



Faculty of Electrical and Electronic Engineering Technology



DEVELOPMENT OF REAL-TIME ENERGY BILLING SYSTEM

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Bachelor of Electrical Engineering Technology (Industrial Power) with Honours

2022

DEVELOPMENT OF REAL-TIME ENERGY BILLING SYSTEM

HADIRAH BINTI ZAHARUDDIN

**A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering Technology (Industrial Power) with Honours**



Faculty of Electrical and Electronic Engineering Technology

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2023

DECLARATION

I declare that this project report entitled “Development of Real Time Energy Billing System” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

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25/1/2023

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Name (if any)

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Date

:

25/1/2023

DEDICATION

*To my beloved mother, Afrizah Zainal Abidin, and father, Zaharuddin Ismail
and*

My dearest family, Hazim, Syafiqah, Nabihah, Najihah and Hakim

My Supervisor, Ts. Dr. Mohd Hatta Jopri

My Senior, Tan Kim Loong



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ABSTRACT

Real Time energy billing system in a residential place is a system that can help with money management in electricity of a household and at the same time saving the energy. This system does not only simplify the billing system of a consumer to a utility company, but it is also able to track how much money that is being utilised in the household on a daily basis by creating a load profile log of a certain household. The advantage of this metering system is able to enhance efficiency of power usage and concurrently lowering its operation cost by lowering the manpower for energy meter reading. Incidentally, the system supports the movement of a greener earth by lessening paper bill receipt that is being handed to utility company customer every month. Besides, this energy monitoring system is able to collect large amount of data and monitoring it in real time. This real-time, large number of sampled data for efficient analysis. The User Interface (UI) is designed using Blynk application and built using Arduino IDE C++ programming language. Blynk app is used as a consumer platform in for real time monitoring, data acquisition, energy analysis and load profiling of a household. The system provides a better perception and a finer analysis in power quality data. The expected result shall be an energy monitoring platform that shows Voltage RMS, Current RMS, power, power usage and shows a daily profile of a system.

ABSTRAK

Sistem meter tenaga pada masa sebenar di tempat kediaman adalah sistem yang boleh membantu pengurusan wang tenaga elektrik isi rumah dan pada masa yang sama menjimatkan tenaga. Sistem ini bukan sahaja memudahkan Sistem meter tenaga pengguna kepada syarikat utiliti, tetapi ia juga dapat mengesan jumlah wang yang digunakan dalam isi rumah setiap hari dengan mencipta log profil beban isi rumah tertentu. Kelebihan sistem pemeteran ini mampu meningkatkan kecekapan penggunaan kuasa dan pada masa yang sama menurunkan kos operasinya dengan menurunkan tenaga kerja untuk bacaan meter tenaga. Secara kebetulan, sistem ini menyokong pergerakan bumi yang lebih hijau dengan mengurangkan resit bil kertas yang diserahkan kepada pelanggan syarikat utiliti setiap bulan. Selain itu, sistem pemantauan tenaga ini mampu mengumpul sejumlah besar data dan memantaunya dalam masa nyata. Ini masa nyata, bilangan besar data sampel untuk analisis yang cekap. Antara Muka Pengguna (UI) direka menggunakan aplikasi Blynk dan dibina menggunakan bahasa pengaturcaraan Arduino IDE C++. Aplikasi Blynk digunakan sebagai platform pengguna untuk pemantauan masa nyata, pemerolehan data, analisis tenaga dan profil beban isi rumah. Sistem ini membangunkan sistem pemantauan tenaga masa nyata dan akan memberikan persepsi yang lebih baik dan analisis yang lebih telus dalam data kualiti kuasa. Hasil yang dijangkakan ialah platform pemantauan tenaga yang menunjukkan Voltan RMS, RMS Semasa, kuasa, penggunaan kuasa dan menunjukkan profil beban harian

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to my supervisor, Ts. Dr. Mohd Hatta bin Jopri and my co-supervisor, Mustafa bin Manap for their precious guidance, words of wisdom and patient throughout this project.

I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) for the financial support through which enables me to accomplish the project. Not forgetting my fellow colleagues, Hasif bin Mohamad and Muhammad Edzham bin Ahamad for their willingness of sharing their thoughts and ideas regarding the project. My highest appreciation goes to my senior, Tan Kim Loong, who helped me days and nights in the making of my project

Finally, I would like to thank my father, mother and family members for their love and prayer during the period of my study. And all my fellow colleagues, lecturers, classmates and the faculty members, as well as other individuals who are not listed here for being co-operative and helpful.



TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATIONS	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	i
LIST OF TABLES	iii
LIST OF FIGURES	iv
LIST OF SYMBOLS	vi
LIST OF ABBREVIATIONS	vii
LIST OF APPENDICES	viii
CHAPTER 1 INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	2
1.3 Project Objective	2
1.4 Scope of Project	3
CHAPTER 2 LITERATURE REVIEW	4
2.1 Introduction	4
2.2 Prepaid vs Post Paid System	4
2.3 Energy Monitoring	5
2.3.1 Energy	6
2.3.2 Load Profile	6
2.3.3 Energy Tariff	7
2.3.4 Conventional Meter and Developed Energy Meter	7
2.3.5 Advantages and Disadvantages	9
2.4 Benefits of Adopting IoT	10
2.4.1 Data Transfer with IoT	10
2.4.2 Data Storage with IoT	11
2.4.3 Data Access with IoT	11
2.5 Review on Previous Related Works	12
2.6 Summary	12
CHAPTER 3 METHODOLOGY	13

3.1	Introduction	13
3.2	Methodology	13
3.2.1	Project Flowchart	14
3.2.2	Gantt Chart	16
3.2.3	Energy Monitoring System Operation	18
3.3	Key Components	19
3.4	Experimental Setup	19
3.4.1	Current Sensor (ACS712 -20A)	20
3.4.2	Voltage Sensor (ZMPT101B)	21
3.4.3	Communication Module (ESP32)	22
3.4.4	I2C OLED	23
3.4.1	Arduino Nano	24
3.5	Software Integration	25
3.5.1	Blynk Application	25
3.6	Project Design	26
3.6.1	Hardware design	26
3.6.2	Electronic schematic diagram	26
3.7	Data Measurement Process	27
3.8	Project Cost	28
3.9	Summary	28
CHAPTER 4	RESULTS AND DISCUSSIONS	29
4.1	Introduction	29
4.1.1	Project Hardware	Error! Bookmark not defined.
4.1.2	Project Set up	31
4.1	Data Monitoring	33
4.1.1.1	OLED Monitoring	33
4.1.1.2	Blynk Monitoring	34
4.2	Data collection	35
4.2.1	Collected data in October	36
4.2.1	Collected data in November	37
4.2.2	Collected data in December	38
4.3	Monthly Mean, Standard Deviation and Percentage Error	39
4.1	Mean value of a 3-Months Data	40
4.1	Standard Deviation of 4-Month Data	41
4.1	Percentage Error of 4-Month Data	42
4.2	Discussion	43
4.3	Summary	44
CHAPTER 5	CONCLUSION AND RECOMMENDATIONS	45
5.1	Conclusion	45
5.2	Future Works	45
REFERENCES		46
APPENDICES		48

LIST OF TABLES

TABLE	TITLE	PAGE
Table 2.1	Prepaid system versus conventional postpaid system	5
Table 2.2	Tariff rates for TNB domestic customers	7
Table 2.3	Advantages and Disadvantages Energy Billing System	9
Table 2.4	: Previous Related Work	12
Table 3.1	Gantt Chart of BDP 1	16
Table 3.2	: Gantt Chart of BDP 2	17
Table 3.3	Project Estimation Cost	28
Table 4.1	Collected data in October	36
Table 4.2	Collected data in November	37
Table 4.3	Collected data in November	38
Table 4.4	Statistic Analysis for October	39
Table 4.5	Statistic Analysis for November	39
Table 4.6	: Statistic Analysis for December	39
Table 4.7:	Mean Value of Data	40
Table 4.8	Standard Deviation of Data	41
Table 4.9:	Percentage error of Data	42

LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 3.1	Project Flowchart	15
Figure 3.2	System Operation	18
Figure 3.3	Block diagram of I/Os of EMoSy	19
Figure 3.4	Current sensor ACS712-20A and its connection to ESP32	20
Figure 3.5	Voltage sensor ZMPT101B and its connection to ESP32	21
Figure 3.6	Voltage sensor ZMPT101B and its pinout reference	22
Figure 3.7	OLED Display and its connection with ESP32	23
Figure 3.8	Arduino nano with pinouts reference	24
Figure 3.9:	Blynk Application	25
Figure 3.10	AutoCAD	26
Figure 3.11	Ultimaker Cura	26
Figure 3.12 :	Project Electronic Design	26
Figure 3.13 :	datat measurement process	27
Figure 4.1	EMoSy in AutoCAD	30
Figure 4.2	EMoSy in Ultimaker Cura	30
Figure 4.3	EMoSy finished Product	31
Figure 4.4	Project Set Up	32
Figure 4.5	Monitoring through OLED for on-site	33
Figure 4.6	Energy Monitoring in Blynk	34
Figure 4.7 :	Clamp meter testing	35
Figure 4.8	System current vs Ammeter in October 2022	36
Figure 4.9 :	system voltage vs voltmeter in October 2022	36
Figure 4.10	System current vs Ammeter in November 2022	37

Figure 4.11 system voltage vs voltmeter in November 2022	37
Figure 4.12 System current vs Ammeter in December 2022	38
Figure 4.13 system voltage vs voltmeter in December	38
Figure 4.14 : Mean Voltage	40
Figure 4.15 : Mean current	40
Figure 4.16 Standard deviation Voltage	41
Figure 4.17: Standard Deviation current	41
Figure 4.18 Percentage error voltage	42
Figure 4.19: Percentage error current	42



LIST OF SYMBOLS

δ - Voltage angle



LIST OF ABBREVIATIONS

V - Voltage



LIST OF APPENDICES

APPENDIX	TITLE	PAGE
Appendix A	Data for October	48
Appendix B	Data for November	51
Appendix C	Data for December	54



CHAPTER 1

INTRODUCTION

1.1 Background

Electricity demand in Malaysia has been escalating for the past decades and is expected to be further increasing in the future. This is in parallel with the speedy industrialization, development of urban areas and especially with the nation's growing populations [1]–[3]. A study reveals that commercial and residential buildings takes up to 48% of Malaysia's overall electricity demand [2]. In a common Malaysian household, the average number of utilized electrical household equipment are about 20 to 30 equipment. [3]. Energy wastage tends to occur mainly with the user's negligent of leaving the unused electrical equipment, such as hair dryer, rice cooker, air conditioner, water heater and oven switched on for the whole day. [4] Even though the equipment is certified with 5 stars energy efficiency label, this misbehavior consumes a large amount of energy at the end of the month.

Recently in Malaysia, Energy and Natural Resources Minister announced the new tariff rates. This new tariff is said not to burden domestic consumers based on the Incentive-Based Regulation (IBR) [5]. The main Electric Utility companies across Malaysia namely, Tenaga Nasional Berhad (TNB) for peninsular Malaysia, Sabah Electricity for Sabah and Sarawak Energy for Sarawak are responsible in setting respective tariffs for each company according to Malaysian's Energy Commission's IBR [6].

1.2 Problem Statement

The utilization of electricity corresponds to the use of power. The longer the utilization of power elicits higher bill of costs at the end of every cycle and unmonitored power consumption will result in overspending [4]–[7]. The conventional energy meter is designed to display kilowatt-hour, which is the quantity of electricity that is being utilized by the consumer over a period of time. [8]–[10] The data is then individually inspected by meter readers from the energy provider companies. Monitoring consumer's energy consumption at real time can't be accessed using this method. This method is not only prone to human error but also time consuming and labour consuming [11]–[13]. The data from the conventional meter and method might not be precise and accurate. [5] Therefore, the limitations of conventional meters are the key drives of this project.

1.3 Project Objective

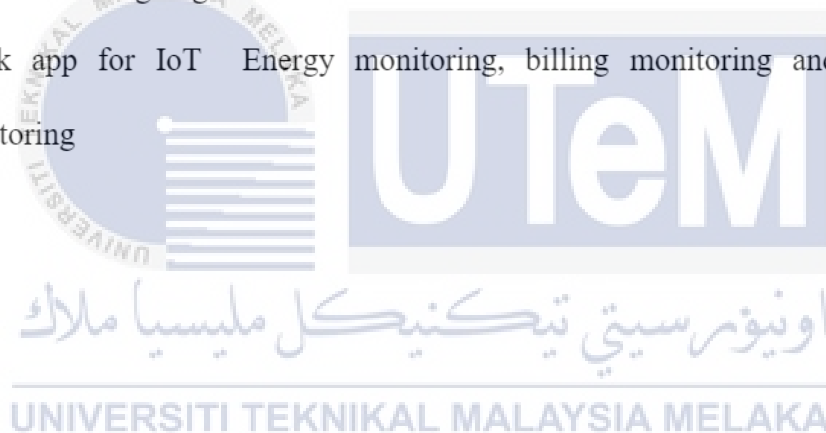
The objectives of this project are :

- a) To design a real time energy billing system using real-time data acquisition with IoT technology
- b) To develop and integrate real time measurement.
- c) To analyze the performance of the system.

1.4 Scope of Project

Project's scopes help to establish its boundaries within the precise objectives, due dates, and project deliverables that is aimed for. Project goals and objectives can be met without running late or having to work too hard by having to define the scope of project. The scope of this project are as follows:

- 1) Energy meter for single phase residential purposes only
- 2) Maximum load of 160W
- 3) Arduino IDE software as programming platform
- 4) Autocad as designing tool and Utimaker cura
- 5) Blynk app for IoT Energy monitoring, billing monitoring and load profile monitoring



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

As a mean to make this project a successful project, several research and studies has been done from multiple sources, this includes scholarly books, article journals, research papers, dissertations and credible internet sources that is related to this project. This chapter highlights the difference between prepaid and postpaid payment, overview of the past projects, IoT in this energy meter system, how data is being stored in this energy meter and some key components needed for this energy meter.

2.2 Prepaid versus postpaid System

Fundamentally, there are three options for paying a service. Before the service provider performs the service, after its execution and payment in between the service execution. For utility companies like waterworks, gas or heating, the typical model for payments is post-paid method which consumers are charged upon the usage of the services at the end of billing cycle [10]. However, in recent years, the demand for pre-paid energy meter has been increasing with the trend of rental accommodation such as vacation homes, Airbnb, homestays , short property rental and sublets or sublease. Some developing countries have made the move to attain sustainability in the power sector through this pre-paid energy meter system [11]. This method may help consumers managing their power consumption at the same time their financial condition. Consumer may budget in advance for how much electricity they planned to use or are authorized to use using a pre-paid

system. Table below shows the comparison between pre-paid and conventional postpaid system

Table 2.1 Prepaid system versus conventional postpaid system

Pre-paid system	Conventional Post-paid system
Payment before usage	Payment after usage
Self-administered	Administration under utility company
Consumers pay by themselves, not needing meter readers to come	Workers from utility company will come and read meters
Reducing man labor and cost effective	More workers and not cost effective

2.3 Energy Monitoring

Monitoring of energy system are now commonly used in monitoring energy consumption in industrial plants and buildings. The residential unit consists of many private households, flats and living quarters do not necessarily have any energy monitoring device excluding the energy meter that is only accessible by the utility company. According to a research, a wastage over 41% of the total energy consumption has been done by these residential energy consumers [12]. The change of the parameters such as voltage, power factor, current could have led to the wastage and thus needed to be monitored. The key to conserving energy is understanding the basics of how energy is being utilized, monitored, and regulated over the period of billing cycle. Research also shows that consumers who are being informed by their energy consumption may better understand and make better judgements in reducing their household's electricity consumption [13].

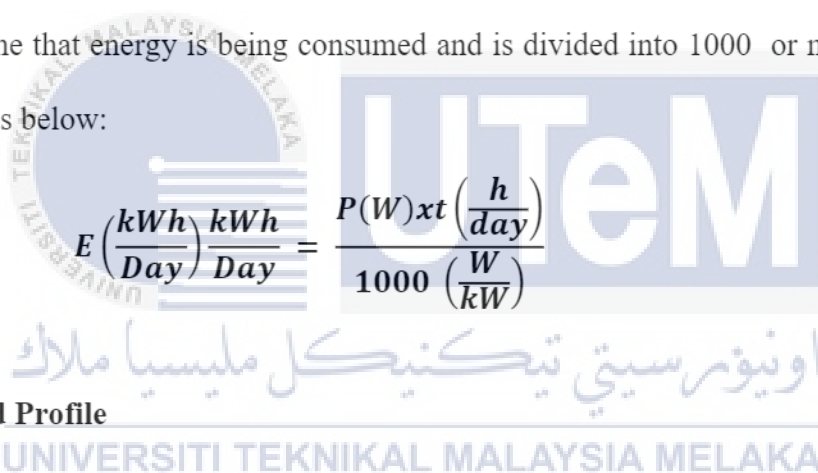
2.3.1 Energy

Energy in physic means the ability to perform work, in other word it is the measure of work that has been done, that is required for a period of time. Energy has the SI unit of Joule or (J), while work has the SI unit of Watt or (W) and both are very closely related to Power (P) as it is the energy converted over a period of time. [14]

$$\text{Energy} = \text{Frequency}(\text{Distance})$$

$$\text{Power} = \text{Energy} / \text{time}$$

Energy consumed is measured in kilowatt hour or (kWh). Energy is Power (P) times the time that energy is being consumed and is divided into 1000 or mathematically, it is shown as below:


$$E \left(\frac{kWh}{Day} \right) \frac{kWh}{Day} = \frac{P(W) \times t \left(\frac{h}{day} \right)}{1000 \left(\frac{W}{kW} \right)}$$

Equation 1

2.3.2 Load Profile

With advancement of smart grids, an abundant of consumer's data that is being connected to the grid has been collected. This data is finer or in other word, a fine-grained energy data. This data is considered to be very valuable as it carries information such as cumulative energy consumption of consumers. With load profile, utility companies can manage to study, analyze and perfectly predict energy consumptions for the future and on which part of the day energy can be efficiently used.[16] This is also an effort in saving energy. Load Profile is essentially an electrical load versus time graph. It is often segmented hourly in a span of 24 hours. Some load profiles even segment its result half hourly. [17]

2.3.3 Energy Tariff

Energy tariff is the how the Electricity utility provider charges their consumers. For example, Tenaga Nasional Berhad (TNB), being one of the electricity providers has a few tariff classifications and with each class has different rates of charge. This includes domestic customers or owner of private residences [18]. Table below shows the latest (effective January 1st 2014) TNB tariff rates for domestic residences customers:

Table 2.2 Tariff rates for TNB domestic customers

Tariff Category	Unit	Current Rate
For the first 200 kWh (1 - 200 kWh) per month	sen/kWh	21.80
For the next 100 kWh (201 - 300 kWh) per month	sen/kWh	33.40
For the next 300 kWh (301 - 600 kWh) per month	sen/kWh	51.60
For the next 300 kWh (601 - 900 kWh) per month	sen/kWh	54.60
For the next kWh (901 kWh onwards) per month	sen/kWh	57.10
The minimum monthly charge is RM3.00	-	-

2.3.4 Calculating Energy Consumption

Roughly, there are 5 steps in calculating the electricity consumption of an appliance in a residential unit.

1) Estimate the duration for a switched-on appliance

Estimation is done roughly of how long the appliance is being used over a period of a day or 24 hours. As example, a computer is being used for 5 hours per day. This means, the time=5, t=5. This number is recorded as a data log.

2) *Know the product wattage*

Most household appliances comes with their wattage sticker either it is at the back or bottom of the appliances, In Malaysia, this sticker is authorized by SIRIM after successfully managed to pass the QC test. This ensures the safety and the reliability of the appliance.

3) *Calculate daily energy consumption*

With the presented formula below, we can find the kilowatt-hours (kWh) over a period of 24 hours

$$E\left(\frac{kWh}{Day}\right) \frac{kWh}{Day} = \frac{P(W) \times t\left(\frac{h}{day}\right)}{1000 \left(\frac{W}{kW}\right)} \quad \text{Equation 2}$$

4) *Calculate monthly energy consumption*

Monthly energy consumption is done by multiplying the value of Kilowatt hour by the number of days in a month.

$$E\left(\frac{kWh}{Month}\right) = E\left(\frac{kWh}{Month}\right) \times 30 \text{ days } [X] \quad \text{Equation 3}$$

5) *Monthly cost to operate the appliance*

The cost of electricity per day for that particular equipment in (RM) based on the tariff of TNB category A residential unit

$$\text{Cost}\left(\frac{RM}{Month}\right) = E\left(\frac{kWh}{Month}\right) \times RM0.21[X] \quad \text{Equation 4}$$

2.3.5 Conventional Meter and Developed Energy Meter

Until today, Malaysia still practices monthly electricity reading and billing with help of meter readers. Conventional meters are electro-mechanical devices that measure the consumption of power and require regular readings to be taken in site. Meter reader will come to each house periodically and take electricity readings manually. Then, bill will be produced after meter reader reads meter that is attached in front of a residential unit, and this process is prone to human errors. This has become an inconvenient way of billing system especially in this modern age which can be solved with help from IoT

2.3.6 Advantages and Disadvantages

With IoT, there are also advantages and disadvantages, Table below summarizes the advantages and disadvantages of energy billing system embedded with IoT and the advantages far exceeds the disadvantages.

Table 2.3 Advantages and Disadvantages Energy Billing System

Advantages	Disadvantages
Able to control electricity consumption	Inconvenience of having to reload
Time saving	Have to keep eye on credit status balance
Labour free system	-
Able to void billing issues	-
Able to avoid shocking energy bills	-
Able to read meter & plan electricity usage	-

2.4 Benefits of Adopting IoT

Internet of Things (IoT) is also known by the name industrial internet. It is the most recent technological paradigm that make able for gadgets and machines to be communicating in a worldwide network. In the application of modern energy meter, this can be a huge benefit as embedding IoT into the system allows communication between the consumers and the electricity utility company with real-time data [19]. Some other advantages for this project include:

- A) Monitoring its power consumption and power quality
- B) Calculating operational costs of power according to real time price
- C) Less human intervention thus significantly reduce human error
- D) Saves time and money

2.4.1 Data Transfer with IoT

Sample s As IoT becomes more and more accessible over the past decades, the interrelation of computer devices and mechanical and electrical machines without the need of human-to-human or human-to-machine advances. This ability is achieved by transferring data over a network. One of the most convenient data transfers is by connecting wirelessly to the global network of networks called the internet. The internet is a global network platform that has the largest number of consumer in the world, as the number of its consumer by 2020 year end is 5 billion worldwide internet user.[14] This shows by transferring data over the internet is the best method

Data Storage with I Data Storage is defined as all of the methods and technologies of virtually storing digital or information by electromagnetic, optical, or silicon-based storage media. Data storage uses the internet medium to store those recorded data. Data storage in IoT works in a manner where data is being read from smart devices and being sent over the network that has the same protocols. One of the protocols is HTTP or (Hypertext transfer Protocol) and then to a cloud . The connection capability heavily relies on Wi-Fi wireless network.

2.4.2 Data Storage with IoT

Data Storage is defined as all of the methods and technologies of virtually storing digital or information by electromagnetic, optical, or silicon-based storage media. Data storage uses the internet medium to store those recorded data. Data storage in IoT works in a manner where data is being read from smart devices and being sent over the network that has the same protocols. One of the protocols is HTTP or (Hypertext transfer Protocol) and then to a cloud . The connection capability heavily relies on Wi-Fi wireless network.

2.4.3 Data Access with IoT

The ability to monitor, transmit, modify, move, access, and retrieve data from the data storage refers to data access. There are many platforms that provides this capability. One of the prominent one in the market is Blynk Application. This IoT platform is an analytic platform that lets user to monitor real time data that has been sent to the cloud. It is prominent for its open-source features. Another great feature of Blynk Application is that it lets sensor to upload data directly to the server and visualize it in graphs and charts including the timestamp. This is great for making a load profile monitoring.

2.5 Review on Previous Related Works

Table 2.4 : Previous Related Work

Title & Author	Advantages	Disadvantages
Internet of Things-Based Smart Electricity Monitoring and Control System Using Usage Data [15]	<ul style="list-style-type: none"> • customizable controller • uses SMACS system for monitoring 	<ul style="list-style-type: none"> • complicated IoT set up of Thingspeak and Virtuino. • not real time energy monitoring
Effective Power Consumption Monitoring of Smart meter through IoT [16]	<ul style="list-style-type: none"> • included energy data logging on portal 	<ul style="list-style-type: none"> • not a real time energy meter system • limited connectivity
An IoT design approach to residential energy metering, billing and protection [17]	<ul style="list-style-type: none"> • able to inteprete real time billing • linked with payment platform 	<ul style="list-style-type: none"> • complicated design • payment not through an app, not user friendly
Design, Implementation, and Deployment of an IoT Based Smart Energy Management System [18]	<ul style="list-style-type: none"> • monitoring through IoT • accurate power consumption accurately 	<ul style="list-style-type: none"> • not for big data • not suitable for load profiling
A Novel IoT based Smart Energy Meter for Residential Energy Management in Smart Grid Infrastructure [4]	<ul style="list-style-type: none"> • system reads data in real time 	<ul style="list-style-type: none"> • non secure open cloud system • billing monitor through web page

2.6 Summary

The related theories aforementioned within the scope of this project have been reviewed in depth. Previous related works are Furthermore, a comprehensive all round literature review of the previous related works was done in order to understand the research thoroughly. Different types of software, hardware of other people's research that are closely related to this project has been discussed in this chapter.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will present the overall process, procedures and method used that is related to this project. Methodology shall function as a guideline aiming for the completion of this project. In this chapter, the project process will be described from the start until the end of the project. Each process will be elaborated in detail within this chapter for a deeper understanding. Furthermore, the methodology must be followed precisely in ensuring the project to be done in a right manner. Last but not least, the project schedule and routine will be covered in this chapter. In his routine and schedule, the activities that has been done within the given period will also be covered.

3.2 Methodology

In this subchapter, the focus will be about the stage of methodology involved in developing this real time energy billing system. Project methodology is a collection of guidelines and procedures that has helped this project to run optimally and smoothly with an organized structure. This project's methodology consists of flowcharts and Gantt chart as it is most often used to depict enumerate a project's progress. This method also helps to ensure project to be done in an efficient manner. This subtopic will accommodate the explanation of each process and procedures of this project.

3.2.1 Project Flowchart

One of the tools to help this with is a project or process flowchart. It ensures the success of the project. The development of project flow chart helps with categorizing of the project's progress. Energy Monitoring System (EMoSy) was developed from 3 categories namely, A, B and C. The process starts with category A which comprises of modelling of the circuit. The modelling was done in Multisim software and the process is only proceeded when the simulation of the modelling works successfully.

The process is then followed by category B of hardware development. As Internet of Things becomes the limelight of technology in this age for its ability to do machine communication without the intervention of human [1], category B of EMoSy development presents the integration of voltage sensor, current sensor and embedding the hardwares into a system with Arduino nano and ESP32. This is a crucial part of developing the EMoSy and can only proceed to the next category when troubleshooting is unnecessary, and the hardware is fully working.

Next, category C composes of field testing of EMoSy. Getting the required and genuine data from EMoSy during the field testing is an essential step before proceeding to the next step which is the data statistical analysis for the system's future improvement [2]. The data statistical analysis will be further elaborated in the next section. Below shows the flowchart of categorization of project development.

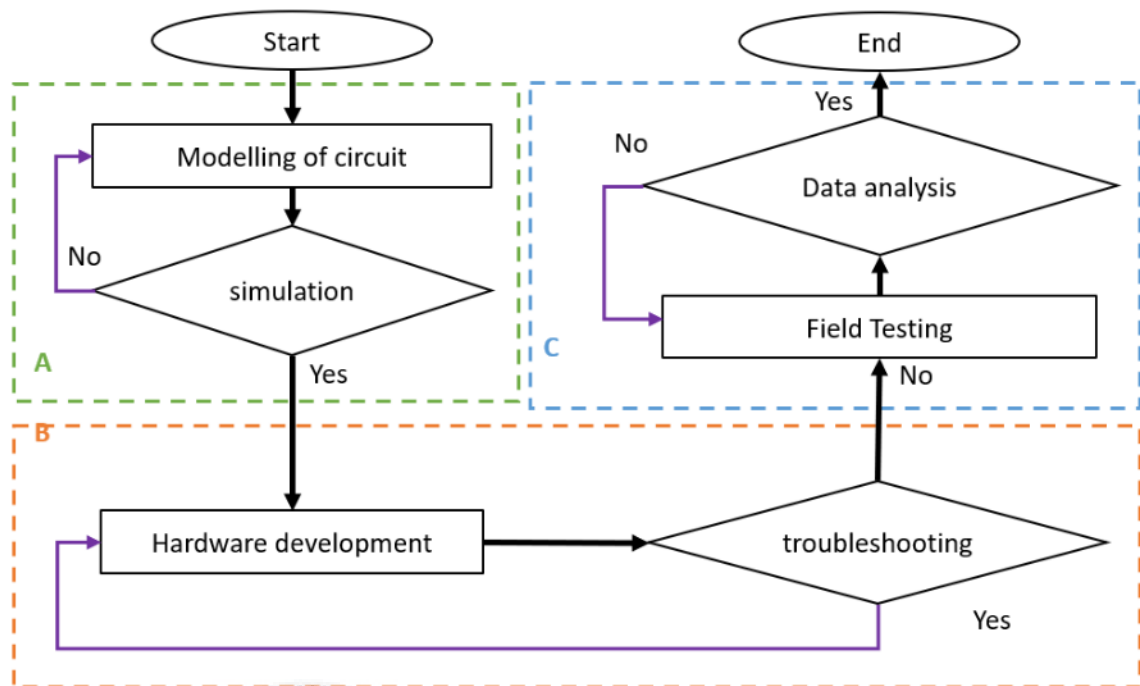
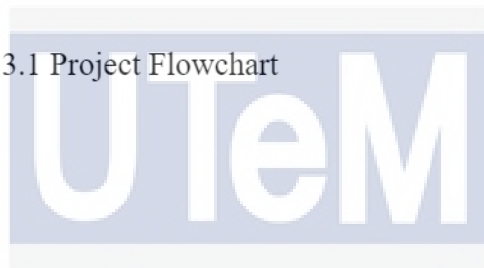
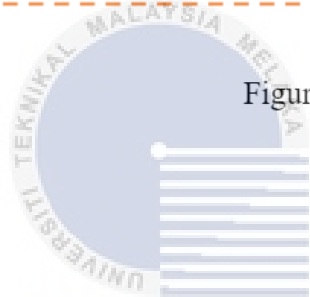


Figure 3.1 Project Flowchart



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3.2.2 Gantt Chart

In making sure progress are done on a weekly basis, a Gantt chart is created for this project from week 1 until week 14 of Bachelor's Degree Project (BDP) 1 and BDP 2. Tables below show the Gantt Charts of this project.

Table 3.1 Gantt Chart of BDP 1

ACTIVITY	WEEK															
	1	2	3	4	5	6	SEMESTER BREAK	7	8	9	10	11	12	13	14	
BDP Title Selection and forms filling																
Identification of project scopes and objectives																
Problem Statement review																
Research on Information, Article Journals and Reference Books																
Writing progress for Introduction and Literature Review																
Selection of hardware components																
implementation of hardware & software components																
Writing Progress on Methodology Chapter 3																
Project Methodology																
Completion and Revision on BDP 1 Report																
Presentation of BDP1																
Correction and submission of BDP 1 report																

Table 3.2 : Gantt Chart of BDP 2

ACTIVITY	WEEK															
	1	2	3	4	5	6	SEMESTER BREAK	7	8	9	10	11	12	13	14	
Purchasing of project components																
Research on Smart meter IoT of past 5 years system																
Design energy meter with IoT																
Coding, do wiring for project components																
Testing of wiring in Fritzing																
Assemble hardware																
Testing of hardware																
Project troubleshooting																
Chapter 4 and Chapter 5																
Review with Supervisor																
Poster & Video																
Modification of report																
Submission of PSM2 report																

3.2.3 Energy Monitoring System Operation

The operation of this project is fairly straight forward. The Energy Monitoring System (EMoSy) device consists of AC to DC Supply board, ESP 32 with Arduino nano, Voltage sensor, Current sensor, and OLED. This meter will be injected with a 5V supply through the AC to DC supply board. When load is connected to the system, the current sensors and voltage sensor send signal into the Arduino with integrated with ESP32. The microcontroller runs several and calculate the Power and consumption of the load.

The integration of IoT in this project comes when the values of RMS voltage, values of RMS current, values of Power is then transferred to the IoT platform through a Wi-Fi module in ESP 32 and router. Then, through the Wi-Fi, those values will be displayed on the Blynk application together with visualization of load profiles graph. The billing of EMoSy will be programmed to be communicated through telegram application as alert notification. Figure below shows the Operation of EMoSy.

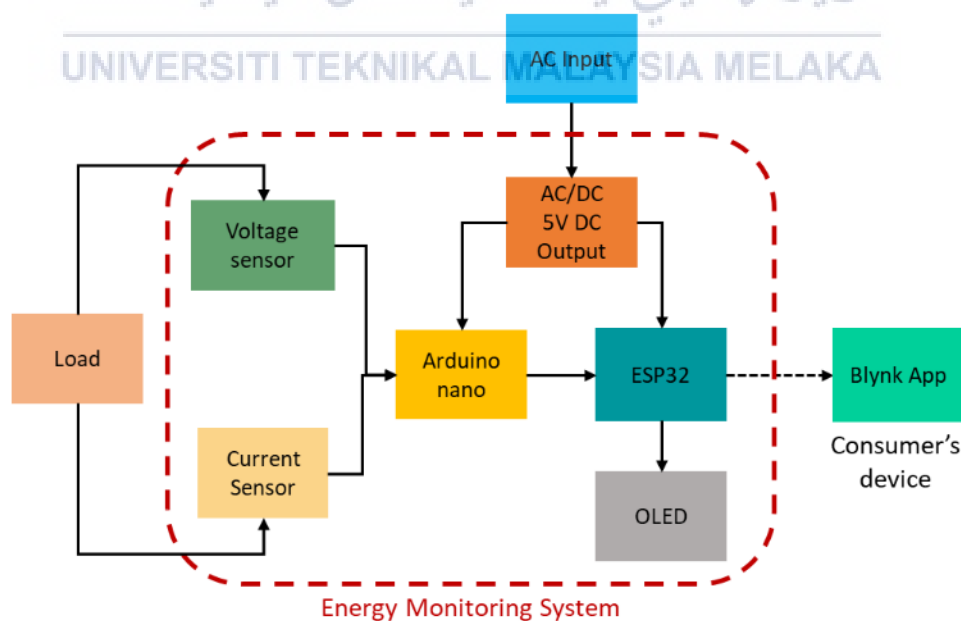


Figure 3.2 System Operation

3.3 Key Components

In this section, several key components will be listed out and described. This includes the chosen input components and chosen output components of the project (I/O). The carefully selected I/Os and microcontroller were chosen based on the advantages that outweighs the disadvantages, the cost affordability, and the availability of the component at the given time. Figure below shows the block diagram of I/Os of this project.

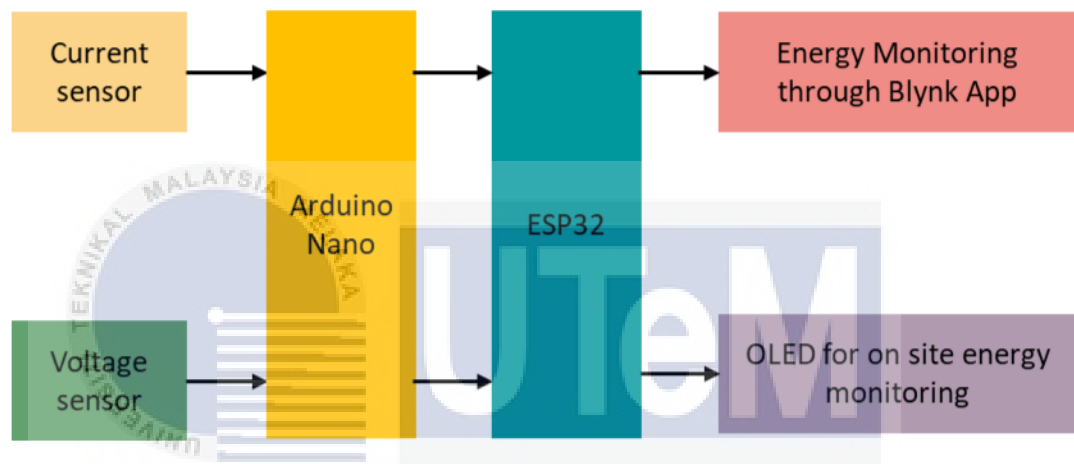


Figure 3.3 Block diagram of I/Os of EMOsy

3.4 Experimental Setup

As described in the previous subtopic, there are several components that serves as the backbone of this project. Significantly, in this subtopic, the focus will be about the hardware that are being integrated into this project. In particular, this subtopic will describe the functions of the inputs of current sensor used, the voltage sensor used, the communication modules used and the hardware output of OLED as a monitoring device.

3.4.1 Current Sensor (ACS712 -20A)

The current sensor used in this project is from the Allegro® ACS712-20A. It is a small AC current sensor module that has a current limit of 20A. The current limitation is adequate for this project application as this project does not deal with super high current value. This sensor needs a 5V supply to operate. It operates by calculating its built-in low resistance current conductor and measuring the current applied to it. The connection of this current sensor is series to the current in the circuit that is being measured. Figure below shows the current sensor.

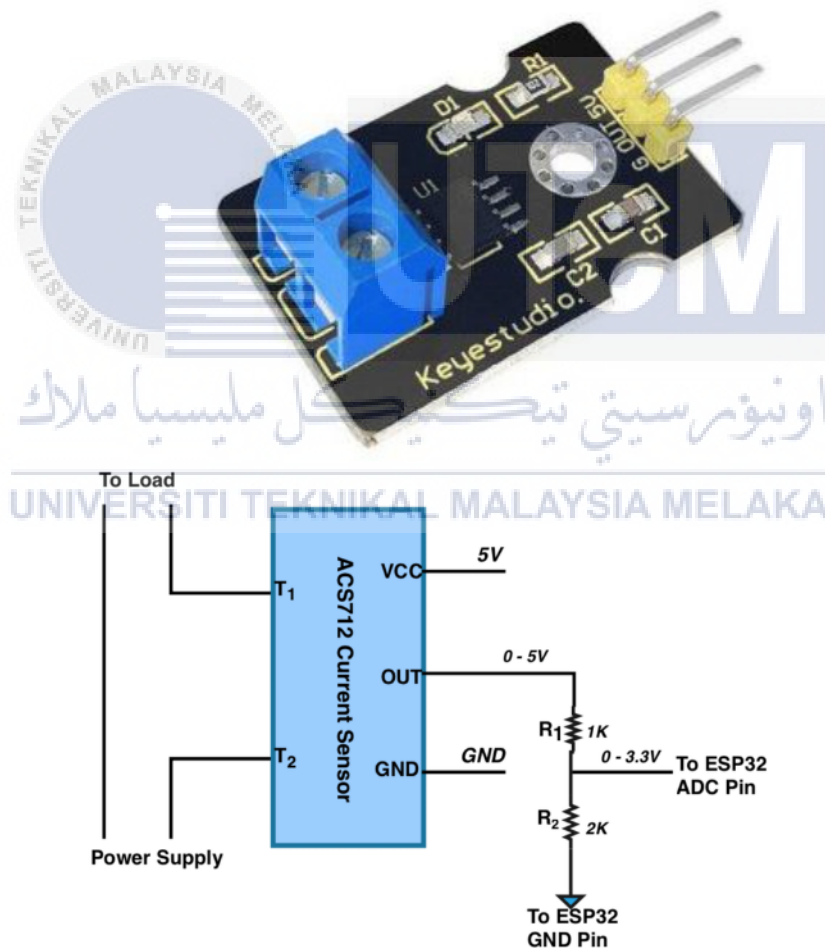


Figure 3.4 Current sensor ACS712-20A and its connection to ESP32

3.4.2 Voltage Sensor (ZMPT101B)

Voltage sensor that is being used in this project is an AC Voltage Sensor Module ZMPT101B. This module is specifically ideal for measuring AC Voltage of this project as it measures within the single phase of 250V. The operating voltage is between 5VDC to 30 VDC. This module is also chosen for its feature of delivering good consistency voltage measurement. The figure below shows the Voltage sensor ZMPT101B.

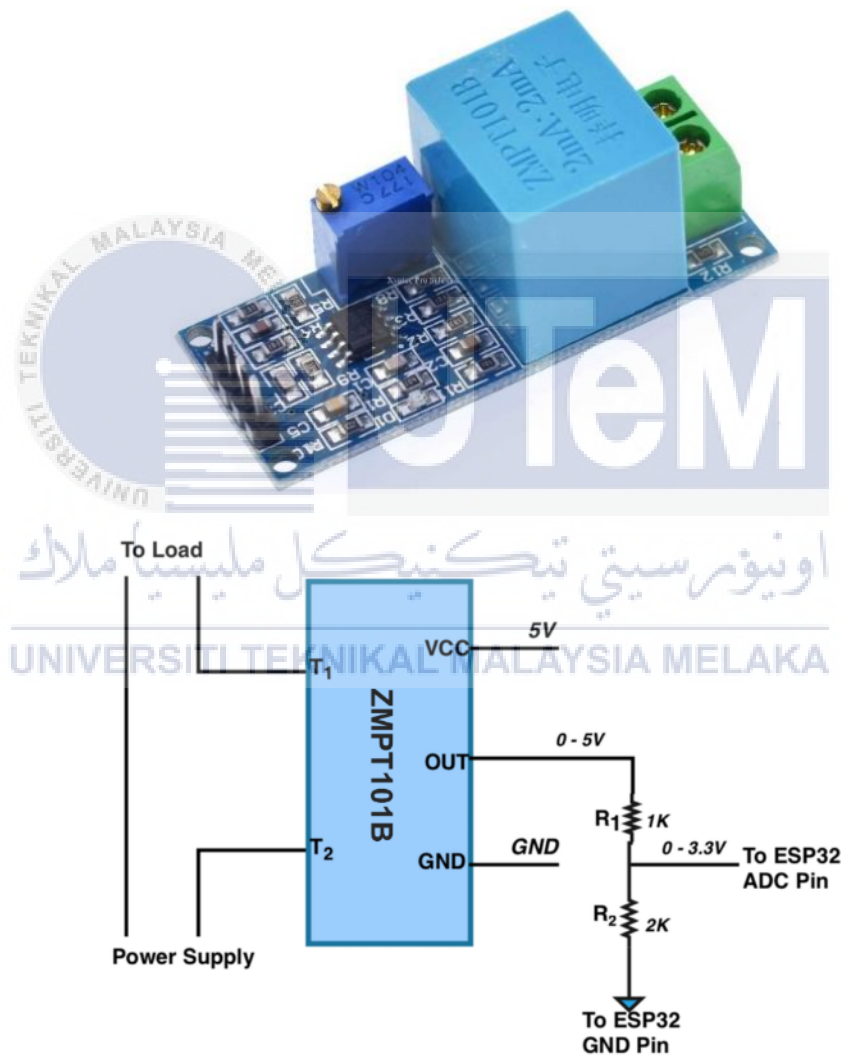


Figure 3.5 Voltage sensor ZMPT101B and its connection to ESP32

3.4.3 Communication Module (ESP32)

ESP32 is chosen as a communication module for this project for its simplicity of operation and its attributes. Although the hardware architecture looks very different than a normal Arduino microcontroller, ESP32 is compatible with Arduino IDE which utilizes the language of c++ for the development environment. The main attribute of ESP32 communication module is its integrated Wi-Fi and Bluetooth wireless communication signal and even has the computational capacity like Arduino microcontroller. In terms of operation, it is better in so many ways and faster in communication speed. ESP. It has 48 pins with several functions Below is the figure of ESP32 and its pinout reference.

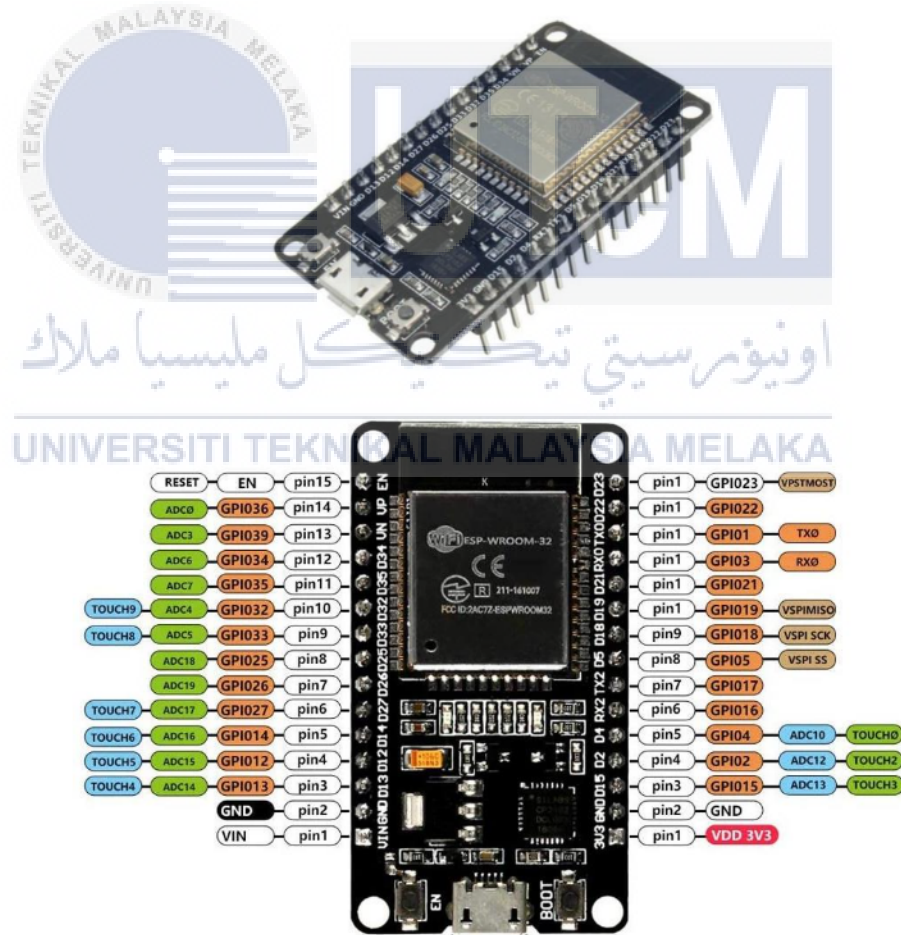


Figure 3.6 Voltage sensor ZMPT101B and its pinout reference

3.4.4 I2C OLED

For direct power monitoring, I2C OLED Graphic Display module is used instead of the normal LCD display. OLED or Organic Light Emitting Diode display is small in size but powerful in action. Thanks to LED properties, the display is an improved display quality. It has high brightness and contrast. The module is also thinner and lighter. The operating voltage is of 3.3V to 7V and its operating current is 20mA max. The screen size is about 1 inch across, it can display up to 21 characters per row with 7 rows of display. This is sufficient for energy monitoring of this project. Below shows the figure of OLED display and its connection with ESP32.

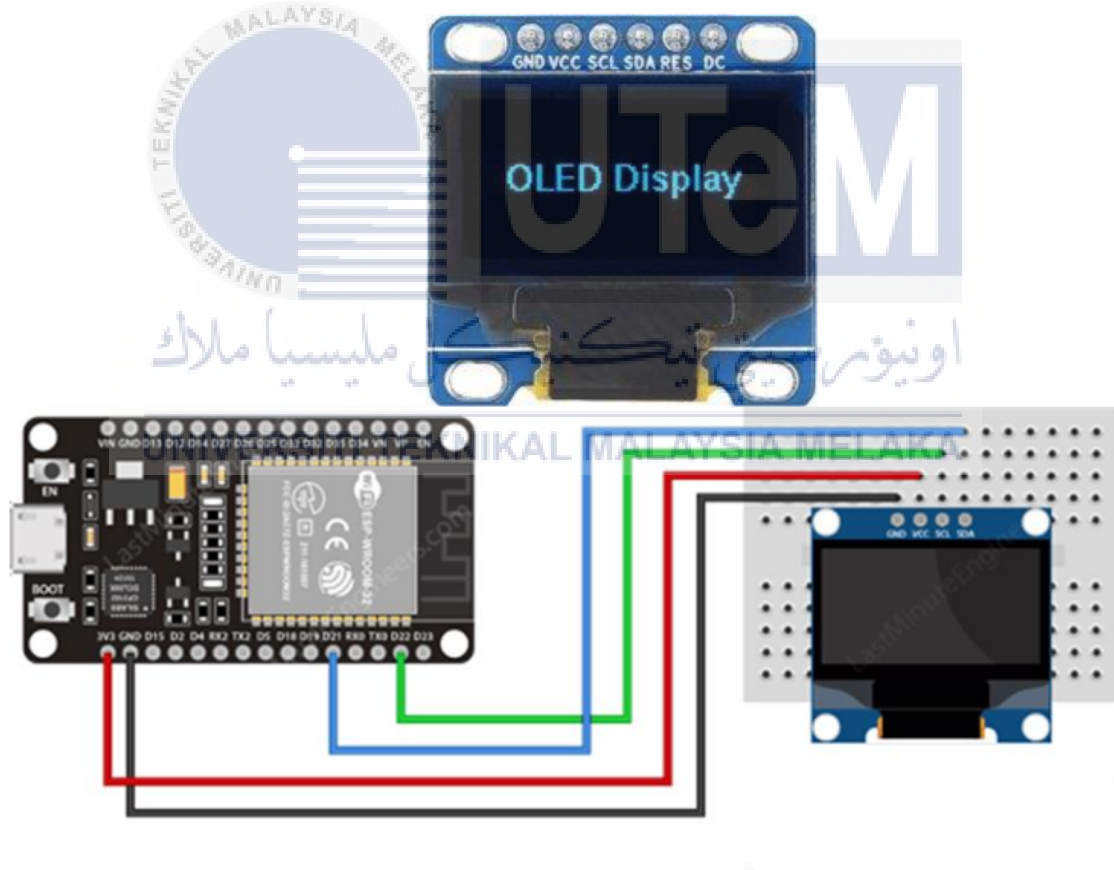


Figure 3.7 OLED Display and its connection with ESP32

3.4.1 Arduino Nano

For stability purposes of current and voltage sensor, another microcontroller is introduced in this project, that is Arduino nano. It is chosen for its compact, completely user-friendly attributes with a built in ATmega328P microprocessor. Its operating voltage is as small as 5V only. It employs 32KB flash type memory which are used by bootloader and has a 16MHz CPU clock speed. It's small in size, approximately 18 x 45mm and only weighs 7g. It has 22 Input Output pins with 16 analogue pins. Figure below shows Arduino nano with its pinout reference.

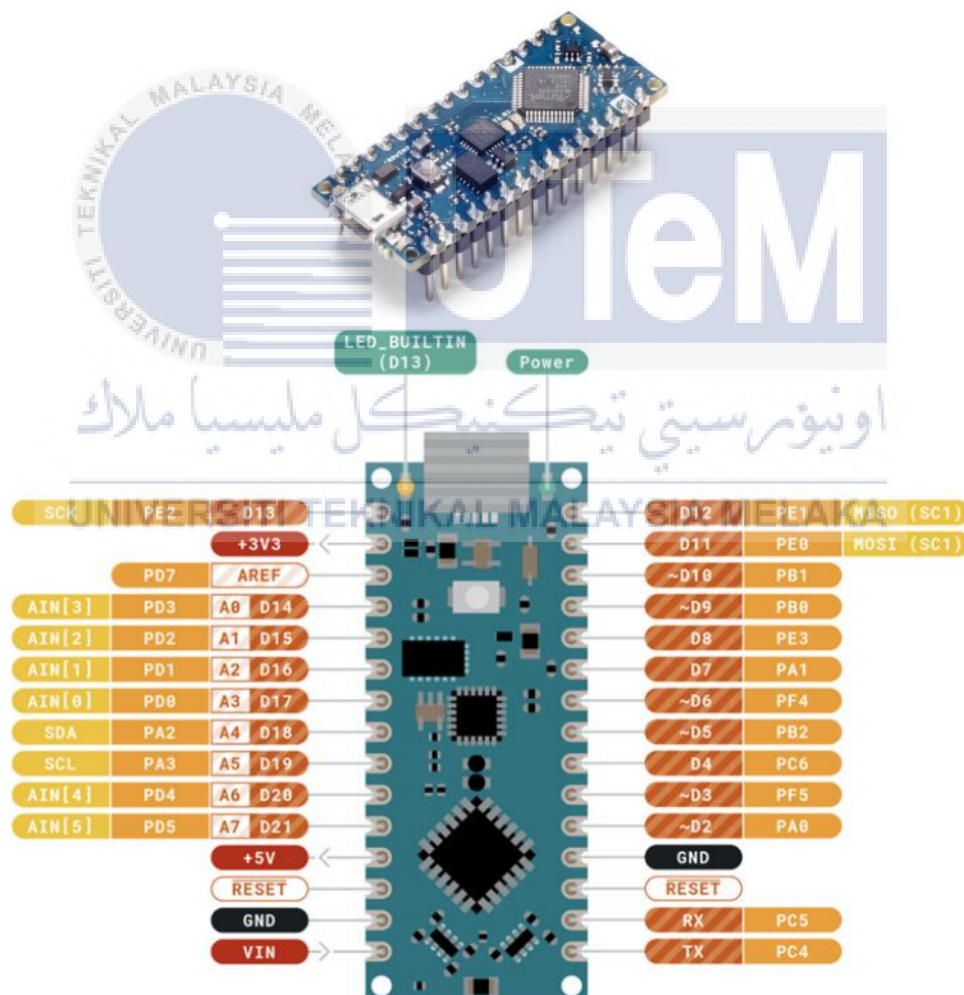


Figure 3.8 Arduino nano with pinouts reference

3.5 Software Integration

3.5.1 Blynk Application

Blynk is a platform that is designed for the Internet of Things. Blynk App is chosen in this project as a monitoring platform of IoT for its characteristics. One of it includes contemporary and user-friendly User Interface (UI). Blynk Application used in this project shall display real time data of current, voltage and power consumption. Users can check these real time data through this app. Figure below shows example of Blynk IOT display.



Figure 3.9: Blynk Application

3.6 Project Design

3.6.1 Hardware design

The electronic components of EMOsY are to be assembled together in a plastic 3D printed casing made in AutoCAD and Ultimaker CURA which was specially design to retrofit distribution board.



Figure 3.10 AutoCAD



Figure 3.11 Ultimaker Cura

3.6.2 Electronic schematic diagram

Electronic design of this project is made in Fritzing design application . Figure below shows the electronic schematic diagram of the project.

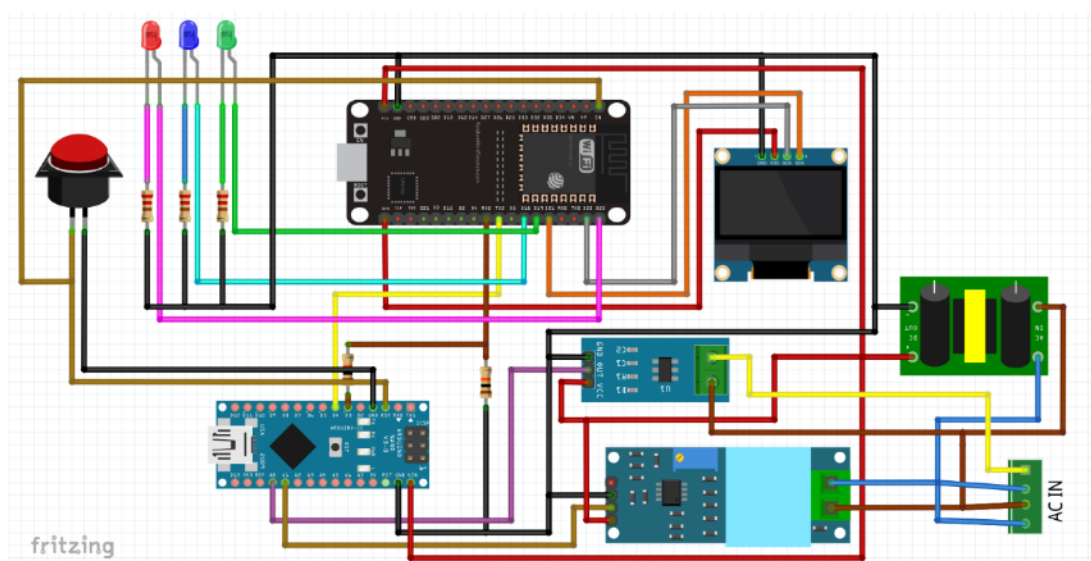


Figure 3.12 : Project Electronic Design

3.7 Data Measurement Process

Data measurement process encompasses around the objectives of the project. In order to achieve success, two components of data measurement are considered and that is:

- a) Data measurement accuracy
- b) Data measurement precision

Data that is obtained from EMOsy are RMS current and RMS voltage. From there, Power is calculated. The measurement takes a mean value every hour of data measurement and measured it for 10 hours per day for 7 days a month. This method of measurement was done repeatedly for 4 months. Figure below shows the data measurement process.

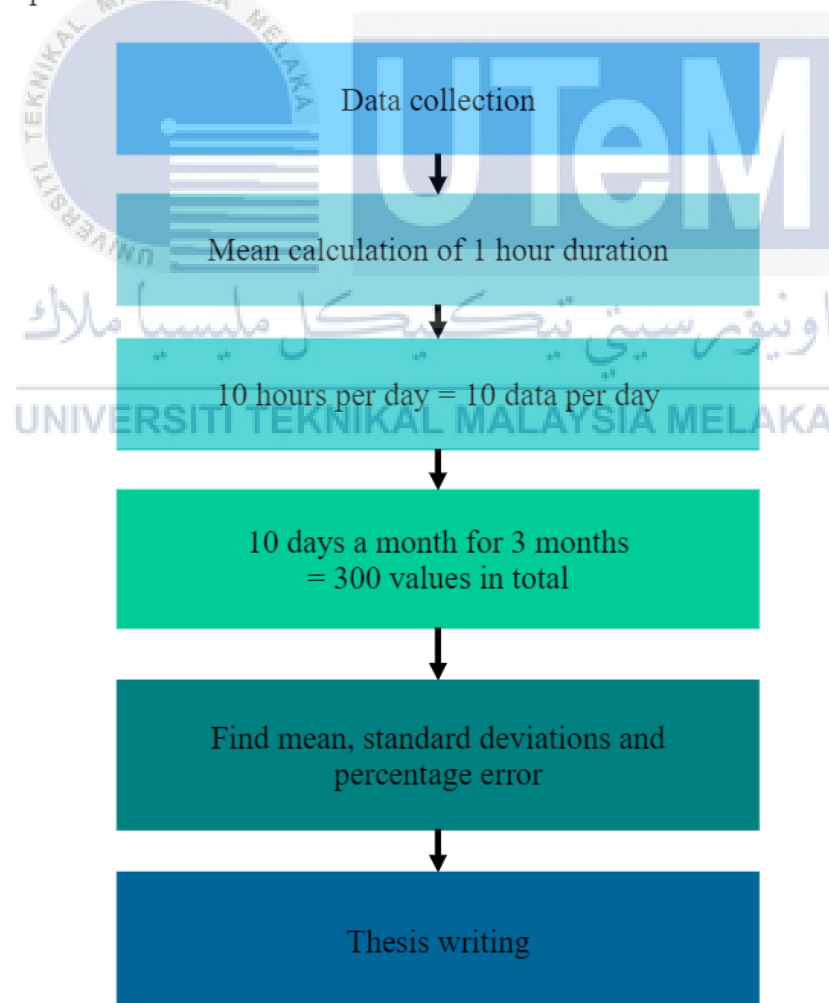


Figure 3.13 : data measurement process

3.8 Project Cost

Table below shows the cost in delivering this project, most of the cost comes from the hardware material, the software used in this project are cost-free.

Table 3.3 Project Cost

No	Material	pcs	Price (RM)
1	Current sensor	1	20.00
2	Voltage sensor	1	11.00
3	ESP32	1	35.00
4	OLED	1	24.00
5	Arduino nano	1	20.00
6	Others (wire, LEDs, resistors, supply board etc.)	1	90.00
Total price			RM200

3.9 Summary

This chapter offers a detailed look at the project's operation and explains the suggested process for creating the Real Time Energy Billing System project. The main goal of the suggested technique is to complete the project's goals without seriously compromising the accuracy of the obtained findings. The method's primary goal is not to achieve the maximum level of precision and accuracy in energy monitoring.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results and analysis on the development of EMoSy This chapter shall discuss accuracy and precision of data with regards data that are obtained by the real time energy billing system. All of the data collected is analyzed in this chapter.

4.2 Project Development

EMoSy is developed in accordance with project methodology aforementioned. This subchapter presents the outcome of project hardware and integrated with sub DB kit made prior specifically to test this project.



4.2.1 EMoSy



Figure 4.1 EMoSy in AutoCAD

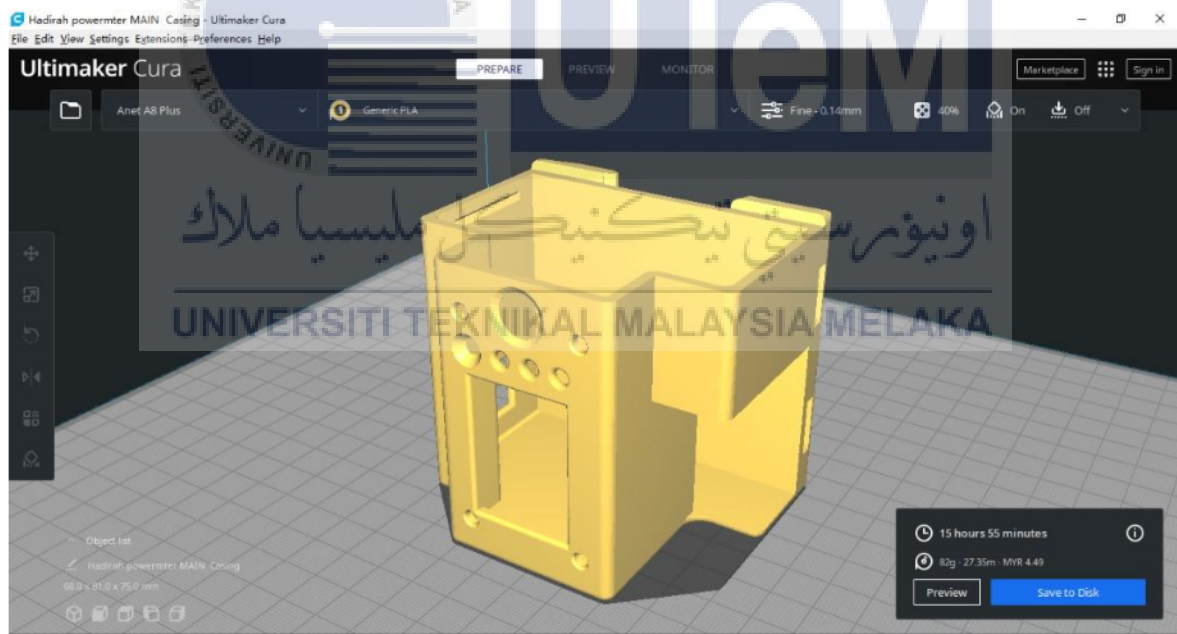
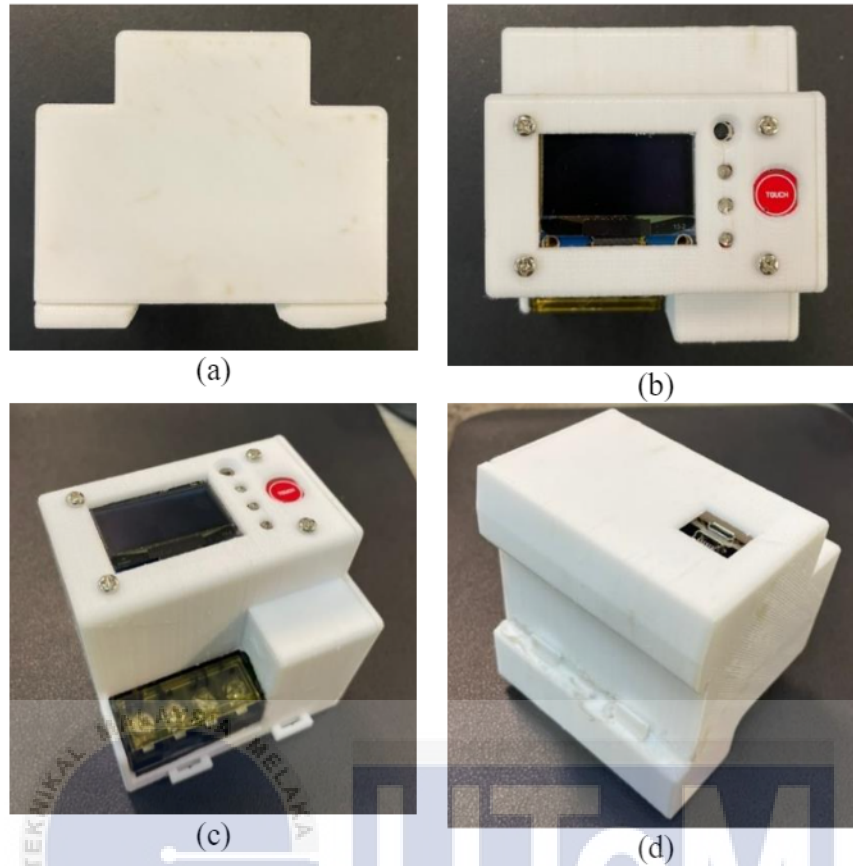


Figure 4.2 EMoSy in Ultimaker Cura



4.2.2 Project Set up

For the purpose of demonstration, the project is set up on a sub DB kit to represent

DB of a residential unit with loads of 2 40W light bulbs and 13A Sockets to plug in loads.

Figure below shows the experimental set up of the project.



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Figure 4.4 Project Set Up

4.3 Data Monitoring

To achieve objectives, data monitoring in this project can be done both through software application and on-site monitoring through OLED, this means, OLED displays the measurement of Current and Voltage

4.3.1 OLED Monitoring

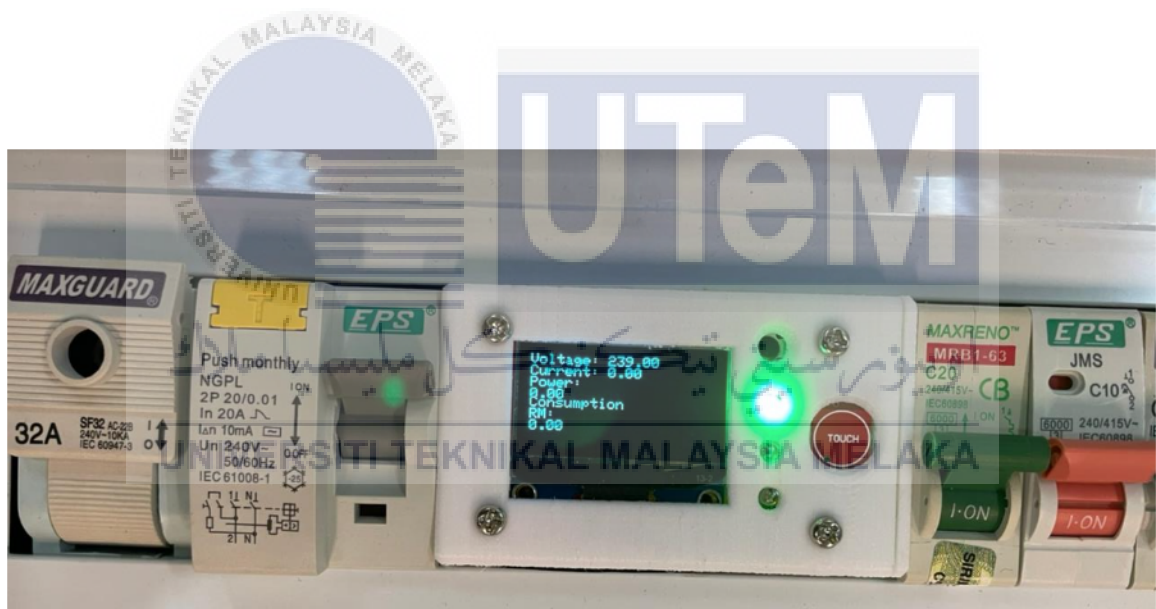


Figure 4.5 Monitoring through OLED for on-site

4.3.2 Blynk Monitoring

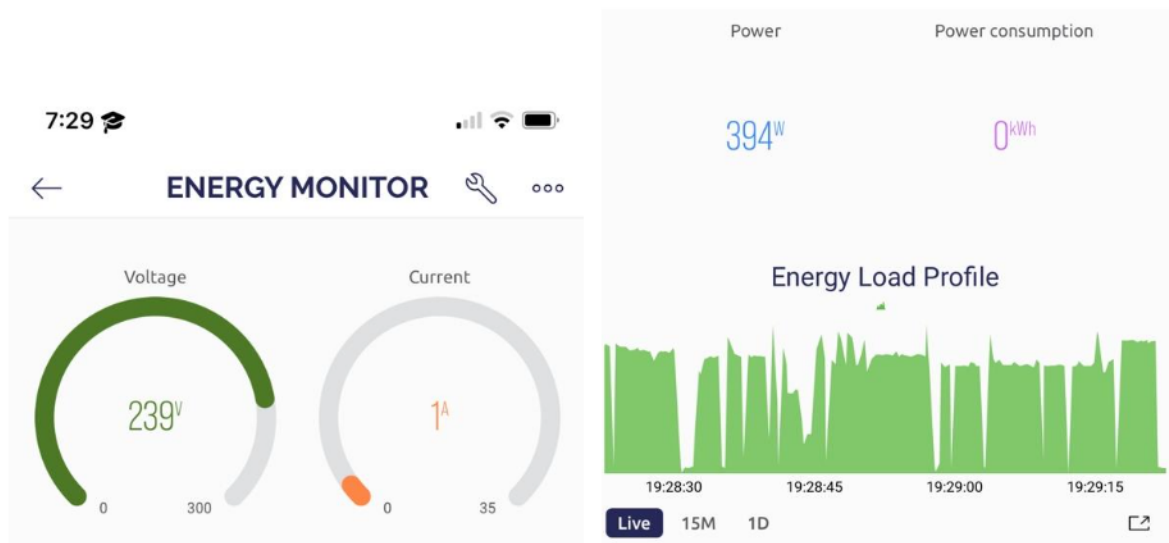


Figure 4.6 Energy Monitoring in Blynk



4.4 Data collection

Collection of EMOsy's data per month are compared with measurement of a clamp meter at the end of every hour as a reference in ensuring data accuracy and precision are being achieved. Loads used for this experiment are low wattage loads, this includes, light bulb, phone chargers, laptop chargers and stand fans. Data are then tabulated and charted in figures below



Figure 4.7 : Clamp meter testing

4.4.1 Collected data in October 2022

Table 4.1 Collected data in October 2022

No	EMoSy Current (A)	EMoSy Voltage (V)	EMoSy Power (W)	Ammeter (A)	Voltmeter (V)	Total Power (W)
1	0.450	239	107.55	0.454	240	108.96
2	0.530	240	127.20	0.520	240	124.80
3	0.450	240	108.00	0.457	240	109.68
.
.
100	0.630	240	151.20	0.639	240	153.36

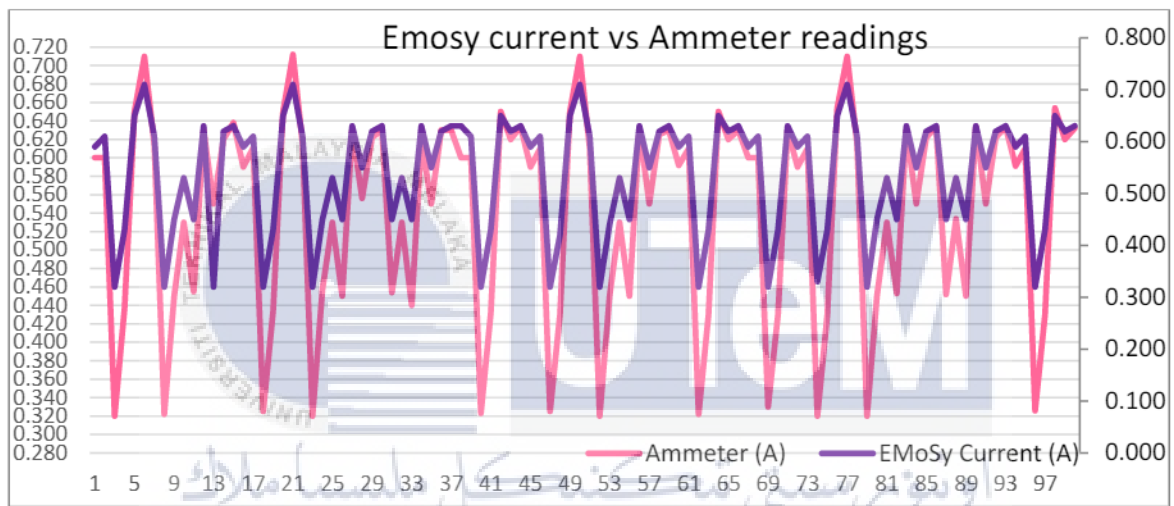


Figure 4.8 System current vs Ammeter in October 2022

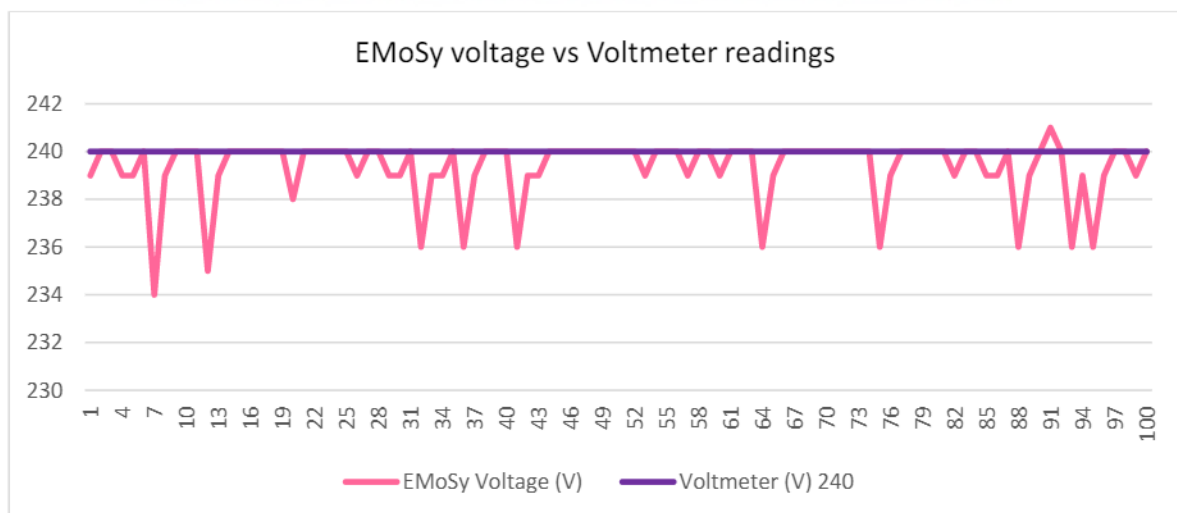


Figure 4.9 : system voltage vs voltmeter in October 2022

4.4.2 Collected data in November 2022

Table 4.2 Collected data in November 2022

No	EMoSy Current (A)	EMoSy Voltage (V)	EMoSy Power (W)	Ammeter (A)	Voltmeter (V)	Total Power (W)
1	0.590	239	141.01	0.600	240	144.00
2	0.610	240	146.40	0.600	240	144.00
3	0.320	240	76.80	0.320	240	76.80
.
.
100	0.630	240	151.20	0.632	240	151.68

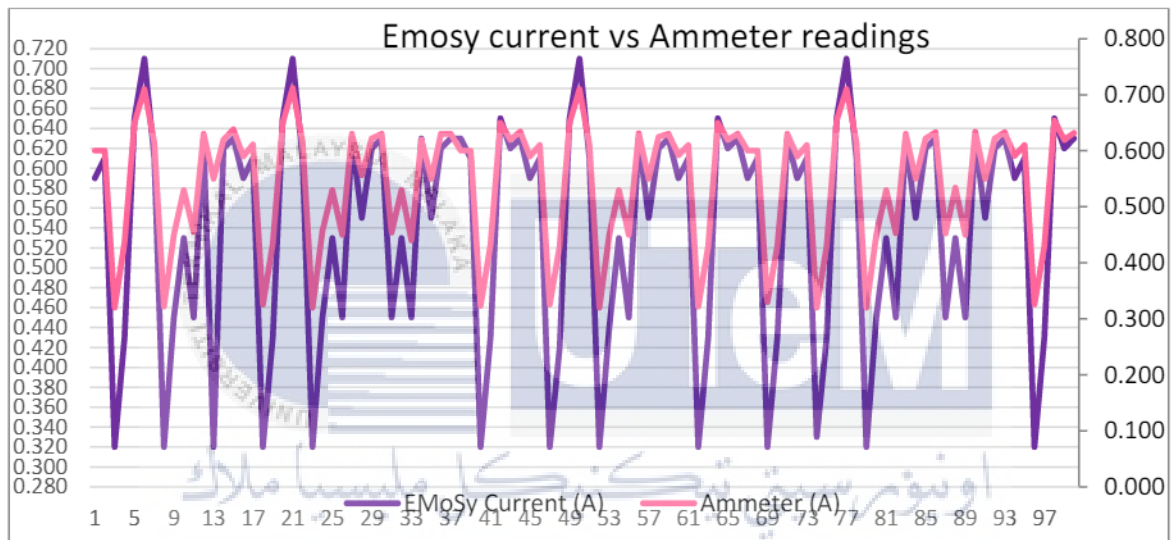


Figure 4.10 System current vs Ammeter in November 2022

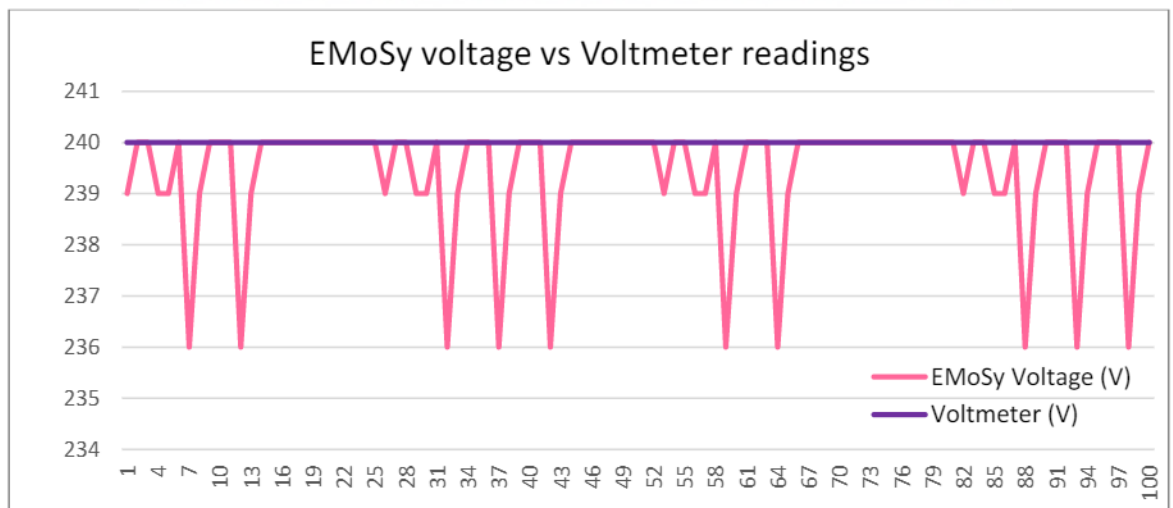


Figure 4.11 system voltage vs voltmeter in November 2022

4.4.3 Collected data in December 2022

Table 4.3 Collected data in November 2022

No	EMoSy Current (A)	EMoSy Voltage (V)	EMoSy Power (W)	Ammeter (A)	Voltmeter (V)	Total Power (W)
1	0.590	239	141.01	0.600	240	144.00
2	0.610	240	146.40	0.600	240	144.00
3	0.320	240	76.80	0.320	240	76.80
.
.
100	0.630	240	151.20	0.632	240	151.68

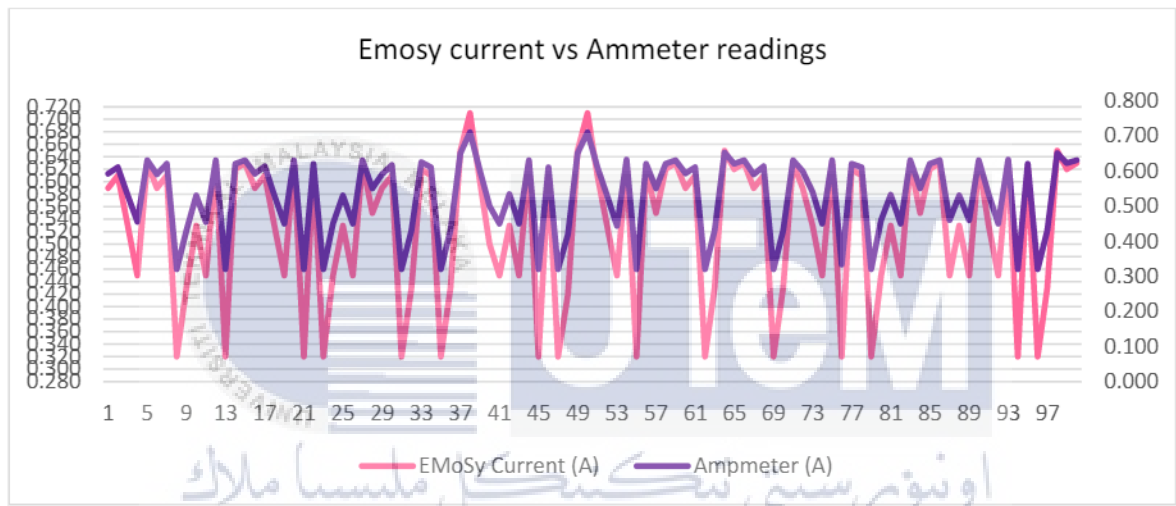


Figure 4.12 System current vs Ammeter in December 2022

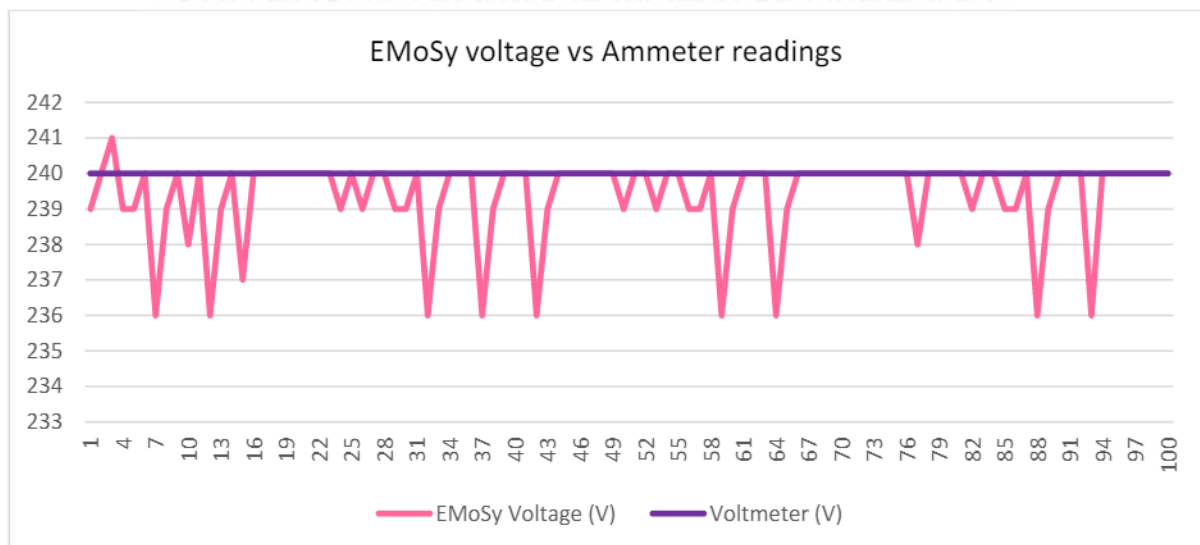


Figure 4.13 system voltage vs voltmeter in December

4.5 Monthly Mean, Standard Deviation and Percentage Error

Formula used in measuring mean, standard deviation and percentage error : [14]

$$\text{Mean}, \bar{x} = \frac{\sum xi}{n} \quad \text{Equation 5}$$

$$\text{standard deviation}, \delta = \sqrt{\frac{\sum (Xi - \bar{x})^2}{n}} \quad \text{Equation 6}$$

$$\text{Percentage error} = \frac{|\text{measured value} - \text{real value}|}{\text{real value}} \times 100 \quad \text{Equation 7}$$

Table 4.4 Statistic Analysis for October 2022

	Mean	Standard deviation	Percentage error
Voltage	239.310	1.316	0.003
Current	0.537	0.115	0.463

Table 4.5 Statistic Analysis for November 2022

	Mean	Standard deviation	Percentage error
Voltage	239.380	1.204	0.010
Current	0.541	0.114	0.003

Table 4.6 : Statistic Analysis for December 2022

	Mean	Standard deviation	Percentage error
Voltage	239.360	1.202	0.275
Current	0.527	0.114	0.277

4.6 Mean value of a 3-Months Data

Table 4.7: Mean Value of Data

Month	October 2022	November 2022	December 2022
Voltage (V)	239.310	239.38	239.360
Current (A)	0.537	0.541	0.527

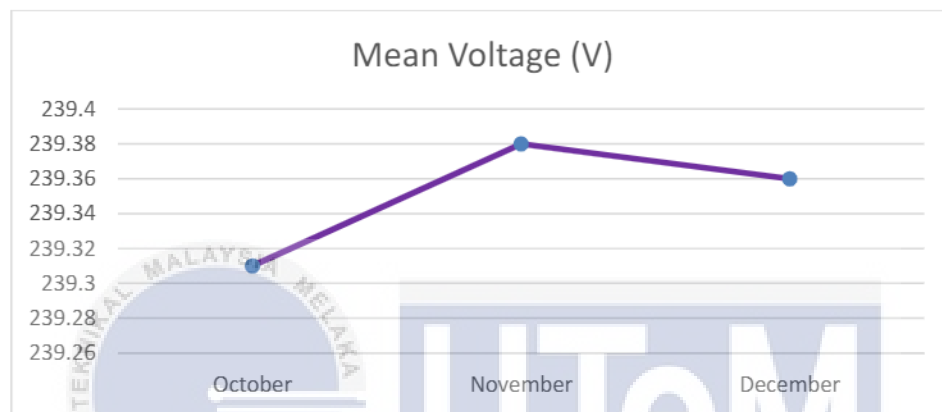


Figure 4.14 : Mean Voltage

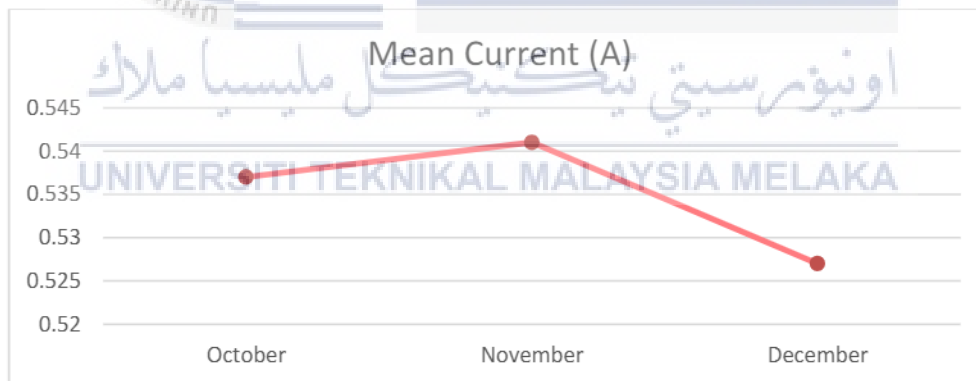


Figure 4.15 : Mean current

From the result, the lowest voltage value for mean is in October 2022 while the highest is in November 2022. On the other hand, for current value mean, the lowest is in December 2022 while the highest is in November 2022.

4.7 Standard Deviation of 4-Month Data

Table 4.8 Standard Deviation of Data

Month	October 2022	November 2022	December 2022
Voltage (V)	1.316	1.204	1.202
Current (A)	0.115	0.114	0.114

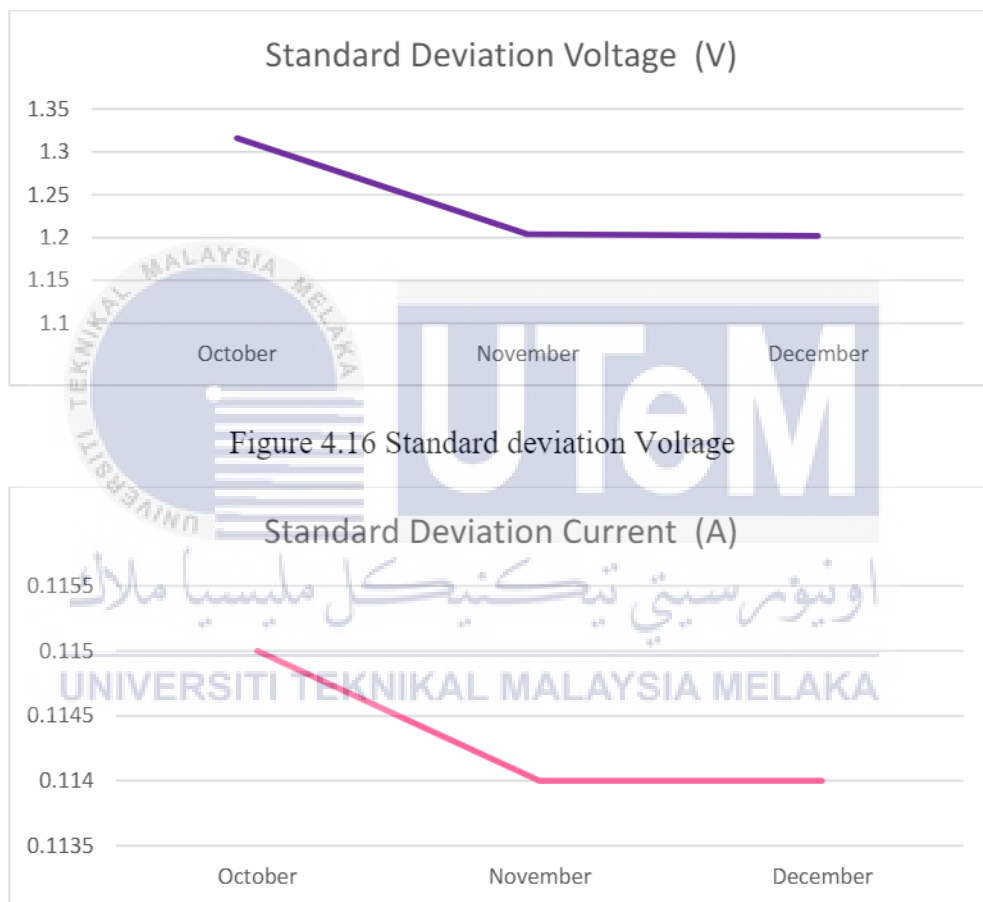


Figure 4.17: Standard Deviation current

From the result, the lowest voltage value for standard deviation for October 2022 is the highest while both the following months are comparably lower than October 2022. Standard Deviation for current has its peak also on October 2022 while both the following months describe the same trend.

4.8 Percentage Error of 4-Month Data

Table 4.9: Percentage error of Data

Month	October 2022	November 2022r	December 2022
Voltage	0.003%	0.003%	0.275%
Current	0.463%	0.010%	0.277%

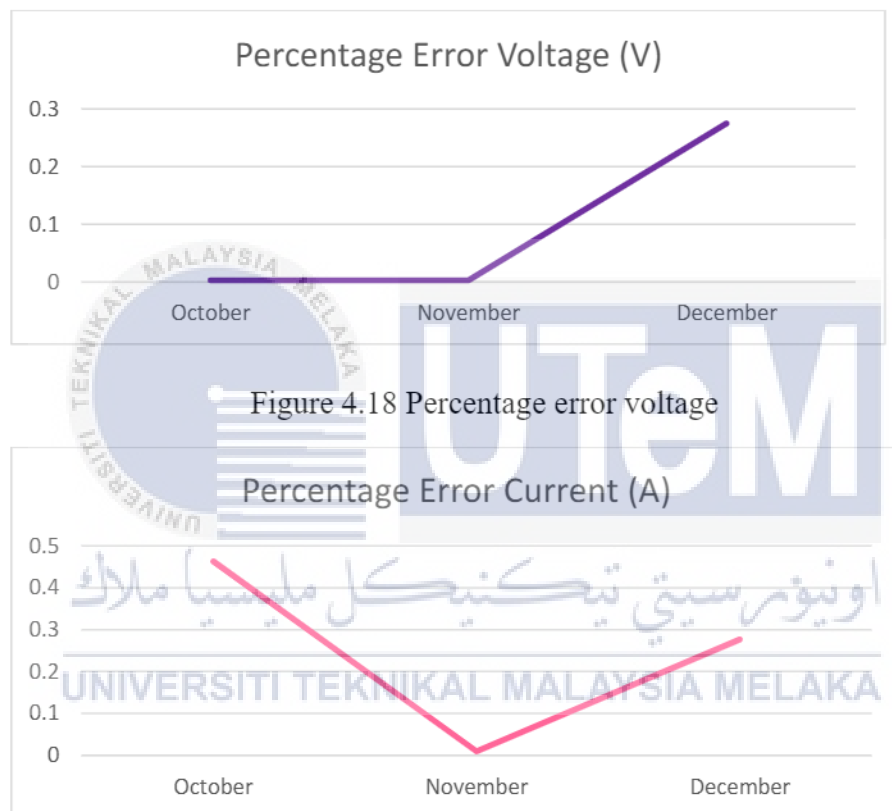


Figure 4.19: Percentage error current

From the result, October 2022 and November 2022 has an almost insignificant amount of voltage percentage error which is 0.003% and increases its peak in December. 2022 While current shows a different trend where the highest percentage error is in October 2022 while November 2022 has the lowest percentage error.

4.9 Discussion

In this section, comparisons of analysed values shall be compared. As the project was tested for approximately 100 hours over a period of 3 months, EMOsY's obtained data are compared with value of clamp meter to better understand the project's accuracy and precision.

Mean value of RMS Voltage over the period does not vary too much, it is still in the range of 1 percent, $\pm 1\%$. However, on the first month, the value of voltage has the biggest difference from 240V. On November 2022, the voltage increases closer to the value of 240 reference voltage and in December 2022, it stabilizes to 239.36V which is still acceptable and in the 1% range of 240V. This shows that in October 2022, Voltage sensor experienced uncalibrated readings and when it is calibrated for November 2022, the value increases close to reference value of 240V but decreases back to 239.6V in December 2022 as it stabilizes.

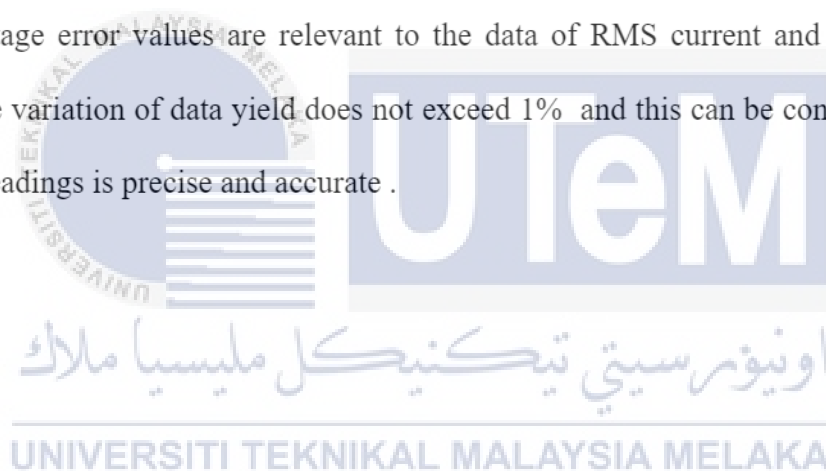
Mean current value of this project shows an interesting trend. While this project measures activities and loads of a single-phase residential unit, current values are dependant on the activities of the household. From October 2022 to November 2022, the trend slightly increases but in December 2022, because there are not as much load uses throughout the month, the trend decreases.

Standard deviation voltage over the period changes significantly as voltage sensor is recalibrated. Decreasing its standard deviation from 1.316 to 1.202, this means, the value of data over 3 months does not deviate as much and is considered reliable. While data of current shows the same trend where the variation decreases over time from 0.115 and stabilizes to 0.114 in December.

Percentage errors of Voltage and Current of the project are affected by the trend of current and voltage. For voltage, it is the same from October 2022 to November 2022 but in December 2022, It increases drastically to 0.275% and for current percentage error, it decreases from 0.63% to 0.010% but increases again in December 2022 to 0.277%. Although the trend of both current and voltage values increases in percentage, the error of each month is less than 1%.

4.10 Summary

From this data analysis, it can be summarized that the mean, standard deviation and percentage error values are relevant to the data of RMS current and voltage of the project. The variation of data yield does not exceed 1% and this can be concluded that the EMOsy's readings is precise and accurate .



CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The development of real time energy billing system is a reliable energy monitoring system as the data obtained considered precise and accurate in measuring the RMS Voltage, RMS current, power and total power consumption in a day or 24 hours. Data that are obtained from the system is instantaneous.

5.2 Future Works

For future works, the system can be enhanced as follows:

- i) Simplicity in billing app, integrating monitoring, load profiling and billing system all in one app. App
- ii) This project can be made suitable for three phase system.
- iii) Smart system that are able to communicate in more than just two ways in a platform.
- iv) Has its own domain and not using other open-source platform to protect privacy of the consumer.

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APPENDICES

Appendix A Data for October 2022

No	EMoSy Current (A)	EMoSy Voltage (V)	EMoSy Power (W)	Ammeter (A)	Voltmeter (V)	Total Power (W)
1	0.450	239	107.55	0.454	240	108.96
2	0.530	240	127.20	0.520	240	124.80
3	0.450	240	108.00	0.457	240	109.68
4	0.630	239	150.57	0.633	240	151.92
5	0.550	239	131.45	0.552	240	132.48
6	0.620	240	148.80	0.626	240	150.24
7	0.630	234	147.42	0.632	240	151.68
8	0.450	239	107.55	0.450	240	108.00
9	0.530	240	127.20	0.539	240	129.36
10	0.450	240	108.00	0.452	240	108.48
11	0.630	240	151.20	0.640	240	153.60
12	0.550	235	129.25	0.550	240	132.00
13	0.620	239	148.18	0.623	240	149.52
14	0.630	240	151.20	0.640	240	153.60
15	0.630	240	151.20	0.630	240	151.20
16	0.610	240	146.40	0.613	240	147.12
17	0.320	240	76.80	0.320	240	76.80
18	0.610	240	146.40	0.619	240	148.56
19	0.320	240	76.80	0.322	240	77.28
20	0.450	238	107.10	0.450	240	108.00
21	0.530	240	127.20	0.532	240	127.68
22	0.450	240	108.00	0.457	240	109.68
23	0.630	240	151.20	0.640	240	153.60
24	0.320	240	76.80	0.329	240	78.96
25	0.620	240	148.80	0.620	240	148.80
26	0.630	239	150.57	0.637	240	152.88
27	0.590	240	141.60	0.598	240	143.52
28	0.610	240	146.40	0.617	240	148.08
29	0.320	239	76.48	0.320	240	76.80
30	0.430	239	102.77	0.430	240	103.20
31	0.650	240	156.00	0.653	240	156.72
32	0.710	236	167.56	0.710	240	170.40
33	0.610	239	145.79	0.610	240	146.40

34	0.320	239	76.48	0.324	240	77.76
35	0.450	240	108.00	0.450	240	108.00
36	0.530	236	125.08	0.534	240	128.16
37	0.450	239	107.55	0.450	240	108.00
38	0.630	240	151.20	0.630	240	151.20
39	0.610	240	146.40	0.610	240	146.40
40	0.320	240	76.80	0.320	240	76.80
41	0.430	236	101.48	0.430	240	103.20
42	0.650	239	155.35	0.658	240	157.92
43	0.620	239	148.18	0.620	240	148.80
44	0.630	240	151.20	0.635	240	152.40
45	0.590	240	141.60	0.590	240	141.60
46	0.630	240	151.20	0.630	240	151.20
47	0.630	240	151.20	0.630	240	151.20
48	0.610	240	146.40	0.618	240	148.32
49	0.320	240	76.80	0.323	240	77.52
50	0.610	240	146.40	0.610	240	146.40
51	0.320	240	76.80	0.322	240	77.28
52	0.450	240	108.00	0.450	240	108.00
53	0.530	239	126.67	0.530	240	127.20
54	0.450	240	108.00	0.450	240	108.00
55	0.630	240	151.20	0.630	240	151.20
56	0.590	240	141.60	0.590	240	141.60
57	0.610	239	145.79	0.611	240	146.64
58	0.320	240	76.80	0.320	240	76.80
59	0.450	240	108.00	0.450	240	108.00
60	0.630	239	150.57	0.630	240	151.20
61	0.550	240	132.00	0.550	240	132.00
62	0.620	240	148.80	0.621	240	149.04
63	0.630	240	151.20	0.630	240	151.20
64	0.590	236	139.24	0.590	240	141.60
65	0.610	239	145.79	0.610	240	146.40
66	0.320	240	76.80	0.320	240	76.80
67	0.430	240	103.20	0.430	240	103.20
68	0.650	240	156.00	0.650	240	156.00
69	0.620	240	148.80	0.620	240	148.80
70	0.630	240	151.20	0.630	240	151.20
71	0.600	240	144.00	0.600	240	144.00
72	0.590	240	141.60	0.590	240	141.60
73	0.610	240	146.40	0.610	240	146.40
74	0.330	240	79.20	0.330	240	79.20

75	0.430	236	101.48	0.430	240	103.20
76	0.650	239	155.35	0.650	240	156.00
77	0.710	240	170.40	0.710	240	170.40
78	0.610	240	146.40	0.610	240	146.40
79	0.320	240	76.80	0.321	240	77.04
80	0.450	240	108.00	0.450	240	108.00
81	0.530	240	127.20	0.534	240	128.16
82	0.450	239	107.55	0.460	240	110.40
83	0.630	240	151.20	0.635	240	152.40
84	0.630	240	151.20	0.632	240	151.68
85	0.590	239	141.01	0.590	240	141.60
86	0.630	239	150.57	0.630	240	151.20
87	0.630	240	151.20	0.640	240	153.60
88	0.610	236	143.96	0.614	240	147.36
89	0.320	239	76.48	0.320	240	76.80
90	0.610	240	146.40	0.611	240	146.64
91	0.320	241	77.12	0.329	240	78.96
92	0.620	240	148.80	0.620	240	148.80
93	0.630	236	148.68	0.636	240	152.64
94	0.590	239	141.01	0.594	240	142.56
95	0.610	236	143.96	0.610	240	146.40
96	0.320	239	76.48	0.320	240	76.80
97	0.430	240	103.20	0.435	240	104.40
98	0.550	240	132.00	0.553	240	132.72
99	0.620	239	148.18	0.620	240	148.80
100	0.630	240	151.20	0.639	240	153.36

Appendix B Data for November 2022

No	EMoSy Current (A)	EMoSy Voltage (V)	EMoSy Power (W)	Ammeter (A)	Voltmeter (V)	Total Power (W)
1	0.590	239	141.01	0.600	240	144.00
2	0.610	240	146.40	0.600	240	144.00
3	0.320	240	76.80	0.320	240	76.80
4	0.430	239	102.77	0.437	240	104.88
5	0.650	239	155.35	0.650	240	156.00
6	0.710	240	170.40	0.710	240	170.40
7	0.610	236	143.96	0.614	240	147.36
8	0.320	239	76.48	0.322	240	77.28
9	0.450	240	108.00	0.450	240	108.00
10	0.530	240	127.20	0.530	240	127.20
11	0.450	240	108.00	0.455	240	109.20
12	0.630	236	148.68	0.630	240	151.20
13	0.320	239	76.48	0.550	240	132.00
14	0.620	240	148.80	0.620	240	148.80
15	0.630	240	151.20	0.638	240	153.12
16	0.590	240	141.60	0.590	240	141.60
17	0.610	240	146.40	0.611	240	146.64
18	0.320	240	76.80	0.325	240	78.00
19	0.430	240	103.20	0.434	240	104.16
20	0.650	240	156.00	0.650	240	156.00
21	0.710	240	170.40	0.712	240	170.88
22	0.610	240	146.40	0.615	240	147.60
23	0.320	240	76.80	0.320	240	76.80
24	0.450	240	108.00	0.457	240	109.68
25	0.530	240	127.20	0.530	240	127.20
26	0.450	239	107.55	0.450	240	108.00
27	0.630	240	151.20	0.630	240	151.20
28	0.550	240	132.00	0.556	240	133.44
29	0.620	239	148.18	0.622	240	149.28
30	0.630	239	150.57	0.630	240	151.20
31	0.450	240	108.00	0.454	240	108.96
32	0.530	236	125.08	0.530	240	127.20
33	0.450	239	107.55	0.440	240	105.60
34	0.630	240	151.20	0.620	240	148.80
35	0.550	240	132.00	0.550	240	132.00

36	0.620	240	148.80	0.630	240	151.20
37	0.630	236	148.68	0.630	240	151.20
38	0.630	239	150.57	0.600	240	144.00
39	0.610	240	146.40	0.600	240	144.00
40	0.320	240	76.80	0.323	240	77.52
41	0.430	240	103.20	0.432	240	103.68
42	0.650	236	153.40	0.650	240	156.00
43	0.620	239	148.18	0.620	240	148.80
44	0.630	240	151.20	0.634	240	152.16
45	0.590	240	141.60	0.590	240	141.60
46	0.610	240	146.40	0.610	240	146.40
47	0.320	240	76.80	0.325	240	78.00
48	0.420	240	100.80	0.430	240	103.20
49	0.650	240	156.00	0.650	240	156.00
50	0.710	240	170.40	0.710	240	170.40
51	0.610	240	146.40	0.610	240	146.40
52	0.320	240	76.80	0.320	240	76.80
53	0.440	239	105.16	0.450	240	108.00
54	0.530	240	127.20	0.530	240	127.20
55	0.450	240	108.00	0.450	240	108.00
56	0.630	239	150.57	0.631	240	151.44
57	0.550	239	131.45	0.550	240	132.00
58	0.620	240	148.80	0.625	240	150.00
59	0.630	236	148.68	0.630	240	151.20
60	0.590	239	141.01	0.592	240	142.08
61	0.610	240	146.40	0.610	240	146.40
62	0.320	240	76.80	0.322	240	77.28
63	0.430	240	103.20	0.430	240	103.20
64	0.650	236	153.40	0.650	240	156.00
65	0.620	239	148.18	0.620	240	148.80
66	0.630	240	151.20	0.630	240	151.20
67	0.590	240	141.60	0.600	240	144.00
68	0.610	240	146.40	0.600	240	144.00
69	0.320	240	76.80	0.330	240	79.20
70	0.430	240	103.20	0.430	240	103.20
71	0.630	240	151.20	0.630	240	151.20
72	0.590	240	141.60	0.590	240	141.60
73	0.610	240	146.40	0.610	240	146.40
74	0.330	240	79.20	0.320	240	76.80
75	0.430	240	103.20	0.430	240	103.20
76	0.650	240	156.00	0.654	240	156.96

77	0.710	240	170.40	0.710	240	170.40
78	0.610	240	146.40	0.615	240	147.60
79	0.320	240	76.80	0.320	240	76.80
80	0.450	240	108.00	0.450	240	108.00
81	0.530	240	127.20	0.530	240	127.20
82	0.450	239	107.55	0.453	240	108.72
83	0.630	240	151.20	0.630	240	151.20
84	0.550	240	132.00	0.550	240	132.00
85	0.620	239	148.18	0.622	240	149.28
86	0.630	239	150.57	0.633	240	151.92
87	0.450	240	108.00	0.452	240	108.48
88	0.530	236	125.08	0.534	240	128.16
89	0.450	239	107.55	0.450	240	108.00
90	0.630	240	151.20	0.634	240	152.16
91	0.550	240	132.00	0.550	240	132.00
92	0.620	240	148.80	0.622	240	149.28
93	0.630	236	148.68	0.633	240	151.92
94	0.590	239	141.01	0.591	240	141.84
95	0.610	240	146.40	0.610	240	146.40
96	0.320	240	76.80	0.326	240	78.24
97	0.430	240	103.20	0.430	240	103.20
98	0.650	236	153.40	0.654	240	156.96
99	0.620	239	148.18	0.620	240	148.80
100	0.630	240	151.20	0.632	240	151.68

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Appendix C Data for December 2022

No	EMoSy Current (A)	EMoSy Voltage (V)	EMoSy Power (W)	Ampmeter (A)	Voltmeter (V)	Total Power (W)
1	0.590	239	141.01	0.592	240	142.08
2	0.610	240	146.40	0.610	240	146.40
3	0.530	241	127.73	0.530	240	127.20
4	0.450	239	107.55	0.455	240	109.20
5	0.630	239	150.57	0.630	240	151.20
6	0.590	240	141.60	0.590	240	141.60
7	0.610	236	143.96	0.620	240	148.80
8	0.320	239	76.48	0.320	240	76.80
9	0.430	240	103.20	0.430	240	103.20
10	0.530	238	126.14	0.530	240	127.20
11	0.450	240	108.00	0.454	240	108.96
12	0.630	236	148.68	0.630	240	151.20
13	0.320	239	76.48	0.320	240	76.80
14	0.620	240	148.80	0.620	240	148.80
15	0.630	237	149.31	0.630	240	151.20
16	0.590	240	141.60	0.592	240	142.08
17	0.610	240	146.40	0.613	240	147.12
18	0.530	240	127.20	0.530	240	127.20
19	0.450	240	108.00	0.450	240	108.00
20	0.630	240	151.20	0.630	240	151.20
21	0.320	240	76.80	0.320	240	76.80
22	0.620	240	148.80	0.620	240	148.80
23	0.320	240	76.80	0.320	240	76.80
24	0.450	239	107.55	0.450	240	108.00
25	0.530	240	127.20	0.530	240	127.20
26	0.450	239	107.55	0.450	240	108.00
27	0.630	240	151.20	0.630	240	151.20
28	0.550	240	132.00	0.550	240	132.00
29	0.590	239	141.01	0.590	240	141.60
30	0.610	239	145.79	0.617	240	148.08
31	0.320	240	76.80	0.320	240	76.80
32	0.430	236	101.48	0.430	240	103.20
33	0.620	239	148.18	0.625	240	150.00
34	0.610	240	146.40	0.610	240	146.40

35	0.320	240	76.80	0.320	240	76.80
36	0.430	240	103.20	0.430	240	103.20
37	0.650	236	153.40	0.650	240	156.00
38	0.710	239	169.69	0.710	240	170.40
39	0.600	240	144.00	0.600	240	144.00
40	0.500	240	120.00	0.500	240	120.00
41	0.450	240	108.00	0.450	240	108.00
42	0.530	236	125.08	0.534	240	128.16
43	0.450	239	107.55	0.450	240	108.00
44	0.630	240	151.20	0.630	240	151.20
45	0.320	240	76.80	0.320	240	76.80
46	0.610	240	146.40	0.610	240	146.40
47	0.320	240	76.80	0.320	240	76.80
48	0.420	240	100.80	0.420	240	100.80
49	0.650	240	156.00	0.650	240	156.00
50	0.710	239	169.69	0.710	240	170.40
51	0.610	240	146.40	0.610	240	146.40
52	0.530	240	127.20	0.530	240	127.20
53	0.450	239	107.55	0.443	240	106.32
54	0.630	240	151.20	0.632	240	151.68
55	0.320	240	76.80	0.320	240	76.80
56	0.620	239	148.18	0.620	240	148.80
57	0.550	239	131.45	0.550	240	132.00
58	0.620	240	148.80	0.620	240	148.80
59	0.630	236	148.68	0.630	240	151.20
60	0.590	239	141.01	0.593	240	142.32
61	0.610	240	146.40	0.610	240	146.40
62	0.320	240	76.80	0.320	240	76.80
63	0.430	240	103.20	0.430	240	103.20
64	0.650	236	153.40	0.652	240	156.48
65	0.620	239	148.18	0.620	240	148.80
66	0.630	240	151.20	0.630	240	151.20
67	0.590	240	141.60	0.590	240	141.60
68	0.610	240	146.40	0.613	240	147.12
69	0.320	240	76.80	0.320	240	76.80
70	0.430	240	103.20	0.430	240	103.20
71	0.630	240	151.20	0.630	240	151.20
72	0.590	240	141.60	0.599	240	143.76
73	0.530	240	127.20	0.540	240	129.60
74	0.450	240	108.00	0.450	240	108.00
75	0.630	240	151.20	0.630	240	151.20

76	0.320	240	76.80	0.333	240	79.92
77	0.620	238	147.56	0.620	240	148.80
78	0.610	240	146.40	0.610	240	146.40
79	0.320	240	76.80	0.320	240	76.80
80	0.450	240	108.00	0.460	240	110.40
81	0.530	240	127.20	0.532	240	127.68
82	0.450	239	107.55	0.450	240	108.00
83	0.630	240	151.20	0.630	240	151.20
84	0.550	240	132.00	0.550	240	132.00
85	0.620	239	148.18	0.620	240	148.80
86	0.630	239	150.57	0.630	240	151.20
87	0.450	240	108.00	0.460	240	110.40
88	0.530	236	125.08	0.530	240	127.20
89	0.450	239	107.55	0.460	240	110.40
90	0.630	240	151.20	0.630	240	151.20
91	0.530	240	127.20	0.533	240	127.92
92	0.450	240	108.00	0.450	240	108.00
93	0.630	236	148.68	0.632	240	151.68
94	0.320	240	76.80	0.320	240	76.80
95	0.620	240	148.80	0.620	240	148.80
96	0.320	240	76.80	0.320	240	76.80
97	0.430	240	103.20	0.430	240	103.20
98	0.650	240	156.00	0.650	240	156.00
99	0.620	240	148.80	0.622	240	149.28
100	0.630	240	151.20	0.630	240	151.20

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