DESIGN A REMOTE TERMINAL UNIT (RTU) FAULT DETECTION SENSOR TO DETECT VOLTAGE IN RANGE OF UNDER VOLTAGE AND OVERVOLTAGE FAULT.

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June 2014

"I hereby declare that I have read through this report entitle "**Design a Remote Terminal Unit (RTU) Fault Detection Sensor to Detect Voltage in Range of Under Voltage and Overvoltage Fault"** and found that it has complied the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation & Automation) with honors"

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(UTeM)

2014

I declare that this report entitle “**Design a Remote Terminal Unit (RTU) Fault Detection Sensor to Detect Voltage in Range of Under Voltage and Overvoltage Fault”** is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidate of any other degree.

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Dedicated, in thankful appreciation for support, encouragement and understandings

To:

My supervisor Datuk Prof Dr Mohd Ruddin Ab Ghani

My beloved father and mother Rosli Bin Dollah and Norhayati Binti Hassan

My family members and all friends

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ABSTRACT

Remote Terminal Unit (RTU) is a data acquisition device that implements in the Distribution Automation System (DAS). The primary function of the RTU is to monitor electrical parameter data, such as voltage from line distribution before transmit to consumers. The data sensed by RTU system will be analyzed and transmit commands to a central computer to take action automatically based on the fault occur. The design of this project will be focused on designing fault detection sensor to emphasis on any value differences in voltage by using microcontroller board (SK40C). The system is developed for single phase faults and the types of faults detect is under voltage and overvoltage. The main heart of this project is voltage sensor and a PIC microcontroller. The microchip will be programmed to a specific voltage for the condition under voltage and over voltage when voltage sensor detects input voltage. Then, at the end of this project, fault detection sensor will be able to detect under voltage and overvoltage faults and ready to interface with complete Remote Terminal Unit project.

ABSTRAK

Remote Terminal Unit (RTU) adalah pengambilalihan peranti data yang dilaksanakan dalam Sistem Automasi Pengagihan (DAS). Fungsi utama RTU adalah untuk memantau parameter data elektrik seperti voltan daripada pengagihan talian sebelum menghantar kepada pengguna. Data yang dikesan oleh sistem RTU akan dianalisis dan menghantar arahan kepada unit kawalan untuk mengambil tindakan secara automatik berdasarkan perubahan voltan yang berlaku. Projek ini tertumpu kepada menghasilkan alat pengesan perbezaan voltan untuk mengesan perbezaan nilai dalam voltan dengan menggunakan litar mikropengawal. Sistem ini dicipta untuk mengesan perubahan satu fasa voltan (230V) sama ada nilai voltan yang diterima rendah atau tinggi dari nilai yang sebenar. Komponen utama projek ini adalah sensor voltan dan PIC mikrocip. Mikrocip akan diprogram dengan bacaan nilai voltan tertentu bagi mengesan keadaan voltan. Kemudian, di akhir projek ini , Remote Terminal Unit (RTU) akan pengesanan perubahan pada voltan dan boleh bersiap sedia untuk di pasankan dengan projek Remote Terminal Unit.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Remote terminal unit (RTU) is an electronic control device that interfaces with distributed control system, such as SCADA (supervisory control and data acquisition) to analyze the electrical parameter at the distribution station. The data are collected from process equipment at remote locations and transfer back to a central unit to define data condition [1]. The data read by remote terminal unit can be in three conditions such as analog input, digital (status input) and digital (control outputs). The data read in an electrical parameter such as RMS value of voltage and current, frequency, power etc.

This project involved designing fault detection sensor voltage for remote terminal unit (RTU) where it is suitable to use in power system distribution. The process design must study information from other circuit in order to get the best design for voltage sensor. Then, the voltage sensor design will be effective to sense the different voltage values in the system. Voltage fault detection can be described into three states which is under voltage fault, overvoltage fault and stable.

In industry application, the RTU will determine the fault status and operate corresponding switching, isolates faults and restore power supply [2]. The distribution station protection device is very important to protect residential areas from fault condition. Moreover, the used current system is imported from another country technologies and used in our local distribution. Since it used imported product then the price must be higher included the maintenance fee. So from this situation decision has been made that local student must study how to develop our protection product.

Since the increasing population and unavoidable demands, it leads to the high increase demands on electrical power. With this increase in demand of power, then the existing system may not fully support for demanding requirements. From the analysis of fault condition, the problem can be reduced by knowing the factor of fault occur.

The main objective of this project is to develop fault detection sensor and it focus for monitoring process only, the protection and controlling part are not covered in this project. The fault detection sensor can only sense the fault condition and display the fault value.

1.2 Problem Statement

At the distribution station, the voltage may drop and rise from its rated value due to lack of electrical equipment's functional abilities. There are many types of fault occur in process distribution voltage to consumers. The fault occurs can be categorized into two types which is balanced and unbalanced faults. The balanced fault normally has less than 5% fault, while the unbalanced fault has single-line to ground fault (60-75% fault), double-line to ground fault (15-25% fault) and line-to-line faults (5-15% fault).

Normally, the voltage consumes to consumer may drop from the distribution line supplying to a specific load whereby the load could be any consumer which cause the consumer voltage drop from its rated value. For example, in the current industry, the voltage may rise or drop from its rated value due to improper operation of the voltage regulating equipment such as transformers or capacitor.

Apart from this problem, this final year project will be a case study to develop and design the fault detection sensor to detect and monitor fault at the substation. This project will provide a fault detection sensor to detect voltage in the range of under voltage, normal voltage and overvoltage.

1.3 Objective

The objective of this project can be described as below:

- To design fault detection sensor to detect fault voltage input.

- Ensure that the design will be able to monitor and display the fault voltage in the range of under voltage and overvoltage.

1.4 Scope of Project

The scope for this project is to design the fault detection sensor on input voltage to detect under voltage and overvoltage. Range of voltage need to be considered is a single phase system (0 to 260V). This fault detection circuit is based on the variable transformer which will supply the AC voltage to the designed voltage sensor circuit. After that, immediately a fault detected process by microcontroller board (SK40C) and display the fault condition on the LCD screen.

Furthermore, the limitation of the entire project is divided into two. First part of the project is to design and build the hardware of the sensor voltage. Its components included variable transformer as input, voltage sensor circuit, microcontroller circuit and LCD display. The voltage sensor will design for 0 to 300V input supply and the output will in the range of 0 to 5V. Then, the output voltage will supply as input to the PORTA of SK40C microcontroller board and the output will be at PORTB and connected to the LCD display

The second part is the development of a C language using Micro C programming that will read the output voltage from designed circuit to determine the range of under voltage and overvoltage condition and display on LCD. The under voltage fault will determine when the input voltage less than 200V and the normal voltage set in between of 200V and 250V. Lastly the overvoltage voltage will be in condition fault when voltage exceeds more than 250V

Finally, after complete these two parts of the project, then the design voltage was ready to use as a voltage sensor to complete Remote Terminal Unit circuit.

1.5 Project Contribution

This project is expected to improve power management and system fault at distribution station. The specific range voltage can be easily described through programming in PIC microchip after detecting by voltage sensor. From that, the system will be able to easily describe the type of fault voltage range, better accuracy and improve the efficiency of power distribution system. The prototype of the voltage sensor design will be used in real Remote Terminal Unit prototype project.

Apart from this final year project, the further development of this project has been determined. The reliability of the system can be improved by setting up the time and date of fault condition when the system detects a fault. Hence, the fault detection sensor does not only record voltage fault, but the time and date also recorded together. After that the analysis of fault can be easily made by knowing what time voltage fault often occurred.

Lastly, this project is not only to design fault detection sensor, but it also includes two studies the importance of fault protection device in the power distribution system. Since the distribution system involved transmitted of high voltage range, then the system must be secured and restrict to harm consumers. Hence, student able gain knowledge by knowing and studies the factor that leads to overvoltage and under voltage fault.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Literature Review

This chapter explains the theory and basic concept of designing voltage sensor and application of Remote Terminal Unit (RTU). The principle idea is created before the design process of voltage sensor is conducted. This chapter also covers all instrument parts that's connected to a remote terminal unit (RTU) e.g. voltage sensor, c language programming, microcontroller board, etc. This will provide a clear understanding of the system and the design.

2.2 Power Distribution Station

Distribution station is the final station that received voltage from power plant before distribute electricity to consumers. The distribution system can be divided into two types, overhead distribution and underground distribution. The overhead distribution is where the electricity distributed through line on wood or electrical pillar. Meanwhile, underground distribution is to be free of electric wires and poles. In addition, when underground distribution system is called hybrid underground/overhead, then it has line voltage on the underground and the transformers and medium voltage line are overhead. But when the system is entirely underground, the medium line voltage is buried and the transformers are mounted on ground level pads [7].

2.3 Distribution Automation

Distribution automation is the system that allowed computers to control automatic the utility distribution facilities with no human intervention [3]. In details, it provides the ability to automatically monitor, coordinate and remotely operate distribution devices, such as relays and sectionalizing switches.

The primary function of distribution automation is to increase efficiency of power supply when there are fault occur. When a fault occurs, several actions are taken by substation operator to determine the reason of fault and this process normally take an amount of time depending on the fault situation. However, with designing distribution automation, the action will be taken by computer-based system and computerized controller can monitor the system and decide on proper actions instantly.

2.4 Remote Terminal Unit (RTU)

The objective of remote terminal unit (RTU) is developed to acquire electrical parameters, data e.g. voltage and current from the line input to transmit commands and instruction to system control data, supervisory control and data acquisition SCADA. The primary function of the RTU is to detect faults, fault location, diagnosis, fault, and switching control to maintain power supply system to load when a fault occurs [2]. The other function of remote terminal unit can be described as below [4] [6]:

- Acquisition other parameters information such as measured values, signals, meter reading, etc.
- Deliver commands or instructions, set points, the control variable, etc. including their monitoring as a function of time.
- Identify the changes in signal input with time data allocation and sequencing recording of status by the central computer.
- Processing of information transmitted to and from telecommunication equipments.
- Communicate with the central computer.

The structure of the RTU is shown in Figure 2.1 (below).

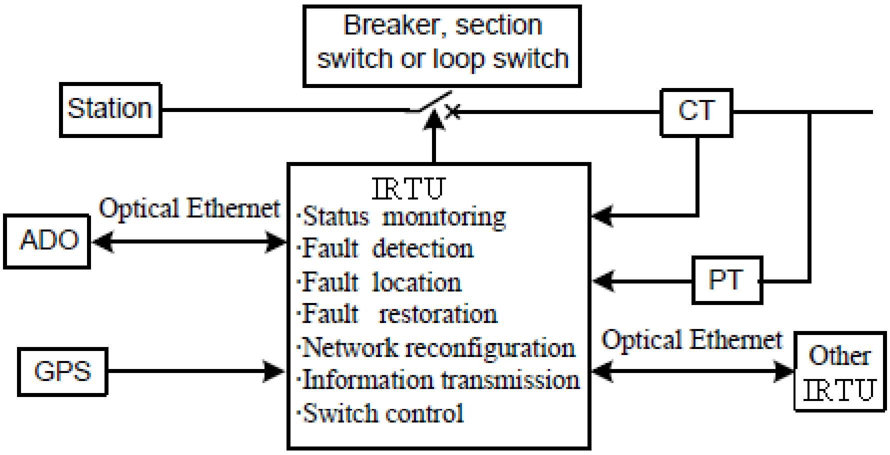

Figure 2.1: Structure of RTU [2].

2.5 Under Voltage

Under voltage is the situation where the value of voltage is lower than the desired value. This problem may occur from the load which is not suitable to use in circuit or lack of electrical equipments to functioning. So, this problem can cause other instruments in the distribution system to operate under normal condition. Then the consumers will receive unrated voltage when this fault occurs.

There are two types of common losses occur in a distribution power system which is the power lines and transformers. The type of losses is referred to core losses and copper losses. Core losses can be divided into two losses which is hysteresis loss and eddy current. Both depend on magnetic properties of core the transformer and the losses is directly fixed and do not depend on the load current. While the copper loss depends on the current in both primary and secondary coils. As the current depend on the load of transformer (P=I^2R), then the copper loss is varying with the load. If the load is increased then more losses form in the transformer windings.

Hence, the increased resistance will convert electrical energy into heat and imposes additional loads on the distribution station. Besides that, poor connections or inadequate sizes also cause to under voltage fault and result in excessive energy losses. Poor connection includes loose cable terminal, corroded terminal, poor crimps and worn/poorly adjusted between contacts.

2.6 Overvoltage

Overvoltage is a situation where the value of voltage increases over 100% from rated voltage. Overvoltage can cause a sudden reduction in loads, failure of electrical control instrument such as voltage regulators, cause insulation failure, etc. Overvoltage in power system can be classified into two main types such as external overvoltage and internal overvoltage.

External overvoltage is a situation generated by atmospheric disturbance and lightning is the most common and the most severe. While internal overvoltage is generated by changes in the operating conditions of the network. Internal overvoltage can be divided into two types, switching overvoltage and temporary overvoltage.

The increasing in transmission voltages needed to fulfil by power substation, switching surges have become the governing factor in the design of insulation for the high voltage power system. In the meantime, lightning overvoltage come as a secondary factor in these networks.

2.7 Relevant Voltage Sensor Design.

2.7.1 Design from Vicor Corp [8].

This project was describing the design of a circuit that can be used to disable the Vicor converter when under voltage is detected. The circuit operates as comparators to monitor input voltage and disable the converter via the Gate in or PC pin when the comparator trips [8]. The Figure 2.2 below show the under voltage and overvoltage lockout block diagram [8]:

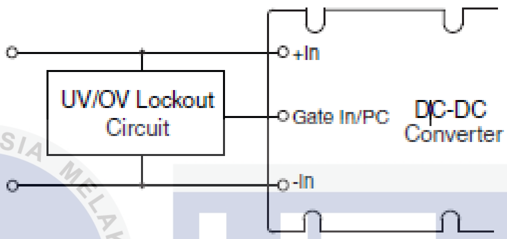

Figure 2.2: Under voltage/overvoltage lockout block diagram [8].

Hence, the Figure 2.3 (next page) shows the under voltage and overvoltage lockout circuit schematic diagram. When an overvoltage occurs, then the second regulator U_2will shunt the references of $U_1$to disable the module. Then R_9 is added to provide current to the cathode U_2, when it is off so that D_3 can isolate it from the under voltage circuit divider. Z_2 act as clamp to prevent damage to U_2.

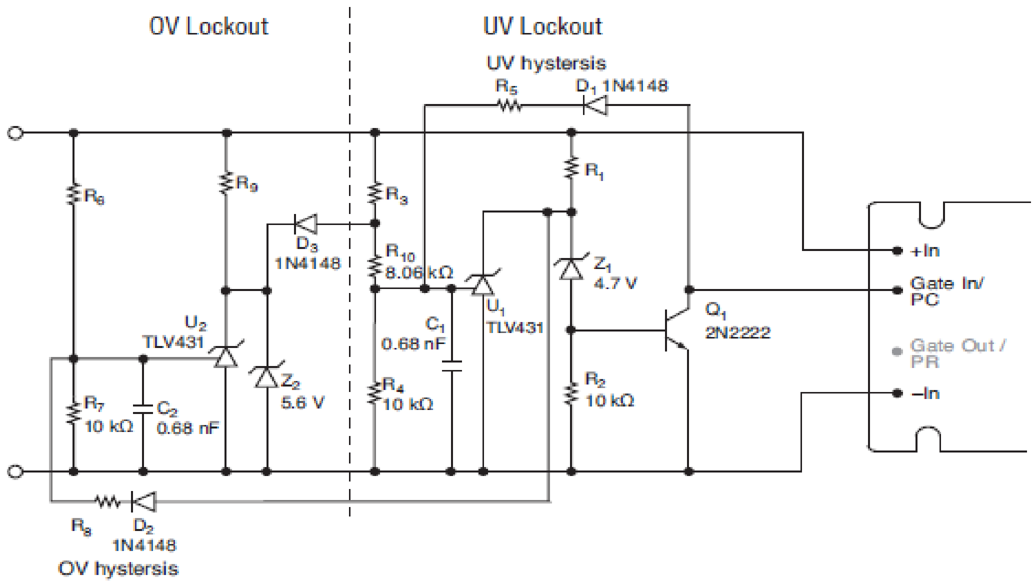

Figure 2.3: Under voltage/overvoltage lockout circuit schematic [8].

2.7.2 Voltage Measurement with A PIC Microcontroller [10].

Voltage Measurement with a PIC Microcontroller was the designed circuit on how to measure a voltage by using a PIC18F4520 microcontroller. In addition, it also included the code needed to measure a voltage, explaining how to correct power and how this circuit works.

PIC184520 is 40pin microchip with multiple function and applications. This PIC microchip is able to read analogue voltage and convert it into digital. This project involved how to create a PIC program and load from the computer to the microcontroller. Besides that, there are other components involved, such as RJ11 jack is shown in Figure 2.4 (below) to show that the connection to allow communication with computer. The method of wiring a PIC has been shown, how to connect an external clock to a PIC and where to connect a voltage source to read its value also included in this paper task [10].

Figure 2.4: RJ11 jack [10].

The pin numbers 1, 4 and 5 are connected to PIC microchip, pin 2 is connected to VDD and pin 3 will be grounded. The pin 6 is not used in this task. Hence, the circuit was set up as Figure 2.5 (next page).

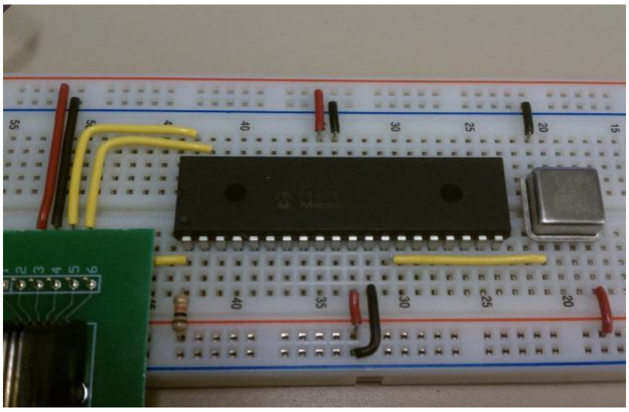

Figure 2.5: Complete circuit voltage measurement [10].

The programming was used Micro C programming to setting the value of voltage needed. Microcontroller also can calculate an analogue value from the digital result of the ADC measurement, but additional code programming is required [10].

2.7.3 Undervoltage and Overvoltage Relay.

A relay is a device that operated as switch application. Relay normally used an electromagnet to mechanistic method to operate a switch and the basic operating relay used such as solid state relay, etc. The function of relay is used to control a circuit from low power signal where the relay is connected between complete electrical isolation and controlled circuit.

Of real industries, there are many types of relay that used to monitor voltage such as under voltage relay, overvoltage relay, current relay, etc. Under voltage relay will sense any voltage in line drops below rated value. The under voltage relay protect loads against a voltage drop in the system by trip the circuit breaker. The base diagram for under voltage relay is shown in Figure 2.6 below.

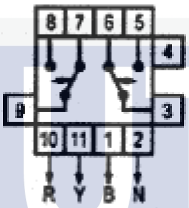

Figure 2.6: Under Voltage Relay Base Diagram [11].

Overvoltage relay operates when the voltage produce in the system has risen from a predetermined value. The overvoltage relay connected to the transformer or a device that transfer electrical in the circuit. The relay is set up to operate at an over voltage present. When the overvoltage relay is activated, then contacts trip or open a circuit breaker.

2.7.4 Voltage Regulator Circuit Design [12].

The voltage regulator is the intelligent part of an excitation control system. Its main function is to keep the terminal voltage of an electrical generator at a constant reference value, independently on loads being connected on or off the generator.

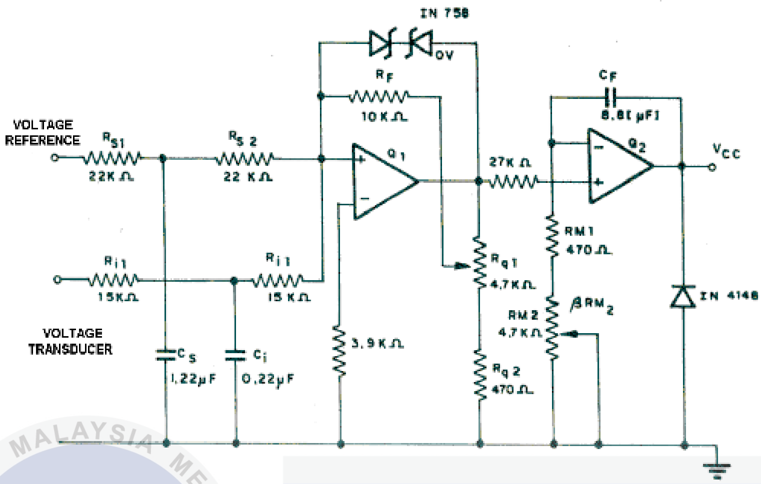

Figure 2.7 Circuit with filters and regulators [12].

Figure 2.7 above shows the design circuit for sense voltage that used filters and regulator concept. The filters in the reference channel and in the voltage feedback path have the 'T' configuration. This design circuit used method Modulus Optimum to regulate the input parameter. An analogue regulator with proportional channel (gain) and an integral channel (time constant) will be used, and this parameter was set at the appropriate potentiometers.

2.7.5 Voltage Divider Application.

The output voltage normally will produced by varying the input voltage. Resistive sensors are sensor which is act as variable resistors. Different input field to the sensor will cause it to change the resistance value. Each voltage divider generally has a nominal resistance, which is its resistance value for zero input. It also offers a resistance range, with a minimum and the maximum resistance value, representing the resistance at minimum and maximum input.

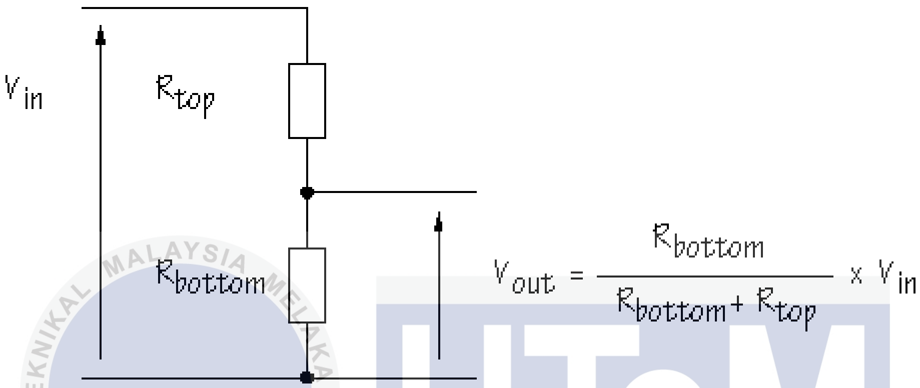

Figure 2.8 Potential Divider Circuits [13]

Hence, the process of converting a resistance to a voltage will be used as in the circuit as shown in Figure 2.8 above. A voltage divider uses two resistors in series to divide the input voltage by the ratio of the resistances. The formula to get the output voltage was also shown in the figure above. In order to get different output voltage with constant value input, one of the resistors in the circuit can be replaced with a variable resistance, then the output voltage is proportional to the change in resistance of the variable resistor.

The voltage divider circuit can reduce the input voltage based on the ratio of the resistors. Sometime cases that, the sensor will produce an output voltage which is outside the range of voltages which can be read by an analog-to-digital converter (ADC). So, this problem can reduce by use a voltage divider to reduce the voltage. For example, if the sensor voltage divider produces a voltage in the range of 0 to 20V, but the analog-to-digital converter requires a voltage in the range of 0 to 5V. Hence the value of resistor divider can be determined to give the ratio of 5/10.

$$\frac{R_2}{R_1 + R_2} = \frac{5}{20}$$

After simplifying it,

$$R_1 = R_2 \times 3$$

Hence, from equation above the value of resistor for R_1 must be set three times from R_2 to get the output requirement.

2.7.6 Rectifier Circuit Design [14].

Half wave rectifier

The half wave rectifier is the circuit design to convert a 12 volt AC signal into 5 volt DC power supply. The process known as rectification which is the input voltage was step down using the voltage regulator method. The half wave rectifier is the simplest possible circuit for converting AC into DC. The circuit consists of a single diode that only allows current to flow in one direction. As shown in the Figure 2.9 below, AC power sourced was connected to the primary side of the transformer and the secondary terminal of the transformer was connected to the diode and resistor in series.

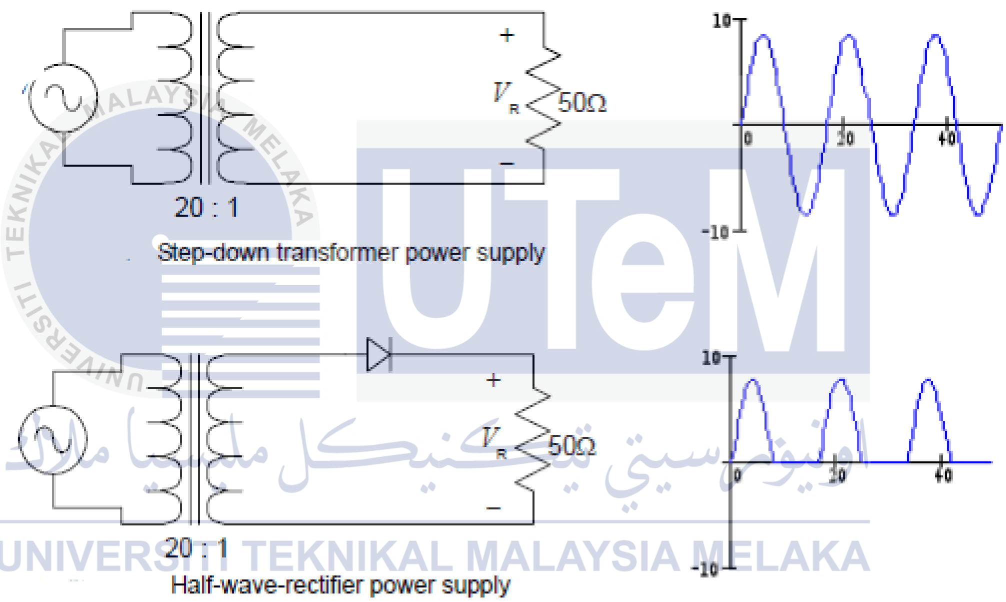

Figure 2.9 Half Wave Rectifiers [14].

The circuit operation is fully functioning when Vac in the positive cycle, then a positive voltage is produced on the secondary side of the transformer. The voltage forward biased is produced by the diode and the current will flow through resistance. When Vac is in a negative cycle, the secondary diode also has a negative voltage. The diode is then reversed biased and ceases to pass the current. As a result, the voltage drop overload is zero. As a conclusion, the half wave rectifier circuit will have only the positive side if the sinusoidal cycle is present and the negative side has been clamped off by the diode.

RC Half Wave Rectifier

For the half wave rectifier we found that the output is always positive. But unfortunately, the positive waveform is rather bumpy and we need to use a capacitor to smooth out these bumps. So, in the circuit application, we have to add a large capacitor in parallel with the load resistance. The capacitor can store energy during the times when the voltage over the load is positive. When the load voltage is clamped to zero, the capacitor then slowly releases its stored energy, thereby smoothing out the voltage over the load. Then, the signal of the waveform and circuit of half wave rectifier is shown in Figure 2.10 below.

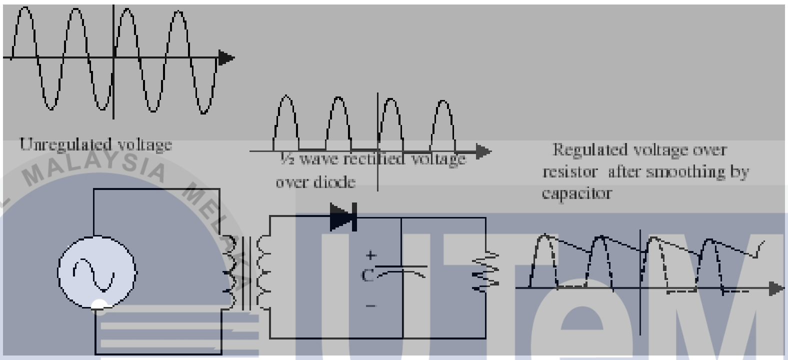

Figure 2.10 Half-wave rectifiers with a capacitor.

Full Wave Rectifier

As shown in Figure 2.11 below, the full wave rectifier is the best circuit design of rectifier method because it would use the power on both sides of the waveform. Compared to half wave rectifier which has had the virtue of simplicity, is lacks efficiency because the circuit design throwing away the negative side of the waveform. The left side of full wave full wave rectifier consists of the full wave bridge. The part of the circuit connected to four specially arranged diodes. There will be a small ripple on full wave rectified but the value is too small even it won't be able to notice on the waveform by using the oscilloscope.

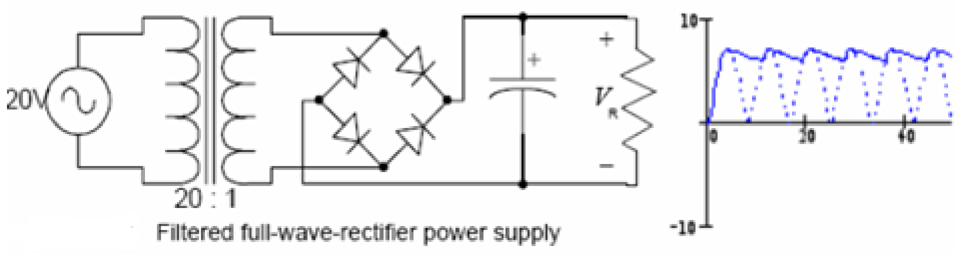

Figure 2.11 Full Wave Rectifier [14]

2.7 Summary of Literature Review

All the information regarding with voltage sensor and remote terminal unit has been studied and summarized in this chapter. Distribution station is the final stage in delivering the electricity to consumers. Typically, the network would include medium voltage, high voltage, power lines, substations, and pole-mounted transformers. The characteristics of power supply given to customers must be within safety range with specific criteria. Variable that need to be considered in the distribution system is nominal voltage, tolerance (+/-5%), frequency (basically 50-60Hz), phase configuration (single phase, two phases or three phases), power factor, earth system etc.

Then, the process design for voltage sensor has been studied to gain knowledge in designing a new voltage sensor for this final year project. After going through all the design from others researcher, it can be summarized that the suitable method to use to design voltage sensor for this final year project is using voltage divider circuit design. The circuit design is easy to understand where the circuit use diode as rectification process, resistance to reduce the voltage and the capacitor to reduce voltage ripples.

Besides that, the programming part has been decided to use C language programming to write in fault range selection. The basic knowledge in C language programming will help to describe the range of under voltage and overvoltage fault. Relevant design using PIC has been summarized in this chapter in order to increase more how to program voltage fault.

CHAPTER 3

PROJECT METHODOLOGY

3.1 Introduction

This chapter will cover the detail explanation of methodology that will be used to make this project complete and working well. Many methodologies or findings from this field mainly generated into journal for others to take advantage and improve as upcoming studies. In this project, the methodology is divided into two parts, the hardware and software development.

The first step in this project is preferred to have a conversation with my supervisor to brainstorming the idea for research and development of this project. In addition, students should always consult consistently every week in order to facilitate project claimable and can get guidance in completing their projects. Therefore, students will have a better understanding and to identify clearly the objective of the project.

The second method to be implemented is the study of literature, which is the step to gather all the information regarding to project. This is stages where to study and research on each data and information obtained by reference of variety sources such as reference books, IEEE journals, proceedings paper, broaches and also information from the internet related to the project.

Based on the research references, it will facilitate the management and implementation of this project. The background research along with a literature review performed and documented on the theoretical concepts used to complete this project. The analysis also includes the use of existing materials, market research, and cost comparison, different type of circuit, connections and compatibility.

Since this project is to design fault detection sensor, the first step is to study the designing process of the voltage sensor. After that is to write programs by using Micro C software. The Micro C programming will be programed to PIC microchip (SK40C) so that it can read under voltage and overvoltage condition when AC voltage is fed to voltage sensor.

For the hardware path would be studied and then the hardware interfacing for this project is built and assembled. Then, action to take is to design voltage sensor and write programs to circuit PIC microchip in order to read voltage fault. After building the hardware interfacing, the overall system will be tested. If the result does not achieve the objective, then checked again all the programming and interfacing.

3.2 Project Planning

3.2.1 Flow of Project

The Figure 3.1 below show the flow process of this final year project.

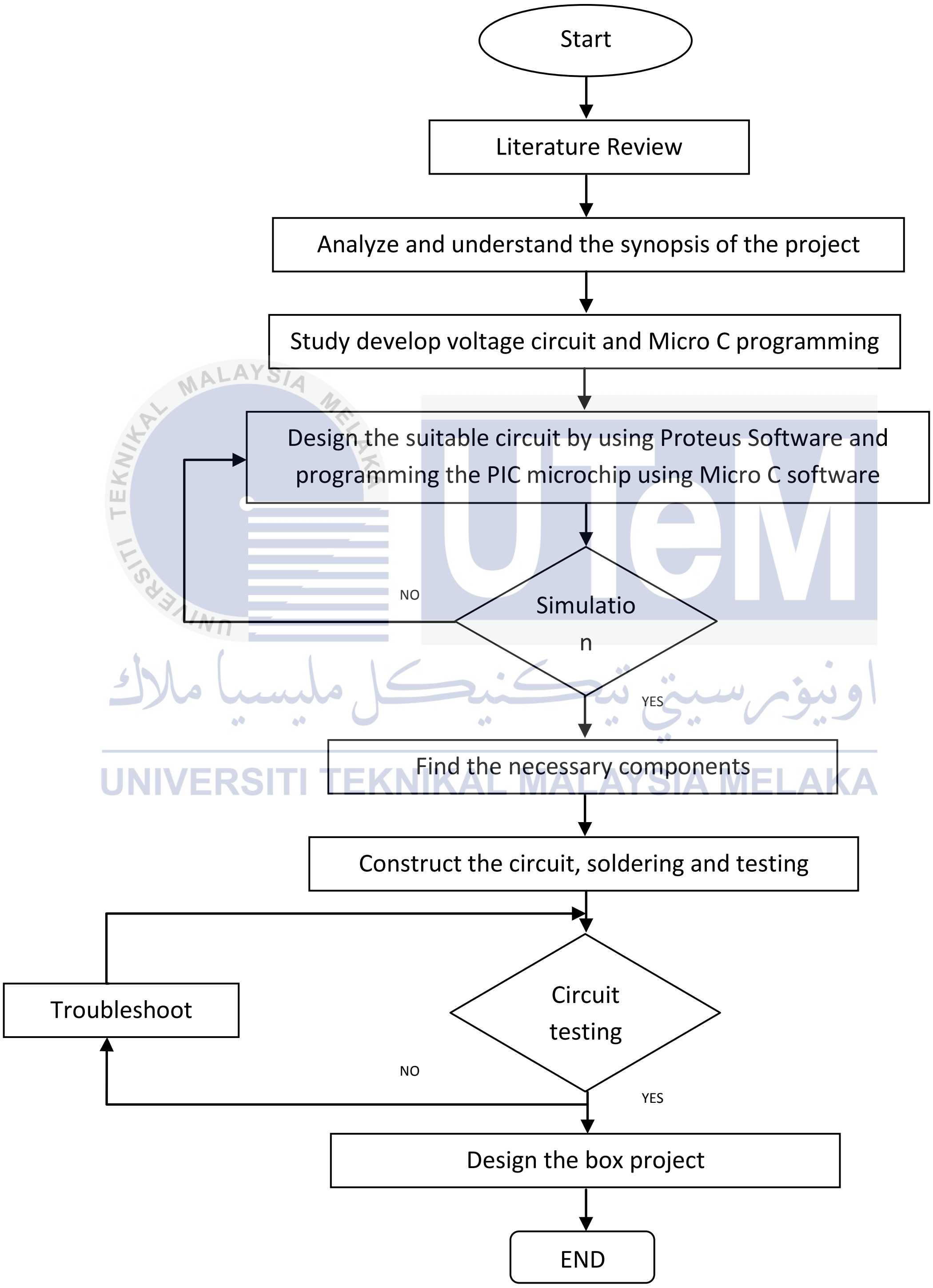

Figure 3.1: Flow chart of project.

3.2.2 Sequence of Circuit Operation

The figure 3.2 below show the flow chart operation of fault detection designed circuit.

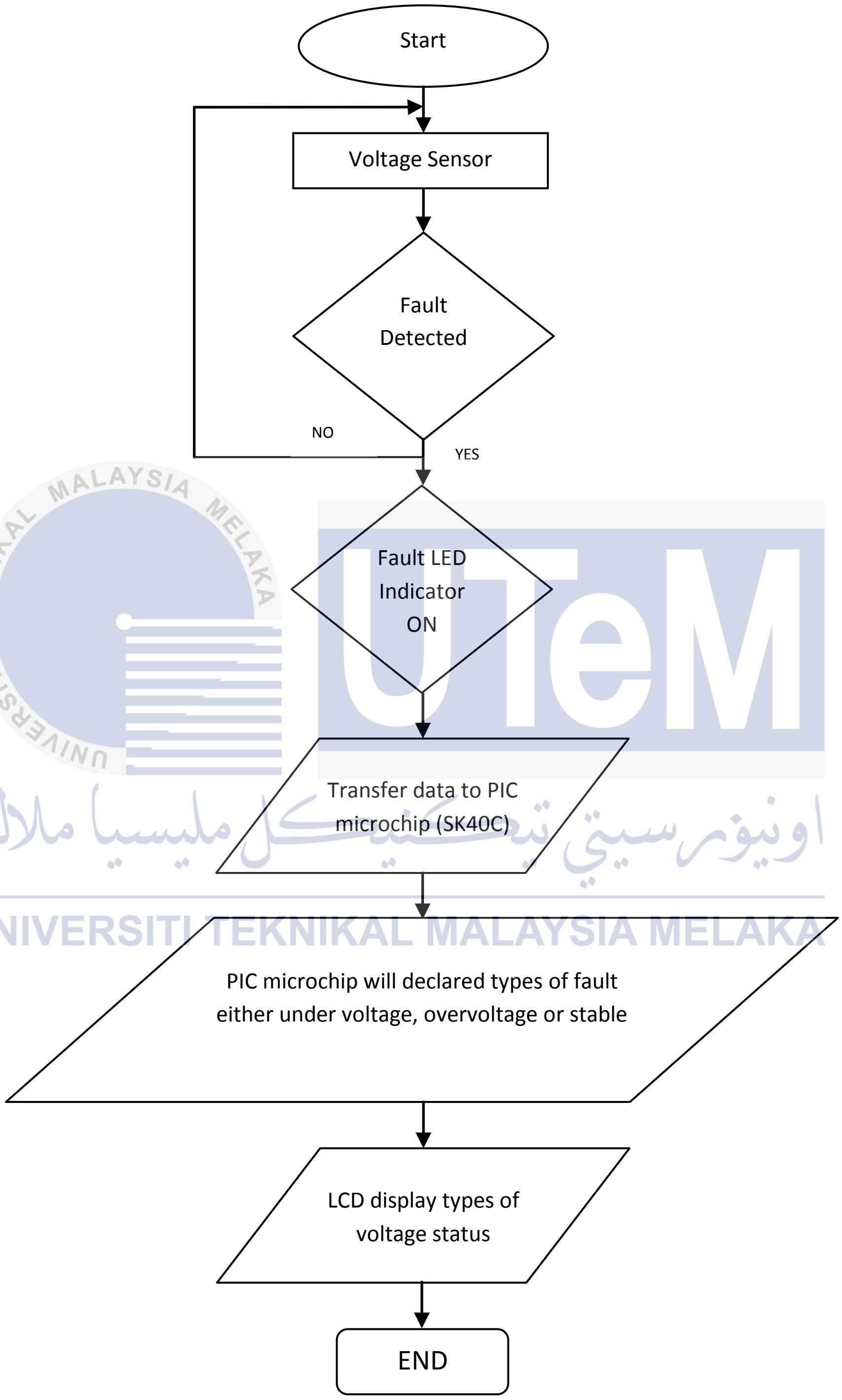

Figure 3.2: Flowchart for sequence project.

3.3 System Design

3.3.1 Overview

The variable transformer is connected to AC power supply (230V) and the output of variable transformer is connected to the voltage sensor. As the input voltage Vac supply to the voltage sensor, the voltage is stepped down by 1K ohm/10Watts resistance before feeding to the diode bridge to get the first step of DC voltage. The output of voltage sensor will be produced within 0 to 5Vdc and feed into the ADC pin of the microcontroller for monitoring the voltage of the transformer.

After converting the AC input supply to positive cycle by using a full wave rectifier method. The circuit will be connected in series of resistor and parallel with the capacitor to get DC output. Then the output from this will be connected to microcontroller ADC for monitoring. The LCD is used to display the voltage condition, which is when the variable transformer is varied to specific voltage the microcontroller will definite type of fault and display the fault condition and voltage value. Hence the block diagram for the faulty system design is shown in the Figure 3.3 below.

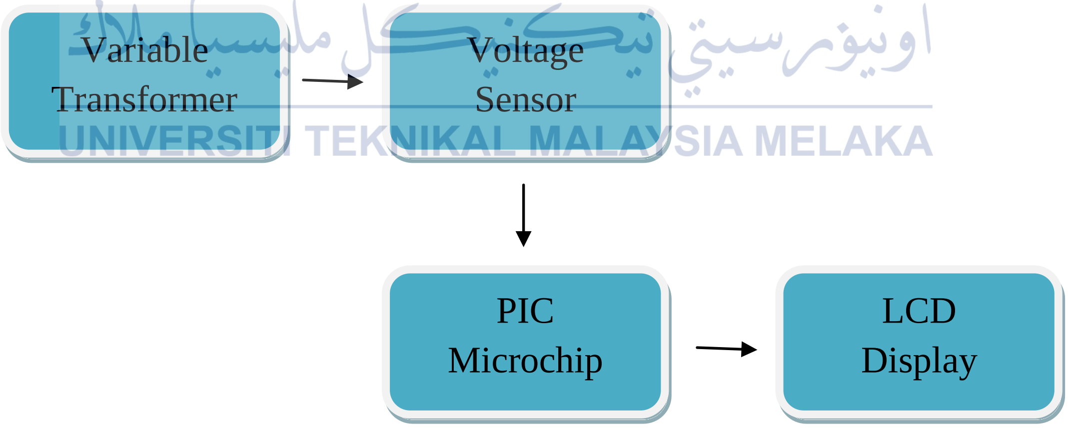

Figure 3.3 Block Diagram of the system.

3.4 Component Details

3.4.1 Variable Transformers

Variable transformer is an iron-core transformer having provisions for varying its output voltage over a limited range or continuously from zero to maximum output voltage, generally by means of a contact arm moving along exposed turns of the secondary winding. In this final year project, the variable transformers can be varied from 0 to 280VAC. Hence, the variable transformer that is shown in Figure 3.4 below will be used as an input to voltage sensor.

Figure 3.4 Variable Transformer

3.4.2 Voltage Sensor Circuit Designed

In this project, the voltage sensor is designed without using the transformer to step down the input voltage. Meanwhile, we are using the resistance to slowly step down the input voltage. Before the input voltage is fed into the rectification process the voltage will go the load of 1K ohm/10Watts. The reason why using the resistance of 10watts power because the load is connected directly to the high voltage input (0 to 230V). Several test has been conducted and the result is concluded by using 10watts resistance as the primary load to the input voltage.

Besides that, the voltage sensor also designed with operational amplifier circuit. The circuit is designed based on comparator op-amp method which means the output of DC voltage will be act as input to the op-amp comparator circuit to differentiate low voltage and high voltage. The condition means when the voltage exceeds more than 230V, then the lamp of high voltage will be turned on. Meanwhile, when the voltage varies from 0 to 230 the low voltage lamp indicator will be turned on. The hardware implementation of voltage is shown in the Figure 3.5 below.

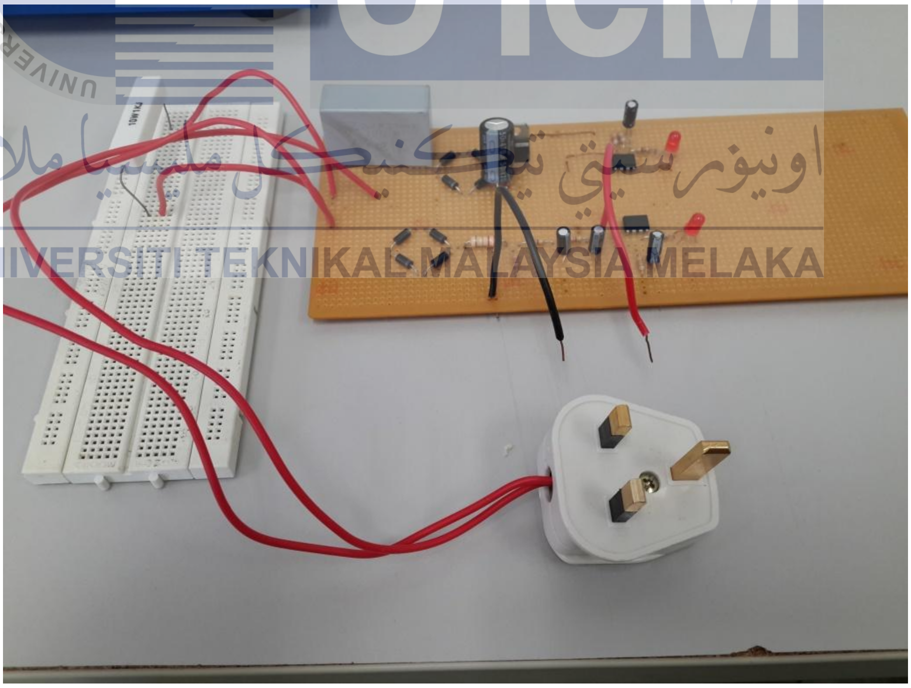

Figure 3.5 Voltage Sensor

3.4.3 Microcontroller (SK40C)

The microcontroller is required to serve the purpose monitoring the transformer information such as temperature, voltage and current through the LCD display, personal computer and triggering the relay when the fault occurs. Modern power networks require faster, more accurate and reliable protective schemes.

Microcontroller-based protection schemes are capable of fulfilling these requirements. They are superior to electromagnetic and static relays. These schemes have more flexibility due to their programmable approach when compared with the static relays which have hardwired circuitry.

Therefore, in order to achieve this task the SK40C microcontroller was chosen because it is another version of 40 pins PIC microcontroller start-up kit and offer an easy to start boarding for the PIC microcontroller user. Hence, all the interfaces must develop manual by user. From this specification, it easier because all the interfacing part can be created to the requirement to achieve objective of this project.

As shown in Figure 3.6 below, the SK40C board comes with basic elements such as 2 programmable push buttons, 1 RESET button, connector of UIC00A/B Programmer (to load programs into PIC), LED indicator, 40 pins IC socket for PIC MCU, UART connector, USB connector and so forth.

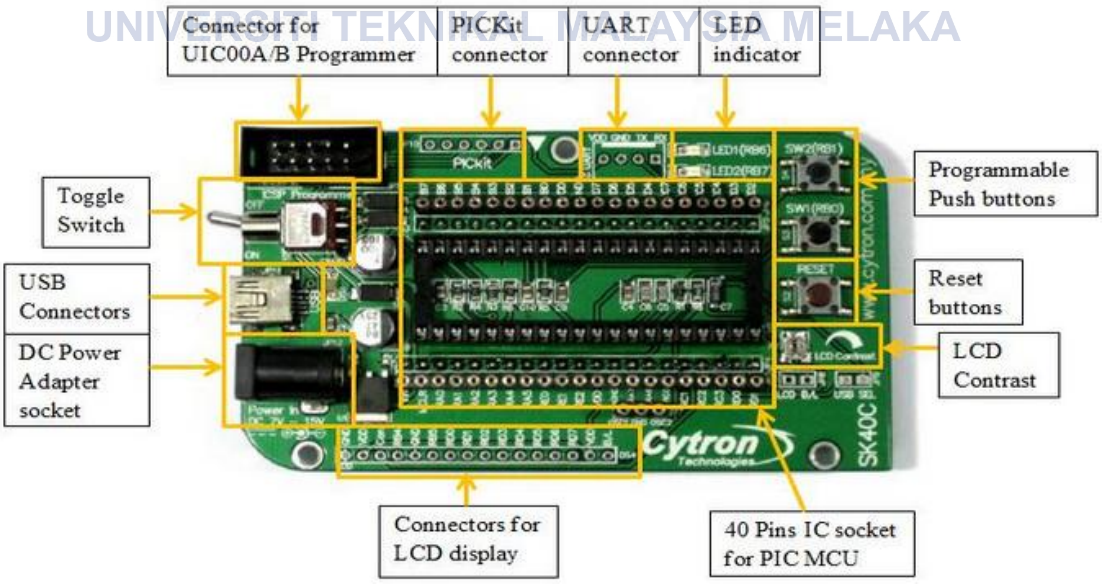

Figure 3.6 SK40C Basic Elements Overview.

3.4.4 LCD Display

LCD (Liquid Crystal Display) screen is display module that would be used in this project to display fault voltage. A 16x2 means it can display 16 characters per line and 2 line column. This is the last stage of the project, where the fault condition will be displayed. This type of LCD is economical, easily programmable, have no limitation of displaying special & custom characters, etc. It also has better contrast and a wider viewing angle. The price is reasonable to student to use as a part of hardware implementation. The model of LCD is shown in Figure 3.7 below.

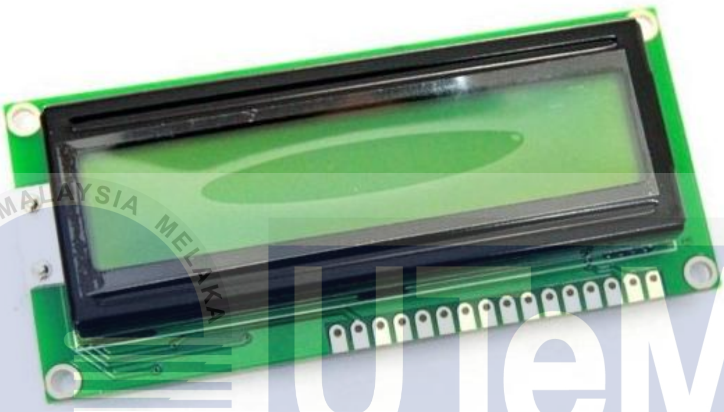

Figure 3.7 LCD (2x16) Green Backlight.

The pin diagram for LCD display has been shown in the Figure 3.8 below. It had 8 pins that will be connected to PIC microchip. In this project, PORTB has been selected as port to be connected to the PORTB PIC microchip.

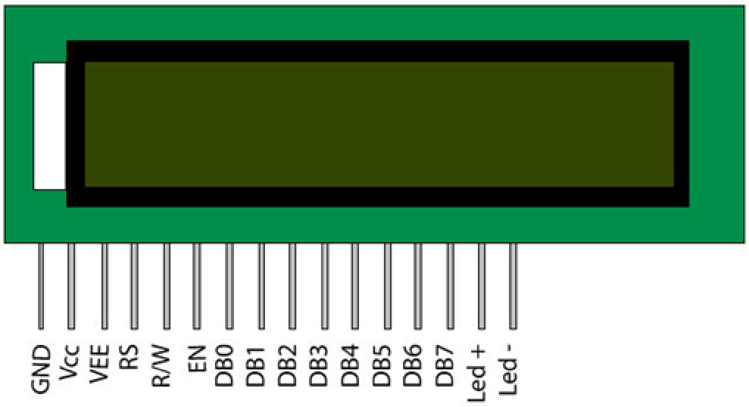

Figure 3.8 Pin Diagram for LCD

The table 3.1 below shows the pin number with its description. The pin 1 selected as ground port, the pin 2 will be a supply of 5V DC voltage, the pin 3 is for contrast adjustment, pin 4 act as command register, pin 5 is function to write or read the data to/from the register, pin 6 has enabled the function, pin 7 to pin 14 is 8-bits data, and lastly pin 15 and pin 16 is backlight supply and backlight ground connector.

Table 3.1 Pin Description for LCD

Pin No	Function	Name
1	Ground (0)	Ground
2	Supply voltage 5V	V_{cc}
3	Contrast adjustment (through a variable resistor)	V_{EE}
4	Selects command register when low and data register when high	Register Select
5	Low to write to the register; high to read from the register	Read/Write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bits data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V_{cc} (5V)	Led+
16	Backlight Ground (0V)	Led-

3.4.5 LM393 Comparator

The LM393 consists of two independent precision voltage comparators with an offset voltage specification as low as 2mV for two comparators to operate from single power supply. The LM393 doesn’t function only as limit comparators, its application area also includes a simple analog to digital converters, pulse, square wave and time delay generators, wide range VCO, MOS clock timers, multi vibrators and high voltage digital logic gate.

LM393 Features:

- Wide supply
  - Voltage ranges: 2.0V to 36V
  - Single or dual supplies: ±1. 0V to ±18V
- Very low supply current drain (0.4 mA) - independent of supply voltage
- Low input biasing current: 25 nA
- Low input offset current: ±5 nA
- Maximum offset voltage: ±3 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Low output saturation voltage: 250 mV at 4 mA
- Output voltage compatible with TTL, DTL, ECL, MOS and CMOS logic systems.

3.4.6 Other Components.

The voltage sensor circuit was designed safely so that the circuit will run without any damage to another component. Selecting the component also an important part of this project based on the input supply. Since the input supply is 230Vac, then the component must have durability to enhance to the power of the voltage supply. All the components used in voltage sensor circuit listed in the Table 3.2 below:

Table 3.2 List of Other Components

Components	Details
Resistor	1Kohm/10Watts, 220Kohm/1Watts, 47Kohm/0.5Watts, 2.55Kohm/0.5Watts, 82Kohm/0.5Watts and 65Kohm/0.5Watts.
Capacitor	220uF, 1.0uF and 0.1uF
Diode	400V Diode Bridge 2Watts
Zener	1N4744 Diode Zener 15V
Regulator	78L05 Regulator 5V
LED	Red

3.5 Software Programming

The software design is the most important role in this final year project, the system cannot be fully approved without display the fault condition through LCD display by program the PIC microchip. An algorithm needs to be developed to enable the PIC microchip to read the input and respond accordingly. The programming language selected for this project is the C program by Micro C software. The C program will interface with the voltage sensor that feed to the ADC PIC microchip SK40C. With the software programmed into it, PIC16F877 will act as the brain of the whole project to monitoring the voltage condition. The flow chart diagram was developed will give an initial description of the software system and it is shown on Figure 3.9 (next page).

3.5.1 Flow Chart of Software Programming

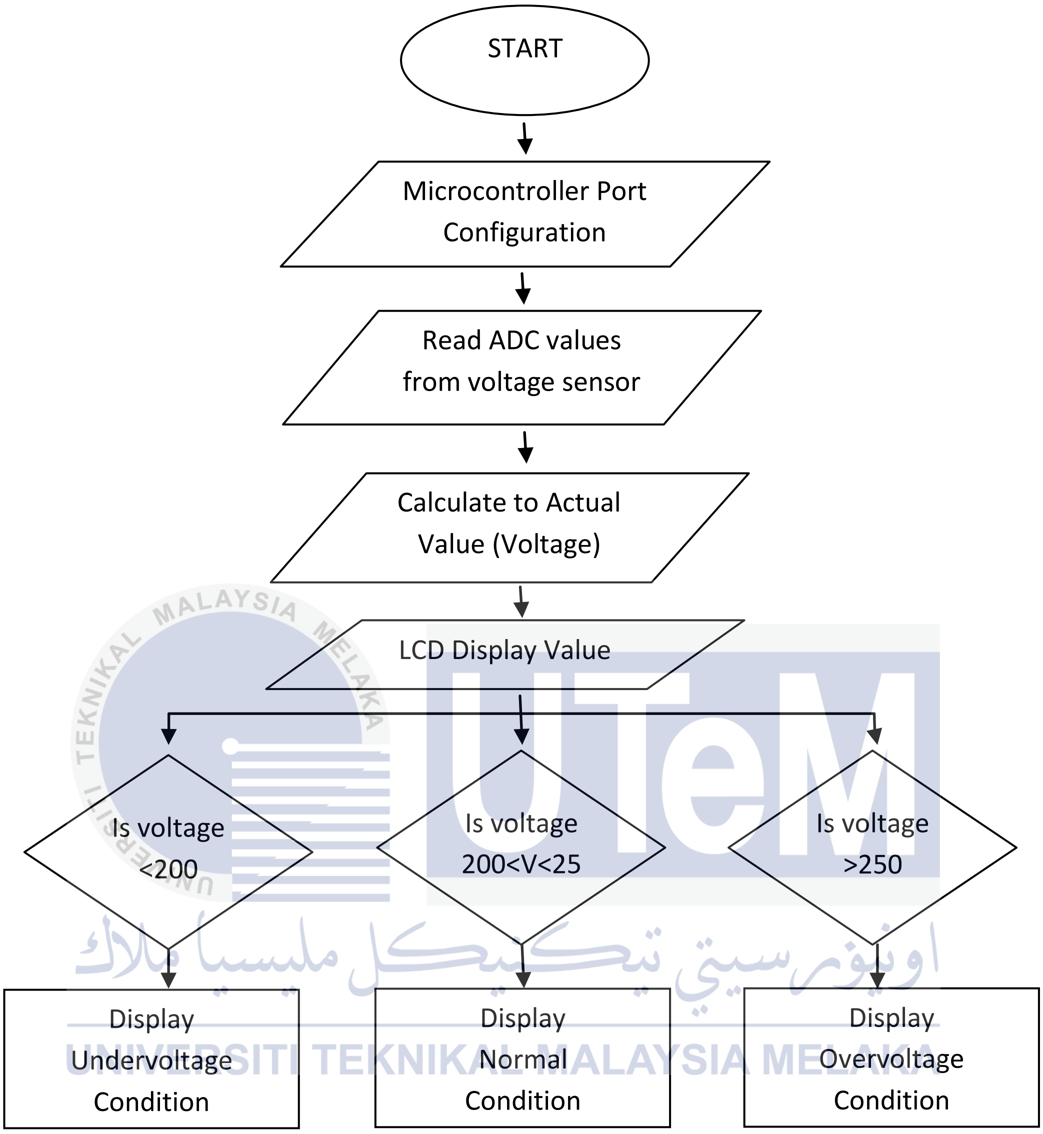

Figure 3.9 Flowchart description of the software system

The flow chart in Figure 3.9 above shows the initial description of the system program code. The first step is to initialize and read the ADC input that send by voltage sensor and display using the LCD_OUT command to the LCD display. The PIC microchip will continuously read the input voltage and check whether the input voltage is in normal, under voltage or overvoltage.

3.6 Simulation Design

3.6.1 Schematic Diagram

3.6.1.1 Complete Schematic Voltage Sensor Circuit

As discussed before, the project complete hardware implementation included variable transformer, voltage sensor, SK40C and LCD display. The voltage sensor circuit consist of regulator part to produce 5V and 15V, operational amplifier comparator and voltage divider circuit.

The first parts of voltage sensor circuit have resistance of 1Kohm/10Watts and is used for sensing the input voltage form variable transformer with a voltage rating of 0 to 300Vac. After that, the diode bridge will act as rectification process to eliminate the negative cycle of Vac input voltage. Then, the pure DC will go directly to the PIC microchip SK40C ADC for monitoring the input voltage.

The PIC microchip SK40C will send the monitored data to the LCD display and define the condition of input voltage. While monitoring the parameters, whenever a fault occurs which might be high voltage or low voltage, the microcontroller will display the fault condition at LCD display together with voltage value. Hence the schematic diagram for voltage sensor is shown in Figure 3.10 below.

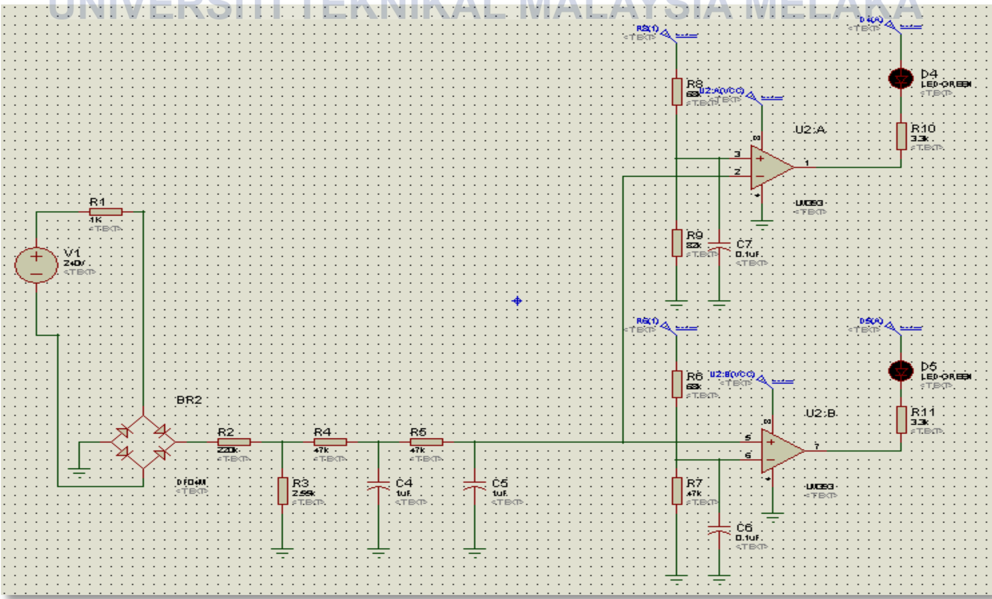

Figure 3.10 Complete Schematic Voltage Sensor Circuit

3.6.1.2 Complete PIC16F877 Simulation

Before the implementation the real hardware, a simulation circuit must be conducted to do pre-test of our project. As shown in the Figure 3.11 below, this is the circuit to simulate SK40C circuit by using Proteus software. The PIC16F788 was placed in the layout and connected to the LCD display. The input of DC voltage 0 to 5V was set up and connected to ADC microchip and the input was variable by using variable resistor. Port B was selected as the connection between the PIC and LCD display.

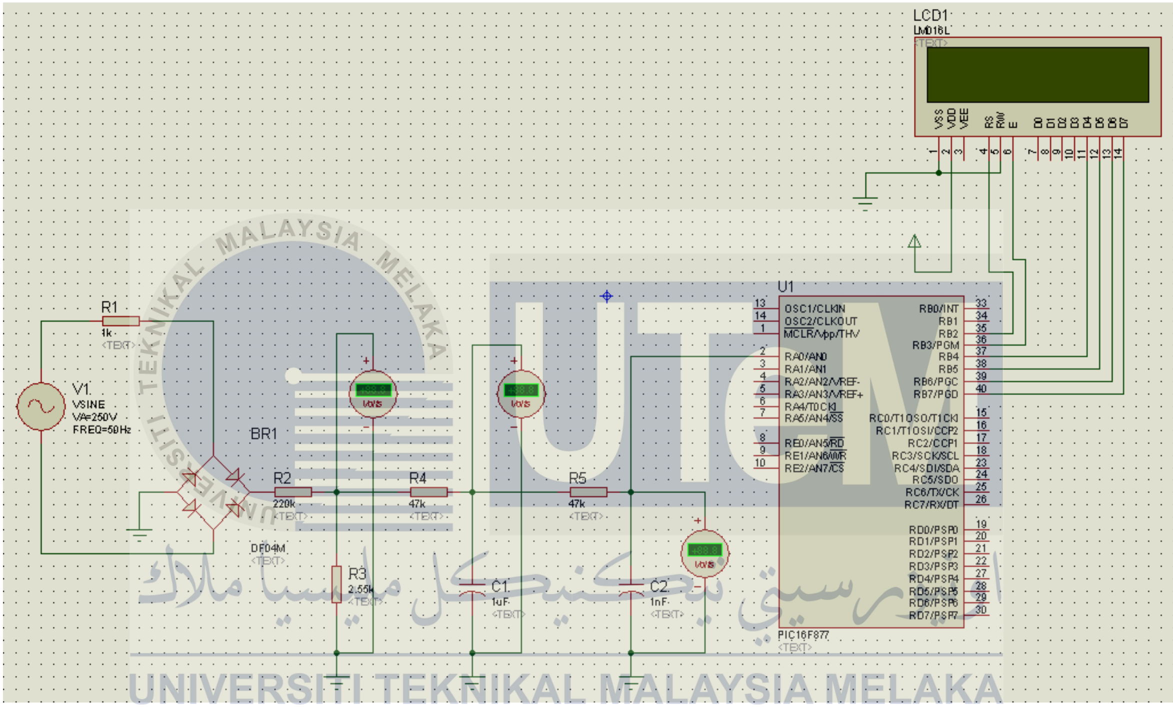

Figure 3.11 Complete PIC Microcontroller Circuit.

3.7 Hardware Circuit Implementation.

3.7.1 Voltage Sensor Circuit Implementation

At first, testing on broad board was done and the working process of the circuit was properly tested, problems were troubleshot and rectified. During testing circuit on broad board, there were several problems encountered such as trip circuit breaker, component burn and the output voltage failed to record. Donut board was used to place the components, which is soldered between each component with less wired that gives out the physical and electrical connections. The hardware implementation of the voltage sensor circuit then shown in the Figure3.12 below.

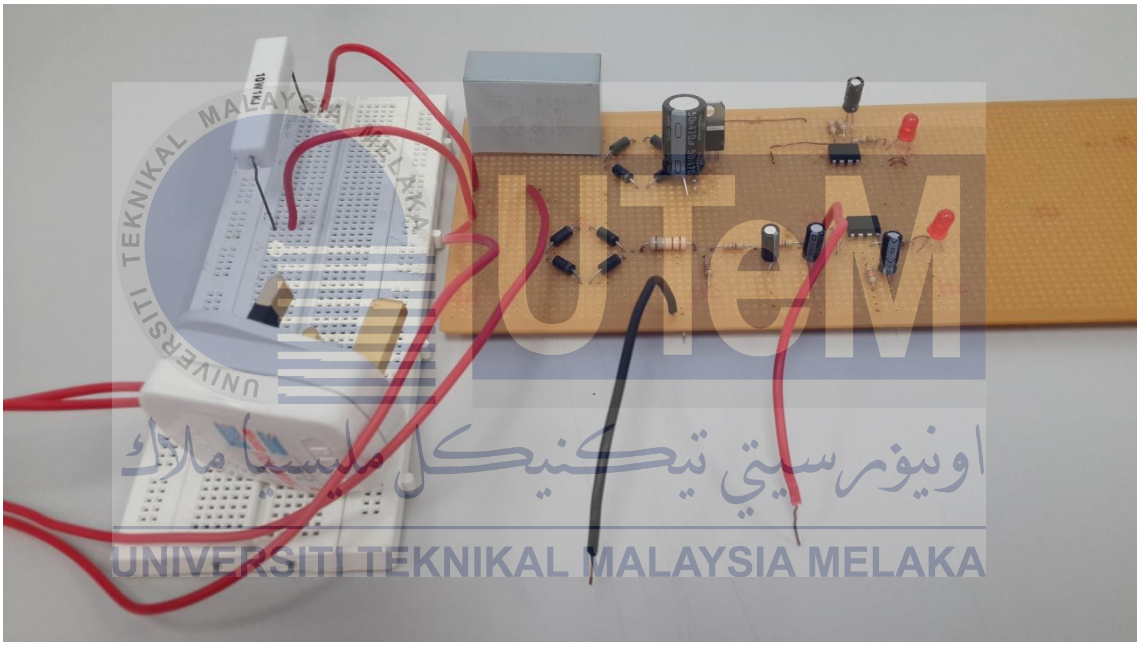

Figure 3.12 Voltage Sensor Circuit (Hardware).

3.7.2 Soldering

After gathering all the components, the next step is the soldering process. Soldering is a process that two metal items are joined together by melting tin metal. Soldering attentions need to be taken into consideration when solder the component to the board. Hand soldering is the traditional method used in this project which basically used for prototypes and small production circuit. The Figure 3.13 below show the soldering picture of the voltage sensor.

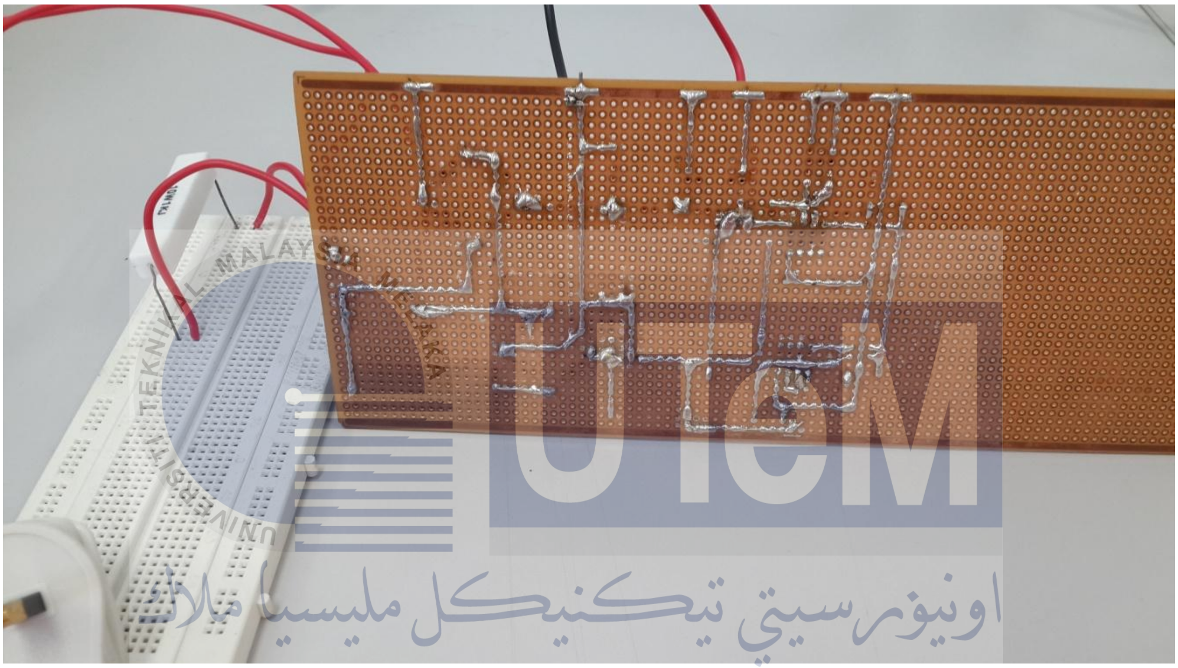

Figure 3.13 Soldering Implementation

3.8 Programming Development.

3.8.1 Programming in Micro C for PIC16F788

SK40C microcontroller acts as the brain of the project. It will monitor the voltage input from voltage sensor and display the parameters on the LCD display. Whenever a fault occurs, it automatically detects the fault error that has been set up in programming. In the industry, when a fault occurs, it will automatically send a trip signal to the relay and thereby protecting the transformer from burning. Through the programming process, an algorithm has been developed which makes the SK40C microcontroller reads the input analogue signals and responds consequently.

3.8.2 Brief of Initialization Ports and Pins.

The main program is divided into multiple parts, it included the parts definition of ports and pins, initialization of ADC and the configuration of LCD display. The input and output pins of SK40C microcontroller is important to declare and commonly used peripherals. The coding will permit SK40C pins to be used as input or outputs based on the task at hand for monitoring and controlling devices. In this project PORTA is used for analogue digital conversion and PORT B used as interfacing with LCD display. The basic programming to define port used in SK40C microcontroller shown in the Figure 3.14 below.


```
// LCD module connections
sbit LCD_RS at RB2_bit;
sbit LCD_EN at RB3_bit;
sbit LCD_D4 at RB4_bit;
sbit LCD_D5 at RB5_bit;
sbit LCD_D6 at RB6_bit;
sbit LCD_D7 at RB7_bit;

sbit LCD_RS_Direction at TRISB2_bit;
sbit LCD_EN_Direction at TRISB3_bit;
sbit LCD_D4_Direction at TRISB4_bit;
sbit LCD_D5_Direction at TRISB5_bit;
sbit LCD_D6_Direction at TRISB6_bit;
sbit LCD_D7_Direction at TRISB7_bit;
// End LCD module connections
```

Figure 3.14 Configure Input and Output Port.

The program begins by defining for LCD display, which is PORTB.4, PORTB5, PORTB6, PORTB7, RS connected to PORTB2 and EN connected to PORTB3 respectively. Defining the ports gives a clear understanding of the program flow.

3.8.3 Main Programming

The main program is the main brain for the PIC to configure the input voltage, serial port LCD and ADC port. The main program is started by defining the flow of each is the port used as an output port or as an input port. When the port is loaded with 0xFF, it signifies that the port is used as an input port, similarly if the port is loaded with 0x00, this means the port is used as output.

```
void main()
{
      initmain();
      Lcd_Init();                              // Initialize LCD
      Lcd_Cmd(_LCD_CLEAR);                     // Clear display
      Lcd_Cmd(_LCD_CURSOR_OFF);                // Cursor off


{
voltage_adc_peak = 0;

for(count=0;count<2000;count--)
{
  voltage_adc = adc_read(0);
  if(voltage_adc>voltage_adc_peak)
     {
        voltage_adc_peak=voltage_adc;
     }

  if (voltage_adc_peak>0)
     {
        voltage = voltage_adc_peak * 0.00488;
        //voltage = (voltage * 100.0)+0.7;
        voltagerms = voltage*128;
     }

  else
     {
        voltage=0;voltagerms=0;
```

Figure 3.15 Output Voltage Calculation

As seen in figure 3.15 above, the program show to calculate to get the actual value as output to display on LCD. We know that the analogue input is converted to digital value when read by PIC microchip, so the value must be gained to 128 to get the actual value.

```
 floattostr(voltagerms,buffer);
 Lcd_Out(2,1,codetxt_to_ramtxt(Line_Clear));
 Lcd_out(2,1,buffer);
 Lcd_Out(2,16,"V");


if(voltagerms > 250)

    {
       Lcd_Out(1,1,codetxt_to_ramtxt("OVERVOLTAGE!!!  "));
    }

else
if ((voltagerms >=200) && (voltagerms <=250) )

    {
       Lcd_Out(1,1,codetxt_to_ramtxt("NORMAL CONDITION"));
    }

else
if (voltagerms <200)

   {
       Lcd_Out(1,1,codetxt_to_ramtxt("UNDERVOLTAGE!!!"));
   }
```

Figure 3.16 Looping Process of Coding

The main program continued by defining the output voltage from the voltage sensor to the ADC microcontroller port A. The main program continues to loop and check for the condition as seen in figure 3.16 above, whenever the voltage is greater than 250, the microcontroller display 'overvoltage' with voltage value on the LCD and also of the voltage is less than 200 is displayed 'under voltage' on the LCD. Similarly, if the voltage it within 190 and 250 it display normal condition on the LCD.

3.8.4 Proteus 7 Professional

Proteus 7 professional help to simulate everything necessary to develop, test and almost the process design and programming also has been tested with Proteus 7 Professional software before transfer the program to the PIC microchip.

The Proteus software helps to develop of both system hardware and software for this project. The Proteus design enables us to progress in our project more rapid, giving us the ability to make hardware or software changes which reduce hardware and software troubleshooting problems.

The project was built and tested in Proteus just by using the software prototype components without using the physical hardware prototype. Therefore, using Proteus software, the voltage sensor, microcontroller (SK40C) were all developed and tested.

3.9 Project Prototype

As seen in the Figure 3.7 below, the system hardware has been developed with all the features of a microcontroller based on the input of the voltage sensor. The voltage sensor circuit is connected to the variable transformer as input supply. The output of voltage sensor then connected to the microcontroller board (SK40C) for monitoring and decision process. The microcontroller will take action based on the programming and display the voltage condition on the LCD.

Figure 3.17 Project Prototype

3.10 Summary of Project Methodology

All the progress of final year project has been discussed in this chapter. Several steps were planned to achieve the objective of this final year project. Apart from that, the simulation and hardware implementation has briefly described in this chapter. The simulation process was conducted at first before implement the hardware for prototype. The voltage sensor circuit was designed and construct in Proteus 7 Professional to simulate get the simulation data. After that, the programming needed to define a fault condition was developed and test using PIC16F788 in Proteus 7 Professional. Since the simulation has been conducted, the next step is hardware implementation. The circuit for voltage sensor was constructed and the soldering process was successfully conducted. The output of voltage sensor was recorded and ready to attach with microcontroller (SK40C).

CHAPTER 4

RESULT AND DISCUSSION

4.1 Overview

This chapter will discuss the result of this final year project. In this chapter there are two types of results will be discussed. It contains simulation and hardware implementation. The simulation circuit has been made by running the simulation through the Proteus software and get the value of the output voltage sensor. The other simulation circuit is to test the coding for microcontroller to display the input voltage condition.

After a software simulation process successful gets the data, then hardware results begin to record. Multimeter has been used to get the value of the output voltage sensor by varying the value of variable transformer from 0 to 280Vac. After that the coding started to burn into PIC16F788 since the coding has run for building and debugging without error and then attached the PIC to the microcontroller board (SK40C). Since completing the circuit has been made, then the variable transformer was adjustable to selected to value to show that the voltage sensor and microcontroller was able to detect and display the fault condition on the LCD.

4.2 Simulation Results

4.2.1 Voltage Sensor Output

Table 4.1 Simulation Output Voltage

Input Voltage (V)	Output Voltage (V)	Gain
0	0	0
10	0.06	166.6
20	0.13	153.8
30	0.21	142.8
40	0.28	142.8
50	0.35	142.8
60	0.42	142.8
70	0.5	140.0
80	0.57	140.3
90	0.64	140.6
100	0.71	140.8
110	0.79	139.2
120	0.86	139.5
130	0.93	139.7
140	1.01	138.6
150	1.08	138.8
160	1.15	139.1
170	1.22	139.3
180	1.29	139.5
190	1.36	139.7
200	1.44	138.8
210	1.5	140.0
220	1.58	139.2
230	1.65	139.4
240	1.72	139.5
250	1.8	138.8
260	1.87	139.0
270	1.94	139.2
280	2.01	139.3

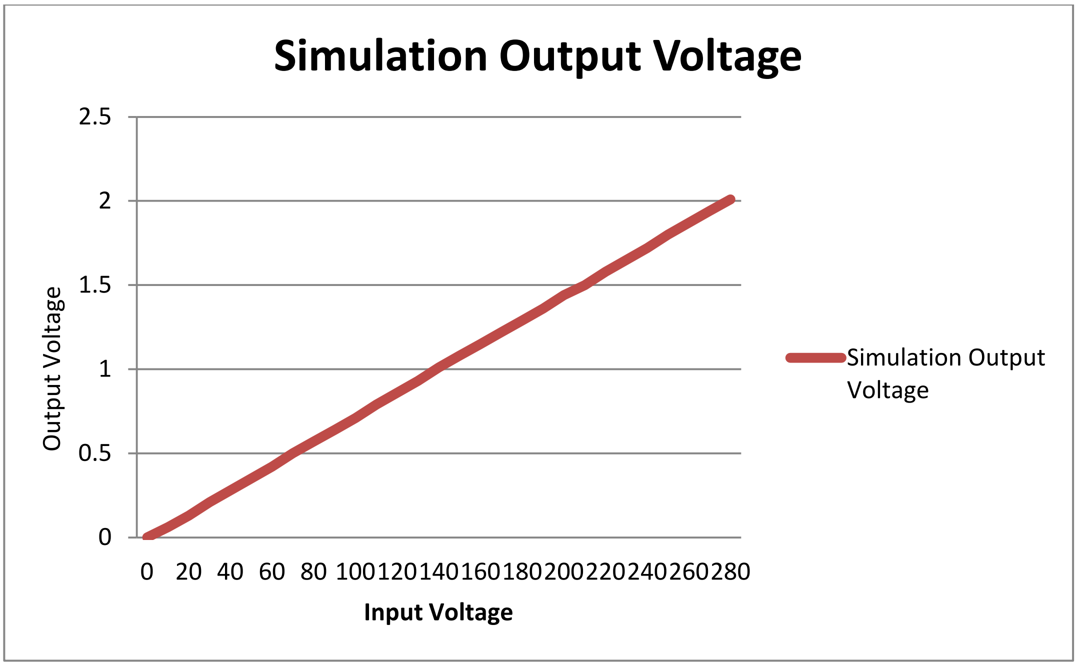

Figure 4.1 Input versus output voltage from simulation.

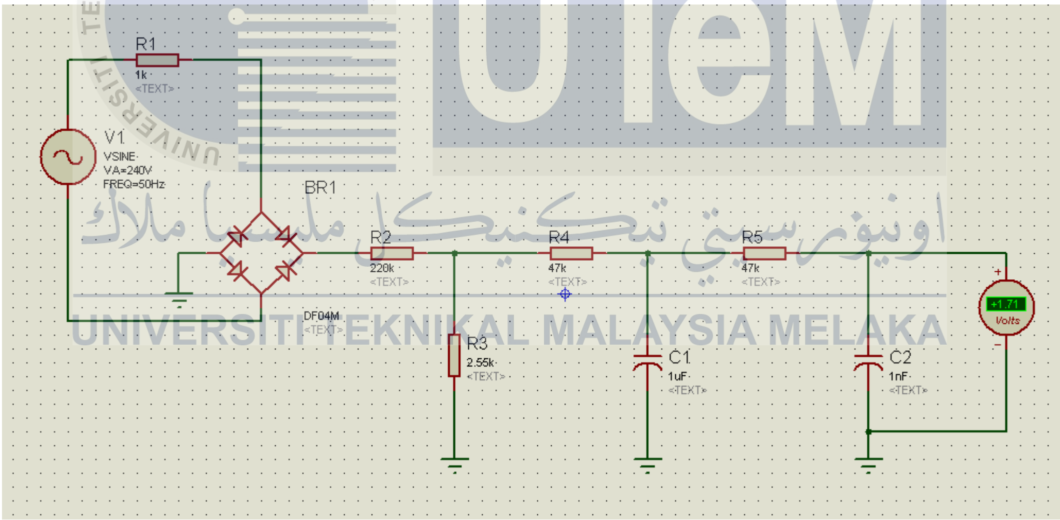

Figure 4.2 Measured Output Voltage.

As seen in table 4.1 (previous page), the data for output voltage sensor circuit was measured from 0 to 280Vac through simulation using Proteus software. The data then were plotted and resulted is the output voltage is linearly proportional to the input voltage (refer Figure 4.1 above). The output voltage was measured at the end of voltage divider after filtering process by capacitor. The schematic for measuring output voltage sensor is shown in Figure 4.2 above.

4.2.2 Simulation from PIC16F788 and LCD.

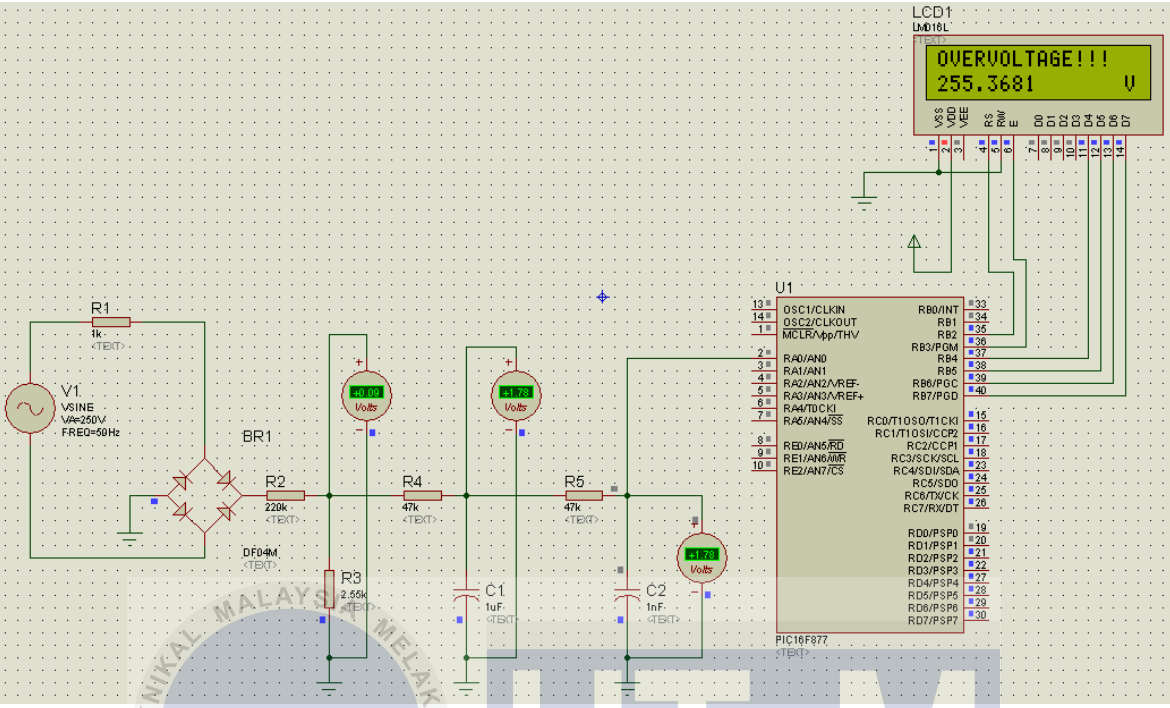

Figure 4.3 Overvoltage Fault Condition

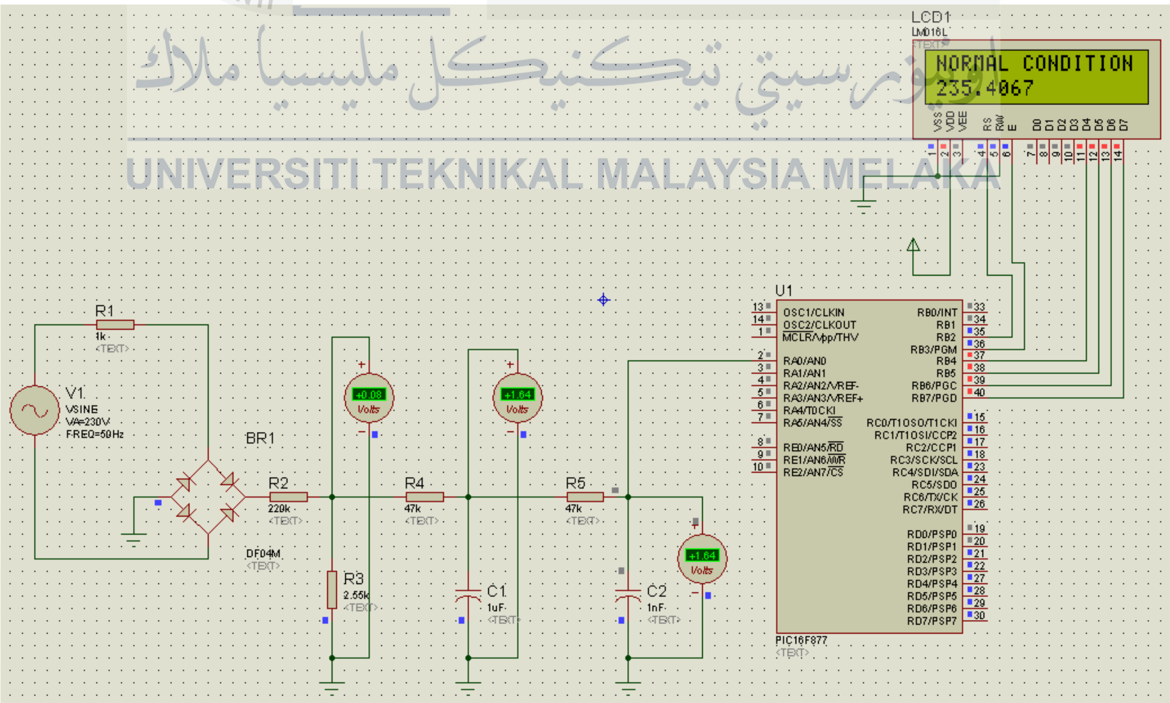

Figure 4.4 Normal Condition

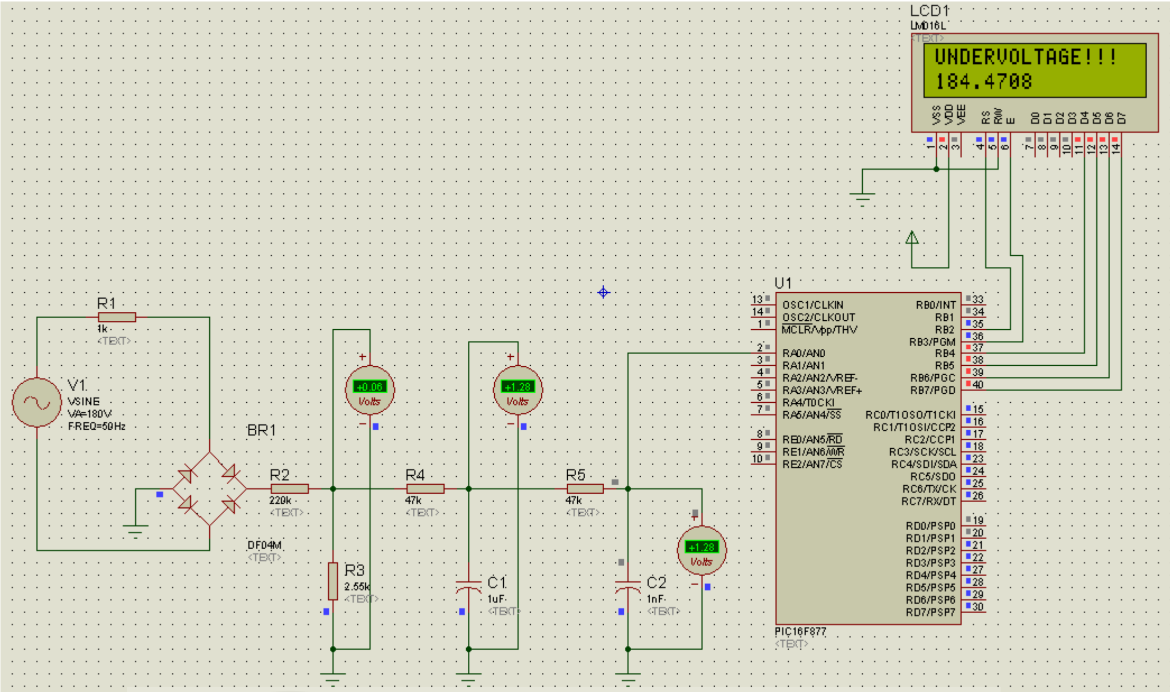

Figure 4.5 Under Voltage Fault Condition

For simulation coding was developed and test using the Proteus software. The programming was added to the PIC16F788 in Proteus to check either the programming can run in PIC microchip. As shown in Figure 4.3 (previous page), when the input voltage in condition exceeds more than 250V then the LCD will display the overvoltage fault condition. Figure 4.4 (previous page) showed when the simulation input voltage within range 200V to 250V then the LCD display normal condition. Lastly, in Figure 4.5 above the LCD display under voltage condition where the input voltage detected less than 200V.

In order to get the real value of voltage, gain must be required to multiple with input of DC voltage. Hence the real value will be displayed on LCD display. The formula on how to calculate stated as in equation below,

$$Gain = \frac{Voltage_{in}}{Voltage_{out}} \tag{1.0}$$

Since the gain of each different voltage input was calculated, the average of gain value will be used in order to multiply with the DC voltage. In simulation result the gain is set at 141.05.

4.3 Hardware Result.

4.3.1 Voltage Sensor Output.

Table 4.2 Hardware Output Voltage.

Input Voltage (V)	Output Voltage (V)	Gain
0	0	0
20	0.569	35.2
40	0.656	60.9
60	0.656	91.5
80	0.805	99.4
100	0.875	114.3
110	0.95	115.8
120	1.015	118.2
130	1.075	120.9
140	1.135	123.3
150	1.185	126.6
160	1.24	129.0
170	1.355	125.4
180	1.375	130.9
190	1.405	135.2
200	1.44	138.8
210	1.475	142.4
220	1.515	145.2
230	1.555	147.9
240	1.605	149.5
250	1.645	151.9
260	1.665	156.2

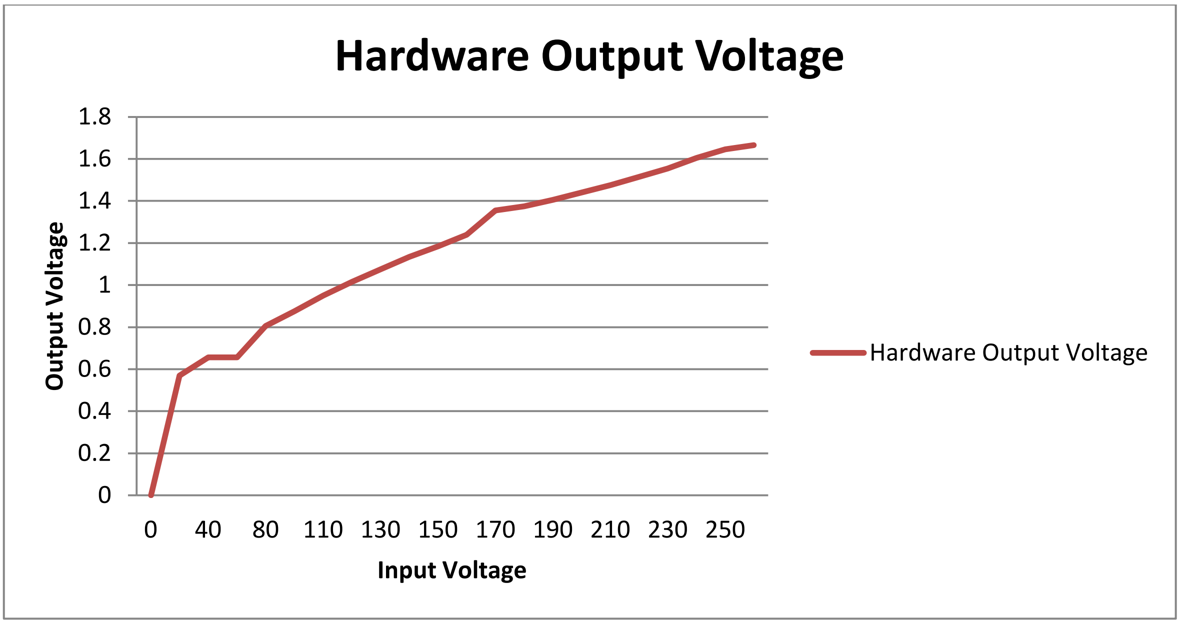

Figure 4.6 Input versus output from hardware.

As shown in Table 4.2 (previous page), the output voltage sensor was recorded by adjusting the variable transformer input from 0V to 260V. The output was measured by multimeter and take by increasing the input voltage of 10V. After that, the graph of output voltage versus input voltage was plotted to analysis the pattern from hardware and simulation (refer Figure 4.6 above). From the Figure 4.6, it shows that the output voltage increases slightly unevenly and completely different from simulation. The result must be effect and error from the process of rectification of diode bridge, resistance as load and filter process by a capacitor. Hence, the output voltage result from hardware implementation is not exactly same as simulation.

4.3.2 Output from PIC Microcontroller and LCD

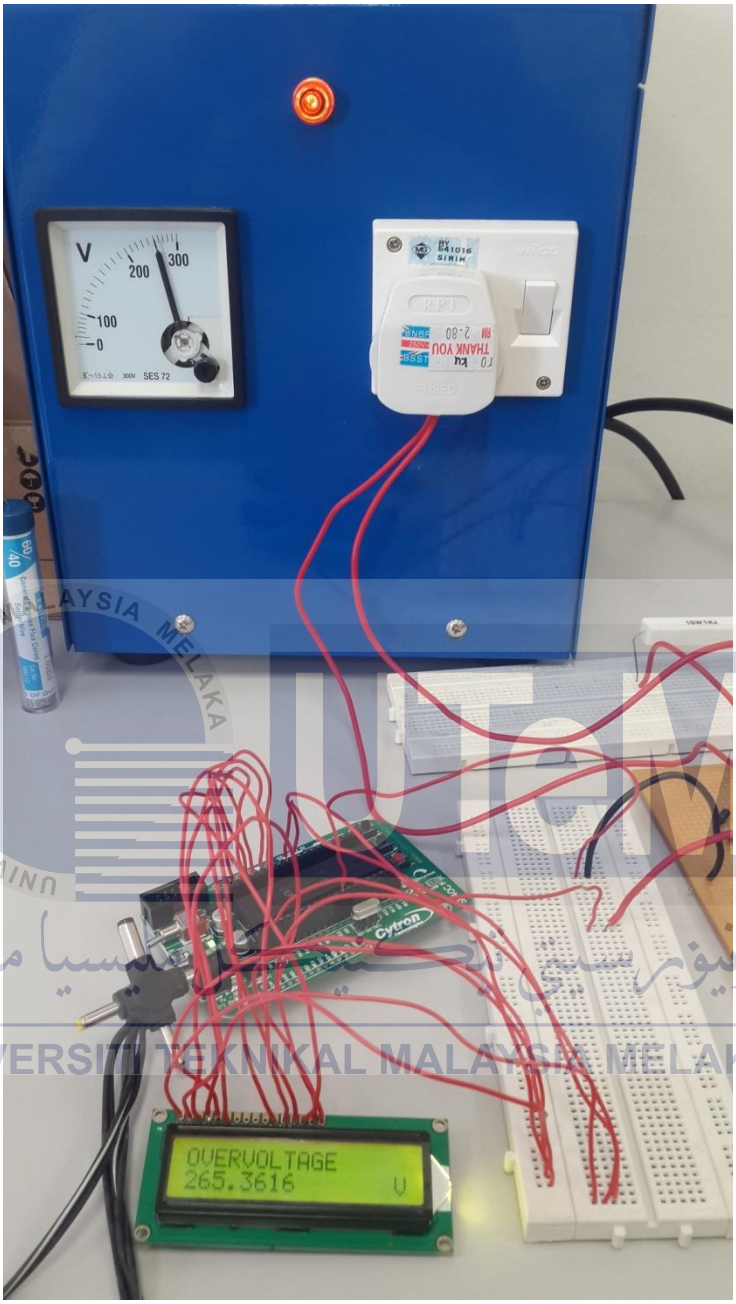

Figure 4.7 Overvoltage Fault

As seen in the Figure 4.7 above, the sensor voltage was fed by a variable transformer up to 260V. Then the PIC will receive the output of DC voltage from voltage sensor and display the actual value through LCD display with fault condition.

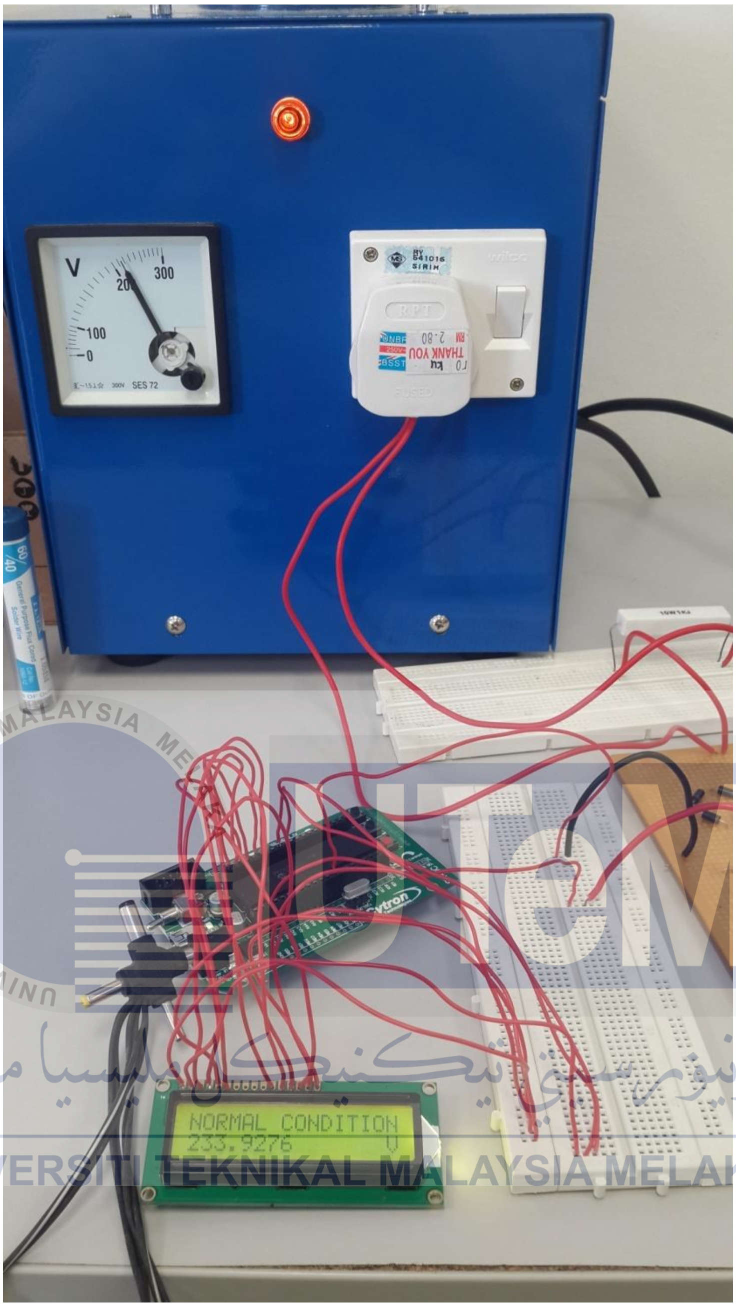

Figure 4.8 Normal Voltage

Figure 4.8 above shows that the detection sensor circuit have normal voltage condition within 200V to 250V. The real situation in the industry the nominal will be in the range of 200V to 240V and it's safe to use as a power supply to electrical equipment.

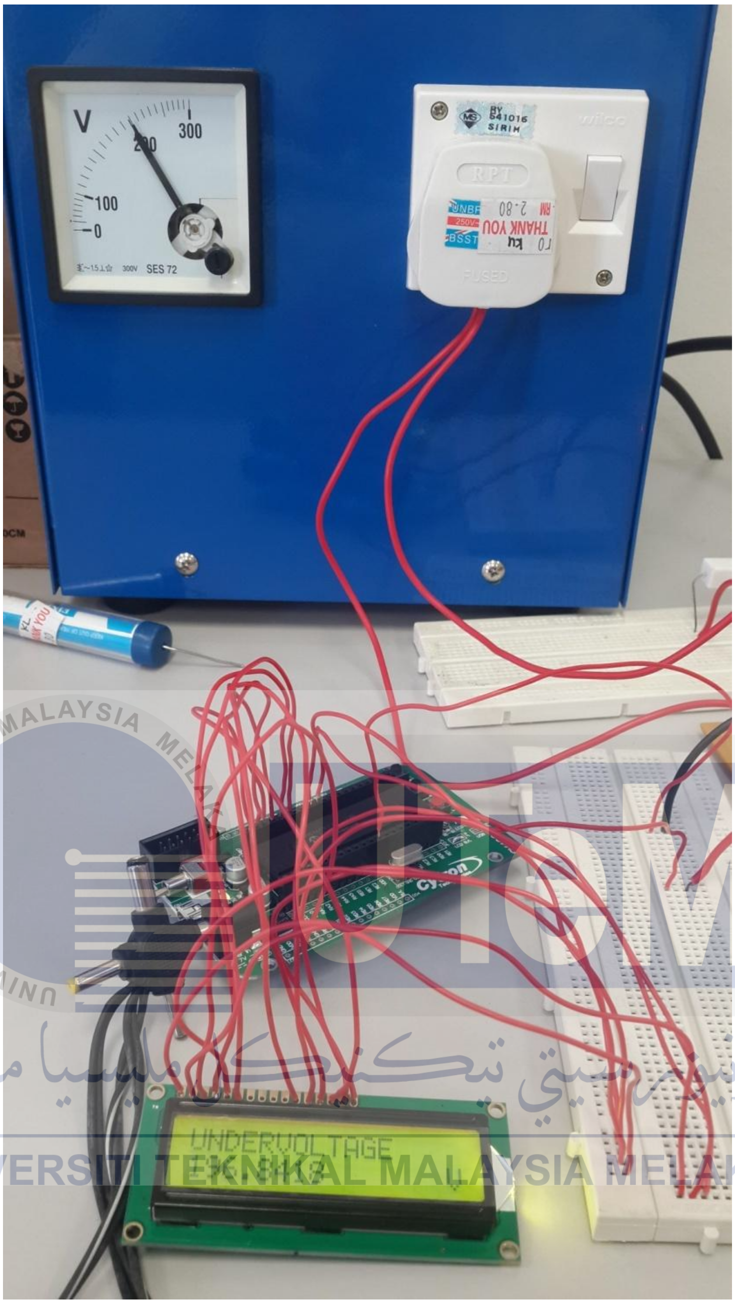

Figure 4.9 Under Voltage Fault

Figure 4.9 above shows under voltage fault condition. The voltage sensor was fed by a variable transformer with below than 200V. The PIC microcontroller then decide the fault occur by programming write to PIC device.

In order to verify the designed circuit can be implemented or not, the prototype for this circuit has been successfully implemented. The hardware result for all three voltage conditions which is under voltage fault, normal voltage and overvoltage was shown in Figure 4.7, Figure 4.8 and Figure 4.9.

At the same time, the selection of the microcontroller board (SK40C) also successfully approved by the accuracy and easy to install. From the Table 4.2 (page 52), the output voltage from the voltage sensor circuit was measured. The gain was calculated to for PIC to convert the DC voltage input to the actual value. Since the increment of DC voltage does not constant, then the average gain was calculated and set at 133.14. This gain value will be multiplied by the DC voltage and calculated by programming that write to PIC device.

Finally, through the observation during hardware testing, the fault voltage display on the LCD was a little bit different from the input voltage. It is because the average gain was used to convert the DC voltage to actual value. Compared to the simulation animating, the fault voltage display on the LCD is mostly same with input AC voltage. The situation for simulation is more accurate because the increment of output DC voltage is constant and the gain is select at 141.05.

4.4 Analysis for Hardware Prototype and Simulation

The Table 4.3 below and Table 4.4 (next page) show several parameters that need to be analysis for this final year project. The parameters recorded from simulation and hardware result include the input voltage, DC output voltage, voltage display, gain, the difference voltage produce and percentage error.

Table 4.3 Analysis Result from Simulation

Input Voltage (V)	DC Output Voltage (V)	Voltage Display (V)	Gain	Difference Voltage (V)	Percentage Error (%)
0	0	0	0	0	0
10	0.06	8.95	166.6	1.05	10.5
20	0.13	19.27	153.8	0.73	3.60
30	0.21	29.59	142.8	0.41	1.30
40	0.28	39.23	142.8	0.77	1.90
50	0.35	49.56	142.8	0.44	0.88
60	0.42	60.57	142.8	0.57	0.95
70	0.5	70.89	140.0	0.89	1.27
80	0.57	80.53	140.3	0.53	0.66
90	0.64	91.54	140.6	1.54	1.71
100	0.71	101.87	140.8	1.87	1.87
110	0.79	112.19	139.2	2.19	1.99
120	0.86	121.83	139.5	1.83	1.53
130	0.93	133.53	139.7	3.53	2.72
140	1.01	143.17	138.6	3.17	2.26
150	1.08	154.18	138.8	4.18	2.78
160	1.15	164.51	139.1	4.51	2.82
170	1.22	174.83	139.3	4.83	2.84
180	1.29	184.47	139.5	4.47	2.48
190	1.36	194.79	139.7	4.79	2.52
200	1.44	205.12	138.8	5.12	2.56
210	1.5	214.75	140.0	4.75	2.26
220	1.58	224.39	139.2	4.39	1.99
230	1.65	234.71	139.4	4.71	2.06
240	1.72	245.73	139.5	5.73	2.38
250	1.8	255.36	138.8	5.36	2.14
260	1.87	265.69	139.0	5.69	2.18
270	1.94	277.39	139.2	7.39	2.73
280	2.01	287.71	139.3	7.71	2.75

Table 4.4 Analysis Result from Hardware

Input Voltage (V)	DC Output Voltage (V)	Voltage Display (V)	Gain	Difference Voltage (V)	Percentage Error (%)
0	0	0	0	0	0
20	0.569	18.19	35.2	1.81	9.05
40	0.656	37.03	60.9	2.97	2.43
60	0.656	57.17	91.5	2.83	4.72
80	0.805	76.67	99.4	3.33	4.16
100	0.875	96.16	114.3	3.84	5.84
110	0.95	105.90	115.8	4.10	3.72
120	1.015	112.40	118.2	7.60	6.33
130	1.075	125.40	120.9	4.60	3.54
140	1.135	135.14	123.3	4.86	3.47
150	1.185	145.54	126.6	4.46	2.97
160	1.24	150.08	129.0	9.92	6.20
170	1.355	165.03	125.4	4.97	2.92
180	1.375	174.13	130.9	5.87	3.26
190	1.405	183.87	135.2	6.13	3.22
200	1.44	193.62	138.8	6.38	3.19
210	1.475	203.36	142.4	6.64	3.16
220	1.515	212.46	145.2	7.54	3.56
230	1.555	224.21	147.9	5.79	2.52
240	1.605	234.30	149.5	5.70	2.37
250	1.645	243.69	151.9	6.31	2.52
260	1.665	255.44	156.2	4.56	1.75

The mathematical equation to calculate the gain for each increment of voltage was stated in the equation (1.1) below. After calculating gain for each increment of voltage, the next step is to calculate the average gain for simulation and hardware. This average gain will be used in programming to convert the ADC value from PIC and display the actual value on the LCD display. The equation to calculate the average gain was stated in equation (1.2). Hence, the difference voltage between voltage display on LCD and given input voltage was calculated in order to identify the different voltage produced and the equation was stated in equation (1.3). Lastly, the percentage error for difference voltage was calculated and the equation used is set-out in equation (1.4).

$$Gain = \frac{Input\ Voltage\ (V)}{DC\ Output\ Voltage\ (V)} \qquad (1.1)$$

$$Average\ Gain = \frac{\Sigma \text{Gain of different voltage,}}{\Sigma Tolal\ of\ Gain\ different\ voltage} \tag{1.2}$$

$$Difference\ Voltage = |Input\ Voltage - Display\ Voltage| \tag{1.3}$$

$$Percentage\ Error = \left|\frac{Input\ Voltage - Dispay\ Voltage}{Input\ Voltage} \times 100\%\right| \tag{1.4}$$

As seen in Table 4.3 (page 58) the result of simulation was recorded and tabulate in order to analyze the display voltage on LCD at every given input voltage. The difference voltage is the difference voltage between input voltage and voltage display at the LCD display. For the input voltage from 0 to 100V, the difference produced quite small (0 to 1V) and accurate with the input voltage. For input range from 100 to 200V, the difference voltage produced start to apart up to 5V difference and the percentage error produced with an average of 2.5%. Then, the when the voltage increase up to 250V, the difference voltage produced become 7V from actual input value with an average 2.8% error.

Hence, for hardware analysis result was recorded and shown in the Table 4.4 (previous page). Through observation from Table 4.4, the difference voltage produced between display voltage on the LCD and input voltage is not constant. If the given input is in between 0 to 100V, then the difference voltage produced from the range 0 to 4V difference with average percentage error of 4%. After that, when the input is varied from 100 to 200V, then the difference voltage produced by display voltage on the LCD and input voltage is around 4 to 6V difference. The voltage difference can be categorized as large difference voltage because the actual value supposedly to display on the LCD not more than 6V. Hence, the input voltage was increased up to 250V and the result of voltage display in LCD is recorded in Table 4.4. The difference voltage produced is on average of 5 to 6V difference voltage.

4.5 Gain Knowledge from Result

The last of this final year project is to get results as evidence that this successful achieved the objective. The analysis from both simulation and hardware implementation has been discussed in this chapter. The fault detection sensor has finally can sense the voltage and display the fault condition when the microcontroller read the input voltage. From the graph analysis, it can be concluded that the circuit of voltage sensor can get smooth output voltage sensor as a simulation if the circuit design using better components and different design application.

Lastly, from both result of simulation and hardware implementation it can be concluded that, the circuit implementation have some error on selected component. Further development of this circuit designed is required so that the output voltage produced by voltage sensor can be constant increment. Constant increment is very important so that the display voltage value on LCD screen same as the input voltage.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This project entitle 'Design a Remote Terminal Unit (RTU) fault detection sensor to detect voltage in the range of under voltage and overvoltage' which design to detect fault occur at distribution station. The project involved designing voltage sensor to feed voltage as input to microcontroller circuit. The microcontroller circuit will declare either the fault occurs is under voltage or overvoltage condition.

From the test on simulation and hardware implementation, we can see that the circuit of this project was able to monitor the fault occur when the input voltage supply to circuit. The microcontroller will display the type of fault depends on the input voltage. The result that discuss in chapter 4 also approved that this project successful achieved the objective.

Finally, it can be concluded that the voltage sensor design was ready and safely to used and fault detection sensor the real project of Remote Terminal Unit (RTU).

5.2 Recommendation

The research and studies on fault detection sensor is very advantageous and challenging. Based on the present time, it can be observed that many fault detection circuits were designed because of demand in the protection industry area. If the protection was not being able to detect whenever the fault occur, then it will lead to damage of appliances.

Based on the work of this project, some improvement and additional requirement will need to be made in the future development. It mentions that to design fault detection circuit for remote terminal unit, but there is no action taken after the circuit detect fault conditions. In the future project development, the relay protection circuit can be added to control the circuit by cutting off the input if a fault occurs. With this implementation, the designing circuit was able to get high recognition as a fault detection sensor for the remote terminal unit. In addition the suitable component to implement for the sense voltage need to investigate and required more research and testing. Hence, the designed voltage sensor is able to display fault voltage at the LCD display without any error and difference value compared with input supply.

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