A : 35mm^2 stranded

C curve

utilisation
cables feeding conventional loads.

technical data

■ power circuit
□ tripping curves: the magnetic trip unit operates between 5 and 10 In
□ breaking capacity
- according to AS/NZS 4898 Icu ultimate breaking capacity (0-C0 cycle):

rating (A)	voltage (V)	breaking capacity Icu (A)
1...63	240	4500

catalogue numbers

11357

C curve C60a

type		rating (A)	catalogue number	width in mod. of 9 mm	quantity per box
1P		6	11354	2	12
		10	11355	2	12
		16	11356	2	12
		20	11357	2	12
		25	11339	2	12
		32	11358	2	12
		40	11359	2	12
		50	11360	2	12
		63	11361	2	12

Based on Schneider Electric Catalogue

Page 2 of 6

APPENDIX E

SCT-0400 Split-Core AC Current Sensor

Measures AC current passing through the center

Electrical Specifications

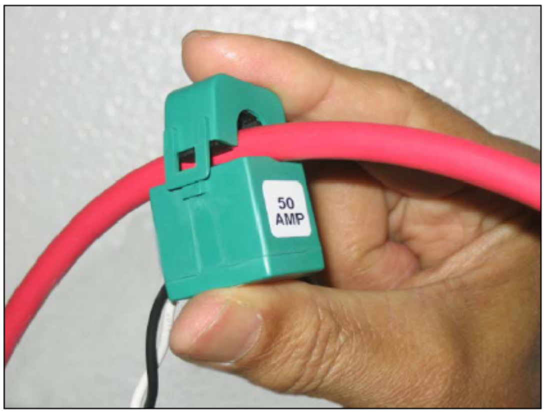
- Output 0.333 V at rated current
- Accuracy ±1%
- Phase angle < 2 degrees
- Rated accuracy at 10% to 130% of rated current
- Operational from 50Hz to 400Hz

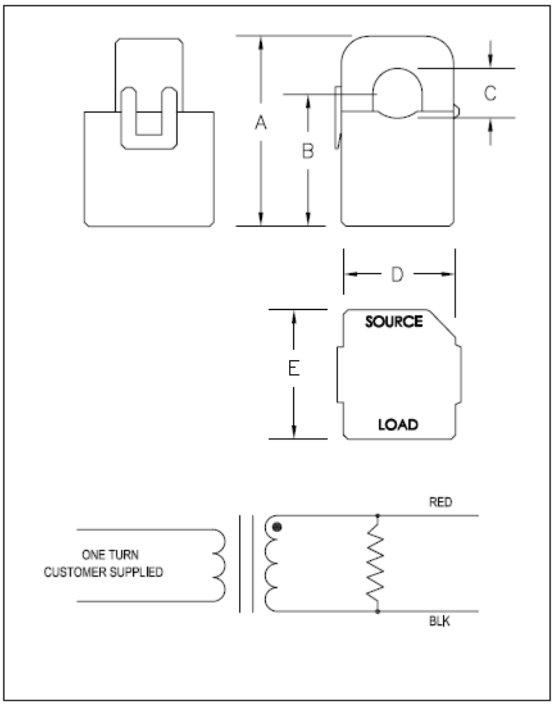
Mechanical Specifications

- 0.40" [10.16 mm] opening, split core
- Leads-8ft. [2.44 m] twisted pair, jacketed, 24 AWG

Features

- UL recognized, CE RoHS compliant
- Precision burden resistor
- Other ratings and specifications are available

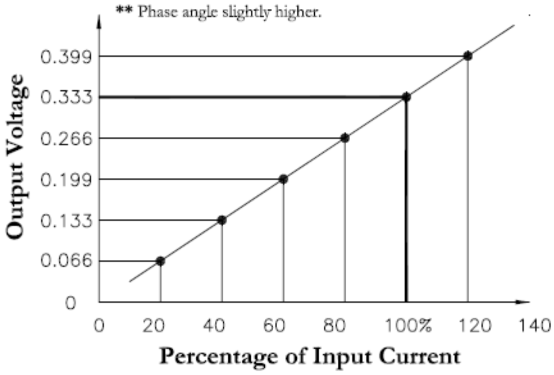




MAGNELAB P/N	RATED CURRENT (Amps)	DIMENSIONS INCHES [MILLIMETERS]				
		A	B	C	D	E
SCT-0400-000*	0-75	1.55 [39.55]	1.09 [27.69]	0.40 [10.16]	1.00 [25.40]	1.05 [26.67]
SCT-0400-005**	5					
SCT-0400-010	10					
SCT-0400-015	15					
SCT-0400-020	20					
SCT-0400-025	25					
SCT-0400-030	30					
SCT-0400-050	50					
SCT-0400-075	75					

* Products with -000 have no burden resistor, and the output voltage is clamped to 22 Volts.

** Phase angle slightly higher.



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