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FINAL YEAR PROJECT REPORT

DESIGN REMOTE TERMINAL UNIT (RTU) VOLTAGE REGULATOR

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(CONTROL, INSTRUMENTATION AND AUTOMATION)

"I hereby declare that I have read through this report entitle "Design Remote Terminal Unit (RTU) Voltage Regulator" and found out that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)

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I declare that this report entitle "*Design Remote Terminal Unit (RTU) Voltage Regulator*" 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 candidature of any other degree.

Signature :……

Name : Muhammad Arif Bin Rashid

Date :……

To my beloved father and mother

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Assalamualaikum w.b.t.

All praises be to Allah, Lord of the Universe, the Merciful and Beneficent to Prophet Muhammad S.A.W, His Companion and the people who follow His path. Foremost, I would like to thank Almighty Allah for allowing me to undergo finish partial of final year project 1 with a safe and blessed. I would like to take this opportunity to express my sincerely gratitude and appreciation to my parents and my family for the support. I would like to thank my family: my parents Rashid Bin Long and Siti Eashah Binti Ayub, for giving birth to me at the first place and supporting me spiritually and physically throughout my life. The special thank goes to my helpful supervisor, Datuk Prof. Dr. Mohd Ruddin bin Ab.Ghani for the continuous support. The encouragement and support that he gave truly help the progression and smoothness of the final year project. Besides my supervisor, I would like to thank my co. supervisor Cik Nur Huda Binti Mohd Amin for her encouragement, insightful comments, and hard questions. Last but not least, I would like to thank again to the people above and everyone who are always be with me and guide me to success. I am grateful to them for enlightening me the first instance of the final year project. There always there cheering me up and stood by me through the good and bad times.

Thank you.

ABSTRACT

Power outages is always happened and its take a longer time for fault detection, isolation and restoration. This problem affects the manufacturing sectors and having an impact on residential areas. Therefore, the voltage regulator is implemented to ensure the problem of unsteady voltage can be controlled immediately. The purpose of this research is to design voltage regulator to regulate the voltage level in the load. The linear voltage regulator is the best selection as it can give fast response to input and output disturbances. At the same time, remote terminal unit (RTU) is employed at the load to monitor the voltage level in the load as well. The design of RTU including RTU hardware circuit board, the RTU using software algorithms, the interfacing for monitoring process and integrate software and hardware together to make the RTU as a complete system. In order to ensure the RTU system achieve its objectives, the methodology uses consists of Proteus software to design and develop the RTU circuit board, mikroC PRO software to program the microcontroller-base, Visual Basic software to create the GUI interfacing for the monitoring system and serial port as a communication media to connect RTU to the control unit in short distances. The findings of this research show that the problem of unstable voltage in the load can be detected quickly by RTU and the signals will be sent to the control unit for further action. The importance of design and development of RTU is being able to provide a system that can continuously collect, process, store data and operate independently through programming and save time and cost. The significance of this research is the improvement of the RTU system whereby the RTU designed is based on existing RTUs. The RTU has an industrial application potential which can be applied in TNB distribution automation and other industrial sectors to monitor weather, temperature, leakage current and others overcurrent. The proposed RTU is to monitor the voltage level and send the information in terms of type fault, the value of fault, substations status and locations, date and time to the monitoring unit.

ABSTRAK

Gangguan kuasa sentiasa berlaku dan mengambil masa yang lebih lama untuk pengesanan kesalahan, pengasingan dan pemulihan. Masalah ini memberi kesan kepada sektor pembuatan dan mempunyai kesan ke atas kawasan perumahan. Oleh itu, pengatur voltan dilaksanakan bagi memastikan masalah ketidakstabilan voltan boleh dikawal dengan segera. Tujuan kajian ini adalah untuk mencipta bentuk pengatur voltan untuk mengawal selia tahap voltan dalam beban. Pengawal selia voltan linear adalah pilihan yang terbaik kerana ia boleh memberi tindak balas yang cepat untuk input dan output gangguan. Pada masa yang sama, unit terminal jauh (RTU) memain peranan penting untuk memantau tahap voltan dalam beban juga. Reka bentuk RTU termasuk perkakasan RTU papan litar, RTU menggunakan algoritma perisian, antara muka untuk proses pemantauan dan mengintegrasikan perisian dan perkakasan bersama-sama untuk membuat RTU sebagai sistem yang lengkap. Dalam usaha untuk memastikan sistem RTU mencapai objektifnya, kaedah yang menggunakan terdiri daripada perisian Proteus untuk mereka bentuk dan membangunkan papan litar RTU, perisian mikroC PRO untuk program mikro-asas, perisian Visual Basic untuk mewujudkan GUI antara muka bagi sistem pemantauan dan serial port sebagai media komunikasi untuk menyambung RTU kepada unit kawalan dalam jarak yang pendek. Hal ini menunjukkan kajian ini bahawa masalah voltan yang tidak stabil dalam beban boleh dikesan dengan cepat dengan RTU dan isyarat akan dihantar ke unit kawalan untuk tindakan lanjut. Kepentingan reka bentuk dan pembangunan RTU adalah dapat menyediakan satu sistem yang berterusan boleh mengumpul, memproses, menyimpan data dan beroperasi secara bebas melalui pengaturcaraan dan menjimatkan masa dan kos. Kepentingan kajian ini adalah peningkatan sistem RTU di mana RTU direka adalah berdasarkan RTU yang sedia ada. RTU mempunyai potensi aplikasi perindustrian yang boleh digunakan dalam sektor industri yang lain TNB pengagihan automasi dan untuk memantau cuaca, suhu, kebocoran arus semasa dan lain-lain. RTU yang

dicadangkan adalah untuk memantau tahap voltan dan menghantar maklumat dari segi jenis kesalahan, nilai kesalahan, status pencawang dan lokasi, tarikh dan masa untuk unit pemantauan.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Energy interruption is the circumstance connected with damaging the energy with an area caused by problem that occurs with electric power stations, transmission, submission or maybe substations. Throughout Malaysia, typical reason behind electric power outage is actually split into 3 which can be coming from Tenaga Nasional Berhad (TNB) process or maybe alternative party participation in addition to client's office space. Regarding TNB process, the key reason why of the electric power outage is actually happened since the short circuit in TNB distribution process and underground line cable which has been dished up. And then, with regard to weather or third part participation incorporates accidents that include TNB installation for example poles and others, pilferage connected with TNB set up, extreme climate for example surges or maybe third party is effective outside of TNB's command for example road constructions. The necessity with regard to more efficient in addition to reliable electric power management improve annually because plenty of electricity created is actually misused by the wrong type of preparing brought on by the weaknesses of the electric power system itself. The particular customization may be produced on the technology in addition to transmission side that may enhance the active power is placed on the distribution side.

Electricity process employed to offer electricity in order to customers with electric power distribution process. The distribution industry connected with automation enables the particular tools in order to carry out variable control connected with distribution system to enhance efficiency, trustworthiness, as well as quality connected with electrical products and services. In order to make it a quality service, voltage regulator must be placed or

installed at a distribution system. Some sort of voltage regulator was created to automatically maintain consistent voltage stage. Within an electrical power distribution process, voltage regulators can be set up at a substation or alongside distribution lines so that almost all consumers obtain constant voltage regarding the amount of power can be driven from the line. Furthermore, a voltage regulator also can be tested at the load to maintain the voltage in the load. At the same time, the voltage level in the load can be monitored through a far distance by placing the remote terminal unit (RTU) at the load.

The remote terminal unit (RTU) is really a standalone information acquisition as well as control unit. The main operation of RTU is to control and acquire information coming from process equipment on the remote area as well as transfer which information returning to the main unit. This kind of remote terminal model (RTU) system was created to inform in case of failing about the small voltage source 400/240V process only. The principle job on this RTU is to find errors due to over voltages along with miss-setting voltages in the Taps at the transformers. It is usually to accomplish the method involving monitoring along with repair in case of errors. The malfunction repair functions is going to be clean and easy to control. This kind of works by using automation strategy in creating of the intelligent RTU as a result of adjustment as well as innovative developments.

1.1 Motivation

The aim of this project is to design the Remote Terminal Unit (RTU) that can stabilize the voltage level that controlled by voltage regulator. As we know, RTU can collect, process, and send the information to the master station for monitoring system. After fully considering all these matters, the non-expensive RTU that can be operated independently is designed and developed. In terms of performance, an RTU can only operate at low voltage 400/230V and has a short distance communication medium. An RTU can contribute equality in terms of monitoring and controlling the data and sending the information to the master station. By interfacing the RTU at the load, the current value in the load can be monitored through a short distance communication. The data will send

to the operator to inform the load condition in the load. Furthermore, voltage regulator is made to keep the voltage level at the steady state in the RTU. The steady voltage level has to be controlled to provide sufficient voltage supply for the RTU.

1.2 Problem Statement

The unsteady voltage level usually occurs at load are defective wiring system and short circuit in the load. When this happen, control room operator have to analyse the load mechanism to recognize what the problem occur in the load before carry any selection to be able to actions. Normally, the process will take long delay to analyse the voltage level in the load. Therefore, it is necessary to create and develop a Remote Terminal Unit (RTU) and voltage regulator which can be interfaced with the load. At the same time, RTU is a flexible system that can process and control the data. It can easily interface with the load. The data from the load will send to the master station by RTU for monitoring system. The data will be visualised using GUI in Visual Basic software. Hence, the operator can easily be informed that the voltage level in the load is being regulated smoothly.

1.3 Objectives

The objectives of this project are:

1. To design and develop a Remote Terminal Unit for hardware and software.
2. To create a voltage regulator that is suitable for the RTU
3. To develop GUI software for distribution automation using RTU models with Visual Basic (VB) interface for monitoring system.

1.4 Scopes

The scopes of this project are:

1. For low voltage devices.
2. The GUI interfacing using Visual Basic (VB).
3. The RTU used is based on microcontroller with PIC16F877A.
4. The communication protocol is based on wireless protocol using serial communication.
5. The simple voltage regulator that is suitable for the RTU

.

1.5 Significance

After the completion of this project, there are several features can be obtained. The simple voltage regulator can be interfaced with the RTU and regulates the voltage level in the RTU smoothly. The data from the load can be collected by RTU. The project can provide a RTU that can collect data, can process and store data and can send the data to the master station for monitoring. The current voltage level in the load can be informed frequently. Lastly, the RTU equipment can easily be integrated and designed to be repairable.

1.6 Report Outline

This report contains five chapters. Chapter 1 is an overview of Remote Terminal Unit, voltage regulator, Graphic User Interface (GUI) and the communication system, including the problem statement, motivation, objectives, and scope of work. Chapter 2 is a Literature Review presents an explanation of design and development of the remote terminal unit (RTU). This includes the past and current RTU design and development circuit. The other research about the voltage control applied in RTU also has been studied. Chapter 3 is about the methodology of the whole project. This chapter describes the hardware and software designing. The Proteus software is used to design the RTU board, mikroC PRO is used to program the RTU function and the Visual Basic (VB) is used to

create the interface for the monitoring system. Chapter 4 shows the result and discussion which presents the complete RTU circuit as a voltage regulator sent to the monitoring system via Serial communication. Finally Chapter 5 presents the general conclusions.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This part studies the past research result and information which is related to development and design remote terminal unit (RTU) and voltage regulator. The past research discovered on how to design new modelling for the remote terminal unit (RTU) and voltage regulator.

2.1 Design and development of remote terminal unit (RTU)

Pattern and also development connected with Wise Remote Incurable Unit (RTU) can be demand for managing the particular voltage downstream connected with 400/240V. The dsign as well as development associated with out of the way RTU signal as well as hardware execution which often manifested inside distribution automation system(DAS). Distribution Automation System (DAS) allows the utilities to practice accommodating handle regarding submitting program to provide proficiency along with top quality regarding electric powered services. The design determined by microcontroller making use of PIC16F877A along with Orcad software package to development world for the RTU. [1][2].

Remote Terminal Unit (RTU) is a standalone data acquisition and control unit. It might over seeing and also management gear on some distant area on the central section of which utilizes inside the Distribution Automation Program (DAS) [3]. The master of this system is RTU and the slaves are digital input and output modules. A inlayed Ethernet controller is employed to produce RTU work as converter regarding Human Machine Software (HMI) and to software together with digital input and output modules. There are computer software methods are widely-used to build criteria for that controller in addition to HMI for monitoring in addition to handling operates for that owner. [2]. RTU will assigned the task for digital input and output modules to work on [4]. The RTU could tracking down wrong doing functioning, controlling operates as well as facts selection for examination. RTU can be major part intended for sensing fault in addition to issue in order to provide information speedily from the management room. That functioning will involve the actual recognition of failing linked with the actual microcontroller (PIC18F77A) which suggests the actual sensor can send the actual signals to the present microcontroller if the fault occurs. RTU able to detect and control under voltage and overcurrent fault [3].

Supervisory Control and Data Acquisition (SCADA) system is a central station which could communicate with some other circle using the communication process. Simply Smart RTU alongside the SCADA is usually capable to conduct clever selections around the syndication automation responsibilities. The intention of developing a very good Microcontroller based RTU with regard to supply automation technique should be to innovate the downstream area of the energy supply technique such as conversation social networking technique [5]. Basically, the particular types of cpa networks depend on the particular seven layers involving wide open system interconnection (OSI) as well as International Standard Organization (ISO). The protocol is made to check the particular reputation of all the so-called feedback in addition to end result subject devices in addition to send the particular repost in accordance with in which reputation. The actual matching protocol and also transmission parameters between attaching devices will be included in developing a difficult SCADA system. The obtainable methods to build up the conversation regarding RTU tend to be Modbus/ASCII, allocated community protocol (DNP3), controller region community (CAN), Overseas Electro-technical Commission (IEC 60870), and also indication handle protocol/internet protocol (TCP/IP). [6]. Planning a system with regard to supervising in addition to curbing machine in addition to

equipment within rural spots for example RTU may be utilized by having a several associated with marketing and sales communications alternatives for example wifi LAN engineering, dial-up modems, private radio sites, Satellite tv conversation, in addition to mobile community. The particular RTU provides a couple places connected with RS485 transmission process and something TCP/IP port along with 10Mbps swiftness for that communication part [2]. Regular RS-232, RS-422, RS-485 along with Ethernet solutions usually are recognized simply by Modbus protocol which in turn consists of ASCII, RTU, along with TCP transmitting method. Though ACII mode or even RTU mode uses serial dock Modbus system, Modbus/TCP manner uses Ethernet system. The interface parameters and transmission setting should be the same to all devices in Modbus network [6]. The particular main computer handle acquired the information by means of verbal exchanges project by way of example IEC 61850 as well as DNP3. Actually the only received information may processed and also exhibited by Graphic User interface (GUI) for the interconnection involving submitting, command and also transmission technique [4].

The design planned based on Global Sytem for Mobile (GSM) conversation shows an intelligent design for distribution automation system. GSM Short Message Services (SMS) providers regarding computerized determination making along with steady overseeing regarding deliver on system ingredients instantly by means of overseeing along with controlling of the relays. GSM will probably send out the particular concept for the command area operators attentive these people around the recent scenario via cell phone whenever files acquired by RTU [4]. This PIC16F877A need to be associated with the actual GSM modem through RS232 cable television having MAX232 converter so as to transfer signal to GSM modem. The technique functionalities GSM modem name Wavecom fastrack and controlled via in command regarding many people connected with operations. RTU will record three kinds connected with details which can be analog, digital and control. RTU measure facts via kV, MWatt, MVar, Hz and Amps plus the analog input offers the other people just like 4-20mA, 0-10V, 2.5 to 2.5V, 1-5V. The data versions with regard to digital can be within status, alarm or indication and also data type with regard to control are usually open and also close, raise or maybe decrease. In addition, it may reset [5].

The design along with the development regarding RTU with small remote telemetry unit designed for different application form inside low voltage technique. It operates in line with PIC16F877 device functioning from 20MHz and also runs via a good 9-24V AC/DC provide. The microcontroller PIC16f877A will be belonging for the class connected with 8-bit microcontrollers involving RISC architecture. The CPU as well as microcontroller will be the core components regarding microcomputers demand current external components most of these ROM, RAM along with I/Os pertaining to perform its purposes. PIC will be operating making use of 5V DC voltage. It is DIP layout and sufficient for its overall project. The digital output of a PIC is 5V to help provide the signal 1 with O due to the 0 signal. Whenever the PIC pins are usually set as digital inputs, it will detect input voltage 5V. PIC features 40 pins, but sole 33 1/0 pins is usually designated in the same way digital input or perhaps output [6]. The crystal oscillator taken is usually 20MHz of which carry out every process line for the system. 20MHz is usually taken considering that it is the maximum frequency the PIC will probably support. The software design consists of MPLAB software development using C programming in addition hardware assembly [3]. For software design, the program to be able to detect faults uses MPLAB software and the program incorporates commands round the given I/O pin, given ports for its timekeeping chip and also analog digital converter, cycle associated with collecting input if genuine line, data location for info writing and memory [3].

2.2 Voltage control in distribution automation system and voltage regulator

A novel coordinated voltage control scheme is usually proposed to enable voltage regulator to efficiently regulate the voltage involving multiple feeders at the presence of DGs in accordance with placing a remote terminal unit (RTUs) from each DG into each line capacitor. These kinds of RTUs coordinate together through communication and application a multi agent system [7]. As real time voltage control is known as a legacy system that can uses method for real time voltage control, based on emergency demand

response program. The method uses the real-time measured data collected by RTUs and determines the tap changer condition and load curtailment required in order to maintain the distribution voltage profile [8]. Voltage control can be solitary of any imperative concerns for the smart distribution control system. By means of these kinds of smart grid technologies, current distribution voltage control schemes in the event that conduct intelligently along with cover ones undesirable effect connected with high penetration connected with renewable distributed generation. The brand new approach the idea improved conventional voltage control model will probably cover current renewable distributed generation impact on distribution network [9].

To ensure operation of a smart distribution program in a great ideal voltage level, voltage regulators are usually deployed in a number of strategic locations with regard to voltage control. Hence the voltage regulation is done at a great relatively low frequency to help avoid excessive wear as well as tear towards the voltage regulators, a good large quantity involving measurements in case be reported by the RTUs and processed through the distribution substation with regard to optimal voltage regulation . RTUs communicate with each other, at each DG unit give the readings and the voltage regulator controller can be capable to determine the maximum and minimum voltage of any feeder and can be competent to efficiently regulate the voltage of your feeder, as well as multiple feeders. Remote terminal units (RTUs) are usually deployed with distribution method buses with regard to measurement in order to report with the distribution substation makes a great control decision and notifies ones voltage regulators to help adjust process voltages [10].

The measurement along with internal calculations usually are done via each RTU, plus the specified parameters tend to be sent in order to another RTU. The actual procedure is continuing until ones estimated maximum into minimum voltage data tend to be delivered for the learn SCADA [9]. For the voltage profile of any feeder, maximum voltage will happen single on the DG connecting buses, capacitors connecting buses, and also the substation bus, provided the R/X ratio of a feeder will be constant down in overall feeder. Assume the idea DG items are usually connected at buses 1 and 3. If P and Q usually are being transferred through bus 1 to be able to bus 2. After that V1 must always

be more than. So are not able to possibly be a good maximum point. Second, assume the item P and Q usually are being transferred throughout only two additional directions. With seeking the contradiction, let V2 always be a maximum point [7]. After calculation of a voltages in each department of a feeder, ones voltage regulator controller calculates ones maximum into minimum voltages of a network. To regulate ones voltages at many buses in appropriate ranges, the difference between maximum into minimum voltages lower the feeders in the event become less than your difference between your own permissible variety defined because of the maximum and minimum voltages of a network [8]. Based at these types of values, the voltage regulator will probably calculate the tap location changing accordingly equally voltage regulator controller need to search for a great suitable tap that will regulate the maximum along with the minimum voltages connected with many feeders [9].

By increasing power consumption as well as increase the speed, future microprocessors will probably operate from straight down voltages as higher currents. At the same time, these kinds of microprocessors can necessitate the highly accurate provide voltage regulation which cannot possibly be done via centralized power system. The good specified regulation accuracy is actually completed from the distributed power system during which a good high-quality power is actually delivered for the microprocessor from the voltage regulator module (VRM), that is to be located towards motherboard next towards load. Generally, one VRM is actually needed for getting a good high power density to operate using a high efficiency. To meet most of these needs in addition to supply the a good speedily transient response, power conversion must end up being accomplished with a high switching frequency, of which delivers a serious design challenge [11]. The generator excitation program will keep generator voltage and controls reactive power flow. Initial technique of generator reactive power control is the generator excitation control applying automatic voltage regulator (AVR). AVR is actually to hold terminal voltage magnitude associated with synchronous generator in a great specified level. One testing carried out while using MATLAB Simulink tool. Testing performed at every one of the blocks of AVR system. Tests were likewise conducted towards the uncontrolled AGC system as well as the integrator controlled method from inserting block diagram directly into Simulink [13]

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter reviews the design and development of voltage regulator and remote terminal unit (RTU) which are to be applied at the load. The function of the voltage regulator is to maintain the steady voltage supply in the remote terminal unit. The remote terminal unit (RTU) will provides monitoring operation and data collection for analysis. Once the RTU process and collect the data from the load, it will send the signal to the master room by using serial port communication. The data will be interpreted by using GUI system in Visual Basic software.

3.2 Voltage regulator

A voltage regulator is built to automatically maintain a good constant voltage level. A great voltage regulator can be a good easy "feed-forward" design or even may include negative feedback control loops. It is going to work with the electromechanical mechanism or perhaps electronic components. Relying towards design, it can be used to regulate solitary as well as further AC or DC voltages. A voltage regulator is used to produce a constant linear output voltage. It's generally used with AC to DC power supply. And also it can be used as well as a DC to DC voltage converter. To regulating low voltage, most

used device is one single IC. 7805, 7812, 7905 etc. 78xx series are design for positive and 79xx series are for negative voltage regulator.

7805 is a three terminal +5v voltage regulator IC from 78XX chips family. LM78XX series are from National Semiconductor. They are linear positive voltage regulator IC used to produce a fixed linear stable output voltage. National Semiconductor has also negative voltage regulator chips family, they indicate with LM 79XX. 78xx is used more than 79xx because negative voltage has a few usability purposes. Figure 3.1 showed the voltage regulator LM7805 circuit.

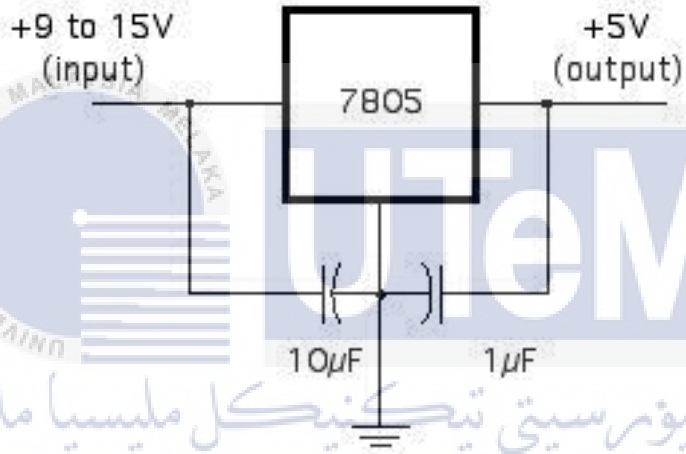


Figure 3.1 : voltage regulator LM7805 circuit [18]

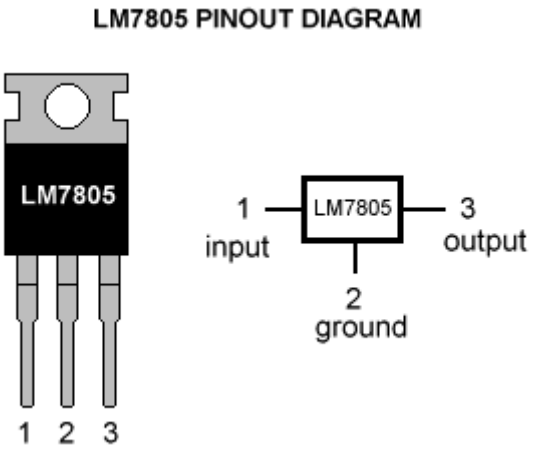


Figure 3.2 : voltage regulator LM7805 pinout [17]

The figure 3.2 showed the voltage regulator LM7805 pinout. Its output voltage is +5V DC. Any input voltage can be supply in the circuit. The output voltage will be always regulated +5V. The range of input voltage is between 8V to 18V. There used two capacitors in this voltage regulator circuit that helped to produce a smooth regulated voltage at output. Use electrolyte capacitor instead of ceramic capacitor.

One limitation of 7805 I have found that is its output current 2A maximum. Otherwise it is a good voltage regulator if you are happy with 2A. If output current is over 400mA, use a Heat Sink with IC LM7805. Otherwise it may fall damage for overheating.

3.3 Remote terminal unit (RTU)

The RTU offers checking problem procedure, managing features as well as information selection with regard to evaluation. RTU may start the deal using the digital as well as output quests. The actual master of the program is RTU and also the slaves tend to be digital and output. The design based on RTU microcontroller PIC16F77A. By using the Proteus software to create the RTU circuit board, the basic of each circuit such as power supply circuit, analog and digital input circuit, output circuit and other related circuits are referred. Furthermore, Visual Basic software is used to create a GUI for graph system

monitoring. The RTU is programmed by using the mikroC PRO software. The table 3.1 shows the RTU specifications.

Table 3.1 : RTU specifications

Specifications	Descriptions
Memory	◆ 16-bit microprocessor and support circuitry ◆ 516K bytes Program Memory ◆ 128K bytes Non-Volatile Database memory
DC power requirements	◆ DC volt 7-12V, 2A ◆ 5 VOLT, 60 mA Digital Input ◆ 5, 12, 24 volt, 20 mA Digital Output ◆ 5 volt Analog Input
AC power requirements	✓ 240 VAC, 200 mA
Slave communication	✓ RS-232 communication
◆ Digital input	✓ Maximum quantity : 4 ✓ Operating voltage : 5VDC, 12VDC or 24VDC
◆ Digital output	✓ Maximum quantity : 8 ✓ Operating voltage : 12VDC
◆ Analog input	✓ Maximum quantity : 8 ✓ Operating voltage : 5 Volts ✓ Resolution : 10 bits

3.4 System Design

Block diagram for the whole system. Figure 3.3 showed the block diagram for the operation system

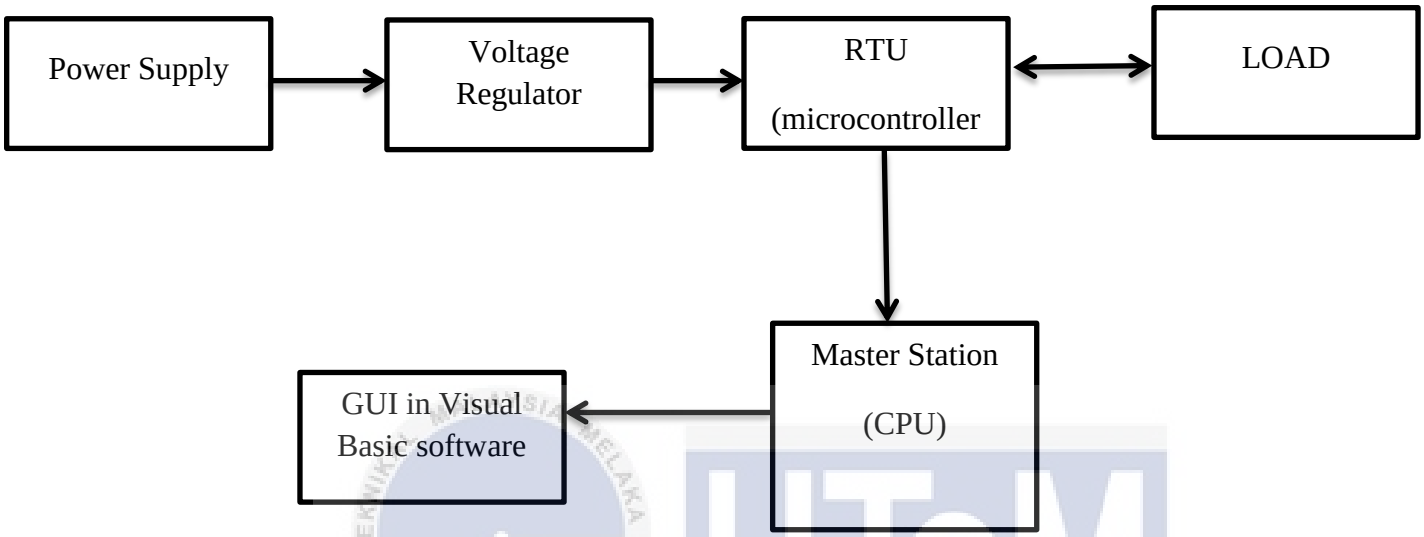


Figure 3.3 : Block diagram for the operation system

The figure 3.3 above shows the flow of the operation system in simple block diagram. The low voltage power supply will be regulated with voltage regulator in the RTU. The voltage regulator will plays the important role to keep the constant voltage level in the RTU. At the same time, remote terminal unit (RTU) will process and collect the data from the load through voltage sensor and current sensor. The current and voltage value in the load will be collected by the RTU. RTU is programmed to process the data and send the signals to the serial port communication. Serial port communication will send the message to master station for monitoring system. The send by RTU will be visualised by using GUI in Visual Basic software.

3.5 Hardware Architecture

Figure 3.4 shows the functional block diagram of RTU hardware. The components interface with the RTU microcontroller (PIC16F877A). The combination of these components make the complete circuit of RTU.

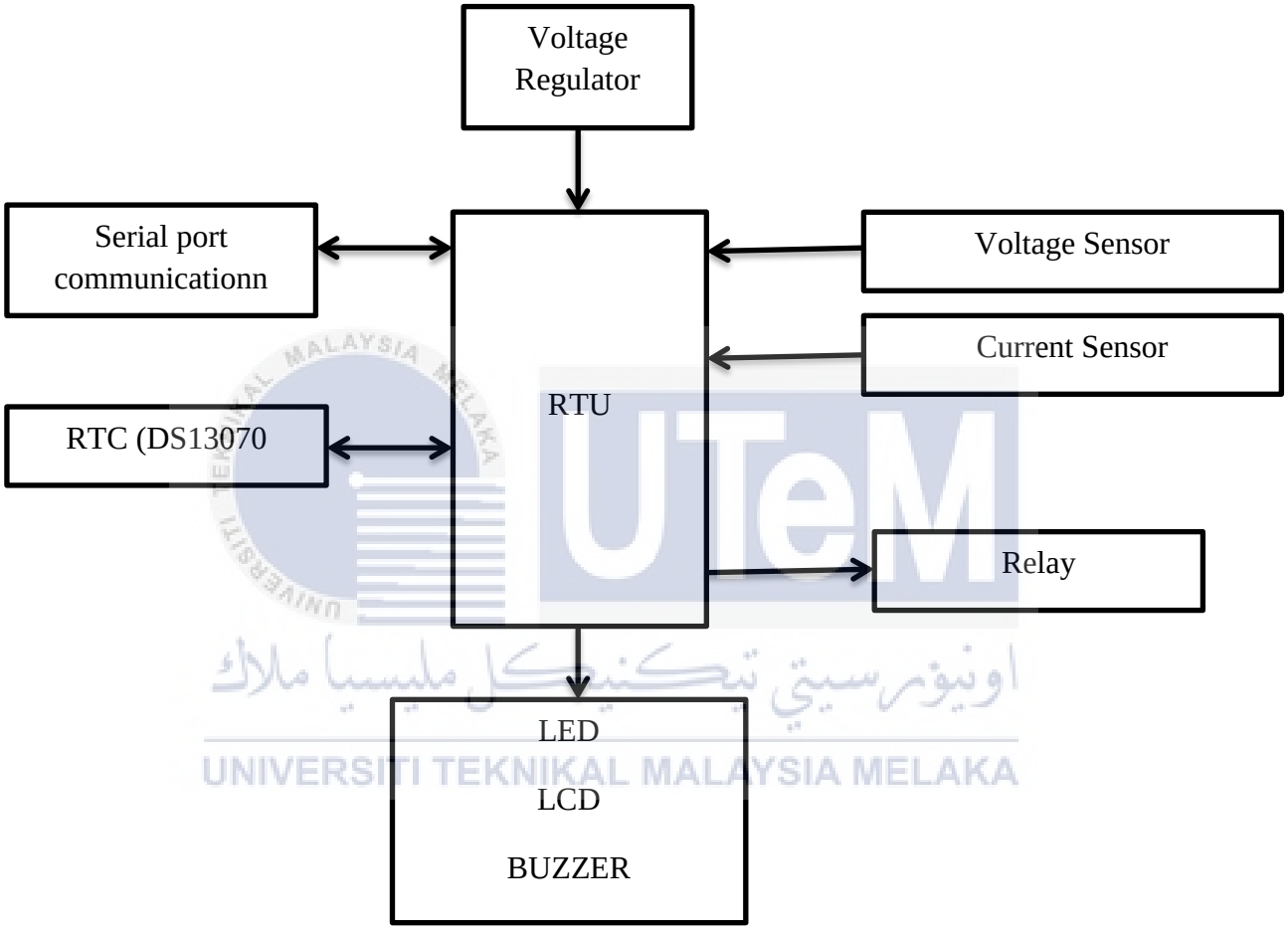


Figure 3.4: Hardware Architecture of RTU

3.5.1 Power Supply

Power supply provides power for an electronic circuit. RTU circuits designed for 12 VDC. However, LM7805 produce heat at 12V. If 9V input voltage be the power supply for RTU, the adaptor AC-DC will be used. Voltage level has been stabilized when the

current drawn by the load is monitored by voltage regulator circuit. A power supply that operates like a voltage regulator will be called a good regulated power supply. RTU functionalities voltage regulator model LM7805. RTU Power Supply Circuit is shown in figure 3.5. The almost all popular type involving voltage regulator IC may be the 78XX series, sometimes called LM78XXseries. The last a couple of digits of your 78XX identity number show the output voltage regulated by the IC. The models are shown in Table 3.2:

Table 3.2: The popular voltage regulator models

Model	Voltage
7805	5
7806	6
7809	9
7810	10
7812	12
7815	15
7818	18
7824	24

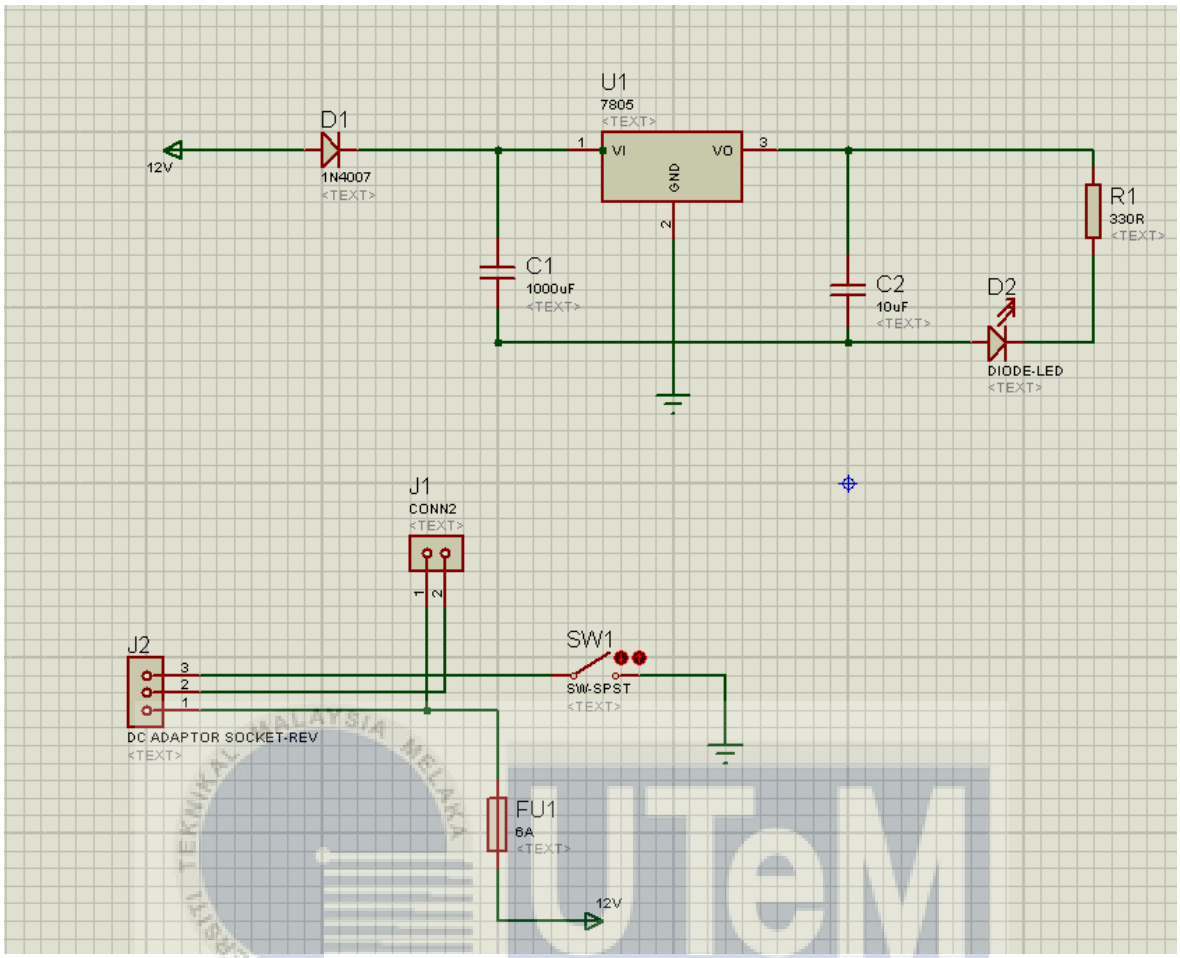


Figure 3.5: RTU Power Supply Circuit

3.5.2 Main Board

PIC16F877A is 8-bit microcontroller has 40 or 44 pins and is suitable with the other PIC devices. The pinout diagram for PIC16F877A is shown in Figure 3.6.

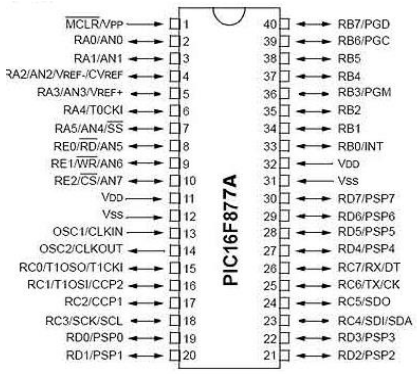


Figure 3.6: PIC16F877A [14]

PIC16F877A is important component in main board circuit. It has EEPROM memory which is will be easier to keep permanent storage and apply to the devices. The flexibility of PIC16F877A makes it applicable in various areas. This chip can be program smoothly after assembling and testing have been finished. This make so easier to build assembly-line production, to keep measurement facts available singular right after final testing. The PIC 16F877A is a programmable microcontroller that can interface with digital or analog input and another input output pins will probably interface in digital inputs. The actual I/O consists of eight optocouplers in digital input, eight open-collector digital outputs that will drive relays and also 4 10-bit analog inputs. Function on each port at the microcontroller is shown in table 3.3. The operating speed used is a 20 MHz clock input. The PIC 16F877A microcontroller has port A - port E and the Table 3.3 shows the function of each port. The figure 3.7 showed RTU Main Board Circuit.

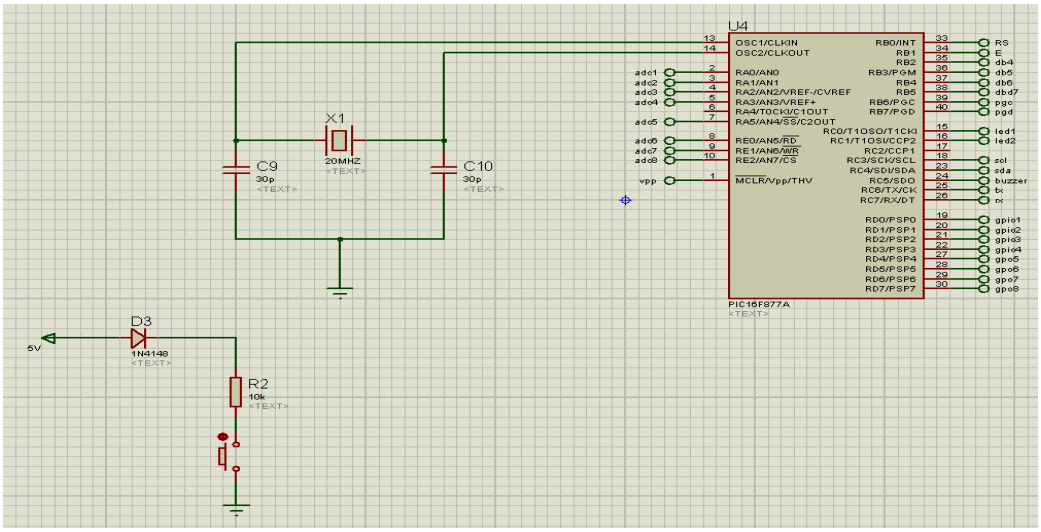


Figure 3.7: RTU Main Board Circuit

Table 3.3: Function on each port

PORT	FUNCTION
A-E	ADC1-ADC8
B	LCD
C	LED, Buzzer, UART (XBee), RTC
D	General purpose input and output

3.5.3 Analog Input

Analog input modules can produce discrete values along analog values by using the resolution of the converter. The actual ideals tend to be saved in binary form, therefore the resolution is actually indicated in bits. The discrete values ideals obtainable, or even "levels", is actually thought to become a energy associated with 2. A good ADC having a resolution associated with 10 bits may encode a good analog input to 1 within 1024 various amounts, because 2^{10} = 1024 with regard to RTU. The range from 0 to 1024 or from -1024 to +1024 depending towards the application. Resolution will also be converted in volt. The LSB voltage is equal to the resolution *Q* of the ADC. The figure 3.8 showed the analog input circuit.

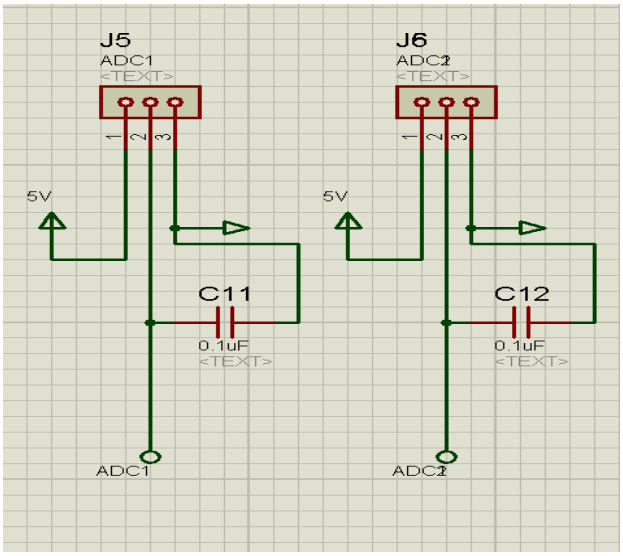


Figure 3.8: Analog Input Circuit

The ADC voltage resolution is equal to its overall voltage measurement range divided by the number of discrete values:

$$Q = \frac{E_{FSR}}{2^M - 1} \quad [16]$$

Where, M is the ADC's resolution in bits and E_{FSR} is the full scale voltage range (also called 'span'). E_{FSR} is given by

$$E_{FSR} = V_{RefHi} - V_{RefLow} \quad [16]$$

Where, V_{RefHi} and V_{RefLow} are the upper and lower extremes, respectively, of the voltages that can be coded. Normally, the number of voltage intervals is given by

$$N = 2^M - 1 \quad [16]$$

Where, *M* is the ADC's resolution in bits. That is, one voltage interval is assigned in between two consecutive code levels. For RTU:

- Full scale measurement range = 0 to 5 volts
- ADC resolution is 10 bits: $2^{10} - 1 = 1024 - 1 = 1023$ quantization levels
- ADC voltage resolution, $Q = \frac{5V - 0V}{1023}$

$$\approx 4.88 \text{ mV}$$

Many analog sensors are resistive in the sense that their electrical resistance varies based on the magnitude of the stimulus that they receive from the environment. It is the job of the electrical circuitry to turn this change in resistance into a change in voltage that can then measure using the A/D converters on the RTU board. In this circuit, it does not matter what the resistance of the sensor R is, the voltage on one terminal of the sensor will always be 5V and the voltage on the other terminal will always be zero. This means the A/D converter will always see 5V regardless of what the stimulus on the sensor R is. Figure 3.9 shows the voltage divider circuit.

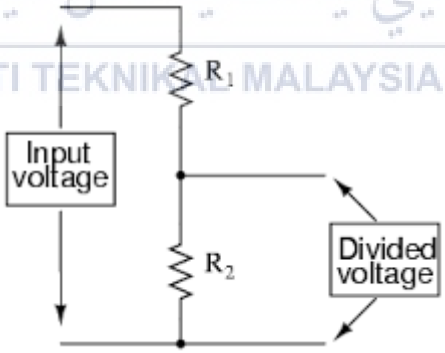


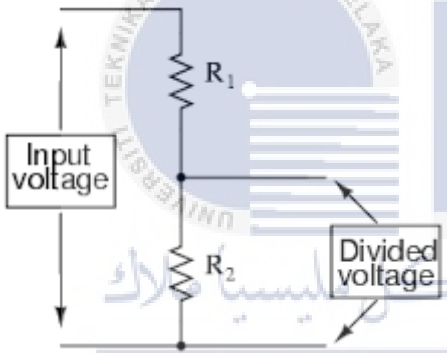
Figure 3.9: Voltage Divider Circuit [19]

The RTU uses a voltage divider in order to convert the stimulus on the sensor into different voltages. Using just two series resistors and an input voltage, we can create an output voltage that is a fraction of the input. The design of sensor R1 has a resistance of 10K while the resistor R2 has a resistance of 4.7K. Table 3.4 shows the voltage divider

calculation. The voltage divider equation assumes that you know three values of the above circuit: the input voltage (Vin), and both resistor values (R1 and R2). Given those values, we can use this equation to find the output voltage (Vout):

$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2}$$ [20]

Table 3.4: Voltage Divider Calculation

<table>
<tr>
<td> 
</td>
<td>$$Vout = \frac{V_{in}R_2}{R_1 + R_2}$$
For Example, V_{in}=12V
$$Vout = \frac{12(4.7K)}{10K + 4.7K}$$
$$Vout = \frac{12(4.7K)}{14.7K}$$
$$Vout = \frac{56400}{14.7K}$$
$$Vout = 3.836V$$</td>
</tr>
<tr>
<td colspan="2">The calculation when V_{in}</td>
</tr>
</table>

V_1(V):	**Vout (V):**	**Load condition:**	
14	4.476	Greater than 253V	Overvoltage
13	4.156	Greater than 253V	Overvoltage
12	3.836	216.3-252V	Normal
11	3.517	216.3-252V	Normal
10	3.197	Less than 216.2V	Undervoltage
9	2.877	Less Than 216.2V	Undervoltage

3.5.4 Digital Input

The digital input monitors the devices through the detecting of the state contacts. These contacts from plant equipment are voltage free contacts. RTU can sense the voltage. There are two ways to detect digital input that are detecting voltage over the digital input stage and provide the contact with over the digital input stage. The digital input circuit is shown in Figure 3.10.

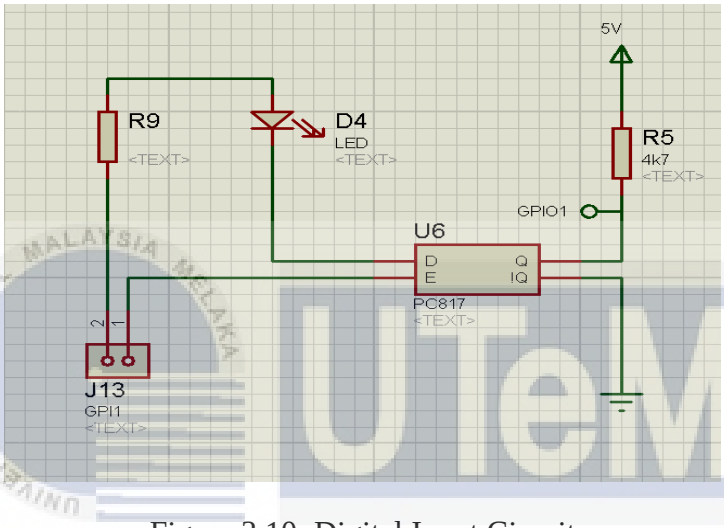


Figure 3.10: Digital Input Circuit

Many types of optocouplers are available in market according to their rating and design like fast optical isolator, analog optoisolator and linear. Rating depends on output voltage drive capacity of optoisolator. The mostly used optoisolator for maximum output voltage are 30 volt, 70 volt and 80 volt. They can easily operate between temperature range of 70°C to 150°C. Optocoupler PC817 is chose to design the digital input of the RTU. Optocoupler PC817 is used to provide isolation between two electrical circuits. It is a electrical component which is used to transmit input signal by using light energy signals. It provides electrical coupling between input and output through light waves. Its main purpose is to avoid changing in voltages at output side to appearing at input side. Higher voltage fluctuations may damage input side electrical components. optocoupler consists of a LED which converts input electrical signal into light energy signal. Photo transistor at the output side detects light signal and turned on when LED light falls on it. In this way its

output becomes low and high according to input signal and LED lights as shown in figure 3.11:

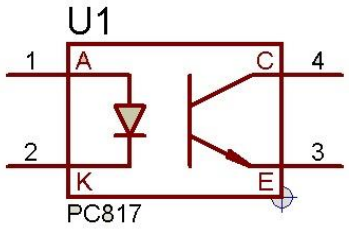


Figure 3.11: Optocoupler PC817 [22]

3.5.5 Digital Output

RTU digital output circuit needs optocoupler 4N27, ULN2803 Darlington transistor array and selectable switch for the input and output signal. Optocoupler 4N27 uses a beam of light to transfer energy from one circuit element to another . It can transmit and receive by a non-conductive barrier. The Darlington transistor has eight NPN Darlington that connected for suitable involving between minimal logic level digital circuitry. All gadgets feature open–collector outputs and freewheeling clamp diodes with regard to transient suppression. The Darlington transistor circuit configuration can be very useful in electronics circuit design. In electronics, the Darlington transistor is a compound structure consisting of two bipolar transistors connected in such a way that the current amplified by the first transistor is amplified further by the second one. This configuration gives a much higher current gain than each transistor taken separately and can take less space than two individual transistors because they can use a shared collector. Integrated Darlington pairs come packaged singly in transistor-like packages or as an array of devices (usually eight) in an integrated circuit. The figure 3.12 showed Darlington pair using NPN transistors

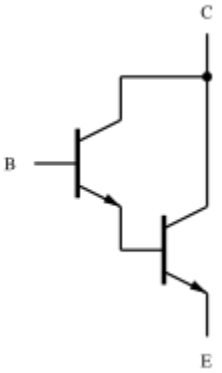


Figure 3.12: A Darlington pair using NPN transistors [23]

A similar configuration but with transistors of opposite type (one NPN and one PNP), sometimes called the "complementary Darlington." The eight NPN Darlington connected transistors in this family of arrays are ideally suited for interfacing between low logic level digital circuitry and the higher current/voltage requirements of lamps, relays, printer hammers or other similar loads for a broad range of computer, industrial, and consumer applications. All devices feature open–collector outputs and freewheeling clamp diodes for transient suppression. The ULN2803 is designed to be compatible with standard TTL families. The digital output circuit is shown in Figure 3.13.

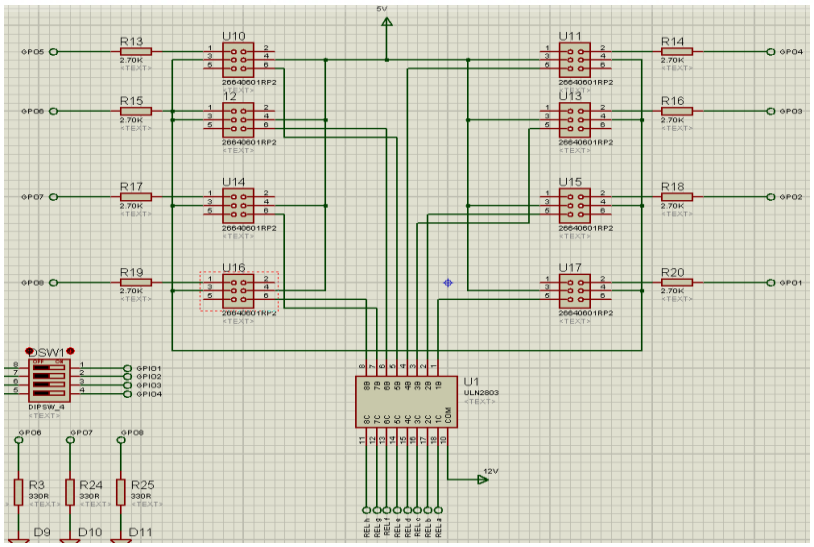


Figure 3.13: Digital Output Circuit

3.5.6 Serial port Communication

Serial port is used as a communication media in RTU. In telecommunication and computer science, serial communication is the process of sending data one bit at a time, sequentially, over a communication channel or computer bus. This is in contrast to parallel communication, where several bits are sent as a whole, on a link with several parallel channels. Serial communication is used for all long-haul communication and most computer networks, where the cost of cable and synchronization difficulties make parallel communication impractical. Serial computer buses are becoming more common even at shorter distances, as improved signal integrity and transmission speeds in newer serial technologies have begun to outweigh the parallel bus's advantage of simplicity and to outstrip its disadvantages. Many serial communication systems were originally designed to transfer data over relatively large distances through some sort of data cable. The term "serial" most often refers to the RS232 port on the back of the original IBM PC, often called "the" serial port, and "the" serial cable designed to plug into it, and the many devices designed to be compatible with it.

In telecommunications, RS-232 is a standard for serial communication transmission of data. It formally defines the signals connecting between a DTE (Data Terminal Equipment) such as a computer terminal, and a DCE (Data Communication Equipment), such as a modem. The RS-232 standard is commonly used in computer serial ports. The standard defines the electrical characteristics and timing of signals, the meaning of signals, and the physical size and pinout of connectors. Rs232 pinout is shown in figure 3.14.

Pin 1	DCD
Pin 2	RXD
Pin 3	TXD
Pin 4	DTR
Pin 5	GND
Pin 6	DSR
Pin 7	RTS
Pin 8	CTS
Pin 9	RI

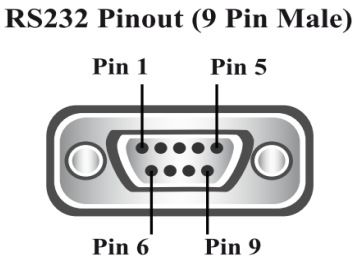


Figure 3.14: Rs232 pinout [24]

A RS232 serial port was once a standard feature of a personal computer, used for connections to modems, printers, mice, data storage, uninterruptible power supplies, and other peripheral devices. However, RS-232 is hampered by low transmission speed, large voltage swing, and large standard connectors. In modern personal computers, USB has displaced RS232 from most of its peripheral interface roles. Many computers do not come equipped with RS232 ports and must use either an external USB to RS232 converter or an internal expansion card with one or more serial ports to connect to RS232 peripherals. Nevertheless, RS232 devices are still used, especially in industrial machines, networking equipment, and scientific instruments. Figure 3.15 shown the serial communication connected with max232.

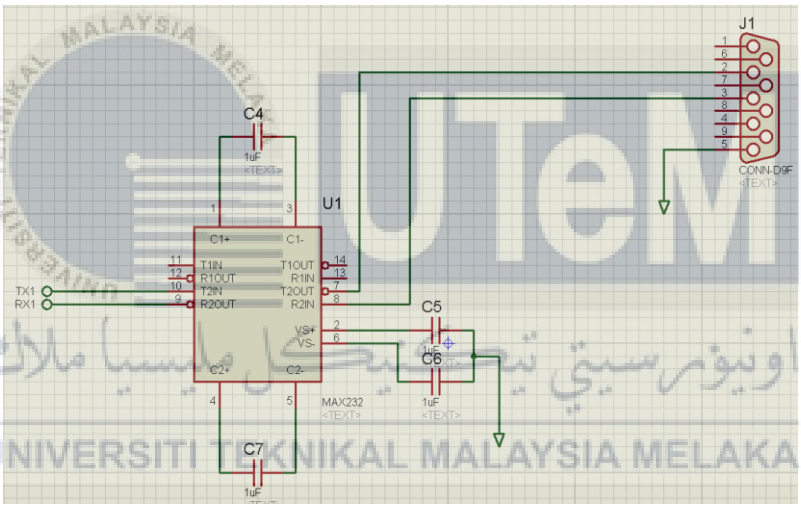


Figure 3.15: Serial Communication Port Circuit

3.5.7 Real Time Clock (RTC)

The RTC is employed as a timer to microcontroller. The architecture of DS1307 shown in Figure 3.16. The advantage of this RTC is to ensure that time is working on when the electricity supply can be tripped because it features 3V backup battery supply. SRS 05VDC-SH AC relay is used whenever fault current is usually recognized. This relay operates at 5VDC and current of 3A.

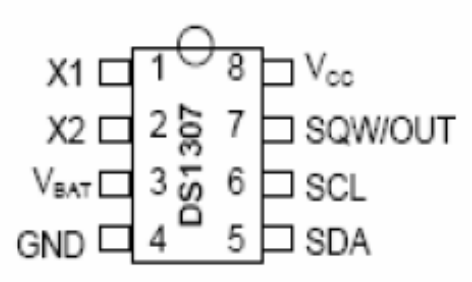


Figure 3.16: DS1307 Chip [15]

The DS1307 can give the data connected with seconds, minutes, hours, day, date, month and also year. These details will be read and also exhibited in LCD. The DS1307 is really a low-powered, whole binary-coded decimal (BCD) time clock. The clock operates in 24 hour because it has backup supply when detects the power failures. DS1307 computer chip is made of 8 pins. The first two pins (X1 along with X2) tend to be associated with the 34. 768 KHz very. The next pin (VBAT) will be the back-up supply input and that is associated with the 3V battery. The SDA pin number could be the data feedback productivity pin number even though the SCL pin number could be the time clock feedback regarding I2C user interface and is particularly helpful to synchronize data mobility on the I2C on the serial user interface. The two pins should be linked with the actual I2C pins in the microcontroller (RC3 and also RC4) and also ripped high. Your SQW/OUT pin number could be the Sq . Wave/Output Drivers. As soon as made it possible for, the SQWE bit set to 1, the SQW/OUT pin number outputs considered one of some square-wave frequencies (1 Hz, four KHz, 8 KHz, 34 KHz). On this RTU design, the SQW/OUT pin number is not utilised. The figure 3.17 showed real time clock circuit.

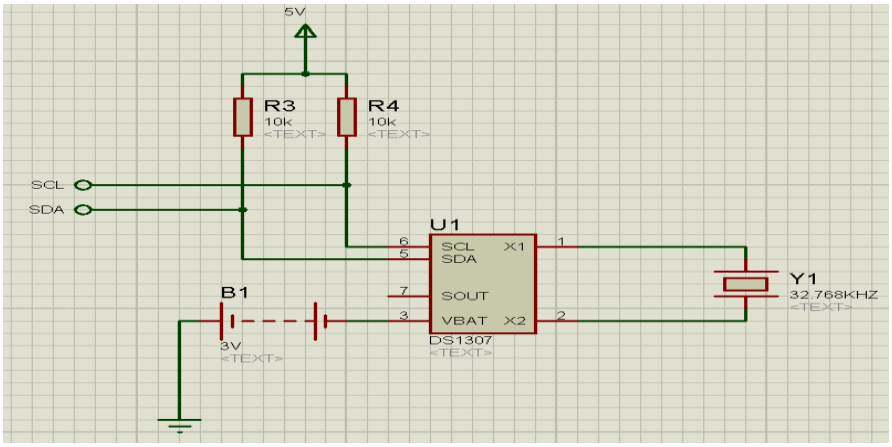


Figure 3.17: Real Time Clock Circuit

DS1307 chip consists of 8 pins. The first two pins (X1 and X2) are connected to a 32.768 KHz crystal. The third pin (VBAT) is the backup supply input which is connected to a 3V battery. The SDA pin is the data input output pin while the SCL pin is the clock input and is used to synchronize data movement on the serial interface. The two pins must be connected to the microcontroller (RC3 and RC4) and pulled high. The SQW/OUT pin is the Square Wave/Output Driver. For RTU, the SQW/OUT pin is not used.

3.5.8 LCD Display

The function of LCD is to display all the RTU events. It can remind the operator to alert when voltage fault occur. The data from the LCD display will be sent to a monitoring system via serial communication in the form of current value, date and time. The graph will display the data saved form the LCD. Figure 3.18 showed LCD Display

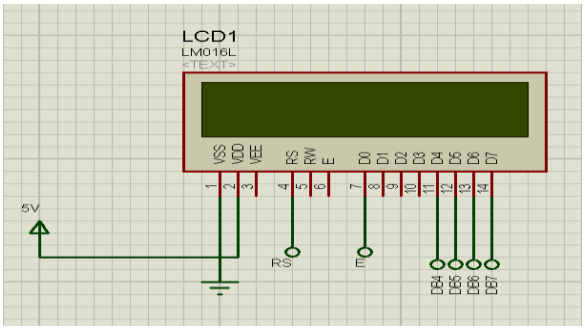


Figure 3.18: LCD Display

3.6 RTU Circuit Design Using Proteus Software

For the design and development of circuit board of an RTU, the Proteus software has been selected. Proteus is a software that will be use to design RTU circuit boards. Firstly, the RTU circuit is developed by using this software. The circuit of input-output, microcontroller and other parts are designed to produce the RTU circuit board.

3.6.1 Proteus Software

Proteus is a Virtual System Modelling and circuit simulation application. The suite combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co-simulation of complete microcontroller based designs. Proteus also has the ability to simulate the interaction between software running on a microcontroller and any analog or digital electronics connected to it. It simulates input and output ports, interrupts, timers, USARTs and all other peripherals present on each supported processor. It consists of two main parts, the ISIS , the circuit design environment that even the simulator VSM includes, and the ARES , the PCB Designer. The ISIS, (Intelligent Schematic Input System) is the environment for the design and simulation of electronic circuits.

The component library includes claims to more than 10,000 circuit components with 6000 Prospice simulation models. Own components can be created and added to the library. ISIS includes a base-VSM engine with support for the following functionality:

- DC / AC voltmeter & ammeter, oscilloscopes, logic analyzers
- Analog signal generators, Digital Pattern Generator
- Timer functions, protocol analyzers (eg RS232, I2C, SPI)

The VSM, (Virtual System Modeling), provides a graphical SPICE circuit simulation and animation directly in the ISIS environment. The SPICE simulator is based on the Berkeley SPICE3F5 model.

It may microprocessor based systems are simulated. With the VSM Engine can interact during the simulation directly to the circuit. Changes of buttons, switches or potentiometers are queried in real time as well as LED indicators, LCD display and wires displayed.

Proteus VSM for microcontrollers [25]

- PIC12 / PIC16 / PIC18
- PIC24 / PIC33
- HC11
- 8051/8052
- BASIC Stamp
- ATMEL AVR
- 8086
- MSP430

The microcontrollers are in the periphery and in the code fully supported.It includes a debugging environment for the program code of the microcontroller. The .HEX file of the compiled software are necessary to stimulate the microcontroller. The clock is simulated in real time.

Proteus VSM Advanced Simulation [25]

- Generating frequency responses

- Analog and digital transient analysis
- Analysis of the analog behavior of digital sources
- Analysis of the noise behavior
- Generation of custom waveforms using the EasyHDL Scripting Language
- Display in magnitude and phase in dB or linear
- Audio analysis of waveforms in exportable WAV
- Meter reading supported by graphics cursor

Proteus VSM USB Simulation [25]

- Debugging USB applications with the support of USB device classes
- Mass Storage Device Class (MSD)
- Human Interface Device Class (HID)
- Communications Device Class (CDC)
- USB Transaction Analyzer
- Illustration of USB Packages

The ARES, (Advanced Routing and Editing Software), is a software for PCB design. It's drag and drop to operate, hardware accelerated and allowed "shape based" auto routing and auto placement. In some versions of an export of 3D circuit DXF files is possible.

3.6.2 Circuit Development using Proteus Software

For methods of designing a RTU, most parts of the basic circuit is taken from Cytron Technologies while other circuits such as the value of resistor, capacitor, the circuit arrangement of power supply circuit and the LCD circuit are taken from internet sources, which are then redesigned to obtain a RTU circuit based on input-output, type of microcontroller and other parts that are needed to produce the RTU board. After completing the RTU circuit design, the development process begins by using Proteus software. Here are the steps to design RTU circuit boards.

3.6.3 Steps for Designing RTU Circuit Boards

The design begins by clicking ‘file’ then choose ‘new’ and create a project name; making sure to click at the schematic and file must be in the format of .PWI file. Click the ‘pick from libraries’ to find components, and then drag to the workplace. If the designer wants to rotate the component, click rotate clockwise or rotate anti clockwise. The number on each component pin needs to follow the sequence by right-clicking and choosing the horizontal or vertical mirror. In library includes the connector, amplifier, discrete, op-amp, regulator and transistor. The selected component will be added in the component mode to ensure that the designer may pick the same component in future easily. After placing the entire component, click place wire to connect one component to another component. The design use place part and place wire as shown in Figure 3.19.

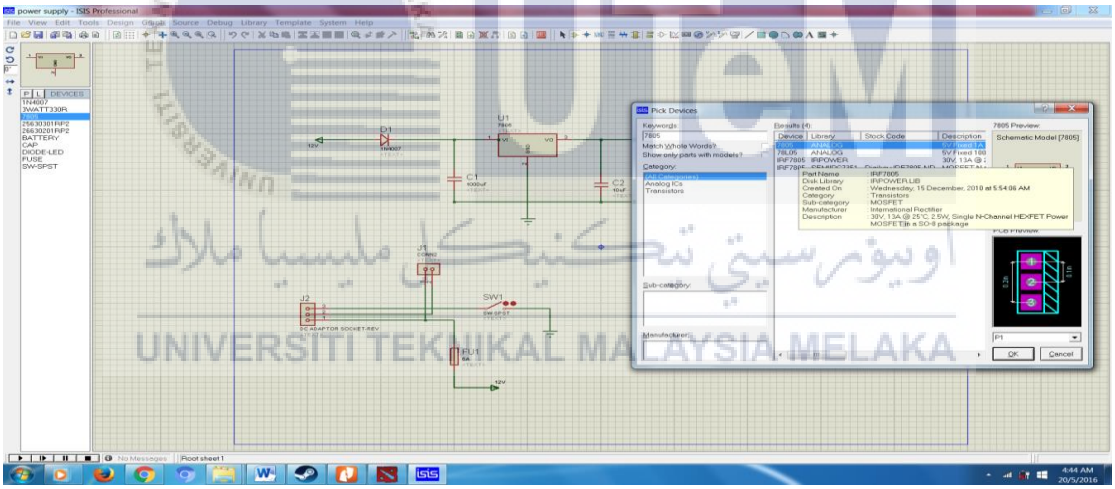


Figure 3.19: Design use place part and place wire

Figure 3.20 shows the complete design of an RTU circuit and the detailed design is attached at appendix B. After the design is completed, click ‘save’ and go to the document libraries and click *.PWI file which is the format for a schematic file.

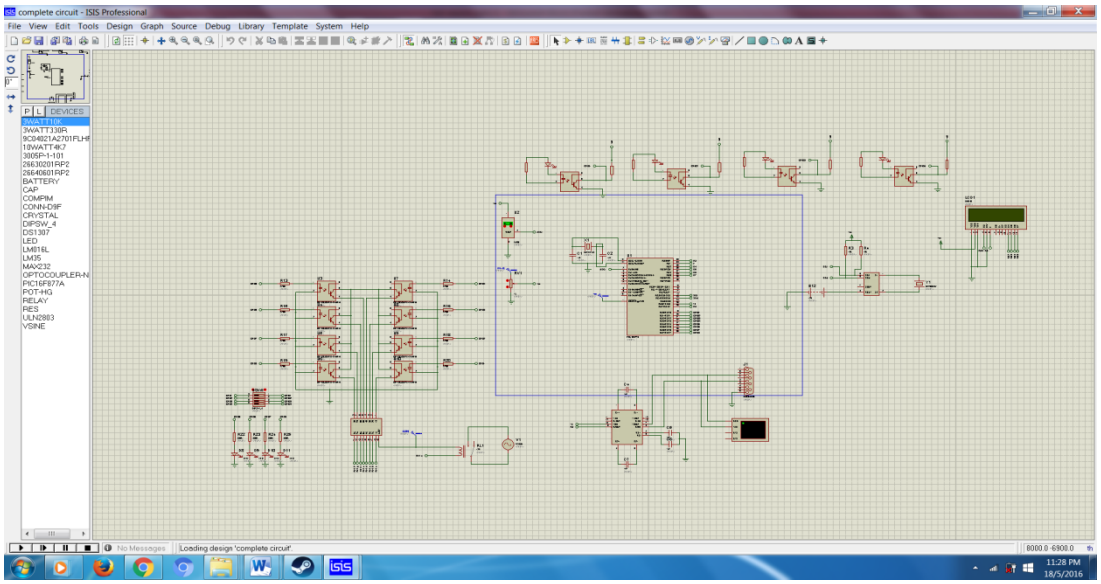


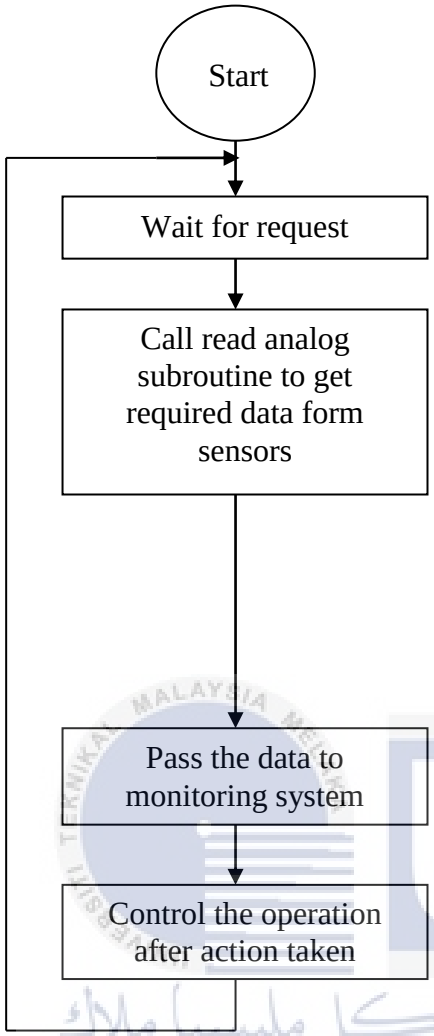
Figure 3.20: A complete RTU circuit design

3.7 Software Description

The software has 3 steps which are I/O scanning function for data acquisition, a database manager and communication functions for data transfer. The software acts as an important role to make the RTU can interface with variety devices either master or slave devices. The design of RTU requires three software which are mikroC PRO and Visual Basic.

3.7.1 Programming of Microcontroller using mikroC PRO

The RTU microcontroller will be program using the mikroC PRO software. Figure 3.21 shows the flowchart of RTU mikroC PRO programming.



- RTU in standby mode and LED on
- Sensor will detect the value lower than 160V as an under voltage or 250V above as overvoltage.
- Relay will cut-off and LED on
- If fault is detected, microcontroller will record the load condition, current value, time and date
- Use Serial input to send data and display at the Visual Basic as a monitoring system
- RTU is reset and control the operation.

Figure 3.21: Flowchart of RTU mikroC PRO programming

3.7.1.1 Steps to Program the Microcontroller

The following are the steps to program the microcontroller to ensure RTU function properly.

1. RS232 receives data from the main controller
2. Data received from software consists of date and time
3. Extract the data components; day, month and year

4. Extract the time components; hour and minutes
5. Trigger alarm and buzzer countdown
6. LCD implementation to display current value, time and date
7. Read status of voltage values at the load.
8. Initialize ADC for voltage values to be read through port 0 and 1 and then convert to its equivalent digital value
9. Initialize timer 1 as interrupt
10. 1 second event triggered to check voltage value whether normal or over limit (overvoltage) or under limit (undervoltage)
11. Convert the analog value read back to digital equivalent at load
12. Update LCD display with data received from the load
13. Buzzer reset implementation

3.7.2 Visual Basic

Visual Basic is a software that can be program is done in a graphical environment. Furthermore, the user may pick on certain subprogram randomly, so each subprogram must be programmed with their own code to ensure it can executed and linked together.

3.7.2.1 Flowchart of an iRTU Monitoring System

The Flowchart of a RTU monitoring system is shown in Figure 3.22.

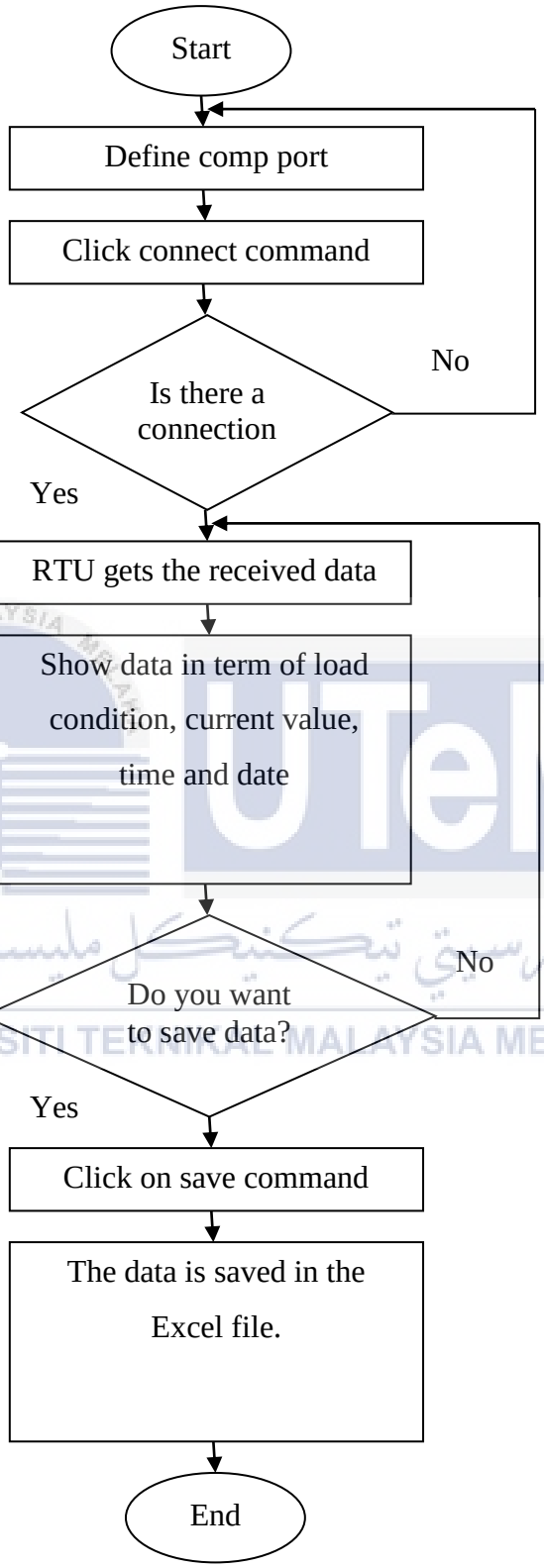


Figure 3.22: Flowchart of RTU Monitoring System

3.7.2.2 Steps of Designing a GUI Interfacing

The following are the steps to design a remote terminal unit monitoring system for central unit to monitor a load condition, date and time.

For Main Display:

1. Handles the loading of the form at initial start-up.
2. Initialize timer parameters (ticks) for 1000 milliseconds equals to 1 second which the timer control allows to perform a task at a specified interval or to wait for a specific duration.
3. 'Connect button' to connect the software to serial input
4. Open serial port. Serial port parameters initialization.

```
Private Sub btnConnect_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnConnect.Click
    SerialPort1.PortName = cmbPort.Text        'Set SerialPort1 to the selected COM port at startup
    SerialPort1.BaudRate = cmbBaud.Text        'Set Baud rate to the selected value on

    'Other Serial Port Property
    SerialPort1.Parity = IO.Ports.Parity.None
    SerialPort1.StopBits = IO.Ports.StopBits.One
    SerialPort1.DataBits = 8            'Open our serial port
    SerialPort1.Open()

    btnConnect.Enabled = False          'Disable Connect button
    btnDisconnect.Enabled = True        'and Enable Disconnect button


End Sub
```

5. Display the port status as connected
6. Disconnect button to disconnect the software from serial input
7. Close port and display the port status as disconnected
8. Serial port implementation for data received
9. Convert the data received from above to integer equivalent values
10. Read previous current values for the load from text file
11. Voltage value at load exceed upper limit (250V) for the first time. Declared as a overvoltage condition

12. Voltage value at the load drops lower than lower limit (160V) for the first time. Declared as a undervoltage condition
13. Voltage value at the load stay within normal operation range
14. Check correct header and end characters
15. Execute thread process to set values of current value readings
16. Set value for initialization using process thread
17. Reset and save button implementation for the laod

The remote terminal unit monitoring system is shown in Figure 3.23.

Figure 3.23: RTU monitoring system

3.8 Gantt Chart and Project Milestone

Table 3.5: Gant Chart for FYP 1

Duty/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Supervisor permission and confirmation of title	√	√												
Research about the design and development of RTU			√	√	√									
Research about the voltage regulator				√	√	√	√	√	√					
Write progress report	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Development of circuit							√	√	√					
Evaluate the system performance									√	√	√			
Submit progress report													√	
Presentation and FYP seminar														√

Table 3.6: Gant Chart for FYP 2

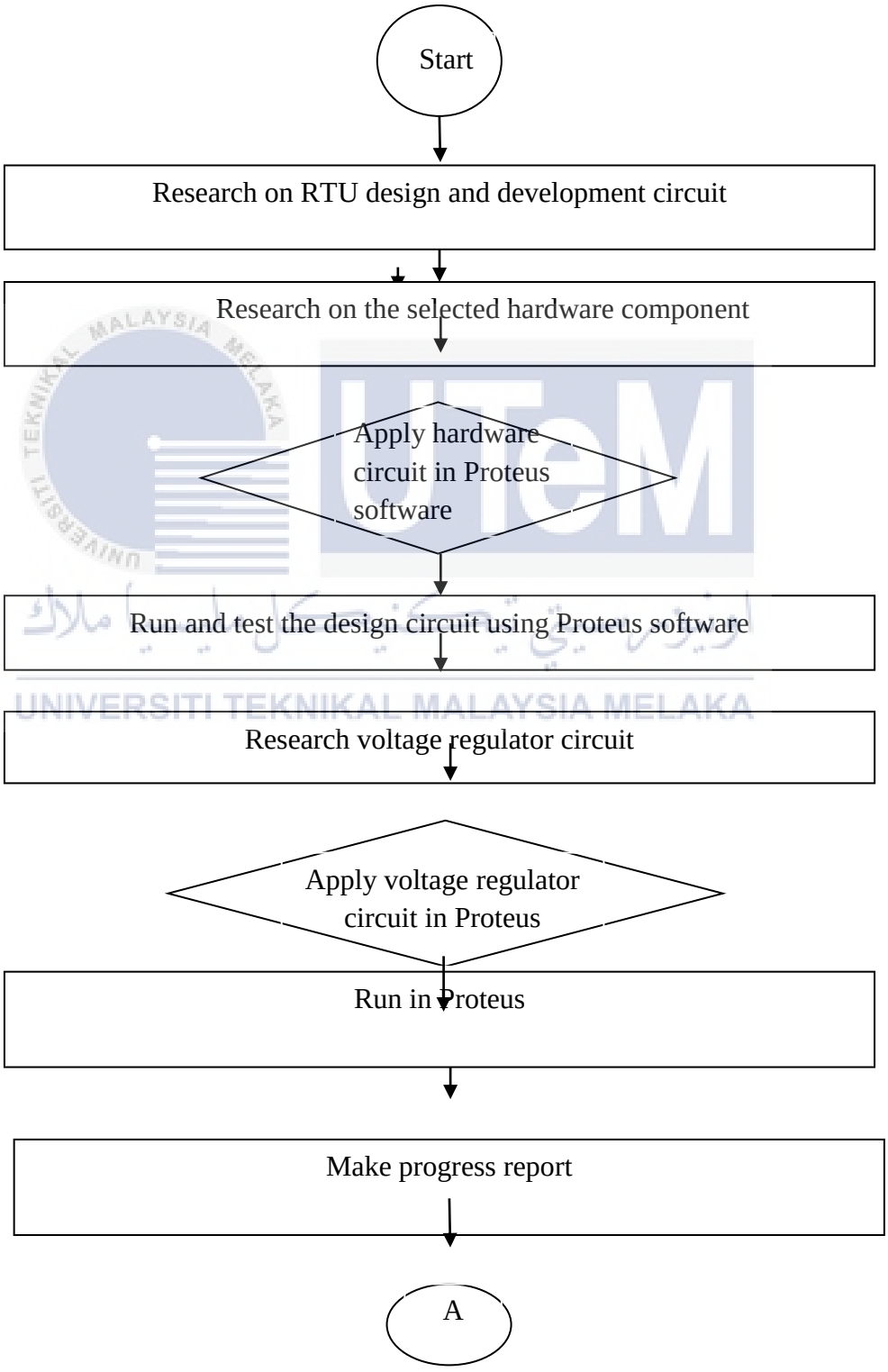
Duty/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Develop the RTU hardware	√	√												
Develop the RTU software			√	√	√									
Design and develop the voltage regulator circuit				√	√	√	√	√	√					
Develop GUI in visual basic software										√	√	√		
Submit draft report													√	
Presentation and FYP seminar														√
Submit full report														√

Table 3.7 : Project Milestone

Duty	Date
Supervisor permission and Confirmation Project Title	18/09/2015
Literature review	20/10/2015
Development of RTU	2/11/2015
Seminar and Presentation Project Proposal	15/12/2015
Development of programming code	16/3/2016
Due Date for Send Draft Report	27/5/2016
Presentation of Project	8/6/2016
Due Date for Send Full Report	3/6/2016

3.9 The flowchart of project workflow

The flowchart of the project for the both semester is shown is Figure 3.24. This flowchart shows the development of the RTU and voltage regulator following the sequence of hardware and software interfacing each other



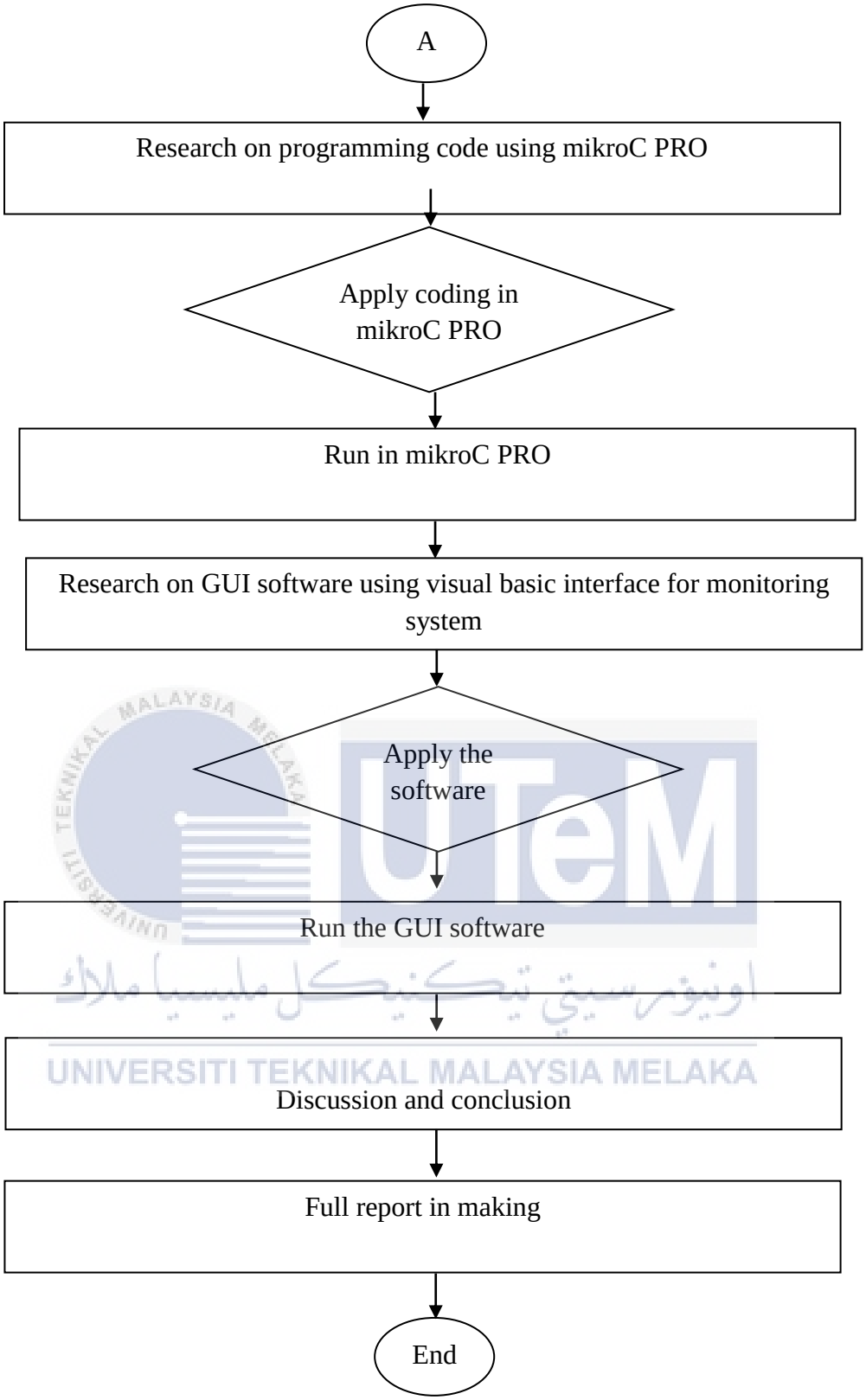


Figure 3.24: Flowchart of project workflow

3.10 Summary

This chapter explains the design and development of RTU. The selected hardware components is apply to ensure that the components used have ability to function very well and solved the problem in the circuit board. The RTU development have four types of software which are Proteus software for designing circuit, mikroC PRO to program the microcontroller, Microsoft Excel for saving the information receiving from RTU and Visual Basic to create a GUI interfacing. The RTU design consist of seven segments which are power supply, main board, analog input, digital input, digital output, real time clock (RTC), serial communication port (rs232) and LCD display. Each seven segment has proper circuit to make the RTU function smoothly. Visual Basic is used to create the GUI for system of monitoring.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter describes about the result of hardware development, the specification and the functioning of an RTU. The experimental result shows the graph of normal, overvoltage and undervoltage condition. The results discuss about how an RTU can detect fault and send the information to a monitoring system via serial port communication and the historical event will be saved on the Microsoft Excel.

4.2 Hardware Development

After studying all aspects of the circuit design, the prototype of RTU production is as shown in Figure 4.1. The RTU is an innovation based on the few circuits that have been designed by previous researchers. The remote terminal unit (RTU) is a standalone data acquisition and control unit. Its primary function is to control and acquire data from process equipment at the remote location. So, the existing RTU can be used in various applications but the designed RTU is predesigned to detect fault in the load and to send the data to the master station for further monitoring.

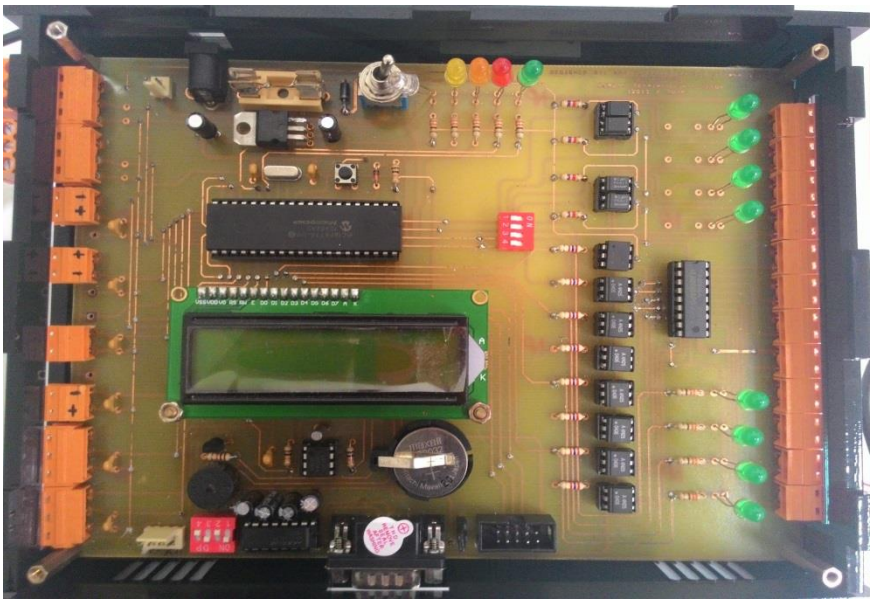


Figure 4.1: RTU Prototype

4.2.1 RTU Specifications

Table 4.1 shows the information of RTU specifications. There are seven important criteria in RTU.

Table 4.1: RTU Specifications

No.	Crateria	Specifications
1.	Memory	• 16-Bit Microprocessor and Support Circuitry • 516K bytes Program Memory • 128K bytes Non-Volatile Database Memory
2.	DC Power Requirements	• DC VOLT (worst case) 7-12V, 2 A • 5 VOLT (nominal per active Digital Output), 60 mA • 5, 12, 24 VOLT (nominal per active Digital Input), 20 mA • 5 VOLT (maximum per Analog Input)
3.	AC Power Requirements	• 240 VAC, 200 mA
4.	Host/Slave Communication	• RS-232 Communication
5.	Digital Input	• Maximum Quantity: 4 (Variable) • Operating Voltage: 5VDC, 12 VDC or 24 VDC
6.	Digital Output	• Maximum Quantity: 8 • Operating Voltage: 12 VDC
7.	Analog Input	• Maximum Quantity: 8 • Operating Voltage :±5 Volts • Resolution: 10 bits

4.3 Software Development

The RTU software platform is based on a real time clock, automatic fault recovery and serial port communication. All the features are designed with the Visual Basic software (VB) as a monitoring master. The operation of the RTU is based on a highly reliable and field-proven real-time. All timed events of the RTU are coordinated by the clock. The RTU has a watchdog timer that is periodically strobed by the microprocessor. Should the processor suffer a lapse due to hardware or software failure, the watchdog timer will time out and all outputs will be disabled. The RTU will then be reset and normal operations will resume. The communication of RTU uses serial port to transmit data. When fault occurs, the data will be sent to master station and stored in the Microsoft Excel. The Excel file collects the data event in terms of number of load, load condition, current value, time and date. The Excel file allows the RTU system executive to access data from the Microsoft excel in an organized and program-independent manner. It resides in the non-volatile RAM.

4.3.1 GUI Interfacing

GUI, or Graphical User Interface, is the user interface of a program and all the objects on it allows a user to interact with it using images rather than text. Visual Basic is an event-driven programming language and integrated development environment developed by Microsoft that makes heavy use of predefined code components. Visual Basic design environment allows for developers to rapidly build or enhance GUI-based programs and applications.

4.3.2 Overall RTU System

When the RTU is switched on, the sensor will standby to measure the incoming voltage and current to the RTU. If overvoltage or undervoltage fault has occurred, the relay will be cut off and then the LED will automatically turn OFF. The data fault will displayed on the LCD at the RTU board. The data will be sent to the control unit system via serial port communication protocol which will transmit data from RTU board and will be received by the personal computer (PC) at the control room. The PC's comps ports need to be initialized and click the button connect to receive all incoming data. When the implemented RTU is connected, the command field will start a connection and request the implemented data from RTU to send the data to the control unit. All the data is collected by the sensor and the data is sent in terms of number of load, load condition, current value, time and date of fault occurrence. For further monitoring, the user can click save button at the main station to save the information of the current situation in the Microsoft Excel. All history data can be found in the excel format that is stored in a Microsoft Excel and this data will facilitate the engineers to check, do system maintenance or repair in the future. Once the operator from the control room notices that fault has occurred at the load, the operator will inform the relevent parties, such as the TNB, to expedite action. When the fault has been rectified, the LED at the RTU board will automatically turn ON and RTU will carry out its work continuously to monitor the next fault event. Figure 4.2 shows the overall RTU system.

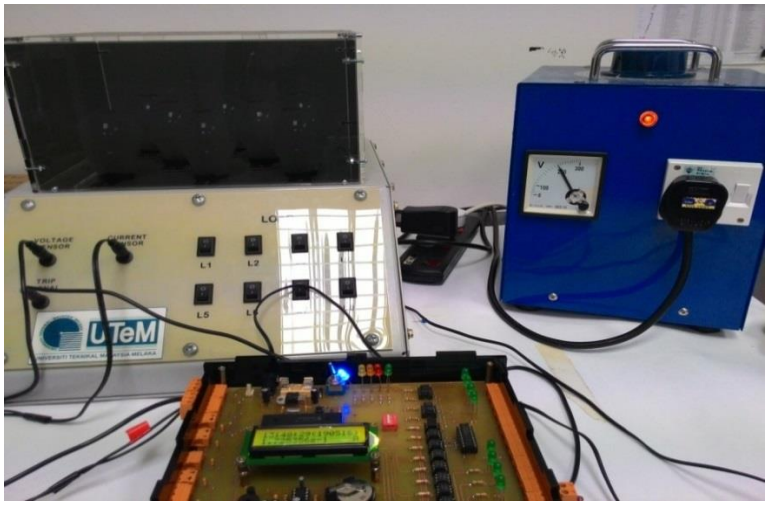


Figure 4.2: Overall RTU System

4.3.3 Fault Detection

After completing the design of RTU circuit, the RTU needs to be validated and tested with the complete system. The test only uses the variable power supply instead of using the real AC sources and the sensor is created by using a voltage divider. The RTU is used to control and monitor the load. The load contains 8 bulbs. To analyze the results, a test was conducted for 3 days in 3 weeks which are on 5 May 2016 at 2.38 p.m, 12 May 2016 at 12.36 p.m and 19 May 2016. Five loads are tested in 3 condition. There are normal condition, overvoltage condition and undervoltage condition. When the condition is normal at the 1 load, the current value detected at the load is 0.4313392 Amp. The normal condition is shown in Figure 4.4. The range of the normal condition is between 250 V and 160 V.

Figure 4.3: 1 load normal condition displayed

The data received from the RTU station is 0.4313392 A which is in normal condition at the load, and will be sent to the master station via serial communication. All the information will be monitored by the operator at the master station so that the operator can identify the current value, load condition and time occurred. Master stations can receive the data by pressing COM13 and click connect button at the main interface. The displayed data is same with the data at the LCD display at the RTU board. The monitoring system interface is shown as a Figure 4.4.

Figure 4.4: System Monitoring at Master Station

For further monitoring, the operator at the master station can click on the save button at the main display as shown in Figure 4.5 to save the data into the Excel file and also able to read a few fault histories. The operator can view the graph in the Microsoft Excel. Figure 4.5 showed a graph at load which is in normal condition.

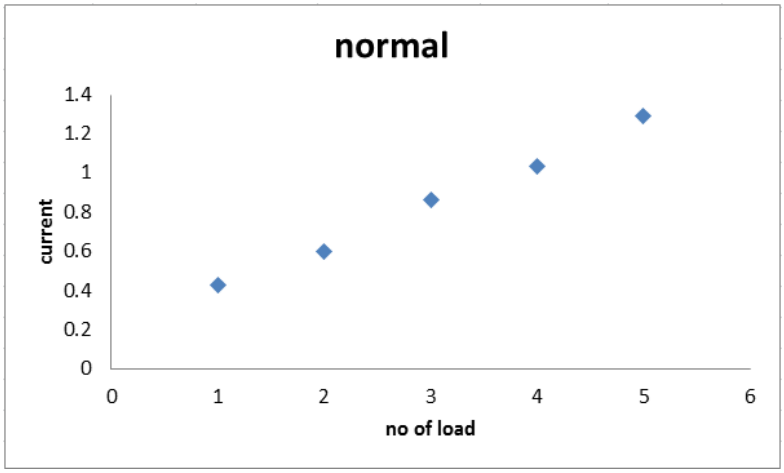


Figure 4.5: Graph at the load in normal condition

4.3.4 GUI Fault Indicator: Undervoltage

Initially, load is in normal condition where the graph shows a stable condition and after a few minutes, undervoltage condition has occurred and has been detected by the RTU where the value of the undervoltage condition is below 160V. As noticed, undervoltage condition will occur if the voltage value is less than 160V. To clear the fault, immediate action has to be taken by certain parties such as TNB to restore the system and after rectifying the fault, the graph at the master station will return to its normal state at 224V. As an option, the reset button is used to reset the RTU manually when the problem has been resolved and if the system has not returned to its normal state after repair, the operator in the monitoring room can press the reset button to ensure the RTU is on standby mode to receive the next event of fault. The graph is shown in Figure 4.6.

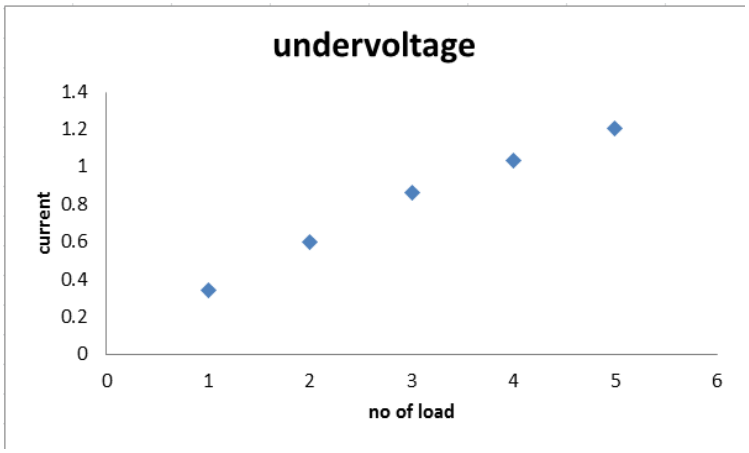


Figure 4.6: Undervoltage graph

At the main station, Figure 4.7 show the LCD display at the RTU indicating the fault occuring at 160V and the fault status is undervoltage at the load. The fault happened on 5 May 2016 at 2.48pm. The information in the load is automatically submitted to the main station for monitoring purposes.

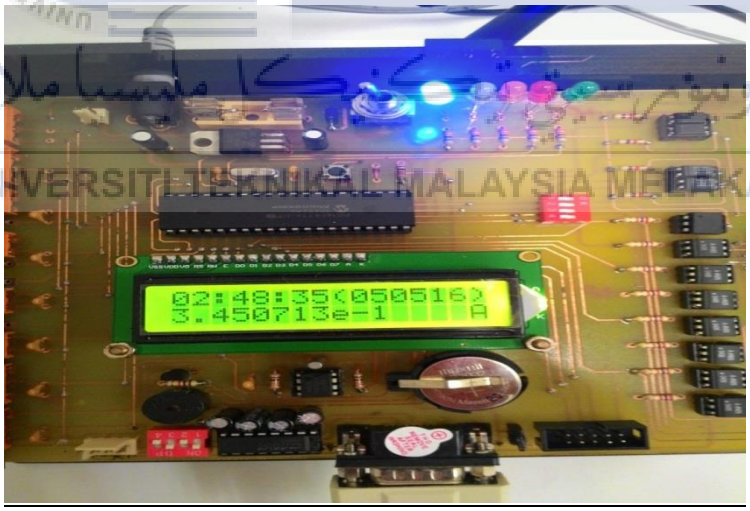


Figure 4.7: Undervoltage condition displayed

4.3.5 GUI Fault Indicator: Overvoltage

Initially, load is in normal condition where the graph shows a stable condition and after a few minutes the graph keeps increasing until the overvoltage condition has occurred and is detected by the RTU and the value of the overvoltage fault is 250V. As noticed, overvoltage fault will occur if the voltage is greater than 250V. To clear the fault, immediate action has to be taken by certain parties such as TNB to restore the system. After the fault has been cleared, the graph at the master station will return to its normal state at 250V. As an option, the reset button is used to reset the RTU manually when the problem has been resolved and if the system has not returned to its normal state after repair, the operator in the monitoring room can press the reset button to ensure the RTU is on standby mode to receive the next event of fault. The graph is shown in Figure 4.8.

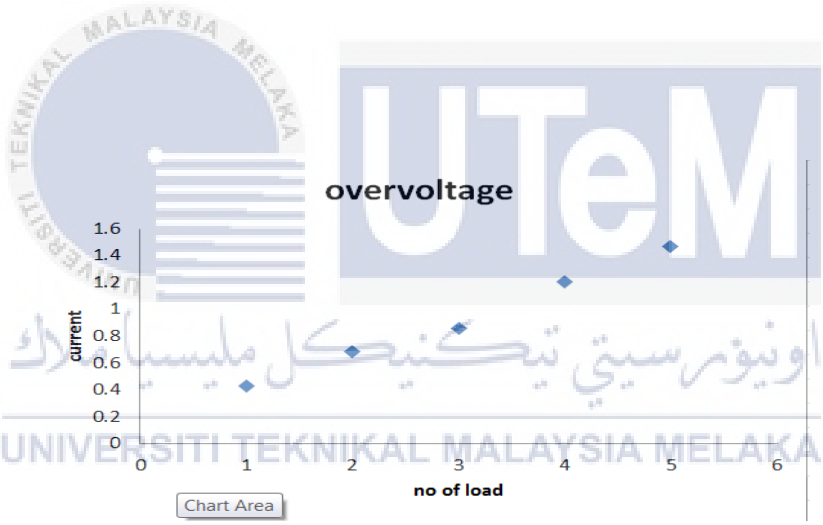


Figure 4.8: Overvoltage graph

At the main station, Figure 4.9 shows the LCD display at the RTU indicating the fault occurring at 250V and status fault is overvoltage at the load. The fault happened on 5 May 2016 at 2.41pm. The information in the load is automatically submitted to the main station for monitoring purposes.

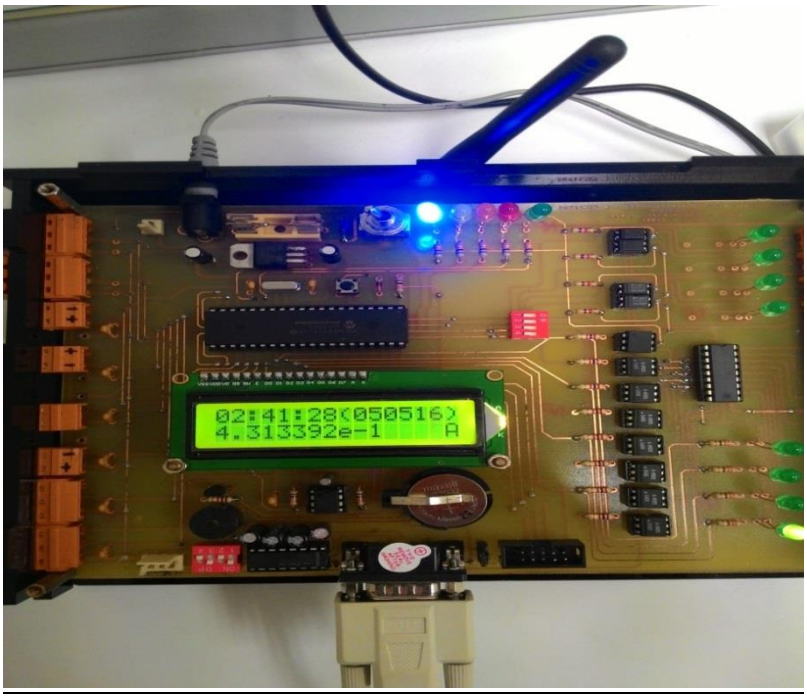


Figure 4.9: Overvoltage condition displayed

The table below showed the data taken from the RTU for 3 weeks. Only 1 day randomly selected for each week to record the data from the RTU in three load condition which are normal, overvoltage, and undervoltage condition. Five loads are tested in every load condition to record the current value, date and time. The table 4.2, 4.3 and 4.4 showed the data taken from the RTU in three selected date which are 5,12 and 19 May 2016 respectively.

Normal (160V<normal<250V)

No of load	current	date	time
1	0.4313392 A	5/05/2016	2.38 p.m
2	0.6039749 A	5/05/2016	2.38 p.m
3	0.8626784 A	5/05/2016	2.39 p.m
4	1.035214 A	5/05/2016	2.40 p.m
5	1.294017 A	5/05/2016	2.40 p.m

Overvoltage (>250V)

No of load	current	date	time
1	0.4313392 A	5/05/2016	2.41 p.m
2	0.6901427 A	5/05/2016	2.42 p.m
3	0.8626784 A	5/05/2016	2.44 p.m
4	1.207749 A	5/05/2016	2.46 p.m
5	1.466553 A	5/05/2016	2.47 p.m

Undervoltage (<160V)

No of load	current	date	time
1	0.3450713 A	5/05/2016	2.48 p.m
2	0.6038749 A	5/05/2016	2.50 p.m
3	0.8626784 A	5/05/2016	2.52 p.m
4	1.035214 A	5/05/2016	2.53 p.m
5	1.207749 A	5/05/2016	2.54 p.m

Table 4.2 : 5 May 2016 (normal,overvoltage,undervoltage)

Normal (160V<normal<250V)

No of load	current	date	time
1	0.3450713 A	12/05/2016	12.36 p.m
2	0.6038749 A	12/05/2016	12.37 p.m
3	0.7764106 A	12/05/2016	12.37 p.m
4	1.035214 A	12/05/2016	12.38 p.m
5	1.294017 A	12/05/2016	12.39 p.m

Overvoltage (>250V)

No of load	current	date	time
1	0.4313392 A	12/05/2016	12.40 p.m
2	0.6038749 A	12/05/2016	12.40 p.m
3	0.8626784 A	12/05/2016	12.41 p.m
4	1.121482 A	12/05/2016	12.42 p.m
5	1.380285 A	12/05/2016	12.43 p.m

Undervoltage (<160V)

No of load	current	date	time
1	0.2588035 A	12/05/2016	12.43 p.m
2	0.517607 A	12/05/2016	12.44 p.m
3	0.6901427 A	12/05/2016	12.45 p.m
4	0.9489462 A	12/05/2016	12.45 p.m
5	1.207749 A	12/05/2016	12.46 p.m

Table 4.3 : 12 May 2016 (normal,overvoltage,undervoltage)

Normal (160V<normal<250V)

No of load	current	date	time
1	0.2588035 A	19/05/2016	1.50 p.m
2	0.517607 A	19/05/2016	1.50 p.m
3	0.7764106 A	19/05/2016	1.51 p.m
4	0.9489462 A	19/05/2016	1.51 p.m
5	1.207749 A	19/05/2016	1.51 p.m

Overvoltage (>250V)

No of load	current	date	time
1	0.2588035 A	19/05/2016	1.52 p.m
2	0.6038749 A	19/05/2016	1.53 p.m
3	0.7764106 A	19/05/2016	1.54 p.m
4	1.121482 A	19/05/2016	1.54 p.m
5	1.380285 A	19/05/2016	1.55 p.m

Undervoltage (<160V)

No of load	current	date	time
1	0.3450713 A	19/05/2016	1.56 p.m
2	0.517607 A	19/05/2016	1.56 p.m
3	0.6901427 A	19/05/2016	1.57 p.m
4	0.8626784 A	19/05/2016	1.58 p.m
5	1.121482 A	19/05/2016	1.58 p.m

Table 4.4 : 19 May 2016 (normal,overvoltage,undervoltage)

4.3.6 Microsoft Excel

The Excel file acts as an Access file which is saved by the implemented master station program. The Excel sheet is shown in Figure 4.10, 4.11 and 4.12. The excel sheet store the received data at the exact time and date on which the data was collected. The benefit of having a database is to provide reliable persistent storage and the ease of extracting data to obtain reports.

Excel file save time and can be retrieved as a single record, which may take several minutes of digging in a paper-based filing system. It can be done by clicks on a save button at the visual basic. Merging Excel file records will be saved in the selected folder.

The RTU uses Microsoft Excel to store the data entry with related records, so that the operator do not have to spend time wading through other records to check spelling, addresses, historical data, such as load condition, current value, date and fault time. The excel file of this system is recorded in few days to ensure the system is working properly and can store the actual data in terms of current value, time and date.

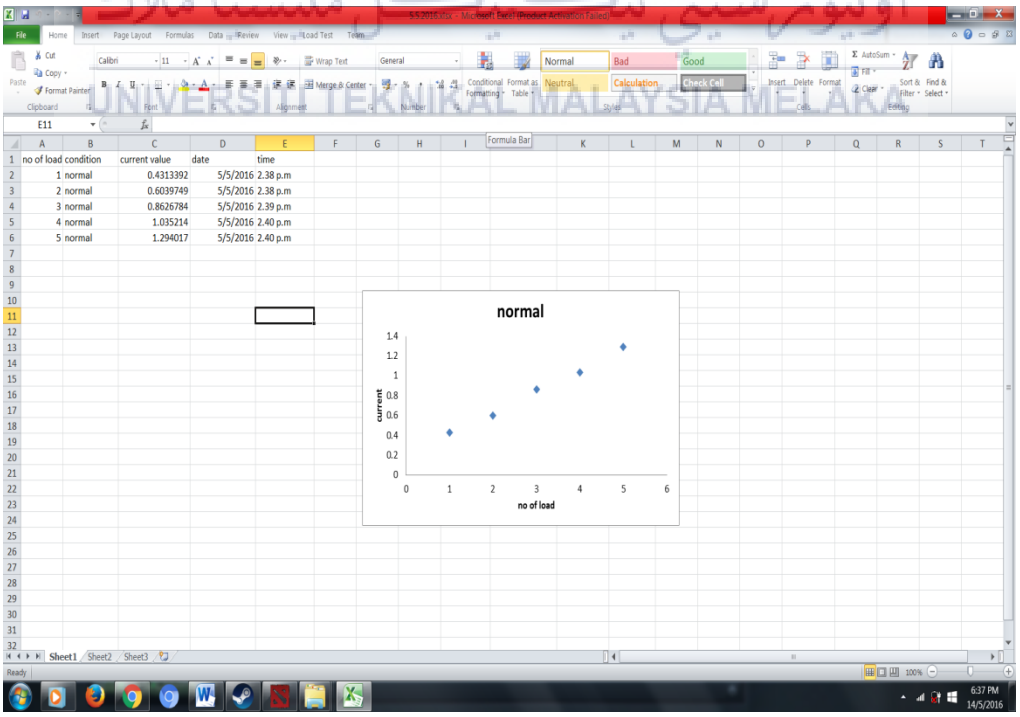


Figure 4.10: Excel sheet for normal condition

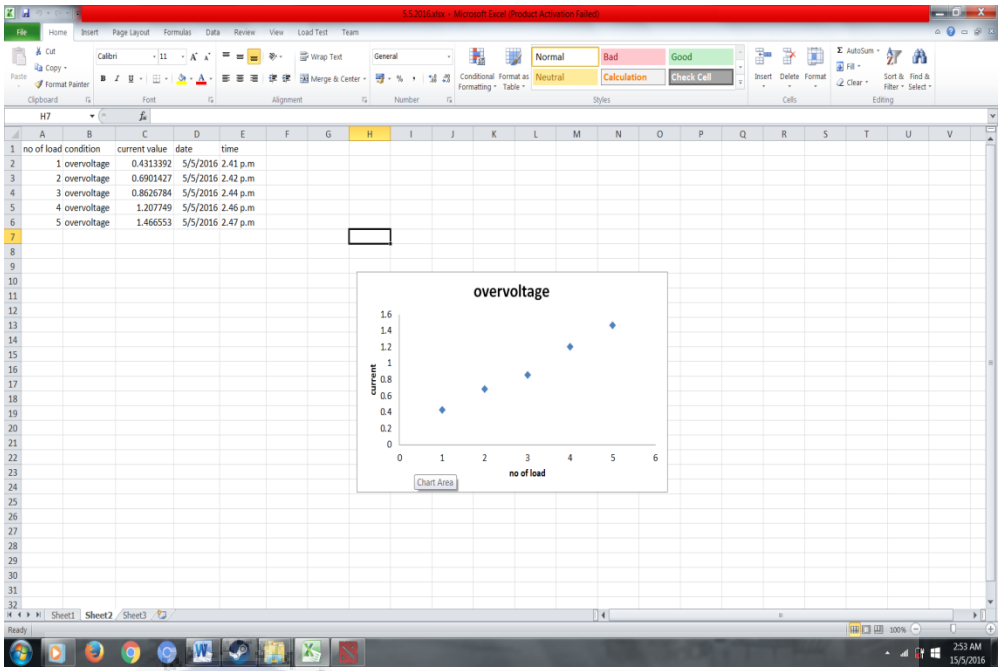


Figure 4.11 : Excel sheet overvoltage condition

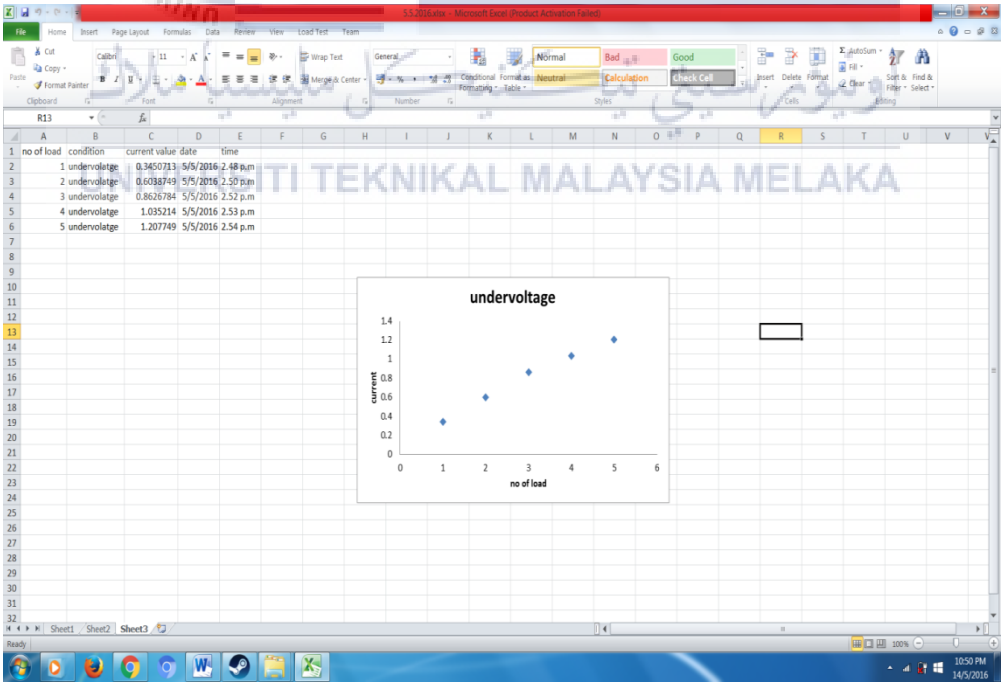


Figure 4.12: Excel sheet for undervoltage condition

4.4 Summary

This Chapter 4 shows the results of the study and methods that have been carried out during the design and development of the RTU. The RTU can operate perfectly for fault detection at the load. The RTU is also able to send data or information to a central unit immediately using serial port communication. Once all the data is received at the central unit, the operator can see all the information such as load condition, current value, date and time in the GUI monitoring systems. The next chapter will conclude all the research activities, attainment of research objectives, significance of research outputs and some recommendation for future research.

CHAPTER 5

CONCLUSION

5.1 Summary

The RTU has a circuit board as a hardware system and a GUI as a software monitoring system. This hardware and software integration uses a serial port communication. However, the serial port communication has a range limitation compared to other communication because the range of serial port is only up to a distance of cable but it is better for an RTU application because the RTU's propose is to control and monitor signals from load and to send the data remotely to the central unit closest to the load settlements.

The design starts with choosing the correct component and completes the RTU circuit design. The components must be well organized to ensure the RTU board is small in size and in order to design a small size RTU, components need to be routed carefully to avoid overlapping on each other because it can cause a short circuit. The RTU uses a double layer circuit which has an upper and bottom layer. Lastly, assemble all the components on the RTU board to complete the design. After finishing the RTU hardware circuit board, the microcontroller needs to be programmed to test the functionality of the RTU.

The mikroC PRO software is used to program the code in the microcontroller. The programming code starts with initializing the communication port which uses the RS232 to receive data from the main controller through serial port communication. The algorithms such as timer are set accordingly to the needs of the RTU. The timer is set in every one second to ensure the fault events are immediately detected. Besides, the programming

algorithm also sets up the real time operation which RTU can give an actual time, date and year when fault types are detected. The algorithm also indicates the load condition and the current values. Based on the programming algorithm code, the RTU is always in a standby mode which is RTU will be ready when fault is detected. Its sensors are coded to detect the voltage value which is less than 160V as an undervoltage fault and greater than 250V as the overvoltage fault. After sensing all the incoming voltage, the algorithm will continue with the action from the relay and LED which as an indication to give a warning that fault has occurred at the load. Finally the current value read will be sent to the monitoring system.

Visual Basic is used to build the GUI interfacing, the first step is to create a main display screen, which can monitor the data such as time, current value and load condition. The VB also has their own algorithm, so the writer needs to create the VB's algorithm to communicate with the RTU. The algorithm begins by connecting the button to serial port, so that data will be transferred from RTU to GUI and the programmer needs to initialize the parameters of the serial port such as port name, baud rate, parity, data bits and stop bits. At the main screen, the user can click on the save button to save the data from the rtu to excel file. The excel file is coded by VB's algorithm to store the data in Microsoft Excel and can provide an easier historical data to the engineer, technician or whoever to check during maintenance or while doing some analysis on previous data for improving the reliability of the RTU in future.

5.2 Attainment of Research Objectives

The first objective is to design and develop Remote Terminal Unit for hardware and software. The modelling hardware is used to create the RTU circuit board using Proteus software and for the software algorithm, uses mikroC PRO software to program the microcontroller PIC16F877A and Visual Basic to create the GUI interfacing code. The first objective is fulfilled.

Secondly, the project objective is to create a voltage regulator circuit that is suitable for the RTU. Voltage regulator circuit is designed using LM7805 IC to regulate low

voltage device such as RTU. Voltage level has been stabilized when the current drawn by the load is monitored by voltage regulator circuit. The second objective is also fulfilled.

The final objective is to develop GUI software for distribution automation using the RTU models with Visual Basic (VB) interface. After the current value read has been sent to the monitoring system, it needs one interfacing monitoring to receive the transmitted data from the RTU. In order to monitor the incoming data, the final objective is also fulfilled.

5.3 Significance of Research Outcomes

The RTU production with a complete design and functionality that meets the objectives was achieved a significance of research outcomes as produce a low cost RTU which is all component is easy to find, the monitoring interfacing use a free software and uses a short range communication systems. The maintenance of the RTU also easy to be fixed and if there have any problem with the circuit board, it easy to be repaired by troubleshooting the circuit. RTU is also capable to wired or wireless application. RTU can sent the data to system monitoring by using a short and long distance communications

5.4 Difficulties Encounter during Research

During doing a research, there are some problems in order to complete the RTU project. The problem is Proteus and Visual Basic software needs to learn from the scratch and struggle to program the microcontroller and to create the GUI interfacing. Other problem came after finished the mikroC PRO programming is the changes of power disturbance. According to the previous power disturbance, the low voltage is 415/240V but now its 400/230V and need to re-calculating the value of undervoltage and overvoltage faults also need to re-program the mikroC PRO programming code. The problem also has with Proteus software which is take a lot of time to route all components to ensure every single line cannot overlap each other because it may cause a short circuit.

5.5 Recommendation for Future Research

The RTU will function when a circuit board is powered up by the external adapter. The adapter cannot supply the current to power up the RTU without electricity power supply. To overcome this problem, I recommend an addition of uninterruptible power supply to ensure the RTU can still operates in absent of power supply.

In this project, the RTU send the information to the master station through serial port communication. The distance between RTU main board and master station depends on the length of RS 232 cable. So the connection between RTU and master station is limited and not widely covered. In these case, I suggest the RTU communication protocol is improved by the wireless connection such as GSM (Global System for Mobile communication). GSM communication has an unlimited distance as along as the network coverage covered in the particular places. The information from RTU can easily send to the operator mobile phone and alert the operator for any fault detected.

The RTU only detects an overvoltage and undervoltage condition. For future research, I suggest to program a new source code into the microcontroller to make the RTU able to detect all power quality problems such as rolling brownouts, voltage sags, spikes, electrical noise and harmonic distortion. Hence, the RTU can be used in various applications of the distribution automation system.

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