IOT BASED MONITORING SYSTEM FOR SMART METER APPLICATION

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IOT BASED MONITORING SYSTEM FOR SMART METER APPLICATION

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

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2020

DECLARATION

I declare that this report entitled "IoT Based Monitoring System for Smart Meter Application" is the result of my own work except for quotes as cited in the references.

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Date : 26 June 2020 ....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

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Signature :

Supervisor Name : Siti Aisyah binti Anas

Date : 02/07/2020

ABSTRACT

The application of smart meters is to calculate bills of electricity consumption by sending the meter reading through wireless communication technology to the centralized recording system for each residential unit. In this project, Internet of Thing (IoT) based monitoring system for smart meter application is developed to provide a supporting supplementary information check with the actual monthly power usage bill from the energy provider. Raspberry Pi Wireless Zero (RPW0), Analog to Digital Converter (ADC), Current Transformer (CT) and a Liquid Crystal Display (LCD) are the main components that needed in order to complete this project. This monitoring system consists of 3 parts which are the front-end power measurement and recording system, back-end cloud storage and mobile application. The front-end power measurement and recording system is formed up by the hardware mentioned above and a signal processing circuit which consists of resistors and capacitors. Furthermore, MySQL database is used as the cloud storage to store electricity consumption detail such as date, time and usage. Lastly, a mobile application is developed using React Native framework with a functionality of monitoring current usage and calculating bill.

ABSTRAK

Applikasi meter pintar adalah untuk mengira bil penggunaan eleltrik dengan menghantar bacaan meter melalui teknologi komunikasi tanpa wayar ke sistem rakaman terpusat untuk setiap unit kediaman. Dalam projek ini, sistem pemantauan berasaskan Internet of Thing (IoT) untuk aplikasi meter pintar telah dibina untuk membenarkan pemeriksaan bil penggunaan kuasa bulanan sebenar dari pembekal tenaga. Raspberry Pi Wireless Zero (RPW0), Analog to Digital Converter (ADC), Current Transformer (CT) dan Liquid Crystal Display (LCD) adalah komponen utama yang diperlukan untuk menyiapkan projek ini. Sistem pemantauan ini terdiri daripada 3 bahagian iaitu sistem pengukuran dan rakaman daya front-end, penyimpanan awan back-end dan aplikasi mudah alih. Sistem pengukuran dan rakaman untuk penggunaan kuasa dibentuk oleh komponen yang disebutkan di atas dan litar pemprosesan isyarat yang terdiri daripada perintang dan kapasitor. Selanjutnya, pangkalan data MySQL digunakan sebagai penyimpanan awan untuk menyimpan perincian penggunaan elektrik seperti tarikh, masa dan penggunaan. Akhirnya, aplikasi mudah alih dikembang dengan fungsi memantau penggunaan semasa dan mengira bil dengan menggunakan rangka kerja React Native.

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ACKNOWLEDGEMENTS

I would like to express special feeling of gratitude to my beloved family members especially my loving parents, Lim Choon Poh and Liew Sheck Hoong who have encouraged and supported me throughout this process.

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LIST OF SYMBOLS AND ABBREVIATIONS

RPW0	:	Raspberry Pi Wireless Zero
IoT	:	Internet of Things
M2M	:	machine-to-machine
GSM	:	Global System for Mobile
GAPMR	:	GSM Automatic Power Meter Reading
SMS	:	Short Message Service
SSR	:	Solid-State Relay
NB-IoT	:	Narrowband Internet of Things
LoRa	:	Long Range network
MCU	:	Main Controller Unit
ADC	:	Analog to Digital Converter
CT	:	Current Transformer
SDA	:	Serial Data line
SCL	:	Serial Clock line
JSON	:	JavaScript Object Notation
MySQL	:	My Structured Query Language
IP	:	Internet Protocol
I2C	:	Inter-Integrated Circuit

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LCD	:	Liquid Clear Display
RTC	:	Real Time Clock
GIS	:	Geographical Information System
QR	:	Quick Response
NTL	:	Non-Technical Losses
AMR	:	Automatic Meter Reading

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CHAPTER 1

INTRODUCTION

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1.1 Introduction

This chapter introduces about the research that is proposed in this thesis. It also provides information of some relevant topics which are conducted by other researchers as project background study in this chapter. The problem statement is highlighted based on the statement in the media, newspaper articles and scholarly articles. Solving the identified problems are the objective of this research. Scope of works and the organization of the research is described in this chapter as well.

1.2 Project Background

M.O. Agyeman et al. (2019) stated that electromechanical meters or a basic electronic meters have been conventionally used to measure energy consumption in the pass [3]. However, these type of meters required a large number of manpower to operate. It also made an unnecessary cost when the suppliers send their employees to obtain meter reading during the billing process.

Taking into consideration the high number of customers, the expenses is quite exacerbating. A. Kumar et al. (2018) mentioned that the cost and time issue which involved in the billing process has motivated the researchers to invent a cost effective and portable hardware which capable to add functionality of smart meter into traditional meter [10].

Apart from that, smart energy meter is developed to achieve the energy saving. A. Y. Devadhanishini et al. (2019) stated that energy saving is the most important and challenging issue. H. W. Yao et al. (2018) indicated that smart meter is a reliable status real time monitoring, automatic collection of information, user interaction and power control device [15]. Hence energy saving could be achieved when customer could monitor their power consumption at real time.

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Smart meters are installed to measure the electricity consumption effectively and avoid any kind of misreading on the actual monthly power usage. Technologically the smart meters are equipped with wireless communication technology which is able to send the meter reading to the centralized recording system for each residential unit. The meter reading information is then compiled by the energy authority and actual monthly power usage bill is produced via mobile application system or email system.

Looking at the smart meter advancement, consumers should be happy equipped with such a great technology but yet some have shown unhappiness due to increase in their actual monthly electricity usage. Therefore, consumers filed complaints to the energy provider stating their actual monthly electricity bill has increased after installation of smart meter into their residential. The energy provider has taken initiatives to resolve this matter but consumers are not convince over the initiatives and leave the consumers with no options to the proof increment in the actual monthly electricity bill.

Hence, this project is to develop a real-time electricity monitoring and measurement system for commercial use and able to provide a secondary information check with the actual monthly power usage bill from the energy provider.

1.3 Problem Statement

As currently smart meters are being installed at individual residential in Malaysia to reaffirm the electricity consumption measurement is accurate and does not lead to any kind of misleading. However, recently after the pioneer smart meter installation in Melaka State, many consumers complained that there was an increment in their electricity billing after replacement of conventional electric meters. After lodging reports to the energy provider and action have been taken by the energy provider, yet consumers are still complaining about the hike. Hence, due to this reason this research proposed to develop an IoT based monitoring system for smart meter application. This system will allow the consumers to real-time monitor their energy consumption and help to compare with the actual monthly power usage.

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1.4 Objectives

The objectives of this research are:

1. To develop a front-end power measurement system integrated with IoT application to transfer data to centralized controller system.
2. To develop a back-end storage system for measured and recorded power from front-end system.
3. To develop a mobile application which able to provide secondary information check with actual monthly power usage.

1.5 Scope of Project

The scope of work of this research is divided into 4 phases as based on Figure 1.1.

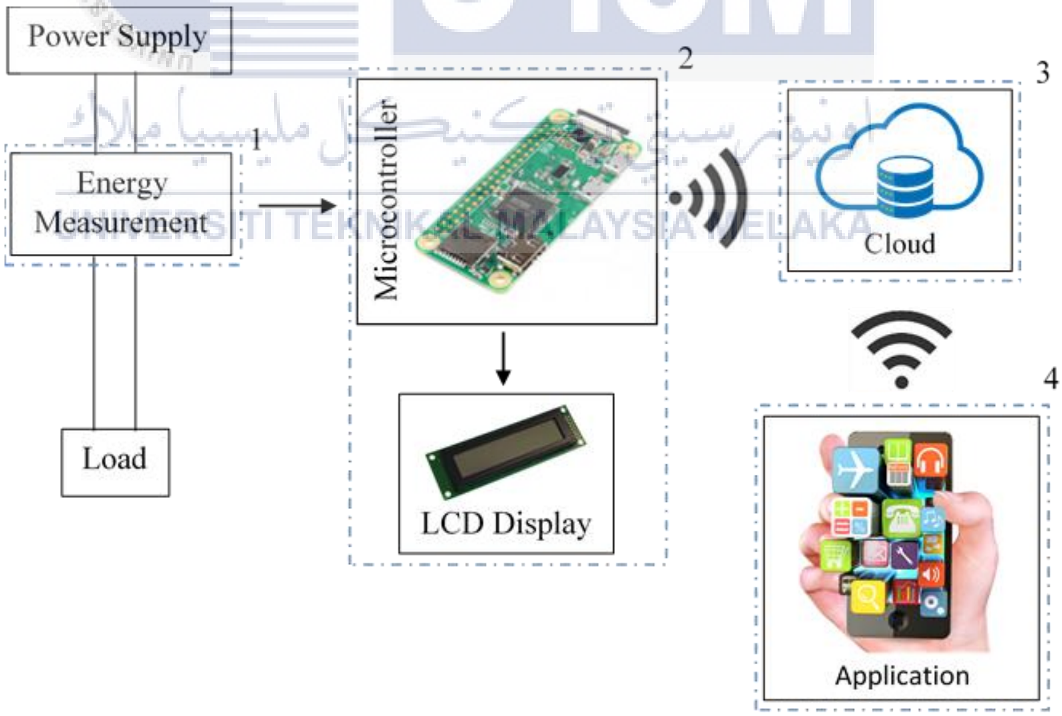

Figure 1.1: Proposed IoT Based Monitoring System for Smart Meter Application.

The first task is to install an energy measurement system/application into Neutral/Live Electric Wire at Power Meter in phase 1. Then, second task is to create embedded code to read the analog to digital power values from energy measurement sensor and into the local Raspberry Pi Wireless Zero in phase 2 and store the power values wirelessly into cloud in phase 3. Third task is to do segmentation on the database server for easier management and accessibility. The fourth task is to design an application for user to access and get their power consumption and billing information.

1.6 Report Organization

This report consists of five main chapters which are introduction, literature review, methodology, discussion and result, and conclusion.

In chapter 1, the main idea of the project is delivered via background study, objectives, problem statement and scope of works. It provides a guideline in order to complete this project.

In chapter 2, study research and background related to the project is conducted. Overall literature will produce a framework that shows the link between research projects with theories and concepts.

In chapter 3, method used in this project is discussed. The way to integrate electronic device, sensor and IoT platform of this project is explained step by step. The purpose of this chapter is to explain the method and techniques used though-out this project.

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In chapter 4, all the data collected from this project are represented. These data will be compared and discussed clearly.

In chapter 5, the overall summary of this thesis will be summarize based on the objectives given previously. In addition, the future work and recommendation related to this study will be discussed too.

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CHAPTER 2

BACKGROUND STUDY

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2.1 Introduction

This chapter mainly describes the topic that is related to IoT-based Smart Energy Meter which have been defined or done by other researchers few years ago. Related information of the previous studies is extracted and used to generate idea for this research.

2.2 Implementation of IoT-Based Smart Energy Meter

Electromechanical watt-hour meter with a rotation disc is the most common type of electrical meter that can be found. The magnetic flux is produced on the conductive metal disc when the power is fed into the induction coils. The disc rotate proportional to the flux and the revolutions are counted for billing. This type of meter has contributed a lot in power sector. However, additional criteria for power grid monitoring and control caused this type of meter being replaced by smart meter [5].

Smart meter is an electronic device which is used to obtain, record and transmit information of electricity [1]. The data is stored in a server for further operations such as calculating consumption fees and displaying dissipation statistics. This information can help users to monitor their electricity usage and resulting a significant energy saving [2]. This would eliminate the need of manual operations [13]. The ability of reducing electricity bills and managing power supply is the reason where the use of smart meter is increasing tremendously [6]. In addition, smart meters are less prone to error [2]. Table 2.1 shows the differences between the conventional meter and smart meter.

Table 2.1: Differences between conventional and smart meter.

Conventional Meter	Smart Meter
Electromechanical	Digital
One-way communication	Two-way communication
Manual Monitoring	Automatic Monitoring
Manual generated fee	Automatic generate fees

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The advancement of the smart meters are significant to our daily life. Hence the usage of the smart meters has been expanding rapidly since 2000s [3]. The smart meter has been integrated by several sensors and supported by communication infrastructure which made two-way communication becomes possible. The smart energy meter system have been implemented for the users to manage their electricity usage using different method such as mobile and website application [1].

There is a research in Schultz claimed that 76.2 percent from 390 sample of single-family household earned more than $55000 per year after installing smart meter [14]. Apart from that, implementing real-time and personalized feedback will reduce energy in the residential segment by around twelve per cent [10].

The Internet of Things (IoT) is increasingly defined as the world of interconnected people and objects among themselves [1]. It is not only about machine-to-machine (M2M) communication but how people and machines interact using common public services. Therefore smart devices – stand-alone device which able to sense, monitor and interact with their surrounding is needed for this type of relationship.

One of the smart energy meter implementation was the Automatic Power Meter Reading System using Global System for Mobile (GSM) Network. This GSM Automatic Power Meter Reading (GAPMR) System has installed in consumer unit and the billing system at the utility center. It retrieves individual house power consumption reading wirelessly. The Store and forwarding features of Short Message Service (SMS) allow the message store in the mobile operator and allow customers to retrieve billing information when GSM signal is stable [3].

There are another implementation of smart meter on a load tracking system which is called PowerPlay. The system able to monitoring loads in smart meter data which consists of almost 100 loads in real time each second. The system indicated that the per-load accuracy is improved by the factor of two compared to a state-of-the-art disaggregation algorithm [7].

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Other than that, the smart meter is used when the Power Ministry deployed 14 smart grid pilot projects which being implemented in India by state-owned distribution utilities after recognizing the value of the Smart Grid Technologies for power sector [9]. The pilot projects have involved the installation of smart meter for the purpose of reducing power loss and improving reliability.

2.3 Communication Infrastructure

2.3.1 Wifi Module

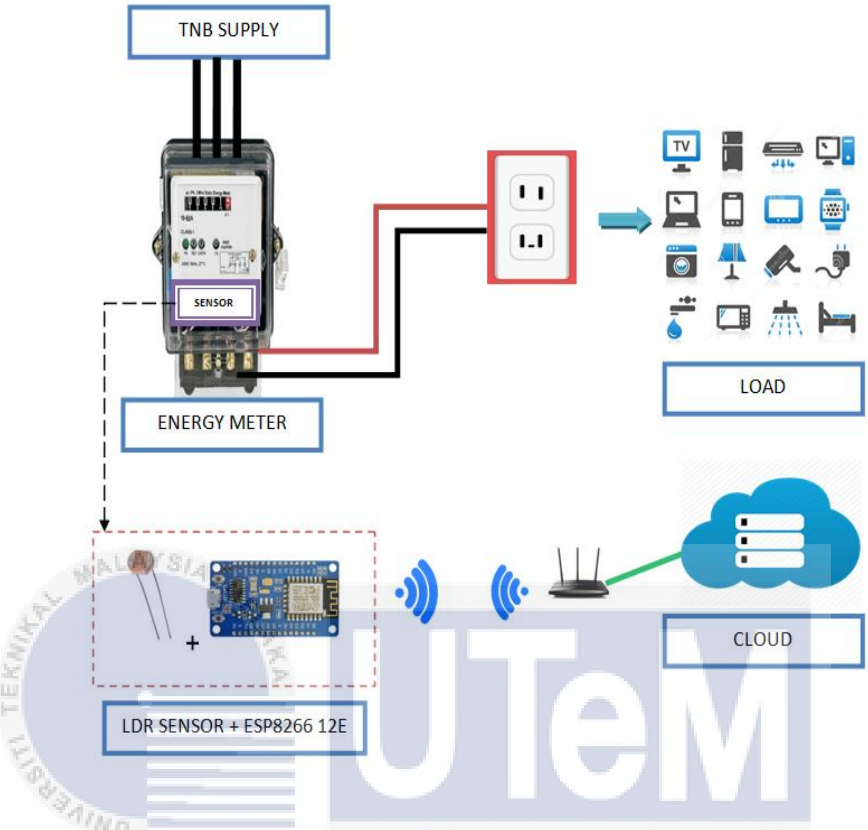

Figure 2.1: Smart Energy Meter system using WiFi Module [8].

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Figure 2.1 shows ESP 8266 12E WiFi module is used as control device and uses to receive the energy data from the energy meter via LDR sensor. The LDR sensor is used to sense the frequency pulses existence based on the LED blinking presents at the energy meter, which shows the proportional active power. A wireless connectivity integration allows the ESP 8266 12E WiFi module computes the transmitted power consumption to the cloud storage. Arduino IDE embedded software design platform is used to calculate the pulses produced by the energy meter. The Arduino IDE embedded software calculates the pulses for the used energy as energy consumption as well as the total bill and costing.

2.3.2 Ethernet

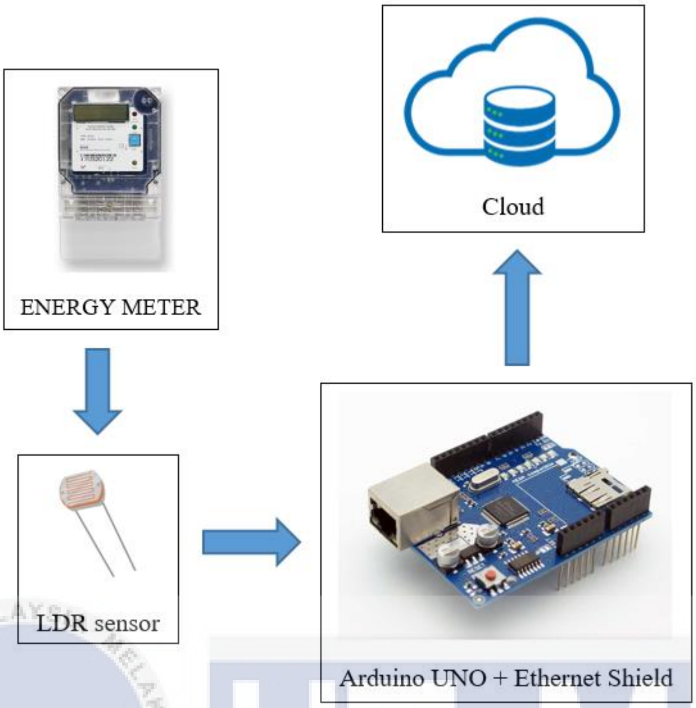

Figure 2.2: Smart Energy Meter system using Ethernet [19].

Figure 2.2 shows the smart energy meter system using Ethernet. The blinking LED light on the energy meter which indicates the consumption unit is detected via LDR sensor. The output from the LDR sensor is fed into Arduino UNO through analog pin. The embedded coding in Arduino UNO is used to calculate energy consumption unit is uploaded into SD-Card storage Arduino UNO board. The total energy consumption is transmitted to the cloud storage via Ethernet. The connection of Arduino UNO and Ethernet shield allowed two-way communication between users and the utility center to share information. User could know about the energy consumption and the utility center could check user information such as location by using same IP address.

2.3.3 Global System for Mobile Communications (GSM)

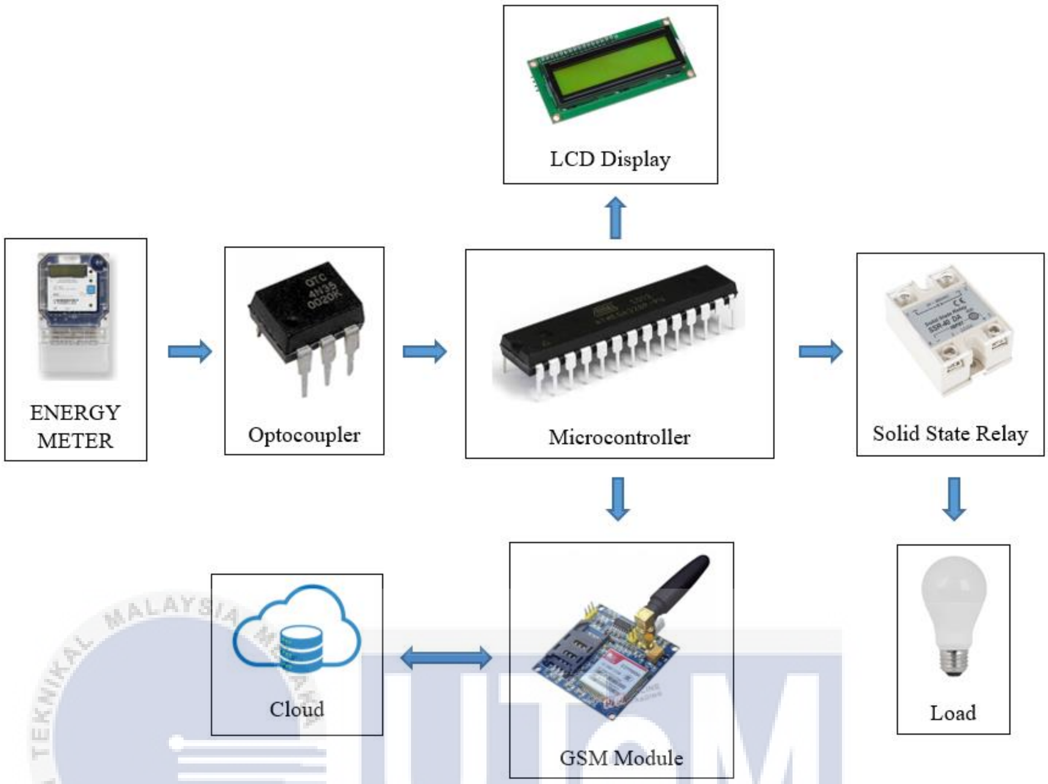

Figure 2.3: Smart Energy Meter system using GSM module [15] [18].

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Figure 2.3 shows the smart energy meter system using GSM module. Optocoupler is an electronic device consists of LED and LDR sensor in it. The LED light in the optocoupler will blink whenever one watt of power is consumed. The blinking LED will be detected by the LDR sensor and the output from the optocoupler is send into ATMEGA328P microcontroller. The embedded coding uploaded in the board computes the total energy consumption and costing. The communication between microcontroller and utility center are secured via GSM module. The Solid-State Relay (SSR) is used to connect or disconnect the supply and the LCD display is used to display current data.

2.3.4 Narrowband Internet of Things (NB-IoT)

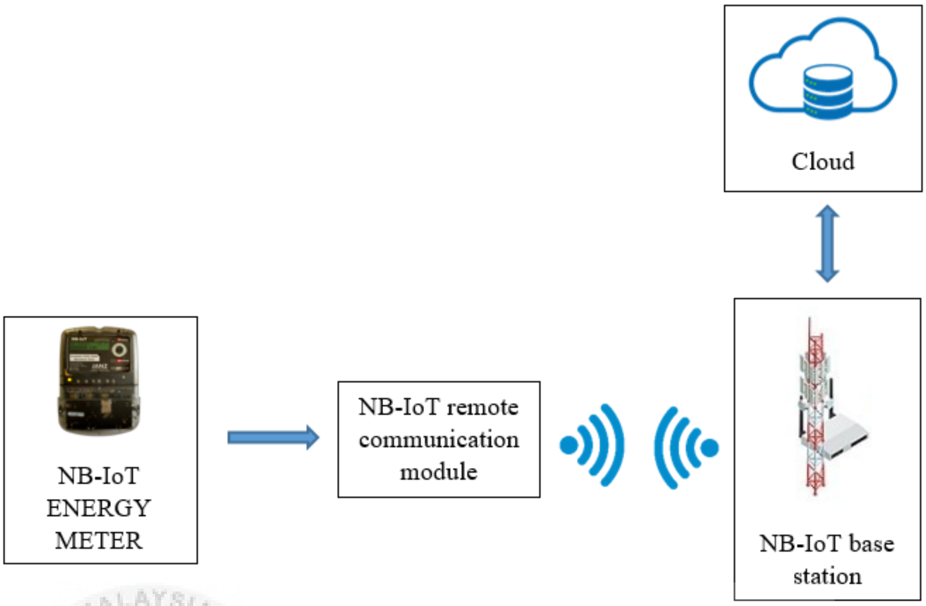

Figure 2.4: Smart Energy Meter system using NB-IoT [16].

Figure 2.4 shows the smart energy meter system using GSM module. The NB-IoT smart meter is configured with uplink communication modules and able to support NB-IoT standard protocol remote communication module. Besides, a NB-IoT remote communication module function to perform data interaction through NB-IoT network. The information from NB-IoT network is stored into database and called out from it with a reliable transmission.

2.3.5 Long Range (LoRa) network

Figure 2.5: Smart Energy Meter system using LoRa network [11] [17].

Figure 2.5 shows the smart energy meter system using LoRa network. In order to build up this system, the smart energy meter with LoRa modem is needed so that it could connect to LoRa network. The real time data such as voltage and current is sent out by LoRa modem to MCU. The MCU with LoRa gateway act as the monitoring system server which could access by web protocol. The data recorded is recorded for further operation such as power consumption and bill calculation.

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2.4 Data Acquisition method

2.4.1 Pulse sensing

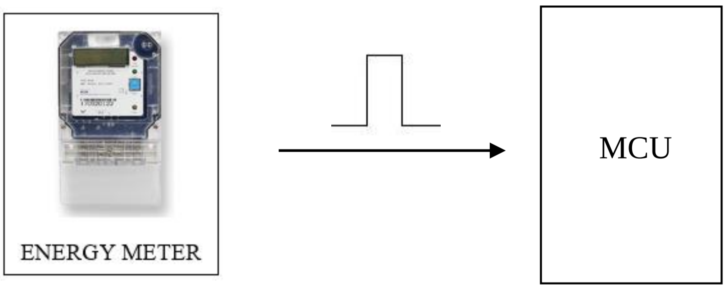

Figure 2.6: Pulse sensing [4].

Figure 2.6 shows that the energy meter send pulse whenever power consumption is equivalent to one watt. The pulse generated from the meter execute the interrupt service routine of Main Controller Unit (MCU) to accumulate the power consumption and send to the utility center.

2.4.2 Current sensing

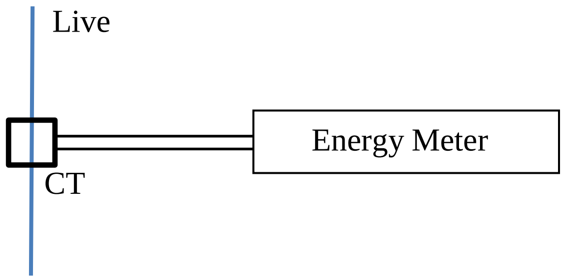

Figure 2.7: Current sensing [12].

Figure 2.7 shows that a current transformer is used as the sensing part to get power consumption. The current transformer has primary winding, magnetic core and secondary winding. The current that pass through the CT of this current transformer is stepped down into a low value depend on the turn ratio. The energy meter can get the original current that pass through CT by reverse engineering and lastly get the power consumption using Ohm's Law, $P = VI$.

2.5 Billing

Estimated Bill is issued when the meter installed at user's premise is inaccessible to Meter Readers during their routine meter reading cycle. However, necessary adjustments will be made on estimated bill and these adjustments will be reflected on the next bill with actual meter reading.

The average consumption per month is determined based on users' previous electricity usage which is the actual meter reading at the premise for the past 6 months. The average usage is then multiplied by the duration being billed and the tariff rate to determine the estimate bill amount.

A normal bill is issued in a normal situation. The bill shows the current and previous meter reading. The difference between current and previous reading is then multiplied by the duration being billed and the tariff rate to determine the estimate bill amount.

2.5.1 Tariff rate

In Malaysia, the rate of charge for each kilowatt per hour is called Tariff rate. Bill for a consumer who occupied a private dwelling, which is not used as a hotel, boarding house or used for the purpose of carrying out any form of business, trade, professional activities or services is calculated under Tariff A – Domestic Tariff. The rate is shown in Table 2.2.

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Table 2.2: Tariff A – Domestic Tariff.

Tariff Category	Rate (RM/kWh)
First 200kWh (1 – 200kWh)	0.218
The next 100kWh (201 – 300kWh)	0.334
The next 300kWh (301 – 600kWh)	0.516
The next 300Wh (601 – 900kWh)	0.546
The next kWh (901kWh onwards)	0.571

The minimum charge for each month is RM3.00

2.5.2 Billing Calculation

The average consumption of the user’s premise can be determined by the formula:

$$\frac{Total\ consumption\ in\ kWh}{Total\ period\ in\ days} \times 30 days = Average\ consumption$$

If the estimated bill is for a period of 35 days, then the estimated consumption is:

$$\frac{Average\ consumption}{30} \times 35 = estimated\ consumption$$

Lastly, the estimated consumption is multiplied by the tariff rate. Assume that the estimated consumption is 300 units, the estimate bill is calculated as Table 2.3. In a normal scenario, the consumption unit is the difference between current and previous reading from the meter.

Table 2.3: Bill Calculation.

Unit Used	Tariff (RM/kWh)	Cost (RM)
First 200 units	0.218	43.60
Next 100 units	0.334	33.40
Total Estimate Bill Amount		77.00

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CHAPTER 3

METHODOLOGY

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3.1 Introduction

This chapter discusses on the methods that used to complete this research. The selection of components, research approach, methods of data collection and analysis will be outlined in this part.

3.2 Overview

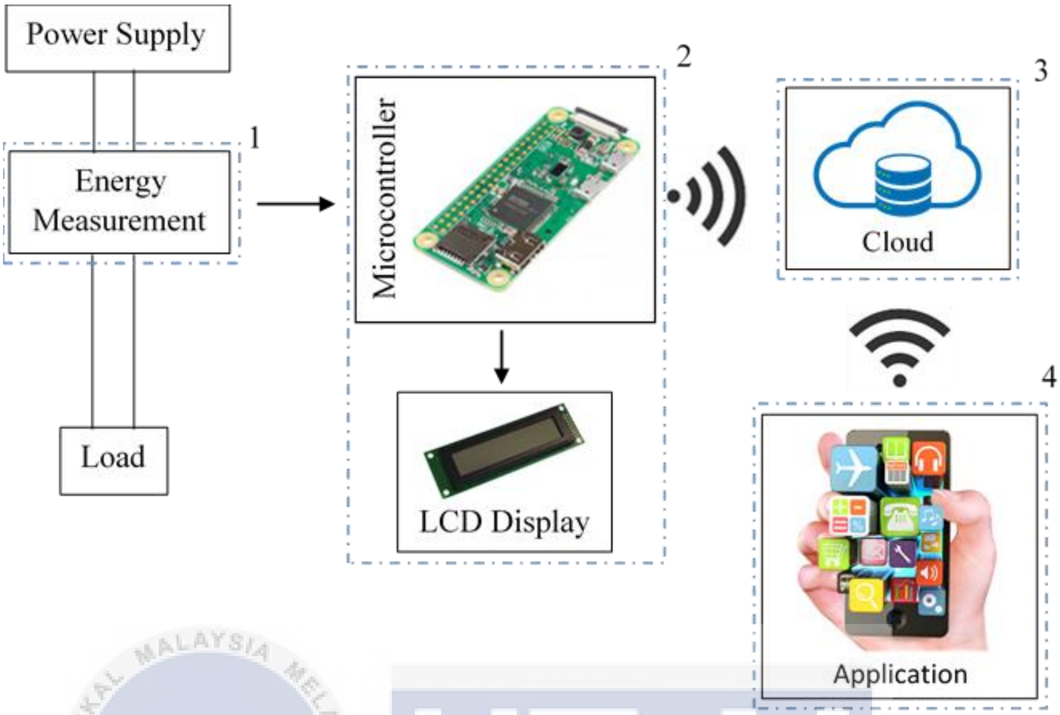

Figure 3.1: Smart Energy Meter.

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Figure 3.1 shows that the smart energy meter is divided into 4 parts which are energy measurement circuit, front-end power measurement system and back-end storage system and application which use to monitor power consumption wirelessly. The energy measurement system is designed to gain analogue data from the power supply while the front-end power measurement system read the data input and record the pulse received. A back-end storage system is used to store measured and recorded power from front-end system. Lastly, an application is developed for user to access and get their power consumption and billing information.

3.3 Energy measurement

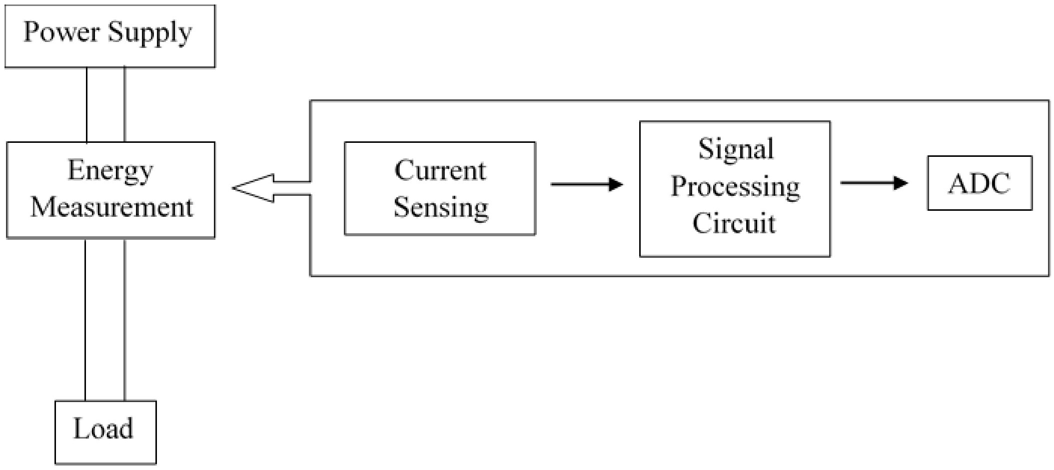

Figure 3.2: Energy Measurement System.

Figure 3.2 shows the energy measurement system in this project. It mainly divided into 3 parts which in current sensing, signal processing circuit and lastly to the Analog to Digital converter (ADC). Current transformer is used as current sensing to measure the current flows from the power supply. Then the signal processing circuit is constructed which includes the circuit element such as burden resistor for the current output from the transformer. The output from the circuit is fed into an ADC module as the microcontroller we used does not have analogue input pin. The ADC is integrated with the microcontroller to get the analogue current signal of the power supply in digital form.

3.3.1 Current sensing

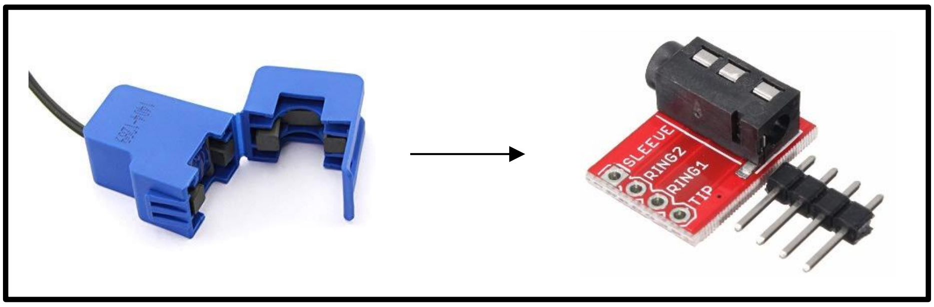

Figure 3.3: Current sensing.

Figure 3.3 shows the current sensing components which mainly formed up by a SCT-013-000 YHDC 100A Non-invasive AC Current Sensor split core type Current Transformer (CT) and TRRS 3.5mm jack breakout board. This type of CT could be clipped onto the wire without the need to do high voltage electrical work. It has primary winding, magnetic core and secondary winding just like other transformers. The maximum current that can pass through the hole of this current transformer is 100A. With a turn ratio of 2000:1, it will induce a maximum 50mA of current in the secondary coil. It sent out the induced current signal through a 3.5mm audio hijack, so a TRRS 3.5mm jack breakout board is used for the circuit. The connection of the TRRS 3.5mm jack breakout board is shown in Figure 3.4.

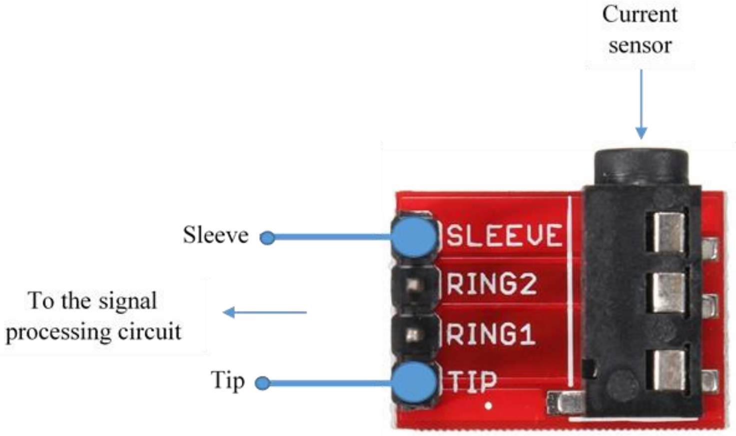

Figure 3.4: Input and output for 3.5mm jack breakout board.

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3.3.2 Signal Processing Circuit

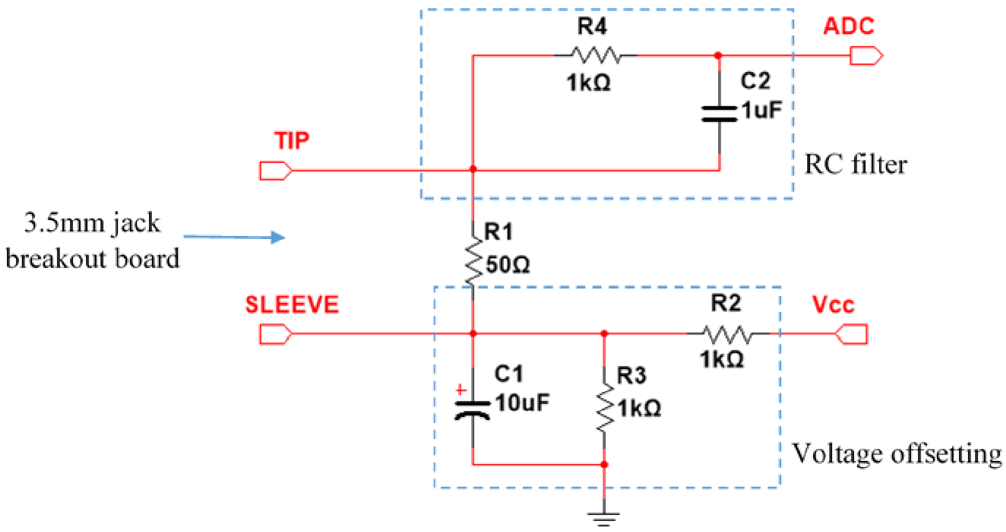

Figure 3.5: Signal Processing Circuit.

Figure 3.5 shows the designed circuit to process the analogue signal before input into the ADC module. By connecting a 50 Ω of burden resistor across the current transformer output, a voltage is induced base on product of resistance and induced current. The input current signal is 40 times of the voltage magnitude across the burden resistor. It is safe to use since the current transformer able to induce the current without cutting the cable load as well as the induced current value is around milli Ampere. Assume 100 Ampere of current is passing through the CT hole, a virtual voltage of 2.5 Volt is produced. The virtual voltage has to undergo voltage offsetting process as an ADC could not read a negative voltage input. The virtual in a range of -2.5V to 2.5V is offset into 0V to 5V. Lastly, the signal undergo RC filtering process before input into an ADC.

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3.3.3 Analogue to Digital Converter (ADC) module

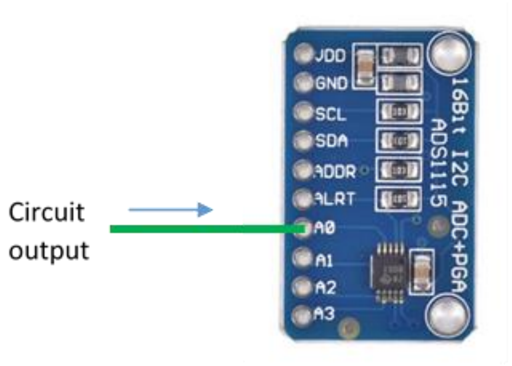

Figure 3.6: 4CH 16-bit ADS1115 Analog to Digital Module.

Figure 3.6 shows the ADC module used in this project. The purpose of the ADC module is converting the analogue input into digital. As RPW0 has no analogue GPIO pin, therefore an ADC is needed in this system. This ADC module is chosen as it is small and precise. Only one analogue input (A0) is used. The output from the circuit is fed into A0 to undergo analogue to digital conversion. The serial digital clock input (SCL) and digital output (SDA) pin is then connected to the microcontroller. Figure 3.7 shows the connection between ADC and RPW0.

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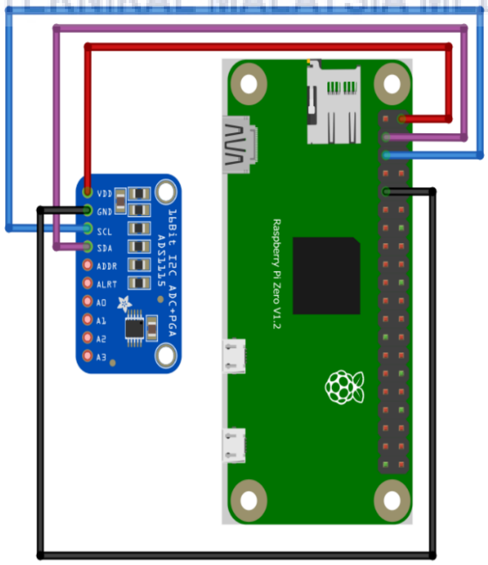

Figure 3.7: Connection between ADC and RPW0.

3.4 Front-end power measurement and recording system

Figure 3.8: Raspberry Pie Wireless Zero (RPW0).

Figure 3.8 shows Raspberry Pie Wireless Zero (RPW0) microcontroller which is chosen to serve as the brain of the system. It received the inputs from the ADC for energy measurement and stored the received data in the SD card. Other than that, it performs the task which send the data into database while the internet connection is available. This microcontroller is chosen as it is smaller in size so that the final product would not be big in size. Besides, RPW0 has built in wireless chip which is used for Wi-Fi network communication. The formula of P=VI is used to calculate the power used in watt. Then it is converted into kilowatt hour and stored into the system.

3.4.1 Method to gain power consumption

The value scale factor is determined by the Programmable Gain Amplifier (PGA) setting. In the default mode, the PGA setting is +/-6.144V. Dividing 6.144V by 32767 yields a scale factor of 0.1875mV/bit. To get the voltage across the burden resistor, the formula below is used.

$$V_n = |(adc * 0.1875m) - V_{offset}|$$

By taking 860 samples in a second, the root mean square voltage is obtained by the formula below.

$$V_{rms} = \sqrt{\frac{1}{860}\sum_{n=1}^{860} {V_n}^2}$$

The current, I_{rms} flow through the CT hole is then calculated by the formula below.

$$I_{rms} = \left(\frac{V_{rms}}{R_b}\right) * CTratio$$

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For Malaysia power supply system, we have a root mean square voltage, $Vrms$ of 240V. Assume that the V_{rms} obtained is 0.35V. The $V_{offset} = 2.5V$, $R_b = 50ohm$ and $CTratio$ is 2000 in the design. The average power is accumulated.

$$V_{rms} = 0.35V$$

$$I_{rms} = \left(\frac{V_{rms}}{R_b}\right) * \frac{CTratio}{\sqrt{2}}$$

$$I_{rms} = \left(\frac{0.35}{50}\right) * 2000$$

$$I_{rms} = 14A$$

$$P = V_{rms}I_{rms}$$

$$P = 240 * 14$$

$$P = 3360W$$

The average power is converted into kilowatt using the formula below.

$$kWh = \frac{P * time(hours)}{1000}$$

The power is measured in every second to calculate real time power consumption, so the follow is derived as below.

$$kWh = \frac{P}{1000} * \frac{1}{3600}$$

$$kWh = \frac{P}{3600000}$$

So, the power consumption in kilowatt for the case V_{rms} equal to 0.35V in that second is calculated as below.

$$kWh = \frac{P}{3600000}$$

$$kWh = \frac{3360}{3600000}$$

$$kWh = 0.933 \times 10^{-3} kWh$$

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Assume that the current is flowing through the CT hole for 1 minute, the power consumption in kilowatt is as follow.

$$kWh = 0.933 \times 10^{-3} kWh * 60$$

$$kWh = 0.056 kWh$$

This concept is used to create the embedded code for calculating power consumption in kilowatt.

3.4.2 Flow Chart for Front-end power measurement and recording system

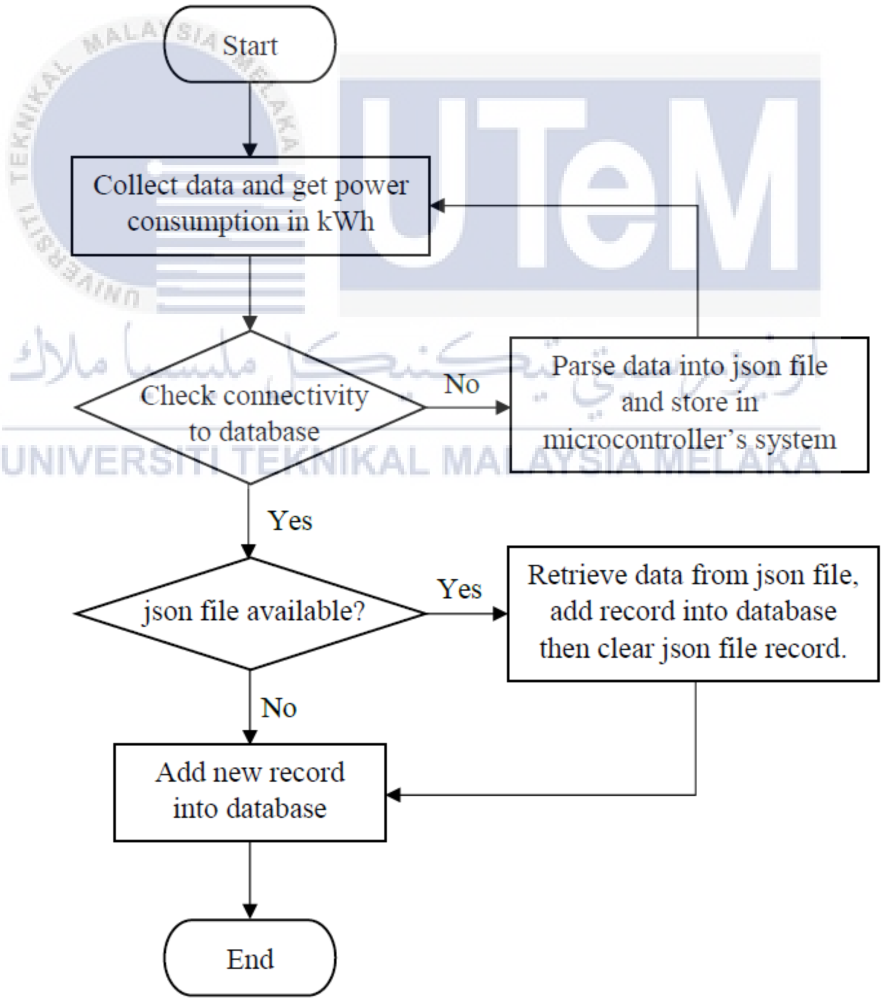

Figure 3.9: Flow chart of the power measurement and recording system.

An embedded code in Python language is written according to the flow chart shown in Figure 3.9. This is the part where the input signal is processed after receiving from the ADC module. Firstly, RPW0 collects the input from ADC module once it is powered up. The formula to gain power consumption in kWh is then implemented. After that, the RPW0 checks connectivity to the database. When the connection is stable, the RPW0 will directly insert new record into the database. A JavaScript Object Notation (json) file is created when the connectivity to database is failed. Whenever the connection is stabilized, the RPW0 will check is there any json file available in the operating system. Then the data in the json file will be added into the database if json file is available.

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3.5 Cloud

Figure 3.10: MySQL database.

Figure 3.10 shows the database which has chosen as the cloud storage for the power consumption record. MySQL database server has an open source nature that allows complete customization to add unique requirements to the database server. Other than that, free to use and strong data protection are the reasons that MySQL is chosen as database for this project. In terms of database authentication, MySQL provides powerful mechanisms for ensuring only authorized users have entry to the database server, with the ability to block users down to the client machine level being possible.

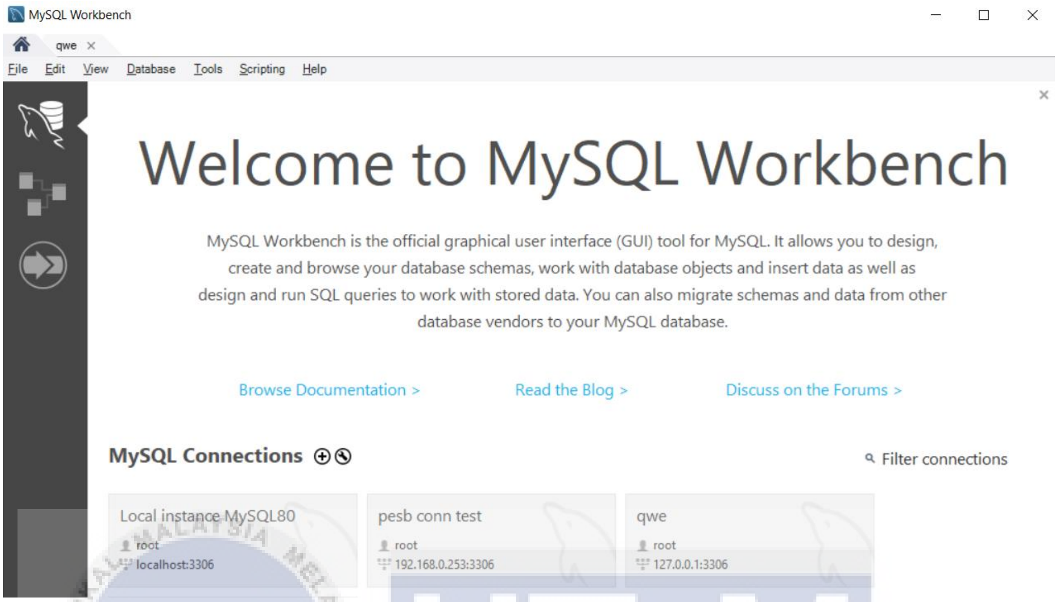

Figure 3.11: MySQL Workbench.

MySQL database can monitor using MySQL Workbench as shown in Figure 3.11. It is free, easy to install and use. MySQL Workbench helps to manage the database in allowing individuals to design, model, generate, and manage databases. Its user account management eases in viewing account information for all users on the MySQL server. Its features such as add and remove users, grant and revoke privileges, change password and modify both global and database permissions have the ability to help in future work.

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3.5.1 MySQL Table

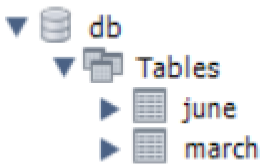

Figure 3.12: MySQL Table List.

Figure 3.12 shows the table list in a database. Each table records the power consumption usage for specific month. There are two tables named 'march' and 'june' indicate that the RPW0 is active in March and June. Table is created when the wanted table name is unavailable. It means that new table named 'july' will be created when the RPW0 is operating in July as it is absent in the table list.

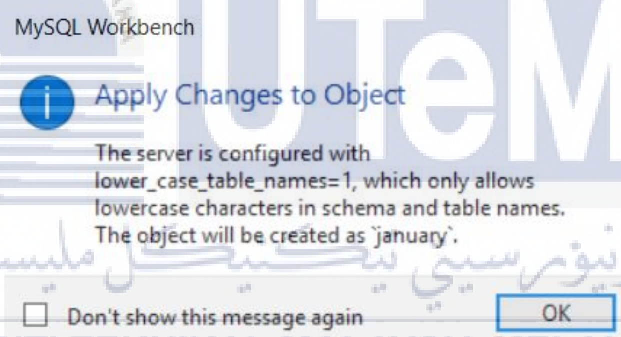

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Figure 3.13: MySQL configuration.

The tables in the MySQL database is set to be in lower case due to it configuration file of the server. Figure 3.13 shows that the MySQL server is configured with lower case table names characteristic which only allows server owner to create schema and table names using lowercase characters. Changing the configuration file is sensitive and may cause the server to be corrupted if do not handle in a proper way. So the configuration file is leave as default. In this case, the table name for January will be created as 'january'.

id	time	usage
4	2020-05-23 00:44:32	20
5	2020-05-23 00:47:42	20
6	2020-05-23 00:49:31	20
7	2020-05-23 00:51:31	20
8	2020-05-23 00:54:18	20
9	2020-05-23 01:06:51	20
10	2020-05-23 01:08:58	20

Figure 3.14: MySQL Table Structure.

Figure 3.14 shows the structure of the table which used to store power consumption. RPW0 get the current time where the data is collected and store in the 'time' column. The data in 'time' column is set as primary key so that record would not be duplicated. The power consumption is stored in 'usage' column in the unit of kWh. The record is inserted into the table by row.

MySQL has a function named 'Truncate Table' which clear all the record in the table. This can be used as the feature to save database storage space. For example, RPW0 can execute MySQL to clear the record of January 2019 in the 'january' table before inserting record of January 2020.

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3.6 Application

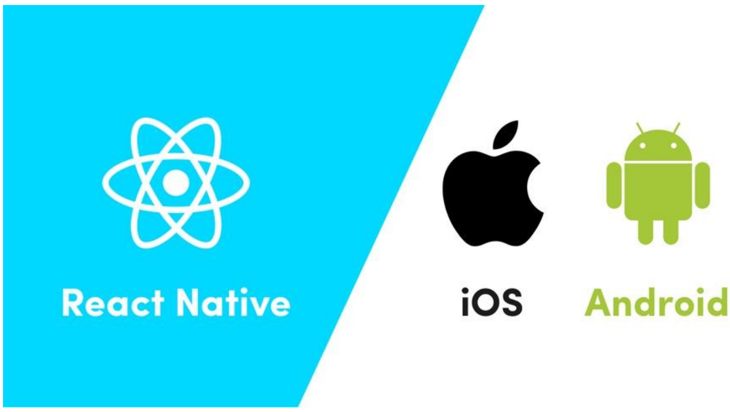

Figure 3.15: React Native.

Figure 3.15 shows React Native framework that is chosen to write a real and native rendering mobile application. Unlike other frameworks such as Native and Hybrid, it supports for both popular operating systems which are IOS and Android without the need to develop separately. React Native allows developers to build cross-platform application using JavaScript language. It allows developer to build apps faster as it could reload an application instantly instead of recompiling.

3.7 Server

In this project, consumer must be able to operate the mobile application anytime and anywhere. Therefore, an online server is important to ensure that the application could access the power consumption data. First things is to get a working computer and working internet with Public Internet Protocol (IP). Many of them was disabled in default, contact Customer Support to get it enabled and make sure the Modem-Router is working.

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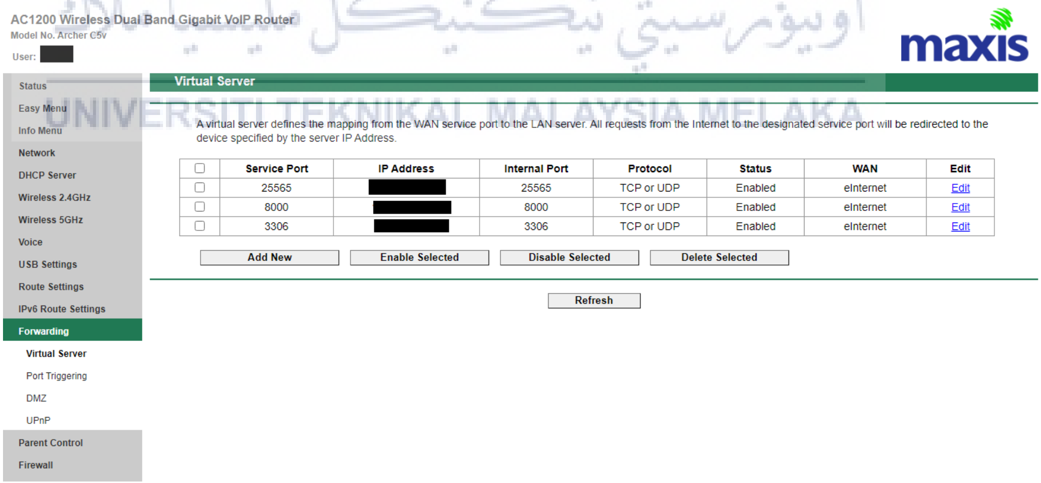

Figure 3.16: Modem-Router Interface.

Figure 3.16 shows the Modem-Router interface. The general idea is to set the computer IP:Port to static then use the Port-Forwarding feature on the Modem-Router to forward any connection made to the Public IP Port to the computer IP:Port. To have something on the server to connect to, some sort of service should running in the computer. In this case, MySQL is installed and run with default port of 3306. The connection is tested by the combination of the Public IP and the port number in https://canyouseeme.org/. Then the Public IP is masked by url-like address.

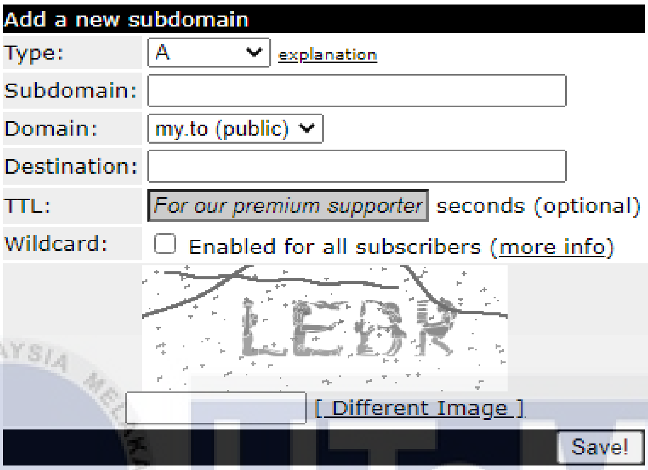

Figure 3.17: Subdomain Interface.

Go to https://freedns.afraid.org/ and register a free account. Then go to "Subdomains" and add new connection as shown in Figure 3.17. Enter the name of the desired url-like address in the subdomain column and the Public IP address in the destination column. The working url now is the combination of the subdomain name and port number of the server or service.

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Lastly, since non-commercial or residential from the Internet Service Provider (ISP) do not have a static Public IP, the Public IP can be updated either manually or automatically with the "FreeDNS Update" service for the set interval. The service is installed in https://freedns.afraid.org/scripts/freedns.clients.php.

CHAPTER 4

RESULTS AND DISCUSSION

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4.1 Introduction

This chapter shows the function and result of the IoT based Monitoring System for Smart Meter application. Before assembling the hardware, preliminary precaution is done by using Multisim simulation to ensure the signal is in desired pattern. Then the prototype is connected as the simulation circuit. The prototype is tested and the accuracy and precision is observed by comparing the experimental reading to the expected reading of electrical devices. The interface and the functionality of mobile application will be shown in figures and further explain in this chapter.

4.2 Preliminary Result

The ADC module has the ability to read voltage of 6.144V. The burden resistor is set to 50 ohms to ensure that the maximum input voltage would not exceed the ADC module limitation. A signal processing circuit is constructed to provide offset voltage to the signal. Simulation is done before setting up the prototype.

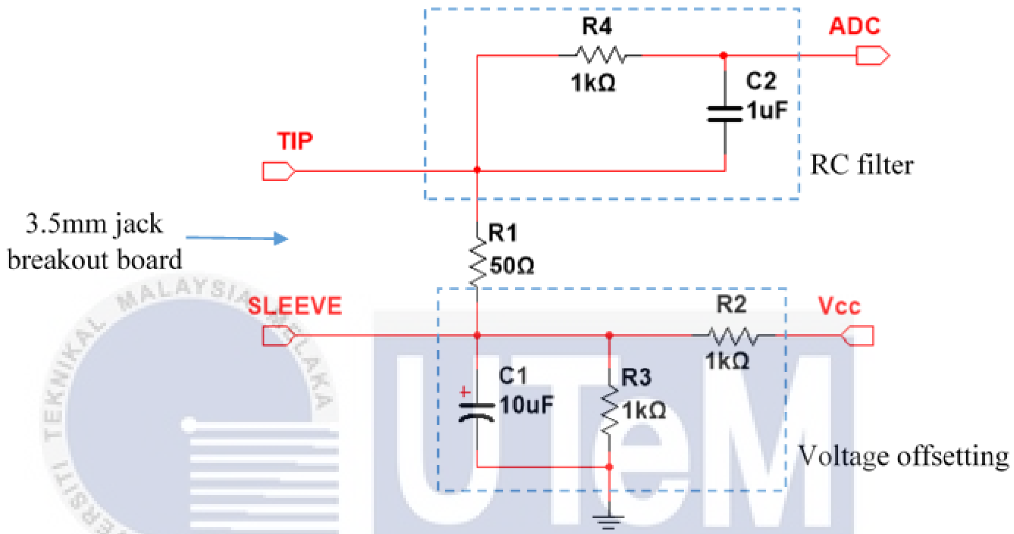

Figure 4.1: Signal processing circuit.

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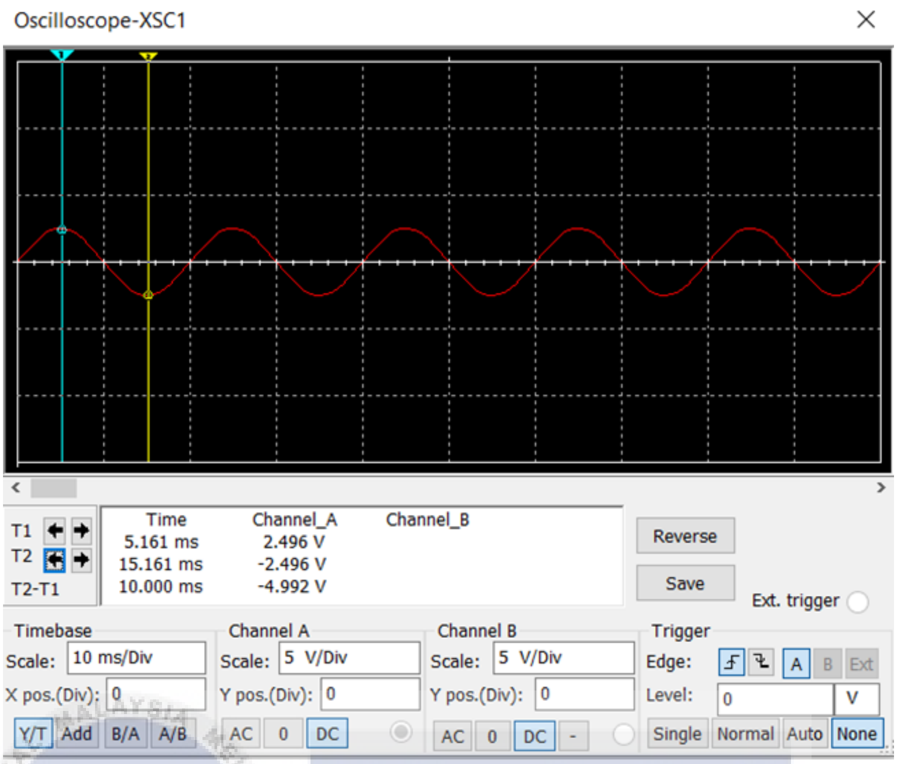

Figure 4.2: Input signal before voltage offsetting.

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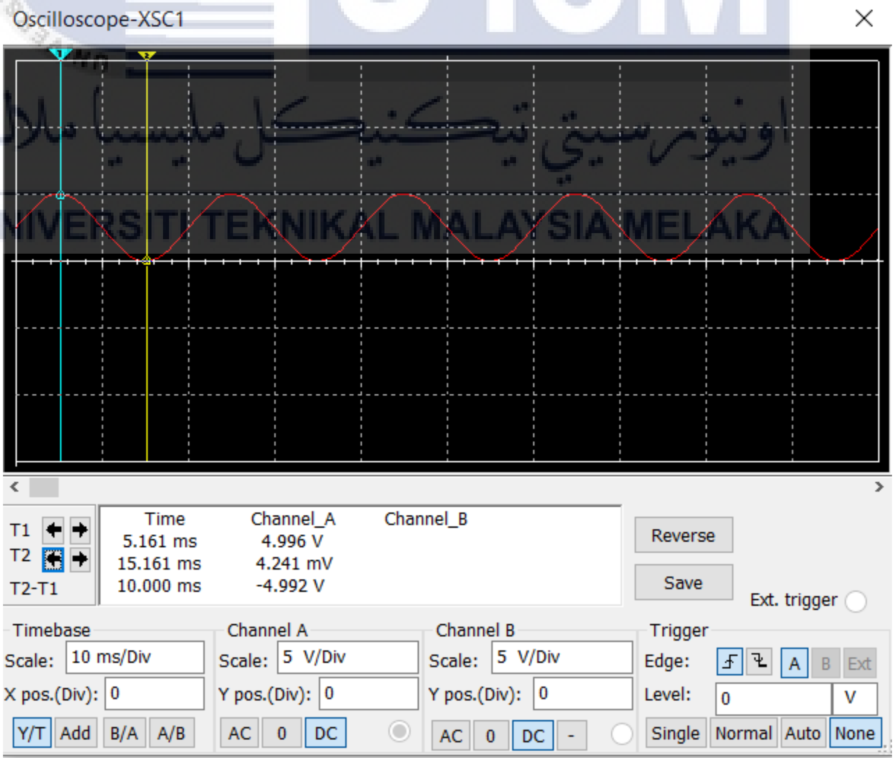

Figure 4.3: Input signal after voltage offsetting.

The current transformer in this project could measure up to 100A in the primary coil and produce 50mA in the secondary coil. From Figure 4.1, by connecting a 50 Ω of burden resistor across the current transformer output, a 2.5V alternating voltage is induced and shown in Figure 4.2. The voltage undergo voltage offsetting process before entering ADC module. Figure 4.3 shows that the voltage is in a range of 0V to 5V after voltage offsetting which is in the range of 6.144V.

4.3 Prototype

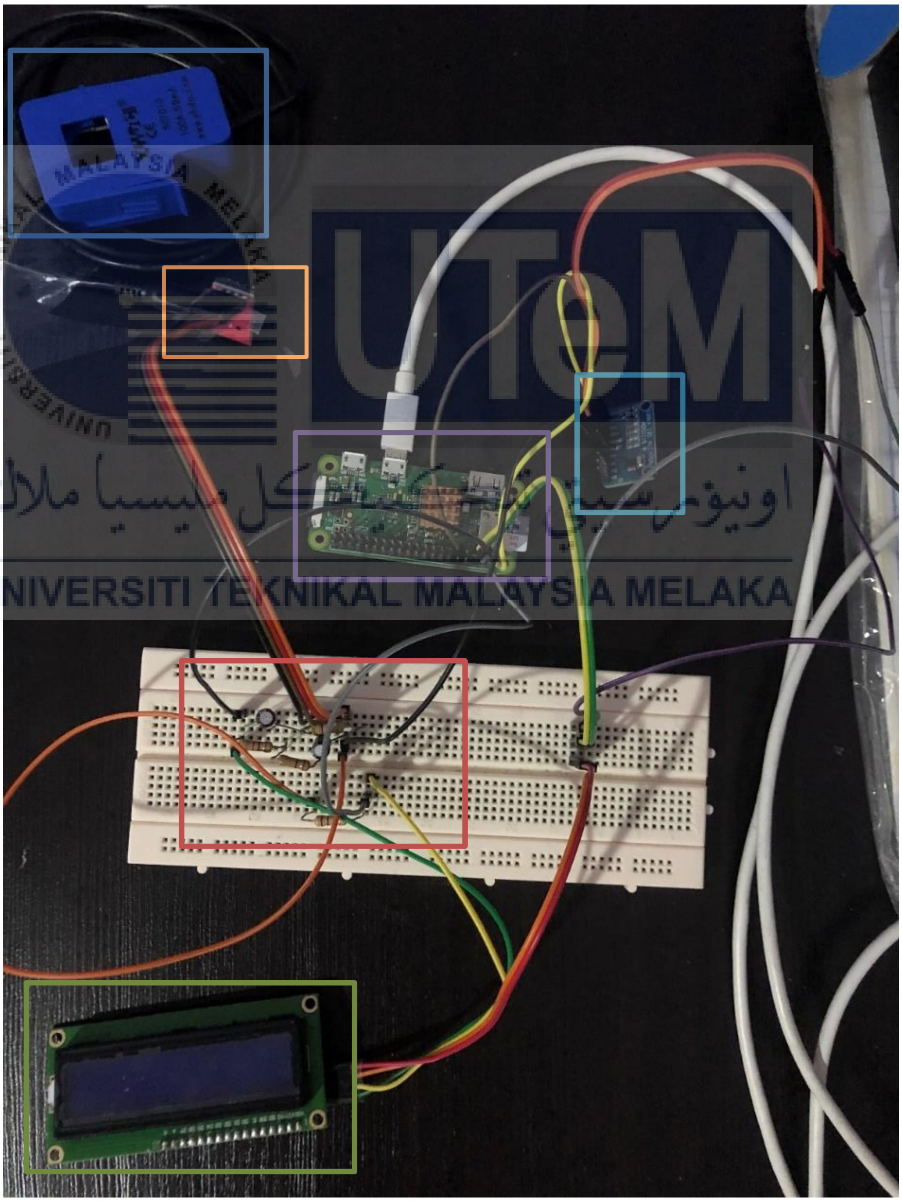

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Figure 4.4: Prototype of the monitoring system.

Table 4.1: Circuit design references.

Color	Components/Circuit
	SCT-013-000 Current Transformer
	TRRS 3.5mm jack breakout board
	Signal Processing Circuit
	ADS1115 ADC module
	RPW0
	LCD screen

Figure 4.4 shows the prototype of the IoT Based Monitoring System for Smart Meter Application. The parts are indicated in color box and shown in Table 4.1. The system is activated whenever the RPW0 is powered up. The signal form the CT is transmitted into the breakout board using 3.5mm jack. Then it go through the signal processing circuit on the breadboard before entering the analogue pin of the ADC module. Then the ADC module and the LCD display is connected to RPW0 using Inter-Integrated Circuit (I2C) protocol. RPW0 process the value from ADC module from display on the LCD.

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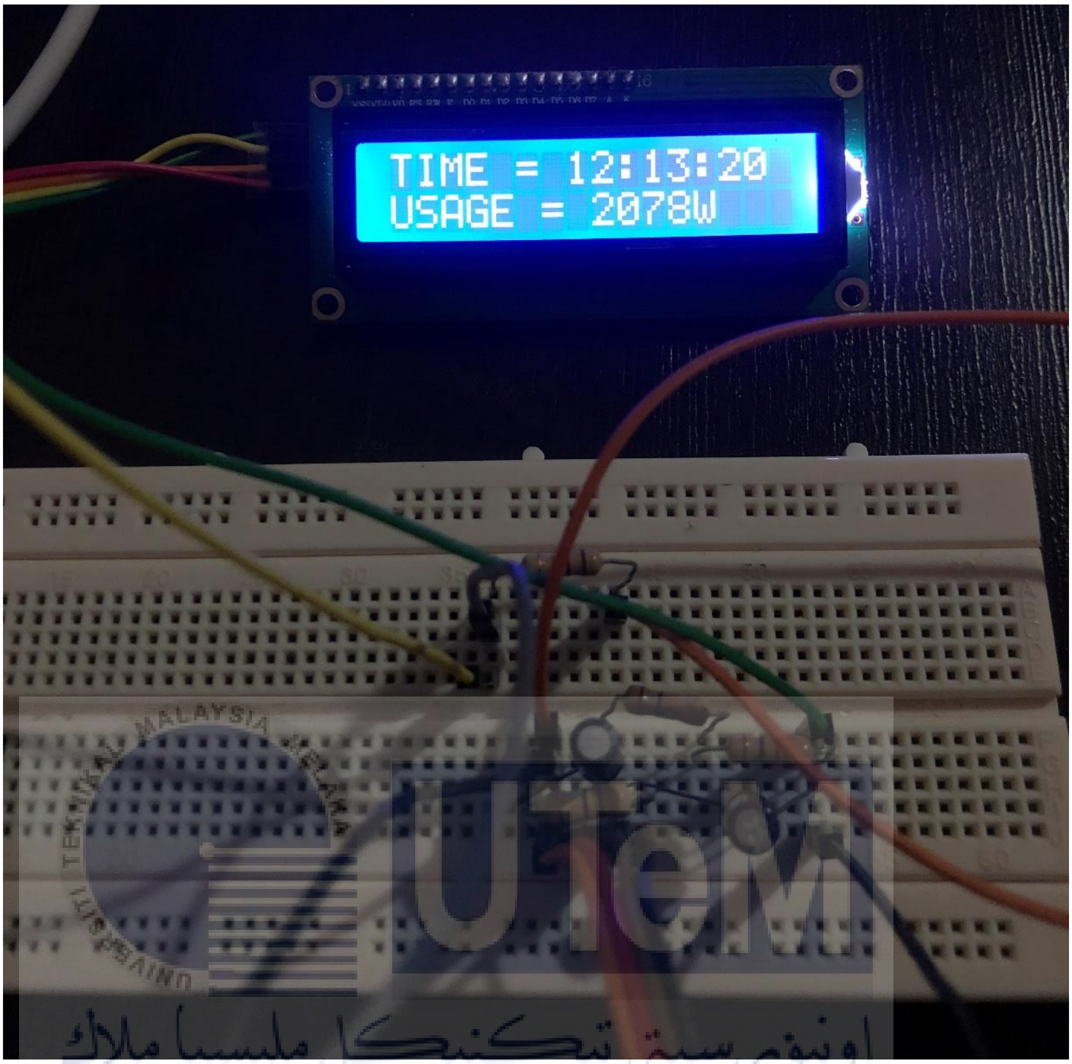

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Figure 4.5: The integrated design during normal run.

Based on Figure 4.5, the LCD display show the current time and the current usage in Watt. The current transformer is clipped on the live wire of the power supply. The power consumption is calculated through the voltage across the burden resistor and lastly displayed on the LCD.

4.3.1 Prototype performance

Perfect system could only exist in simulation but not in real world. So the performance of the system is analysed to determine whether it is accurate and precise. The average and the standard deviation of the system is accumulated by taking reading from the experiment. Several reading is recorded from the system when the RPW0 is measuring an activated load. Table 4.2 shows the 10 recorded experimental result when the designed prototype is measuring a load.

Table 4.2: Experimental result.

n	x (W)
1	2076
2	2078
3	2082
4	2076
5	2076
6	2080
7	2078
8	2077
9	2079
10	2078

n = 10, $\sum x = 20780$

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So the arithmetic mean of the system is:

$$mean = \frac{\sum x}{n}$$

$$mean = \frac{20780}{10}$$

$$mean = 2078$$

Then the standard deviation of the system is calculated as follow:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - mean)^2}{n-1}}$$

$$s = \sqrt{\frac{-2^2 + 0^2 + 4^2 + -2^2 + -2^2 + 2^2 + 0^2 + -1^2 + 1^2 + 0^2}{9}}$$

$$s = 1.94$$

The mean is the average reading and the standard deviation indicates how different the individual readings typically are from the average reading. The system is precise since there is recorded experimental values do not have a large gap.

Then the accuracy of designed prototype is observed by measuring different electrical device with different power consumption. The system could be said to be accurate when the experimental values are similar to the expected value of the electrical devices. The results is shown in Table 4.3.

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Table 4.3: Comparison between expected and experimental value.

Expected value (W)	Experimental value (W)
3000	2994
2100	2078
1500	1486
600	603
300	298

4.4 IoT application

The communication in RPW0-MySQL and MySQL-mobile formed the IoT application in this project. RPW0 upload the power consumption in unit of kWh into MySQL database every minute. The latest data in the database is called whenever the user open the mobile application. The mobile application allows user to accumulate the total power consumption and bill for the selected period. Server is created to handle request from the mobile application.

4.4.1 RPW0

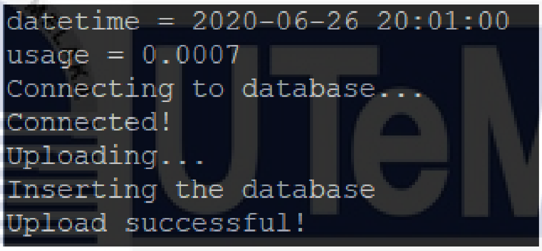

Figure 4.6: Power consumption data uploading from RPW0.

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Figure 4.6 shows the RPW0 is uploading the power consumption details into the MySQL database. The data is uploaded directly whenever there is a connection between RPW0 and the database.

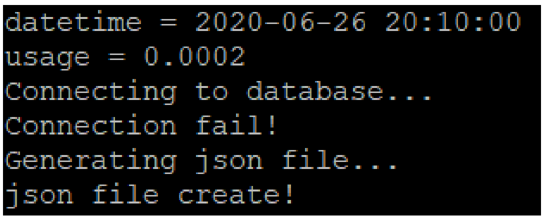

Figure 4.7: RPW0 generating json file.

Figure 4.7 shows the RPW0 is generating json file which contains the power consumption details when the internet connection is failed. This is the prevention of data loss caused by internet connectivity in this project. The data is retrieved from json file and uploaded into database whenever the connection is stabilized. The RPW0 read the first record in the json file and upload into the database. When the action is done, it clears the first record and the second record will be the first record in this situation. This process repeat until the record in the array of the json file return nothing.

4.4.2 Server

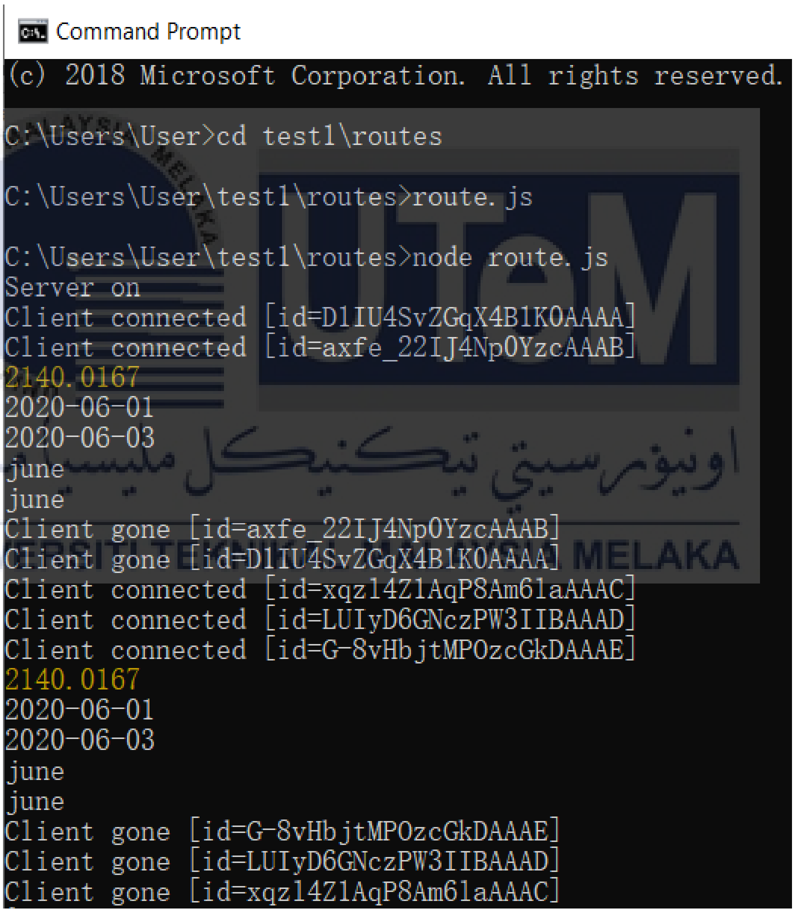

Figure 4.8: Server.

Figure 4.8 shows the server that handle request from the mobile application. Every request from the mobile application will set as new client and execute command. Then the command prompt shows client gone whenever the user close the mobile application. There are mainly two type of requests in this server which are getting the latest record for power consumption and calculating the bill for a certain range of date.

4.4.3 Mobile Application

The mobile application is done by using React Native framework. It supports for both most popular mobile operating system which is IOS and Android. Therefore, this part will show that the mobile application is function well for both operating system. The mobile application mainly formed by 3 pages which are main, calendar and bill. The main page shows the latest power consumption record from the database. There is a menu icon at the top left corner which allow user to open the application drawer for functionality selection. A calendar with a historical date range of one year from current month. For example, the calendar provides data selection from July 2019 to June 2020 when the mobile application is opened by June 2020. There is also a reset button on the top right corner to improve user experience. Lastly, the power consumption will be accumulated for the selected date range and display in the bill screen after multiplying with Tariff rate in the server. The results is shown in the figures below.

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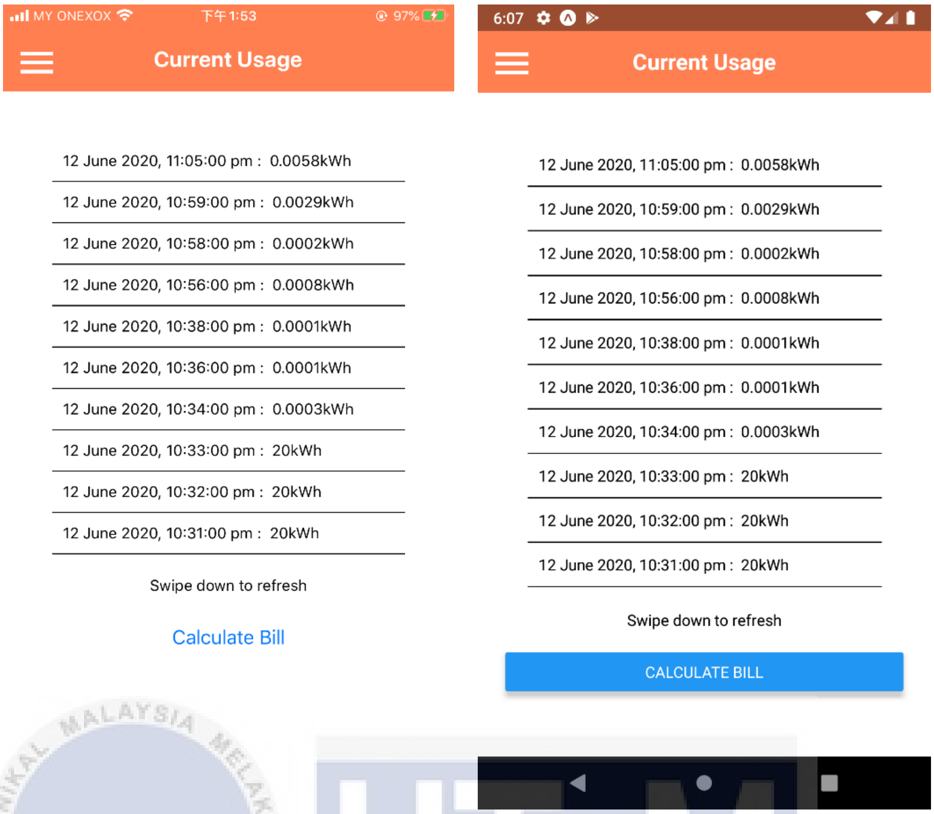

Figure 4.9: Mobile application main page.

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Figure 4.10: Mobile application drawer.

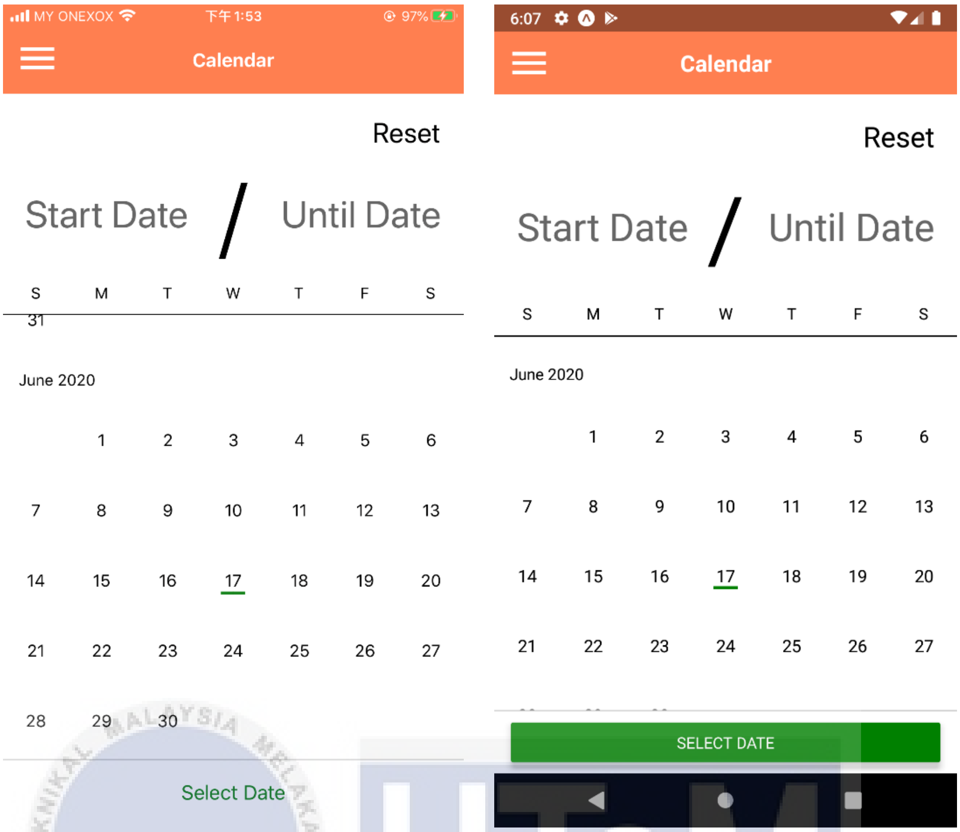

Figure 4.11: Mobile application calendar page.

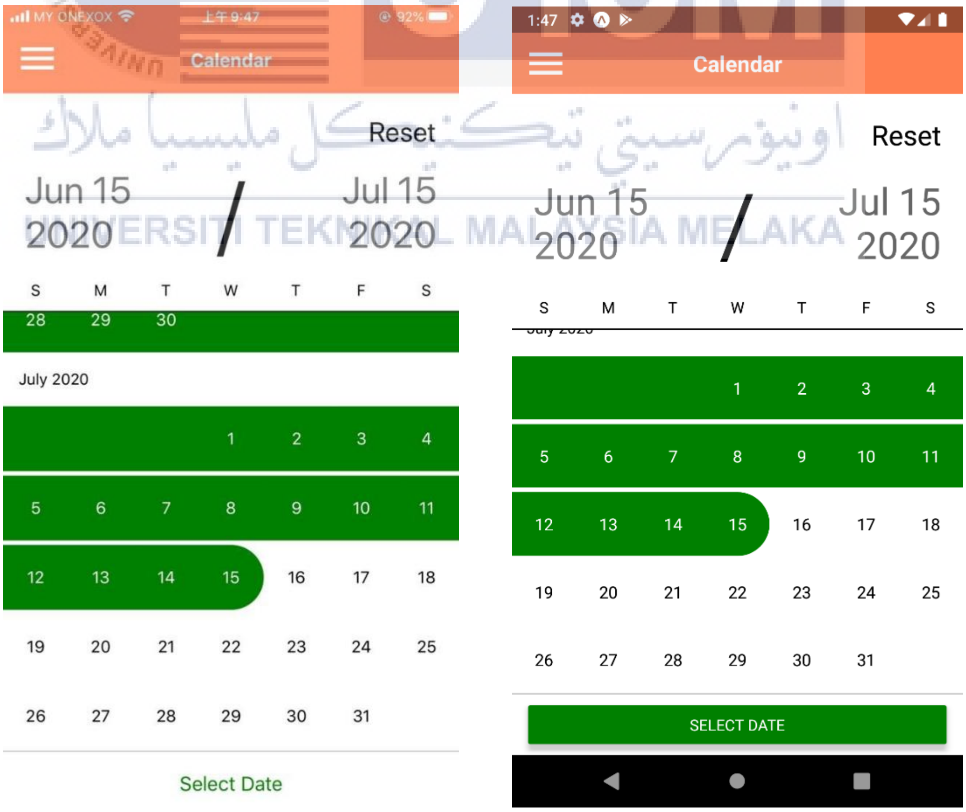

Figure 4.12 Mobile application calendar selected date range.

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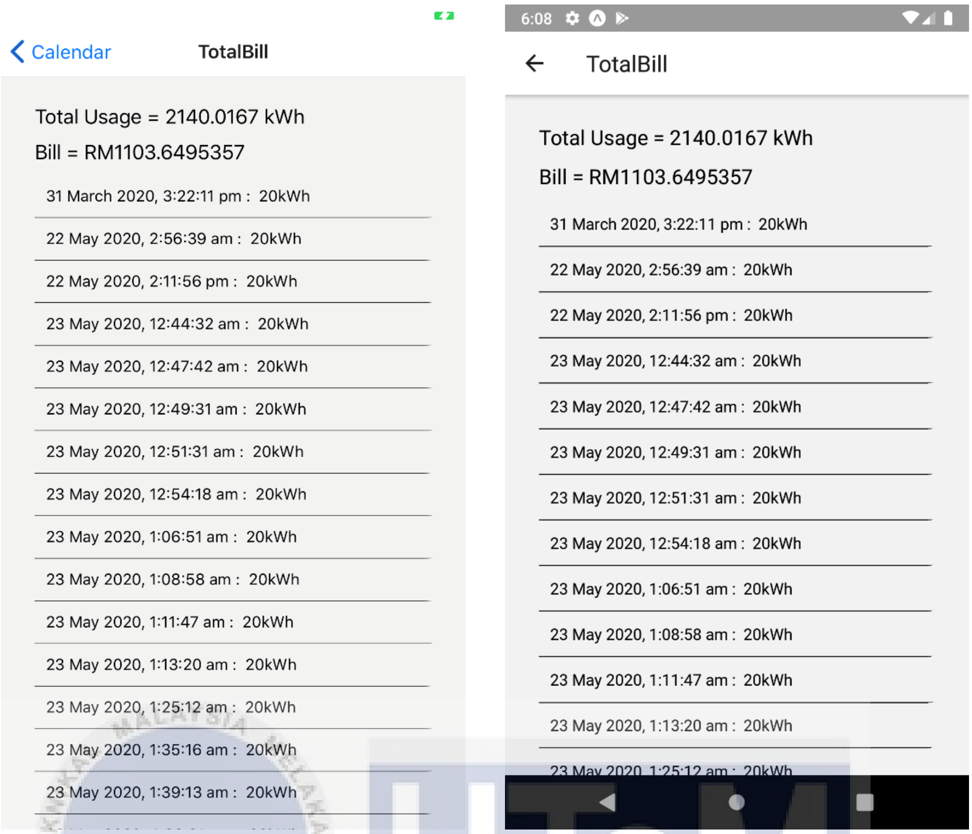

Figure 4.13: Mobile application bill page.

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CHAPTER 5

CONCLUSION AND FUTURE WORKS

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5.1 Conclusion

An attempt has been made to build a working prototype of "IoT Based Monitoring System for Smart Meter Application". This prototype is used to read and record the power consumption of the residential unit using WiFi communication infrastructure. The LCD display make the energy unit reading to be handy and allow consumers to know current usage even there is no internet connection. With the data recorded in database, consumers could check their current usage and calculate bill through the mobile application. Since consumers could monitor their power consumption anytime, the awareness of not wasting the utilization of energy is enhanced.

As a conclusion, all of the objectives of this project had achieved. The front-end power measurement system able to transfer data to the centralized controller system. A back-end storage system for measured and recorded power from front-end system is completed through MySQL database. The mobile application is completed with the functionality of monitoring current usage and bill calculation for a range of date.

5.2 Recommendation

This project can be improved by adding Real Time Clock (RTC) to the system. When the RPW0 is initialized, the date and time in the system is not updated until there is internet connection. This can ensure that the data recorded is always matching to the current date and time.

Besides, the Geographical Information System (GIS) can be added into the system for improvement. This feature allows the design to record the location where it applied. This give benefit to the utility centre to compare the power consumption whenever there is a feedback or complaint filed from the consumers.

Every RPW0 has it unique serial number. Hence, this characteristic can be used to differentiate the schema used in the MySQL database. The serial number could be converted into Quick Response (QR) code and paste on the front-end power measurement system. The mobile application could add on the feature to scan the QR code so that the consumer could get the power consumption detail which belong to their system.

The mobile application interface can be improved by showing details in bar chart or graph. Bar chart or graphical method provides easier understanding for user to see their power consumption details. Controlling some smart electrical device such as turning on and off a smart air conditioner by using the mobile application would be a great improvement for this project.

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Other than that, this design can be improved by adding electricity theft detection feature. Non-Technical losses (NTL) due to electricity theft account takes about ten to forty percent of total generation capacity in many developing countries [18]. The implementation of Automatic Meter Reading (AMR) has worsen this situation due to the elimination of worker visiting. Hence, this feature could significantly help in monitoring smart meter application.

Lastly, three phase power meter could be developed based on the single phase power meter idea. Three-phase electric power is a type of polyphase system and is the most common method used by grids worldwide to transfer power. It is more economical because it uses less conductor material to transmit electric power compared to the others at the same voltage. So, this can ensure a larger market for the design.

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