IOT-BASED SMART ENERGY METER

MOHAMAD AZHAR BIN AMLEY

Bachelor of Engineering Technology (Electrical)With Honors

UNIVERSITI MALAYSIA PAHANG

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Position : SENIOR LECTURER, FACULTY OF ELECTRICAL AND ELECTRONICS ENGINEERING TECHNOLOGY

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Date : 22/02/2022

IOT-BASED SMART ENERGY METER

MOHAMAD AZHAR BIN AMLEY

Thesis submitted in fulfillment of the requirements
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ABSTRACT

During this era of Industrial Revolution 4.0, the statistic of household appliances has drastically showing huge different of number in the recent years. This has made the consumption and demand for electricity increased time by time. Because of the diminishing the energy resources, a solution is needed to assist in tracking, measuring, and controlling electricity consumption. Due to the fact that conventional energy metres do not provide information on power usage at the system level, users are unable to track or log the amount of electricity used by individual appliances. To close the data gap on system energy usage, we propose investigating, implementing, and designing an Internet of Things enabled, minimalistic, cost-effective, and reliable smart energy metre that will assist consumers in obtaining information on their electrical appliance's energy consumption. This would not only assist customers in ensuring that their devices operate at the recommended energy consumption level. This will also make it simpler for them to access historical energy expenditure trends, which would lead to increased knowledge and conscious energy conservation. This system enables the users obtain their monthly consumption that has been calculated using TNB’s tariffs and also the electricity utilities organization able to obtain the meter’s reading monthly without their workers visiting each user’s house. This can be accomplished through the use of a IoT-Based smart energy meter module unit that continuously monitors and records energy meter readings in its permanent memory. This system continuously records the readings and, upon request, the consumer can view the live meter readings on a webpage smart phone or tablet. In the designed system, SDM230 digital energy meter is used as the input to measure and collecting the single phase electrical loads parameters and to be sent to the ESP32 microcontroller by using MODBUS RTU to TTL conversion. After the data sent, the microcontroller will calculate the monthly bill by using the energy data received. These data are sent again to the Blynk server by using Wi-Fi connection, and displayed on the user’s smartphone or the utilities provider.

ABSTRAK

Semasa era revolusi industri 4.0 ini, statistik menunjukkan pengunaan barangan harian telah meningkat dengan satu jumlah yang amat besar saban tahun. Perkara ini telah menyebabkan pengunaan dan permintaan terhadap kuasa elektrik meningkat setiap tahun. Dalam menghadap kekurangan sumber tenaga, maka adalah satu keperluan untuk mencari sebuah solusi, mengukur dan mengawal pengunaan elektrik. Meter pengukur elektrik yang sedia ada, tidak akan memberi maklumat tentang penggunaan kuasa terhadap perkasas, hal ini menyebabkan pengguna tidak menyelia penggunaan elektrik mereka. Untuk mengatasi masalah ini, kami telah mencadangkan dan menyiasat, implemen dan mereka sebuah internet pelbagai benda, minimalis dan kos efektif serta efisien meter pengukur kuasa elektrik; yang akan menggalakkan pengguna melihat data penggunaan eletrik mereka daripada perkakas yang mereka telah gunakan. Perkara Ini membolehhkan mereka menyelia pengunaan mereka dan melihat corak pengunaan mereka pada setiap ketika, dan pada akhirnya boleh mendatangkan kesedaran terhadap kepentingan konservatif kuasa. Sistem ini membolehkan pengguna untuk melihat penggunaan bulanan mereka berdasarkan tarif TNB, dan TNB sendiri boleh mendapatkan maklumat itu tanpa pekerja mereka datang ke setiap rumah untuk mencatatkan bacaan. Perkara ini boleh dicapai dengan penggunaan teknologi internet segala benda yang akan sentiasa menyelia dan mencatat bacaan pada meter pengukur elektrik dalam kawasan yang tetap. Sistem ini akan berterusan merekod bacaan meter dalam keadaan semasa dan boleh diakses melalui laman web, telefon pintar dan tablet. Sistem yang telah direka akan mengunakan meter pengukur electric digital iaitu SDM230 yang akan mengukur dan menghantar parameter elektrik terhadap perkakasan rumah yang menggunakan pendawaian satu fasa menggunakan komonikasi MODBUS RTU kepada TTL. Data yang telah dihantar akan diproses oleh pengawal mikro ESP32 dan jumlah bill bulanan akan dikira berdasarkan pengunaan tenaga semasa mengikut kepada kiraan julat harga tariff yang telah ditetapkan oleh TNB. Semua data yang diterima dan diproses akan dihantar sekali lagi ke dalam server Blynk menggunakan komunikasi Wi-Fi. Applikasi Blynk yang menerima data itu akan memaparkanya di dalam aplikasi Blynk yang boleh diakses oleh pengguna atau TNB.

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LIST OF SYMBOLS

Wh	Watt Hour
KWh	Kilo Watt Hour
MV	Mega Volt
MHz	Megahertz
GHz	Gigahertz
W	Watt
A	Ampere
V	Volt
Mb	Megabytes
Kb	Kilobytes
Km	kilometer
m	meter

LIST OF ABBREVIATIONS

MCU	Microcontroller Unit
IT	Information Technology
IoT	Internet Of Things
TNB	Tenaga Nasional Berhad
TTN	The Things Network
GUI	Graphical User Interface
LORA	Long Range
LoRaWAN	Low Power Wide Area Network
ADC	Analogue Digital Convener
AC	Alternating Current
DC	Direct Current
LCD	Liquid Crystal Display
SEM	Smart Energy Management
DCC	Safe National Communication Network
ISM	Industrial, Scientific, Medical
CSS	Chirp Spread Spectrum
P2P	Point To Point
SF	Spread Factor
M2M	Machine To Machine
MAC	Medium Access Control
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
GSM	Global System For Mobile
SMS	Short Message Service
LPWAN	Low Power Wide Area Network
HTTP	Hypertext Transfer Protocol
OMS	Outage Management System
LDR	Light Dependent Resistor
IIOT	Industrial Internet Of Things
WMbus	Wireless Metering Bus
CPU	Central Processing Unit

BLE	Bluetooth Low Energy
PCB	Printed Circuit Board
CAD	Computer-Aided Design
ARES	Amateur Radio Emergency Services
TTL	Transistor-Transistor Logic

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Growing energy demand, distributed generation, renewables integration, and advances in IoT networks, which aim to manage the power system network with various levels of automation, manage outages, and so on, have all drawn attention to the importance of making electric grids smarter and more effective. It contributes to increased electricity efficiency in one way, namely by - grid system versatility for different solutions. The smart grid, which combines a conventional electrical grid with an IoT network that includes smart metres, would aid in the management and control of different parameters of a customer's consumption pattern in near real time(Malik, Zia, Ahmad, Butt, & Javed, 2019).

Building a smart grid entails integrating a series of new smart technologies into an existing electricity network. Smart MCUs in backend IT networks, smart metres, and a communications network are among them. Smart metering is a term that refers to the automated monitoring of energy usage and its daily transmission to the entity that provides the energy. It usually allows bidirectional communication(Lamont & Sayigh, 2018).

In today's world, calculating the amount of energy utilised over a period of time in domestic applications requires human intervention. The user is unaware whether his or her electricity use exceeds the tariff value, which makes a significant difference in the cost for even a unit above the price. Smart metering is the automated tracking of energy usage data and its daily transmission to the energy supplier organisation, which usually allows bidirectional communication. Smart metering allows for more precise billing of energy used based on actual demand, as well as tariff decision-making for load curve flattening and invoice reduction. The benefits to the entire society that could arise from the implementation of smart grid solutions (smart grids) based on a smart metering infrastructure are another incentive to introduce smart metering in the electricity sector. Electric metres or electricity metres are electrical devices that can detect and show energy consumption in the form of readings. Since the late 1800s, traditional metres have been in general usage. These electric metres may be used in both the production and distribution of power in an electric grid and may be fitted to handle data interchange with electronic equipment.

Nowadays, there lot methodologies used to design a smart energy meter that successfully proposed in literatures. This is because the demands on electricity have increasing and the conventional electric grid has to be changed with the most reliable and effective in term of cost of grid application. As example Wireless Sensor Networks (WSN) that include the ability to set up a reliable smart electric power grid application. Also, its function in order for measuring the energy consumption, logs the real data parameters and display time of use(Candia et al., 2019; Mehta, Khanam, & Yadav, 2021)

Figure 1.1 shows RF communication usually used for smart energy meter for transmitting data. Wi-Fi is one of the type of wireless network protocols. It is commonly used for networking in local area of devices that provides internet access; with Wi-Fi, digital devices allowed to exchanging data by using radio frequency wave in order to receiving or transmitting data packets. This type of radio frequency communication are most widely used in home, work station that link to the computers, smartphone, television and other home appliances that enable Wi-Fi connection features.

The network's devices are asynchronous, meaning they only transmit when they have data to submit. Multiple gateways accept data packets sent by end-node devices and forward them to a centralised or non-centralised network server(Kshirsagar, 2020). The term "smart electric metre" referred to a device that measures the amount of power consumed(Onibonoje, 2021). Real-time or near real-time monitoring of energy use, remote controllability, the ability to collect events such as device status or power quality, and a dashboard user interface for real-time electricity monitoring are all elements of a smart electric metre.

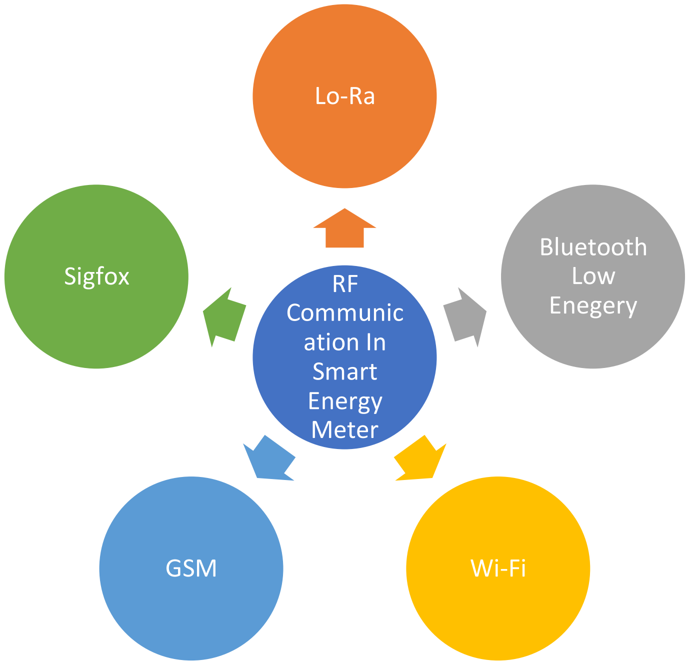

Figure 1.1 RF Communications in smart energy meter

(Piyal, Hossan, & Arafat, 2021)

The smart metre is an automated energy metre that collects data from customers' load devices, analyses their energy consumption, and then communicates the information to the utility provider and/or system operator for better monitoring and invoicing. Smart metres monitor electrical data such as voltage and frequency, and real-time energy usage data is recorded (Santhosh et al., 2021). With a smart metre, the metre and the central system will communicate in both directions.

Furthermore, smart metres have the capability of remotely disconnecting and reconnecting particular loads, and they may be used to track and regulate users' gadgets and appliances in the future to handle demands and loads inside "smart buildings." A smart metre is made up of a number of sensors and control devices as well as a specialised communication network(Patel, Mody, & Goyal, 2019). Smart metre data includes a unique metre identity, a data timestamp, and power use numbers, among other things. Smart metres may collect diagnostic information and data about home equipment, as well as monitor energy usage to establish parameters, and then communicate the data to utilities and receive command signals to optimise the customer's bill and power consumption.

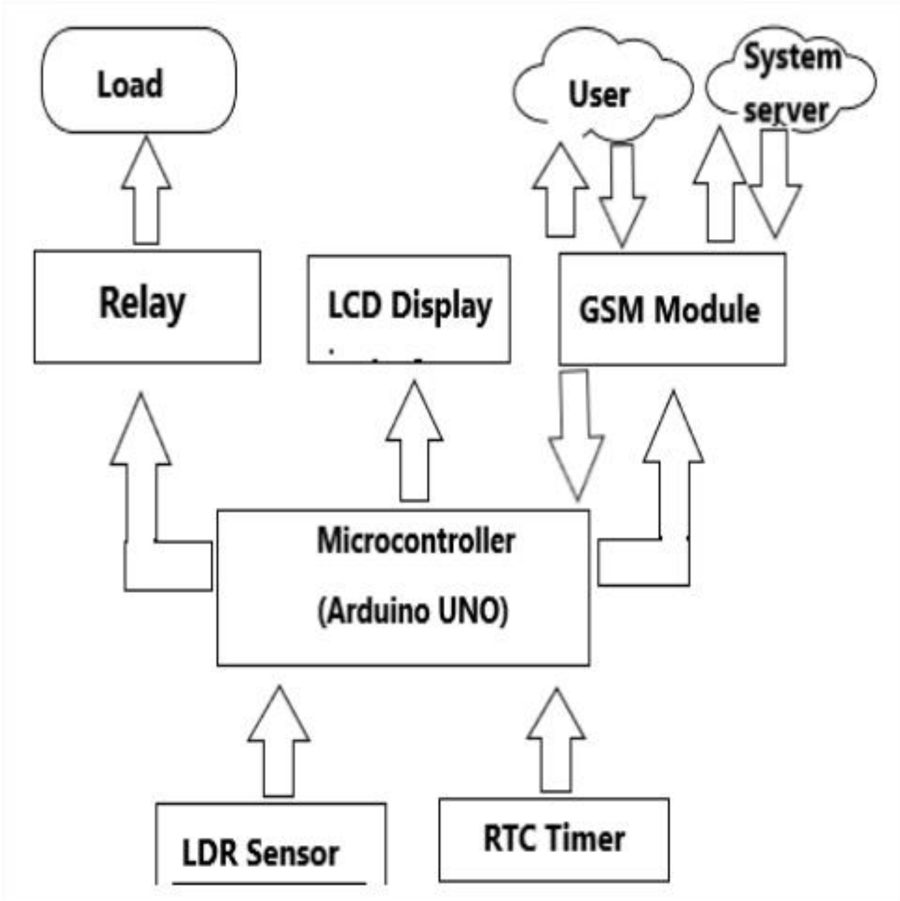

Figure 1.2 Block diagram GSM-based Smart Energy Meter
(Patel et al., 2019)

Figure 1.2 below show one example of smart energy meter using GSM integration, which has been set to send SMS directly to the consumer in a certain date. But it has limitation that will cost of money when sending SMS to costumer, and real time data monitoring is disable. Among the existing smart energy meter, with various of wireless communication, Wi-Fi is more reliable and efficient since most of household have Wi-Fi connection in their house(Murdan & Kullootee, 2020). To sum up, Wi-Fi has a high speed rate of transferring data, wide communication, easy to configure and accessed and safe, and most vital low power usage.

1.2 Problem Statement

In Malaysia's current billing scheme, distribution company like Tenaga Nasional Berhad(TNB) is unable to keep up with changing user maximum demand. Particularly, if bills are paid on time, the user faces issues such as not getting due monthly electric bills for bills that have already been paid, as well as low efficiency of energy supply and demand(Kshirsgar, More, Hendre, Chippalkatti, & Paliwal, 2020). The conventional energy meter that has been used in a period before needs many manpower and workers to monitor the reading every month, this may lead to incorrect reading measurement that has been taken(Jithin Jose, Mohan, Nijeesh, & Benny, 2015; Saha, Mondal, Saha, & Purkait, 2018).

The solution to both of these issues is to keep track of the customers' load on a regular basis, which will allow for reliable billing, tracking maximum usage, and detecting the threshold impacts. Both of these aspects must be considered when implementing an effective energy billing scheme. Electric vitality is reviewed by user with a single traditional electro-mechanical and computerised metering system, and they periodically schedule the bill by assumption based on his history of power use. For example, when the user is on holiday or is stationed for a long period of time. This can caused to the ignorance of energy consumption importance to consumer(Muralidhara, Hegde, & Rekha, 2020; Sahana et al., 2015).

Recently, there are many research have been done about smart energy meter and most of them using wireless technology such as Lo-Ra, Bluetooth, ZIGBEE and Sigfox. However, these technologies have limitation about their range of communication and accesses to the network gateways. In addition, these projects are not implemented in the real environment and the limitation of these technologies that has been used is not measured. (Oza et al., 2020). Hence, the capability, applicability, functionality and its efficiency in the real environment is important(Labib et al., 2017; Muralidhara et al., 2020).

1.3 Objectives

The main objective of this project is about to develop and program an efficient IoT-Based Smart Energy Meter to monitor consumer's monthly consumption in term of voltage, current, power and monthly fees. To make sure this main objective could be achieved successfully, there are several objectives are needed:

- To design a smart energy meter for disseminate real-time information to both consumer and utility; thus, overcomes the limitations of the conventional energy meters

- To fabricate an IoT-based energy meter using the Wi-Fi technology for monitoring energy consumption and expected bill information over the Blynk Platform using an integrated GUI

- To deploy the developed smart meter in a real environment to verify its functionality and analyse its performance

1.4 Project Scope

The scopes that are related to this project are:

- This project is focused on how to obtain the data reading (voltage, current, power, energy and bill consumption) flow from the sensors and the digital meter. This process involved C++ programming in order to send the reading to the Blynk Server.
- For Electronic Design, Espressif ESP32 microcontroller would be used in the Wi-Fi module to read the input and send the data to the gateway. Digital energy meter would be connected to the microcontroller as to read the parameters needed and to be calculated in the programming code, by using Modbus to serial communication
- Design software to be used in this project are Proteus, Multisim, Arduino IDE to design, write, edit and identifying the commands of the C++ Programming language. In addition, Proteus also would be used in order to simulate the circuit design either it is runnable or not.

1.5 Significant Of Research

The significant of this research is about to help the user and electric utilities provider to collect data from their electric energy meter and easily access the final monthly bill in their smartphone, tables or computer. For electricity provider, this research may help them to applied IoT and integrate Wi-Fi technology in order to obtain the consumption energy usage from their customers without send their staffs or worker every month to take the reading manually from the electricity energy meter that has been mounted on houses or buildings. For the users, this might help them to monitor their monthly bill and their energy computation by just looking in their smartphone. The application installed is easy access and friendly user and in the same time eco-friendly because there are no physicals paper would be printed and send to them.

1.6 Organization of Thesis

Chapter 1 shows the brief introduction about current situation in Malaysia’s electricity billing system, smart meter energy and Wi-Fi technology. In this chapter, we can obtain the project background, problem statements, objectives, project scope, significant of research and the organization of proposal has been thought in the project.

Chapter 2 is about the literature review about the mostly electricity energy meter have been used currently all over the world, explanation about smart meter energy, IoT, Wi-Fi technology, and the summaries of related work have been done by researcher.

Chapter 3 contains the methodology of this project, which is this project’s flowchart, idea of the new microcontroller should be used, the smart energy meter design prototype and its flow chart. Beside that’s, all the component and software used also written in this chapter

Chapter 4 has the discussion and result on the IoT-based smart energy meter. All the result and validation are explained in this chapter. Discussion on the performance, advantages, limitation and troubleshooting can be read in this chapter.

Chapter 5 contains of the conclusion that made in the end of this project, and what could be improved to fabricate better IoT-based smart energy meter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, it provides an overview of current knowledge about this project, allowing you to identify relevant history, mechanism theories, methods, and gaps in the existing research about IoT-based smart energy meter. This literature review is obtained from books, scholarly articles, and any other sources relevant to a particular issue, area of research and theory. In addition, it describes, summarises, and evaluates these works in relation to the research issue at hand.

2.2 Brief Introduction of Electrical Meter

Electrical meters are used to monitor electrical energy and to bill the user for generated energy. It is the most suitable and indispensable tool for defining commercial transactions, estimating energy balances between countries, and evaluating the efficiency of machines and traditional, advanced, and renewable energy systems(Commission, 2003). Static electrical energy meters, which are based on the analogue to digital conversion (ADC) of current and voltage signals from sensors, are displacing inductive meters due to their additional multifunctional metering capabilities (e.g., the integration of active and reactive energy, as well as the simultaneous measurement of other significant electrical quantities) and ability to of transmitting the measured the voltage and current data to be calculated(Bernieri, Betta, Ferrigno, & Laracca, 2012).

Digital electric meters are a form of meter. The old type is using a mechanical system for monitoring the current flow from the service wires into the home, but it also includes an analogue to digital converter (ADC) to convert the obtained into a digital signal. In a new type of digital electric meter, AC (alternating current) sensors would detect voltage and current flow in the wires(Hou, Shu, & Zhang, 2007).

This kind of digital meter is slightly more accurate than mechanical or ADC digital meters when it comes to absorbing all of the power in a circuit. An automatic meter has a liquid crystal display (LCD) on the front that can be read manually or the signal can be sent to the service supplier by a high-frequency signal sent over the electric power wires.

Figure 2.1 The Digital Meter Unit

In the case of other types of digital meters, a passing service vehicle fitted with the necessary equipment could read the meter from the meter's radio frequency signal. A automated meter can monitor total electricity usage regardless of whether a building has solar panels or wind turbines that feed energy back into the grid. The meter would record the direction of energy flow, which would be indicated on the meter by the display "delivered" or "received".

2.3 Brief explanation of Smart Energy Meter

An energy meter can be defined as the device that measures energy consumed by the electrical load. Energy is the product of power and time known as kilowatt hours (KWh). The energy meter measures energy in joules. A basic working principle of the energy meter is the conversion of electrical energy into mechanical work. However, with the current technology leaps, this conventional energy meters are no longer considered as standard and industries are changing them to make them “smart”.

Figure 2.2 GUI for smart energy meter in smart phone

A smart meter is a mechanical device that measures the electricity consumption of a building in real time. Smart meters are one of the primary sources of real-time monitoring data. Smart meters measure a more detailed reading of the KWh to help the utility to expand the power quality and network connection. The SEM is the device that enables the technology of a smart grid as it is possible to produce a new planned billing system, encourage productive force circulation and so on.

Comparison between the conventional energy meter and the smart energy meter shows in Table 2.1. Both type of the meters was compared in terms of display, measuring and recording ability as well as communication capability. Figure 2.3 and Figure 2.4 shows both the pathway of a conventional energy meter and the smart energy meter respectively.

Table 2.1 Comparison between the Conventional and the Smart Energy Meter

	Conventional Energy Meter	**Smart Energy Meter**
Display	Analogue	Digital
Measure	How much energy is used usually within a month	Rate and amount of energy used usually in terms of hourly.
Recording	Distribution staff comes to record the reading manually.	Sends the data electronically to distribution companies using wireless communication networks.
Communication	No communication capability.	Two ways communication between the meter and the database.

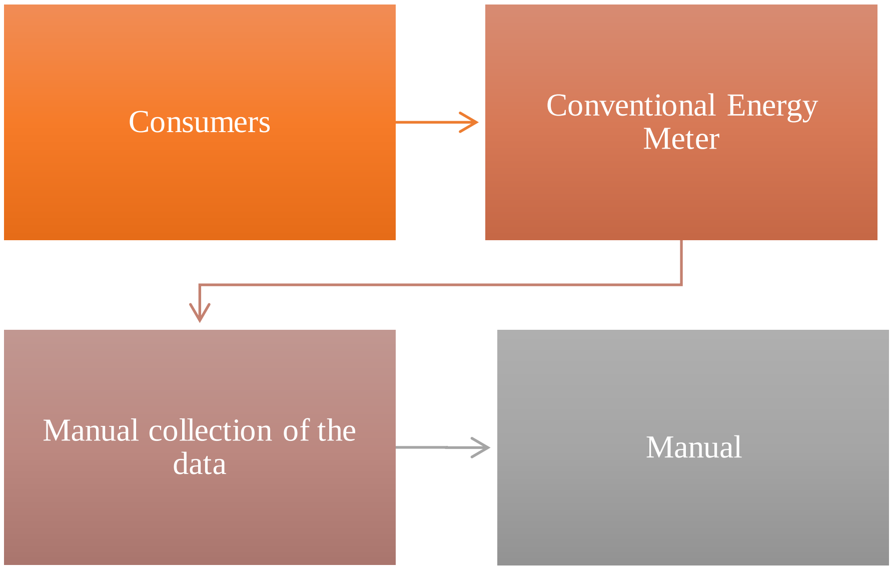

Figure 2.3 The Pathway of the Conventional Energy Meter

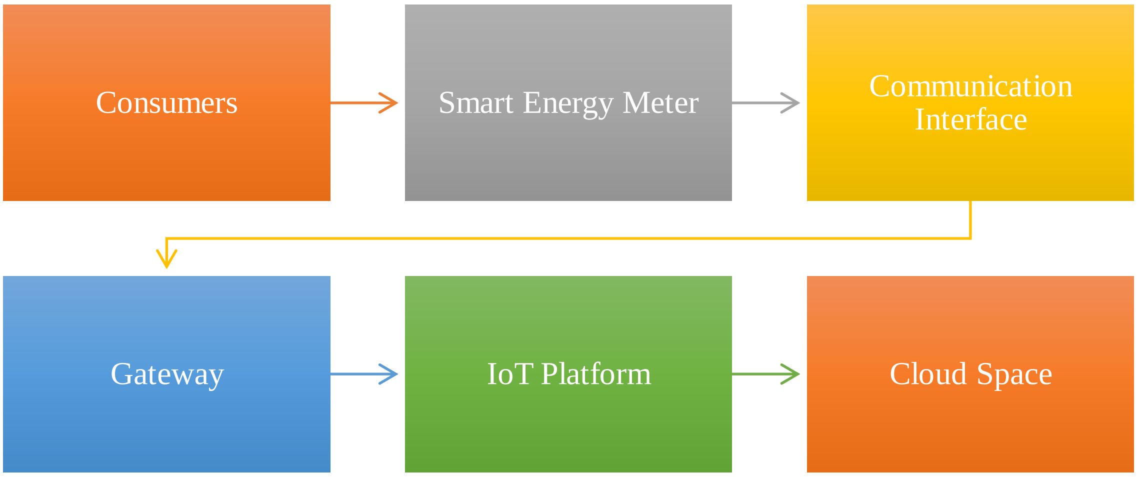

Figure 2.4 The Pathway of the Smart Energy Meter

Smart metres are the next generation of metres that will eventually replace traditional metres, which enable users to monitor and send their own metre readings to their supplier to ensure accurate billing. Smart metres operate by automatically and wirelessly transmitting the user's actual energy consumption to the supplier through a safe national communication network (DCC). They do not need to rely on projected energy bills or have their own daily readings if they have a smart metre. Additionally, smart metres have an in-home monitor. This monitor provides near-real-time details about the user's use and the associated costs.

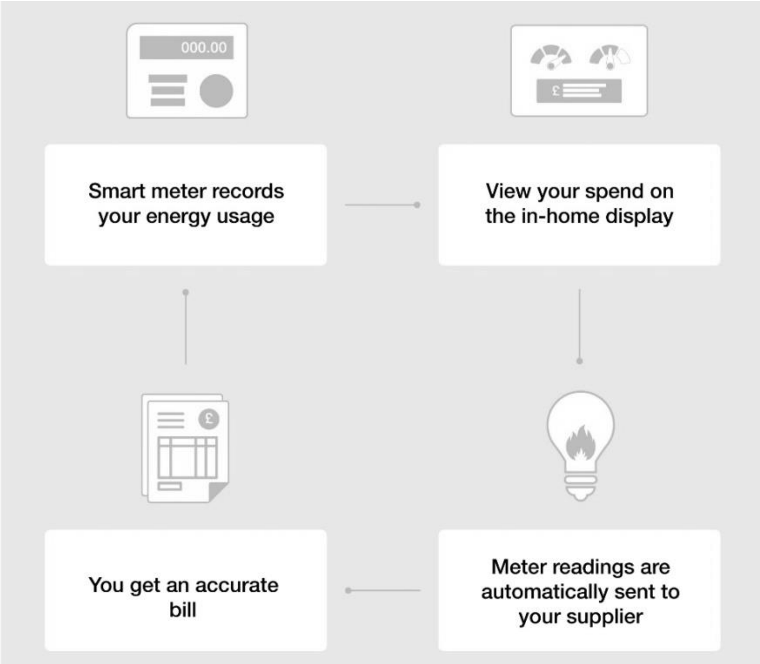

Figure 2.5 How smart enegery meter works

Figure 2.5 above shows the simple illustration flowchart on smart energy meters mechanism of working.

2.4 Components of Smart Energy Meter

To run a basic smart energy meter that able to obtain the energy reading, Microcontroller unit, voltage sensor and current sensor are needed. In several project and products that has been sold in market, the design and component might be slightly different each other. All of them using a lot of combination of components, as example a product using Arduino with Digital meter which has built-in voltage and current sensor and the other smart energy meter using Raspberry Pi with single unit of voltage and current sensor.

2.4.1 Microcontroller Unit

In a single unit of smart energy meter, a microcontroller is needed because of its function. Any of models of brand of MCU might be used such as commonly used, Arduino Uno, Raspberry PI, ESP32 and many more. The differences of these MCU, may affect the efficiency of smart energy meter because all of them has limitations and its advantages according to their capable storing data, read data input and being programmed.

Figure 2.6 The Espressif ESP32 units

Figure 2.6 shows the MCU used in smart energy meter, however, there others MCU existed also can be used as controller such as Arduino, Lopy4, ESP8266 and many more.

2.4.2 Digital Energy Meter

The digital energy meter is a device that commercially distributed energy. The energy meter allows the systematic pricing of energy consumed by the individual consumer to measures the amount of electrical energy consumed on everyday usage. These meters operate by continuously measuring the instantaneous voltage in volts and current use amperes as the SI unit and this product give instantaneous electrical power in watts, then integrated against time to give energy used.

Figure 2.7 The digital meter unit

Figure 2.7 above shows a digital energy meter used in smart energy meter, this energy meter functions as sensor to read and measure electrical parameters, instead of using voltage and current sensor separately; in this digital energy meter, those sensor already built-in and more accurate and high durability.

2.5 Wi-Fi Technology

Wi-Fi is one of wireless networking that using radio frequency in order receiving and transmitting data. Wi-Fi is the acronym of wireless fidelity, figure 2.8 shows the Wi-Fi technology. In 1991, NCR Corporation/AT&T in the Netherlands, was invented Wi-Fi. This technology enables information and data exchanges more than two devices. Wi-Fi technology enables local area networks for operating without any cables and wiring for transmitting. This is the most vital thing why Wi-Fi chosen in home and industries. Figure 2.8 below shows the Wi-Fi connection from the router.

Figure 2.8 The Wi-Fi Technology

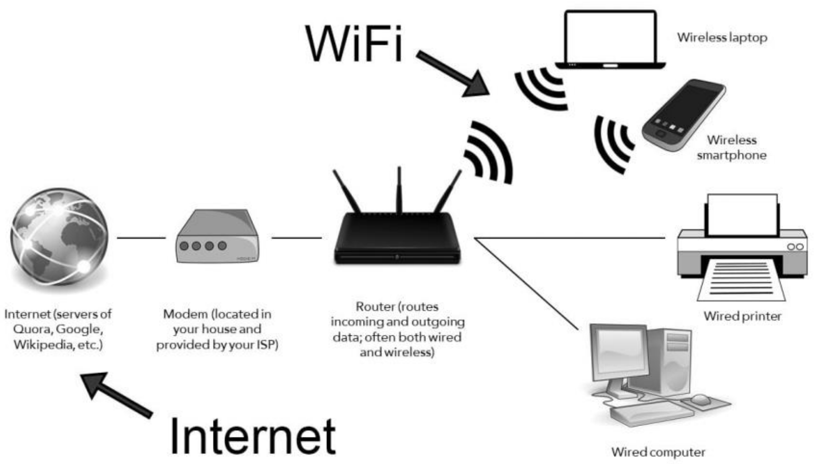

Figure 2.9 How Wi-Fi works

Wi-Fi is a wireless technology that enables high-speed internet and network connections without the use of cables or wires. The wireless network is comprised of three critical components: radio waves, an antenna, and a router. Radio waves are crucial in enabling Wi-Fi networking. Computers and mobile devices are equipped with Wi-Fi cards. Wi-Fi compatibility has been utilising a novel invention to connect constituents on the ground to the community network(Murdan & Kullootee, 2020).

The mechanism of Wi-Fi connection as shown in figure 2.9. The broadcast is connected in order and is finished via stereo system surf and the value of cables from the monitor to categorization prone. Wi-Fi enables a user to connect to the internet from any location within the specified region. Wi-Fi compatibility can significantly reduce the amount of force required to browse with a gaze to the corporation using their inspiring cable television(Aboelmaged, Abdelghani, & Abd El Ghany, 2017). The radio signals are delivered by antennae and routers and are picked up by Wi-Fi receivers, which include computers and mobile phones equipped with Wi-Fi cards. When the computer detects signals within the router's range of 100-150 feet, it automatically connects the device.

The Wi-Fi range is determined by the surroundings, whether it is indoor or outdoor. The Wi-Fi cards will detect and establish an internet connection between the user and the network. The speed of a device connected via Wi-Fi improves as the computer comes closer to the primary source and decreases as the computer gets further away(Murdan & Kullootee, 2020).

2.6 Internet of Things

IoT is a form of interconnected network, internet-connected computers capable of storing and distributing data over a wireless network without the intervention of humans. A connected medical system, a biochip transponder (think livestock), a solar panel, a connected vehicle equipped with sensors that alert the driver to a range of possible problems (fuel level, tyre pressure, necessary maintenance), or any entity equipped with sensors and capable of collecting and transmitting data over a network are all examples of 'things'.

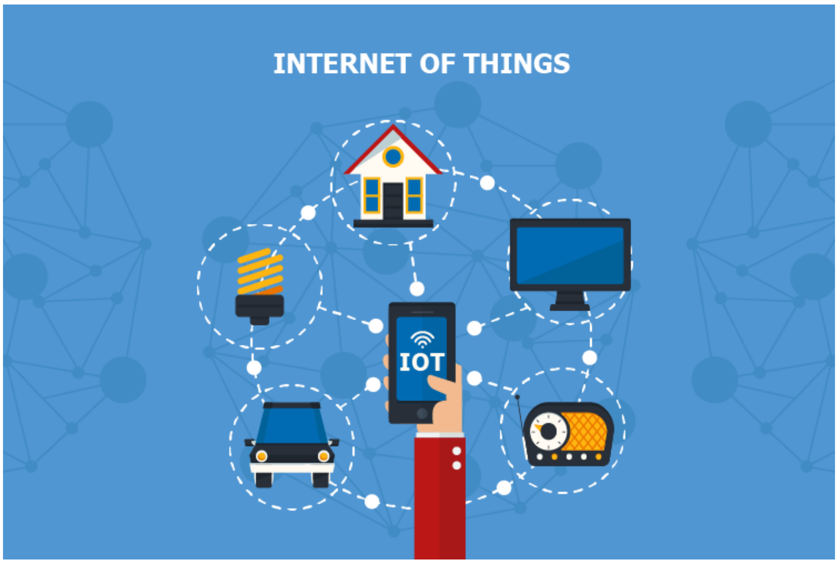

Figure 2.10 The application of IoT

Businesses are now inspired by the IoT and the promise of rising sales, lowering operating costs, and optimising performance. Businesses are often motivated by a need to comply with regulatory requirements. Whatever the cause, IoT system implementations include the data and insights required to streamline workflows, envision user trends, automate processes, comply with regulatory requirements, and compete more effectively in a changing market climate.

The key premise behind the IoT definition is to expand on the word "Internet" by combining it with the term "things." As a result, it broadens the range of computers that can access the Internet, communicating the idea of a pervasive, widespread network. As we know it, Internet is a worldwide computer network comprised of interconnected networks that use structured networking protocols to provide a range of information and communication services(Evans, 2011). The referred global network, however, is no longer limited to computers under this current IoT paradigm. All is now connected. Any "thing" from the tiniest wearable to the most powerful machines, and even anything unrelated to technology, such as a piece of clothing, would be able to communicate with one another.

2.7 Blynk Application

Blynk is an IoT platform for iOS or Android devices that enables remote control of Arduino, Raspberry Pi, and NodeMCU. This application is used to generate a graphical user interface (GUI) or human machine interface (HMI) by compiling and addressing the available widgets. Blynk was created with the IoT. It is capable of remotely controlling hardware, displaying sensor data, storing and visualising data.

Figure 2.11 Blynk Framework

The platform is composed of three key components. Firstly, Blynk Application, It enables users to develop stunning interfaces for their projects by utilising the given widgets. Secondly, Blynk Server that is in charge of all communication between the smartphone and the hardware. The user has the option of using the Blynk Cloud or running their own private Blynk server locally. It is an open-source application that is capable of managing thousands of devices and can even be run on Arduino, ESP32, and other microcontrollers. Lastly, Blynk Public Libraries, It establishes connectivity with the server and processes all incoming and outgoing commands for all popular hardware platforms.

2.8 Related Works to Smart Energy Meter

Saikat Saha, Anindya Saha, Swagata Mondal and P. Purkait do research on the design and implement of IoT using smart energy meter in 2018. The technology of smart grid using two way communications network such as the smart meter is using the advance infrastructure meter that used to connect with the communication network. The contribution is to make the design, the fabrication and also the operation of IoT based on smart meter energy using Arduino technology(Saha et al., 2018). In the same year of 2018. A. R. Al-Ali, T. Landolsi, M. H. Hassan, M. Ezzeddine, M. Abdelsalam and M. Basset conducted research on smart utility meter based on IoT. This paper design to integrate the smart utility meter by using the IoT technology. So the meter can has a unique network address that can programme to monitor the reading. Consumers can access the meter throughout personal devices(Al-Ali et al., 2018).

Bibek Kanti Barman and friends conducted research on IoT using smart energy meter for the efficiency of energy utilized in the smart grid. From this research, monitoring and controlling the energy consumption is one of the priorities for the smart grid. Smart metering energy was proposed by using the IoT to control and then calculated the energy(Barman, Yadav, Kumar, & Gope, 2018). In 2018 Smart Meter is designed to implement IoT technology was researched by Chang Pei Yi, Hsin Hong Chen and Yeong Chin Chen. From this paper the amount of power consumption that has increased will cause the power used to overload. So the authors want to focus on the architecture of designing the monitor for Serco Terminals. Smart meters can provide the digital power network that can be traced to the direct access to the information of power consumption using the smart energy meters(Yi, Chen, & Chen, 2018).

Hossein Hejazi had conducted a research in 2018 to design and implement IoT on the energy metering. He said that research is important to furnish a good management about the energy distribution. He used Gateway HTTP in order to retrieve data consumption from the node and sensor(Yaghmaee & Hejazi, 2018). In 2018, Ignacio had conducted a research about smart city's lighting by using Lora technology. The propose of this project, he wanted to replace the other wireless technology such as Wi-Fi, ZIGBEE, 6LOWPAN because most them being used by many vendors. LoRaWAN was chosen because of its capability receiving and transmit data in wider area. In this research he also had made comparison the efficient between these technologies(Pascual Pelayo, 2018).

Anitha. K and Anitha. V had conducted a research on smart meter using IoT, in 2018. Their design is using GSM and Arduino as microcontroller. They used voltage sensor and current sensors that converted to the 8 bit flash adc. The reading will be sent by GSM module to the user mobile and utility control center (Prathik, Anitha, & Anitha, 2018). In 2018, Leopoldo Angrisani made a research on the smart power meters' reality on the energy consumption. The objective of this research is to identify the reality awareness about the energy importance. In this project they are using Lopy4 as microcontroller and Wi-Fi module. The voltage and current sensors is connected to

ADC before connected to the MCU(Angrisani, Bonavolontà, Liccardo, Schiano Lo Moriello, & Serino, 2018).

In 2018, Prof M.J Boosyen had conducted a research about the newest low-powered communication technologies for replacing GSM-based technologies in any IoT-integration system. He said that there are few requirement needed for wider range of IoT technologies network such as has only one direction communication, low data usage which is take only 10 bytes in an hour, has low power consumption and the most vital is low costing in a large scale project(Durand, Visagie, & Booysen, 2019). Jetmir Haxhibeqiri in his research paper A Survey of LoRaWAN for IoT: From Technology to Application in 2018 had survey about LoRa and LoRAWAN technologies aspects and improvement by years from 2015 to 2018. In this paper also show how this system function. It also described how IoT applications and developments that already used LoRaWAN as the underlying wireless network technology(Haxhibeqiri, De Poorter, Moerman, & Hoebeke, 2018).

Ana Lavinia Petrache and other researchers conducted research on Measuring Environmental Values in Low Power IoT Devices. This research shows Pycom works, Raspberry Pi devices and Waspmote functioning and low power need as part of (IoT) and the ability to collect data from the environment(Suciu et al., 2018).Jittiwat Samuhasilp and Wanchalerm Pora from Chulalongkorn University in the research stated to determine status and power that will be reviewed when outages happened. Next, an outage notification will be sent by AMR to utilities for the evaluation of a situation. Authors also stated it would be not suitable for utilities to view every meter at the affected area of the network and as we know long-range transmission will be provided with low power consumption in LoRaWAN technology. A LoRaWAN system having some limitations to avoid congestion in the network by following the specifications concerning Duty Cycle and Data Rate for the capacity network. They recommended the system of LoRaWan that can be employed in an AMR setting especially for an outage management system (OMS) and on-demand reading feature(Samuhasilp & Pora, 2018).

LIU Fangxing and his friend in the paper titled Estimation of Smart Meters Errors Using Meter Reading Data in 2018 conducted a way of using meter reading data for online smart meters to check the error determinant. Therefore, he approached the tree topology grid of the meter reading branch for the data analysis by using the meter number reading(Fangxing, Qing, Shiyan, Lei, & Zhengsen, 2018). In 2018, Shobhit Jain and Pradish M have stated in their research paper about an end-to-end LoRA connectivity in prototype implementation for smart metering solution and the visualization platform finalize. In this paper, they also applied new technology on the present energy meter's setup in developing countries that can expedite the communication in a real-time or almost to the real-time that includes the additional features such as Automated Meter Reading (AMR)(Jain et al., 2018).

Abdullah Irfan in 2018 conducted a research system interconnected by wirelessly to enable remote control and to manage energy at distribution end by monitoring its. This system is also capable of more security, better efficiency, and consumer's control compared to old conventional systems and also designed IoT that based smart meters for smart grid is suitable for remote monitoring and the system could be fully control(Irfan et al., 2018). Next, in 2018, Sugianto and his friends had written a survey about using the modified LoRaSim performance through simulation. They define the starting position of the gateway and mobile gateway movement was set. Secondly, the start position of the first node was defined and for simulation as many as could be the nodes that will be created. Lastly, the result displays that performance of LoRa mobile gateway can be obtained(Sugianto, Al Anhar, Harwahyu, & Sari, 2018).

Thomas Anderson in 2019, has conduct a research about the efficiency of an energy in order to sense in LPWAN. In his research, he investigated the LPWAN in the measurement of temperatures application. The key factor in his research is to determine the baseline energy usage for a single LPWAN device and the factors that must be fixed and improved. To sum up, his research to determine the factors must be set to reduce energy usage in LPWAN(Andersen, 2018). In 2019, Himanshu K. Patel and friends from Nirma University conducted research on Arduino –based smart energy meter using the GSM. This paper introduced a system to remove the interventions in the reading of bills at the meters. This system is implemented based on the GSM shields of the Arduino model as the microcontroller with the relay and also the LDR sensors(Patel et al., 2019).

Qasim Malik, Aamir Zia, Rehan Ahmad, Muhammad Asim Butt and Zain Ahmad Javed conducted a research on the design and the operating of smart energy meter that effect the energy utilization in the smart cities. Voltage Ampere Power Smart Meters (VAMPS) has provided some utility with efficient ways to collect all the data used. VAPSM low cost in production and provides flexible design by using a microcontroller. VAPSM communicates with the consumer(Malik et al., 2019). In 2019, Adrian I. Petrariu, Alexandru Lavric and Eugen Coca conducted research on the design of implementation and testing of the LoRaWAN gateway in the real environment. This paper presents a multiple channel of gateway by using the technology of LoRaWAN. This is for validating the performance of the gateway that is used in The Thing Network (TTN) to the cloud network. This Gateway is design to implement and to test the gateway in the real environment in the rural area and also in the urban areas(Petrariu, Lavric, & Coca, 2019).

From the same year, Lucas Maziero has done research on monitor the electricity of the parameters in the Federal University of Santa Maria by using the LoRaWan technologies. LoRaWAN communication network verifies the performance in a real environment. In his paper work on how a LoRaWAN technology monitoring system of electrical quantities. The network of LoRaWAN can produced the performance of metrics to be generated, this is because it can help to mitigate costs and also will increase the strength to reliable the network (Maziero et al., 2019). Niharika Hegr had written a journal in 2019 about IoT based smart energy paper to monitor consumption of energy at device level. She said that the common problem is costumer not able to monitor or log their home electricity consumption. She used ThingSpeak to be connected to the energy meter, which able to collected the data and ready to be sent to customer mobile application(Muralidhara et al., 2020).

In 2019, Shivam Kumar made a research on IoT based smart energy, this is for make energy utilization more efficient in smart grid. He said efficient energy utilization is very importance according to develop a smart grid in power system. In his project, he used ESP 8266 as microcontroller and Wi-Fi module as transmitting and receiving devices(Barman et al., 2018). Zohaib Sultan had done research about GSM based smart meter, in 2019. This smart meter is wireless controlled. This project is an enable customer to pay their electricity monthly using prepaid that need to be sent via SMS. The reading is obtained from the EEPROM and ready to be processed by GSM and sending the monthly bill to the customer(Sultan, Jiang, Malik, & Ahmed, 2019).

In 2019, Agustin and friends has made a research on LoRaWAN and Iot are used as solution for smart cities. They had proposed an intelligent infrastructure in roads or public area's lighting. They also install air quality sensors as the result for better real urban scenario. They were using LoRa module for wider area of transmitting and receiving data which is distance to the gateway is 1.20 miles. The controller used in this project is ATmega32u4(Candia et al., 2019). In 2019, Pedro Miguel had made a research about dual-protocol sensor node in the IoT-based technology application. The main objective of his project is about for developing IoT-based in Wi-Fi and LoRaWAN technology by using FiPy microcontroller from Pycom. It is also can be used in energy measurement. It has capability in order to sense the voltage and current flows, and to be calculated to power consumption(Ferreira, 2019).

In 2019, Emiliano Sisinni and friends conducted an innovative range extender for LoRaWAN that was based on an enhanced LoRaWAN node. It is about the Industrial IoT that shows the integration of the infrastructure. The e-Node that was used was a chipset from Semtech (SX1301 - SX1257). LoRaWAN gateways RF frontends are usually embedded in the devices(Sisinni et al., 2019). Next, Zakir Hasan and some other researchers had written a journal about making a designed and constructed low-cost intelligent energy metering system, in 2019. They also developed a web application of the energy metering system for remote monitoring. This could help to less the manual labor and power usage of the consumer recorded(Haque, Choudhury, & Alamgir, 2019).

In 2019, Lorenzo Vangelista had conducted a survey on a battery lifetime comparison. This comparison was between Wireless MBus and LoRaWAN smart meters that use the way measurement campaign on real time and carrier class networks. The result shows a much longer life span in LoRaWAN meters compared to the WM–Bus meters. Results obtained of the measurement also make the LoRaWAN meters overcome WMBus meters significantly as far as for the battery lifespan(Vangelista, Dell’Anna, & Palazzzoli, 2019). K. V. Jyothi Prakash in her research in 2019 had stated that by smart energy meter, amount of power consumed by the consumer will be known by the end of the day and they could plan the consumption of power. Besides, distributors as well as consumers have the notified power consumed by the consumer that makes no meter reading manually by the man power or distribution staff necessary anymore. Author also said that smart energy meters will show the solution to make it less the wastage of power and help to create awareness of unnecessary usage of power(Prakash, Chethana, Tamkeen, Kala, & Kavya, 2019).

Luis F. Ugarte in the paper talks about the Long-Range (LoRa) in the field of long-range communication is LoRa communication technology. This is also to show that the best performance and way to overcome noise in the interference. Moreover, because of the low cost for IoT applications, this technology became the best way to use in the UNICAMP, in 2019(Ugarte et al., 2019). Next, F. Abate and his friends in their research paper also in 2019 had developed based on a common chip for the smart meter. This also could know the power use and the meter features. This experiment used a chip known as ADE7913. Then, a microcontroller through SPI interface will also have a DC/DC power converter integrated and isolated(Abate, Carratù, Liguori, Ferro, & Paciello, 2018).

In 2019, U. Ramani conducted research about energy management IoT based for smart homes. This research to monitor energy from the solar and using Arduino controller energy meter. IoT with Esp8266 Wi-Fi module home automation was also used. Authors said that the module is used to monitor both the data and controlling the energy stage from the consumer perception. After that, data will be sent to the cloud via that Wi-fi module. Lastly, data is embedded into the Arduino controller, then the controller monitors for the data’s parallel with the use of IoT and LCD displays the data(Ramani, Santhoshkumar, & Thilagaraj, 2019). In 2019, Pape Abdoulaye Barro had the research and the objective to extend the advantages of IoT to people especially those who stay in areas that have no Internet connectivity or are limited. Authors said that collapse of the LoRaWAN servers typically will spread out in the cloud into a single box which provides all necessary needs by using TTN that is anytime available(Barro, Zennaro, & Pietrosemoli, 2019).

Dina M. Ibrahim in her research paper considering the IoT requirements focusing on the network technology revolution of LoRaWAN, in 2020. Author also shows how this revolution is the strong candidate in tackling and solving the IoT challenges and also how LoRaWAN can tackle these problems and supports discussion with the specifics of LoRaWAN characteristics(Ibrahim, 2019). In 2020, Alvin Yusri and Muhammad Imam Nashruddin conducted a research based on LoRaWAN IoT networks that planning for smart metering services in the dense urban scenario. The authors have stated that LoRaWAN IoT network had planned to deliver the smart metering service in the urban area. LoRaWAN network advantage has a low power consumption used in the wide area that considered as a suitable IoT networks for the connection of smart meter. It is because of the LoRaWAN has a very low power and longer battery life. This network also using the unlicensed of certain frequency and also using the low cost that others technology(Yusri & Nashiruddin, 2020).

April 2020, Pravin Kshirsagar did research on smart electric meters using LoRa. This is some suggestion of using the smart energy meters based IoT and also Aduino. The Aduino has efficient energy that can help the consumer get the low power of energy. Aduino also has two UARTS that help to work faster (Kshirsagar, Uvarsha, Danusha, Devi, & Vrraju, 2020). Anshu Prakash Murdan, Krishna Kullootee have conducted the survey based on Wi-Fi and LoRaWAN based on the interactive control system for household energy management in 2020, by using low cost, intelligent IoT using microcontrollers and sensor meters. From this research, they designed and also implement the energy management by using such Wi-Fi for internal use and using LoRaWAN for long-range distance to deliver the external used(Murdan & Kullootee, 2020).

Wayan Mustika, Wisang Jati Anggoro, Eka Maulana, Fitri Yuli Zulkifli were doing research in development of smart energy meter using LoRaWAN at campus area in 2020. LoRaWAN technology offers long-range connectivity. The smart energy meter that used LoRaWAN technology can monitor the energy consumption. The authors designed a firmware for data acquisition and a transmission by using the LoRa modulation, a payload, and also the implement of hardware(Mustika, Anggoro, Maulana, & Zulkifli, 2020). Gamal Abdunnasir Alkawsi, Nor'ashikin Ali and Yahia Baashar stated their research in 2020 about an empirical study of the acceptance of IoT using smart meter in Malaysia about the effect of electricity saving knowledge and environment awareness. This research shows the demand for electricity. By using the smart meter energy system, it can decrease the environmental awareness of energy consumption that will adverse the environment consequences(Alkawsi & Baashar, 2020).

In 2020 Christopher Paolini, Hrishikesh Adigal and Mahasweta Sarkar conducted research on the upper bound on LoRa smart meter of uplink rate. The smart meter can be used to measure the electricity consumed. Then it can turn into sample and transmit to the energy utility as an uplink command to allow the utility to maintain the nearest of approximately to the electrical grids. The smart meter that uses LoRa technology will transmit the uplink massage in the measurement of power energy to the electrical utility(Paolini, Adigal, & Sarkar, 2020). Also in 2020, Ariel Antonowicz, Piotr Derbis, Mariusz Nowak and Andrzej Urbaniak conducted research on smart meters in the use of voltage control system of power networks. This paper involves three phases of energy meters that used the voltage control system as a sensor to get the low power network. The Loriot cloud model is using the LoRaWAN network to convert from DLMS protocol to the LoRa protocol that is connected to the end note of the meter(Antonowicz, Derbis, Nowak, & Urbaniak, 2020).

Akekapong Kongsavat and Chulakorn Karupongsi has made research about path loss, in 2020 about based LoRaWAN for smart meter in urban area at Thailand. They said in order to design wireless communication system, the most accurate path loss (PL) is needed and very important. They design is using LoRaWAN-based architecture that has end device (ED), gateway (GW) and network server (NS)(Kongsavat & Karupongsiri, 2020). In 2020, Edgar Saavedra and friends had research about smart metering that has limitation on low costing and self-powered. The main propose of their designed device is for measuring currents flow at main electrical supply periodically. The data obtained is sent by using Sigfox technology(Saavedra, Del Campo, & Santamaria, 2020).

In 2020, Marcos Torres Padin had conduct a research on LoRa integrated technology in smart buildings. The objective of his research is about to implement the harvest of energy with using solar panel and its effect toward the device's lifespan. For data collection he used Pycom microcontroller as node data collection and Lora technology in order to transmit and receive the data obtained from the node(Torres Padín, 2020)[68]. Maruli Tua Baja Sihotang had conducted a research on LoRaWAN IOT for smart city located in Bandung, Indonesia in 2020. Their smart city model consists of smart environment, smart society and smart economy. They were proposing LoRaWAN technology should be used in the next smart cities planning because of its specification up-to-date and has the latest technology(Sihotang, Nashiruddin, & Murti, 2020).

In 2020, Sagar Rathee, Aayush Goyal and Anup Shukla had conduct a research project smart meter system that enables payment using prepaid code. In their project, they are using Arduino as microcontroller and 60 ampere three phase electric meter to testing if it works properly. Then Raspberry PI was used the system's server. This server would count the total number has been transmitted and would storing the data with the timestamp(Rathee, Goyal, & Shukla, 2020). In 2020, Nagib Mahfuz and his friend from American Internation University Bangladesh (AIUB) conducted the research about implementing the SEM so that vendors are able to ensure the proper energy consumption. This smart energy meter is developed by using components that are available at the existing market and also the price components are low-cost. For example, GSM Modem, Arduino Nano, RTC and LCD(Mahfuz, Nigar, & Ulfat, 2020).

Lekhika Chettri stated in the paper smart energy digital electric meter for home appliances that IoT based, in 2020 proposed a system with an improved architecture that used low-cost components that use existing electric meters as a tool. This is effectively controlling electricity consumption for the home appliances. This particular idea used (ESP8266) which is a wireless module, an Android application. The system also had a current sensor and an Arduino microprocessor. In addition, authors also talk about the energy management system by integration compared with the old energy management ways and concept for an IoT. The result shows that the scheme was more effective and efficient. Besides, after a short time interval the collected data will automatically update through Wi-Fi(Salau, Chettri, Bhutia, & Lepcha, 2020). Lastly, also in 2020, KM Poonam Maurya and Arzad Alam Kherani in their paper had built an open source and discrete event in LoRaWAN network simulator, called modular hybrid simulator LoRaWAN. Python was used for the script of the developed simulator. The authors said that the objective of this development is to show a clear understanding of LoRaWAN communication in terms of the protocol. The proposed simulator is designed to execute reception independently and from different events of transmission by using the multiple modules(Maurya & Kherani, 2020).

Table 2.2 Summary for related works

Reference	Research description	Limitation / Advantages
(Yusri & Nashiruddin, 2020)	Research about the LoRaWAN IoT network planning to deliver smart metering services was conducted in the dense urban area.	Low power wide area technologies
(Kshirsagar et al., 2020)	A research on smart electric meter that using smart energy meter using IoT and Arduino.	Has energy efficient, fastest and has two UARTS.
(Patel et al., 2019)	Research on a system that removes intervention in meter readings and bill.	Using a GSM shield module on Arduino as the microcontroller together with the LDR sensor and relay.
(Murdan & Kullootee, 2020)	Present design and implementation for household energy management.	Low cost, intelligent IoT -based microcontrollers and sensor meter.
(Mustika et al., 2020)	Designed a hardware implementation, payload format, and firmware for data acquisition and transmission using LoRa modulation.	Offers long-range connectivity.
(Saha et al., 2018)	Research on Smart grid technology based on communication two-way networks.	-
(Al-Ali et al., 2018)	Design an integrated IoT-based smart utility meter.	Consumers can access the meter throughout personal devices.
(Alkawsi & Baashar, 2020)	Research on using a smart meter system is a type of behavior that supports the environment, electricity consumption may have adverse consequences on the environment	-

(Malik et al., 2019)	Research on Voltage Ampere Power Smart Meter (VAPSM) provides the utility with an efficient way to collect data.	VAPSM low cost in production and provides flexible design by using a microcontroller
(Paolini et al., 2020)	Research on LoRa based smart metering structure can transmit uplink messages with power measurement to an electric utility.	LoRa use in low data rate, long range devices for consumer smart metering and demand response applications.
(Barman et al., 2018)	A research on smart energy meter is proposed based on IoT	-
(Petrariu et al., 2019)	Presents a multi-channel Gateway for LoRaWAN technology.	presents a low-cost and high performance multi-channel Gateway for LoRaWAN technology
(Maziero et al., 2019)	A research on how a LoRaWAN technology monitoring system of electrical quantities.	To mitigate costs and increase the robustness and reliability of the LoRaWAN network
(Yi et al., 2018)	Design of the monitoring the servo terminals.	Power network digital and traceable and can directly access the power consumption
(Antonowicz et al., 2020)	Research on three-phase energy meter in terms of use as a sensor in the voltage control system.	LoRaWAN network based on the Loriot cloud platform and DLMS
(Muralidhara et al., 2020)	Research how to overcome costumer problem, that they not able to monitor their monthly device level consumption	IoT based energy meter that enable the costumer monitor each consumption from their device using Thingspeak.
(Yaghmaee & Hejazi, 2018)	A research about implements IoT in the smart meter energy. This is vital in order to create the necessary infrastructure to obtain data from customer energy meter	Using HTTP Gateway retrieves data from the node sensor and send to the server.

(Sultan et al., 2019)	A project that implements GSM in smart meter energy by using EEPROM, enables prepaid paying method to easier their customer.	This project enables their customer paying their monthly bill only suing prepaid which is the prepaid code must be purchase first, that the code generated must be sent Via SMS to the electricity provider.
(Martinez-Blanco et al., 2020)	A research that using IoT and ESP32 microcontroller to connect voltage and current sensor and the data collected and ready to be sent to the server.	This project will shows the data consumption each device used and user can monitor their energy composition via many type of devices such as smartphone and computer.
(Pascual Pelayo, 2018)	A master thesis has been done to made comparison between the existing wireless technology such as LPWAN, 6LOWPAN, Wi-Fi, ZIGBEE and the LoRaWAN.	LoRa technology has been chosen because it capacity to transmit and receive data in wider area comparing the existing wireless technology
(Kongsavat & Karupongsiri, 2020)	A research about path loss about path loss, based LoRaWAN for smart meter in urban area at Thailand. This research is significant in order to design an efficient communication system.	-
(Prathik et al., 2018)	A research implements IoT in smart meter using voltage and current sensor and connected to the microcontroller. This project using GSM module to transmit the reading to the user and electricity organization	The system will display the energy has been consumer by the user every day and will reduce their cost of collecting the data manually from home by their workers.
(Saavedra et al., 2020)	A research conducted to measure the limitations on smart meter, which is are they low cost and low powered? Their using newest microcontroller from Pycom which is Lopy4.	A very simple electronic has been designed with using Sigfox integration and low cost using below than 100 euros for this single project.

(Angrisani et al., 2018)	A research about smart energy meter used to raise awareness about energy consumption. Lopy4 and Wi-Fi module are used in this project. User’s camera is used to detect electronic devices in home such as water heater, television and many more.	Able to raise awareness about energy consumption to the customer because the application will tell the user the composition on single electronic device once it being captured and detected.
(Torres Padín, 2020)	A research that implements LoRa technology in smart building. In this project, the author using Pycom microcontroller, LoRa module and TTN.	Using LoRaWAN technology for longer area in building and the system has low power consumption.
(Candia et al., 2019)	A research on implementation of LoRaWAN in smart cities. This is importance for energy saver because they were using LED lamp for the street lights. The microcontroller used in this project is ATmega32u4 and using LoRa module.	The users and public department able to get the real situation on the public street which is the air quality. They user may avoid the low quality air areas and the public service department may put precautions on the road to avoid accident. The light is set automatic according to the area light, if there a need to switch on the in several area, the system will do.
(Sihotang et al., 2020)	A research that propose LoRaWAN should be used in next smart city development according to its latest technology capable transmit and receiving data wider that Wi-Fi module.	-
(Rathee et al., 2020)	A project about energy meters that using prepaid payment. This project using Arduino as microcontroller and for the server they were using Raspberry PI.	This project enables the customers pay their monthly electricity bills by only using prepaid code. This is eco-friendly because no paper receipt bill be printed in hands.
(Durand et al., 2019)	A research about the newest low-powered communication technologies for replacing GSM-based technologies in any IoT-integration system	Iot enable end users accese by using website portal, smart phone application and tablet

(Ferreira, 2019)	A research about dual-protocol sensor node in the IoT-based technology application. The main objective of his project is about for developing IoT-based in Wi-Fi and LoRaWAN technology by using FiPy microcontroller from Pycom.	-
(Andersen, 2018)	A research about the efficiency of an energy in order to sense in LPWAN. In his research, he investigated the LPWAN in the measurement of temperatures application	-
(Haxhibeqiri et al., 2018)	A survey of IoT	-
(Mahfuz et al., 2020)	Research about implementing the smart energy meter that vendor can ensure the proper use of energy.	Using low-cost components such as Arduino Nano, LCD, GSM Modem, and RTC.
(Salau et al., 2020)	A research on the concept of an IoT and energy management system integration.	Used Android application, wireless module (ESP8266) and also consists of a current sensor (ACS712) and an Arduino UNO microprocessor.
(Laveyne, Van Eetvelde, & Vandevelde, 2018)	Research on to the communication requirements of different uses cases for smart metering.	-
(Suciu et al., 2018)	A research on low power requirements as part of IoT and its capability for collecting data from the environment.	Pycom, Waspmote and Raspberry Pi devices.
(Samuhasilp & Pora, 2018)	Research on how LoRaWan can be employed in an AMR setting including for the on-demand reading feature and the polling algorithm for outage management system (OMS).	LoRaWAN technology can provide very long-range transmission with low power consumption

(Fangxing et al., 2018)	A research on a method of online smart meter error calibration using meter reading data.	The data analysis using sum meter reading and branch meter reading in tree topology grid.
(Sisinni et al., 2019)	Research on an enhanced LoRaWAN node, and its integration in the infrastructure of Industrial Internet of Things (IIoT).	The e-Node that used was SX1301-SX1257 chipset from Semtech.
(Haque et al., 2019)	A research on a web application for remote monitoring of the energy metering system	Designed and constructed low-cost intelligent energy metering system
(Ibrahim, 2019)	Research on the revolution of LoRaWAN network technology considering the IoT requirements.	Can addressing and fixing the IoT challenges
(Jain et al., 2018)	A research on implementation of end-to-end LoRA connectivity for smart metering solution and discuss final visualization platform	Can expedite the communication in a real-time or near real-time also including the additional features like Automated Meter Reading (AMR).
(Vangelista et al., 2019)	A research on the LoRaWAN meters outperforms the WMBus meters significantly as far as the battery lifetime is concerned.	-
(Prakash et al., 2019)	Research on the power consumed by the consumer will be notified to the distributor as well as consumer such that no manpower is necessary for meter reading.	Smart Energy Meter bring the solution of creating awareness of unnecessary usage of power and help to reduce the wastage of power.
(Maurya & Kherani, 2020)	A research on the objective of this development to give a good understanding of LoRaWAN communication protocol.	Python was used for the script of the developed simulator.
(Ugarte et al., 2019)	Research on LoRa communication is technology in the field of long-range communication, and has its good	Low cost for IoT applications.

	performance and overcoming noise interference.	
(Ramani et al., 2019)	A research on IoT based energy management for smart home by monitoring the energy from the solar and energy meter using Arduino controller and home automation.	The energy from the solar and energy meter using Arduino controller and home automation by IoT with Esp8266 Wi-Fi module.
(Abate et al., 2018)	Research on the smart meter based on a common chip and could calculate the power consumption and the meter characterization.	This experiment used ADE7913 chip
(Barro et al., 2019)	A research on the LoRaWAN servers normally spread in the cloud into a single box that provides all the required functionalities by using TTN.	-
(Irfan et al., 2018)	Research on the designed IoT based smart meter for smart grid	Smart grid is capable of load management, theft detection, remote monitoring and full control of the system
(Sugianto et al., 2018)	A research on define the start position of gateway, then set the movement of mobile gateway.	Simulation using modified LoRaSim.

2.9 Summary

This chapter explains about literature review for the briefing introduction of the electrical energy meters, the Wi-Fi Technology, Blynk Application and the IoT. In addition, this chapter also briefs the explanation of smart energy meter such as the components used on smart energy meter and how the smart energy meter works. The related works shows systems and designs in smart energy meter, but each of them has different wireless communication. Next, this chapter also contains the related work to the project titled, IoT-based smart energy meter. The component of this project also explained in detail. In next chapter, the methodology and the flow of this project will be explained and discussed in depth.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the flow of this project would be discussed in detail from the problem identified to the project idea's implementation. Also, the flow of the IoT-Based smart energy meter will be explained in detail in this chapter. Besides that, the reason of choosing right microcontroller and sensors also discussed.

3.2 Flowchart of Methodology

In the beginning of this project as shown in figure 3.1, problems were identified in the current smart energy meter that using IoT-based technology. Based on the journals, papers and article reading, the most significant project is they are using such non-updated microcontroller such as Arduino and Raspberry (except Raspberry PI 3). These microcontrollers are not IoT-BASED since the microcontroller could not connect directly (have to connect to extended module) to the wireless communication technology. Therefore, this project is about to implement latest, efficient and reliable technology to overcome the problem identified.

After the problem has been identified, the research on other article had been done in order to make this project is clear. The layout used in this project is plywood and the Wi-Fi modules mounted on this plywood wall. After modelling phase, implementation design according to the real situation by making connection on the home appliances such as bulb and water heater and iron clothes, and its parameters, like voltage, current, power, energy and monthly bill to be measured and calculated. Next, the design needs to be checked and identified if there any problems occurred in this system. The testing stage would be done to confirm either project ran in the right way. If any problem is found, the system would be enhanced and optimized otherwise, the final result is to be recorded.

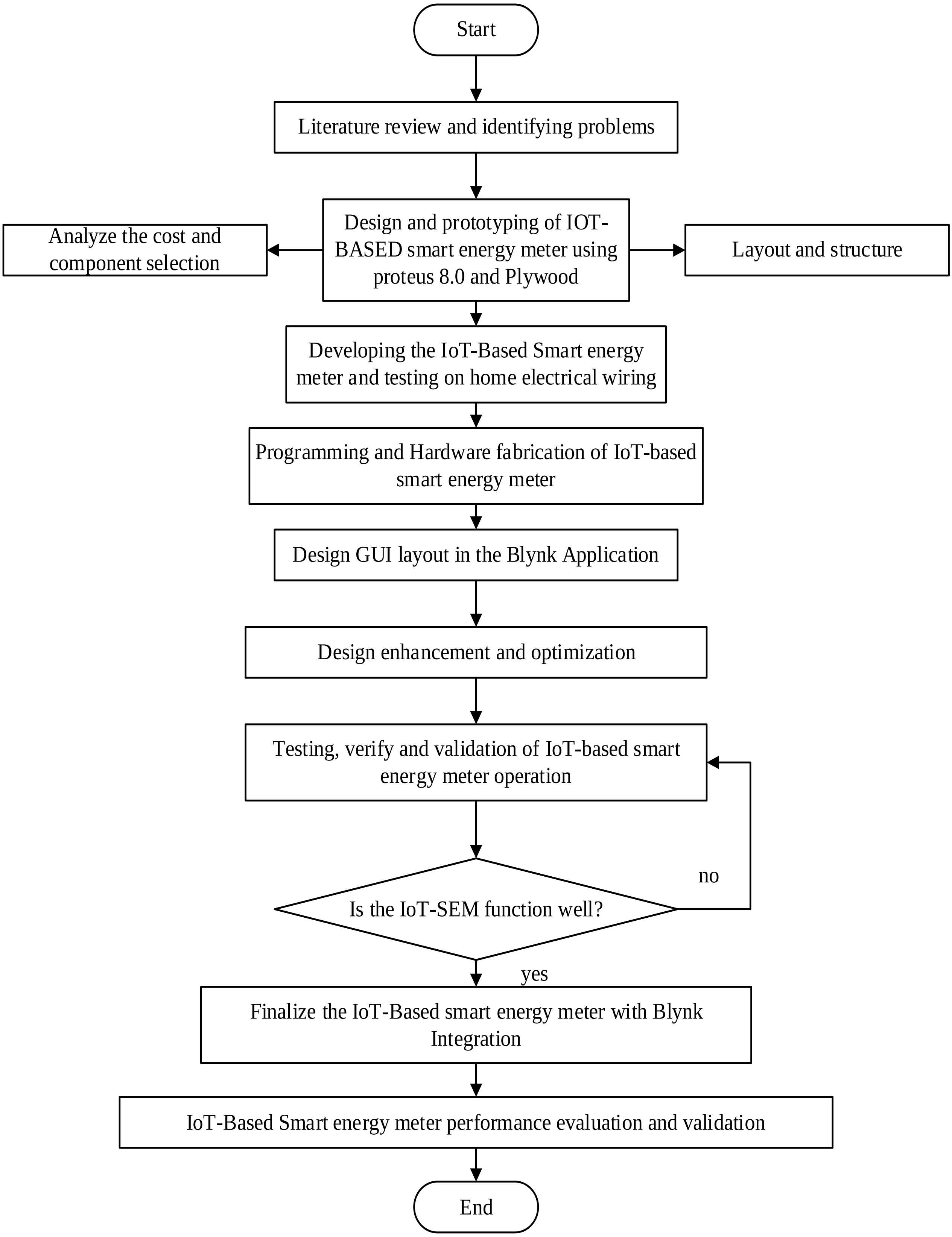

Figure 3.1 The flowchart of this project

3.2.1 Literature Review and Identify Problems

To identity the problems and limitation in existing digital energy meter, and smart energy meter, literature review on existing product, papers, journals and thesis had been done. At least 70 references, most of them are research paper had been reed. From this research, we can analyse the existing product or research, what they had go through, and what component they selected, what wireless communication they chose.

From this phase, the major problem has been identifying as stated in the problem statement; user faces issues such as not getting due monthly electric bills for bills that have already been paid, as well as low efficiency of energy supply and demand. Next, The conventional energy meter that has been used in a period before needs many manpower and workers to monitor the reading every month, this may lead to incorrect reading measurement that has been taken. The limitation of the range of wireless communication and its access to the network gateway. Last but not least, non IoT-based component selection.

3.2.2 Design of Smart Energy Meter Prototype

During this phase, voltage and current sensor are tested in Proteus first by using simulation as shown in figure 3.2. But there are problem occurred, this voltage and current sensor are not working properly and not accurate compared to the existing digital energy meter. The percentage error recorded for voltage reading is 334.5V which has 39% percentage error.

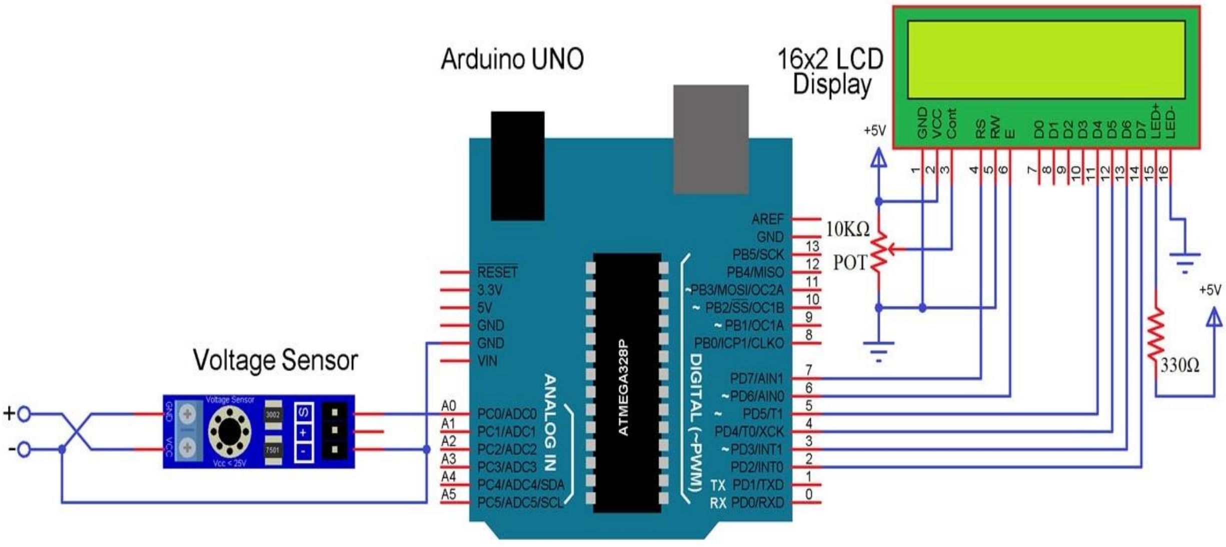

Figure 3.2 Circuit Simulation In Proteus

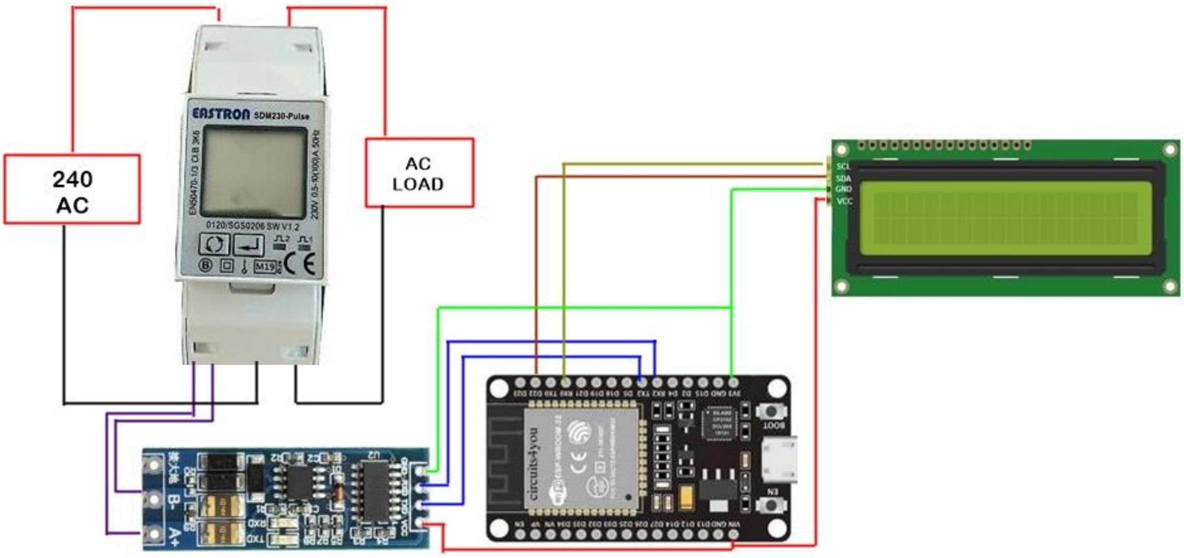

Figure 3.3 Final circuit connection

Since there no logging mode in voltage and current sensor; it only calculating when Arduino is switch on, when it turn on, all the calculation will loss, there no energy logging hence no old monthly bill will be calculated when Arduino turn off. To overcome this problem, we replace digital energy meter which enable logging and save the data even the microcontroller is switched off. In figure 3.3, shows the final circuit consist of digital energy meter, microcontroller, Modbus converter and LCD display.

3.2.3 Design of Smart Energy Meter Prototype

To design an IoT-based smart energy meter, cost analysis and component selection must to be done. Based on research, the limitation exists on the existing smart energy meter because the selection of the microcontroller, thus we must replace the microcontroller with suitable one. The suggested new microcontroller is ESP32 which enable and built in Wi-Fi and Bluetooth connection. The other features will be elaborated and explained in the purpose of material.

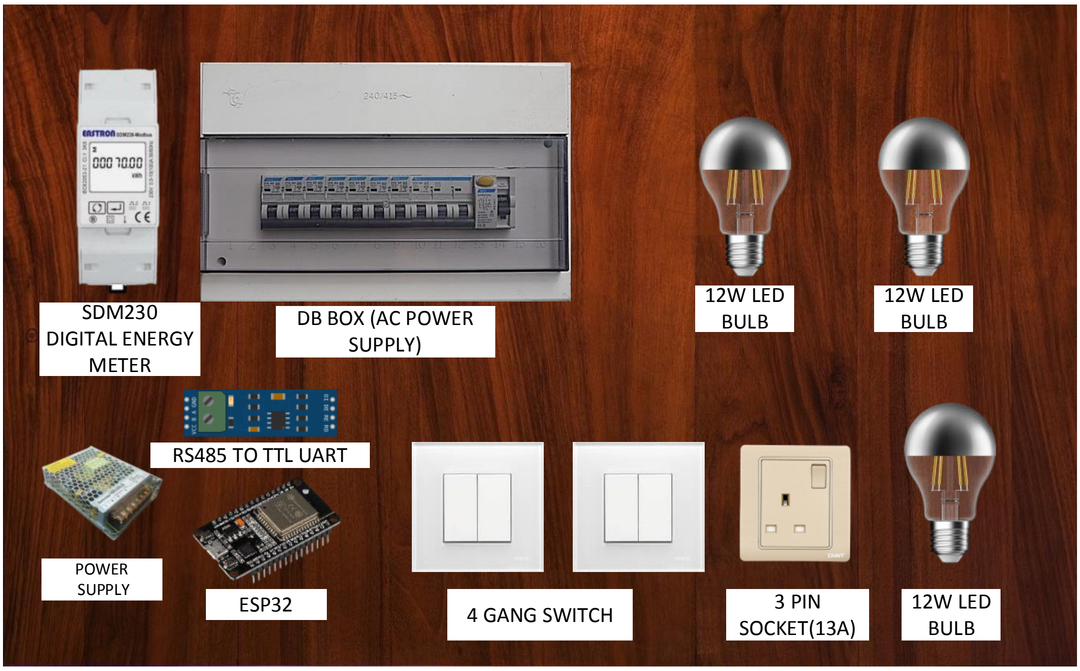

Figure 3.4 The Layout of Demonstration and Main Part of Smart Energy Meter

Figure 3.4 above shows layout design of the system include electronics and electrical parts. To develop IoT-Based Smart Energy meter, the product must be tested and validated by connecting to the real environment of domestic single phase electrical wiring; which are the home appliances connected to measure the parameter. Since it too hard reconstruct or do rewiring in any house, the testing and demonstrating have to be done in mini single phase circuit (same as home electrical wiring) but it is mounted on plywood. Safety precaution also include by installing DB box, main switch, ELCB, and MCB, to make the testing phase safe since we testing on high alternating current voltage, 240V, 50Hz.

The only main components of the smart energy meter, is any Modbus digital energy meter, RS485 to TTL UART converter, microcontroller, that's it. These main parts is soldered on PCB board and placed in junction box. In real application, these junction box must be installed near to DB Box since the TTL converter is connected to Modbus digital energy meter.

3.2.4 Developing and Fabrication Phase

Plywood is used in this project as the medium to mount all the electrical components, as it cheap, strong, light and portable, these make the demonstration can be done anywhere as long there are AC power supply there. Electrical appliance such as switch gang, bulb holder, and bulb and DB box also mounted on this plywood. The plywood is cut into 60cm x 50 cm dimension, and the wiring placed back of the plywood.

Figure 3.5 Cutting plywood and finishing process

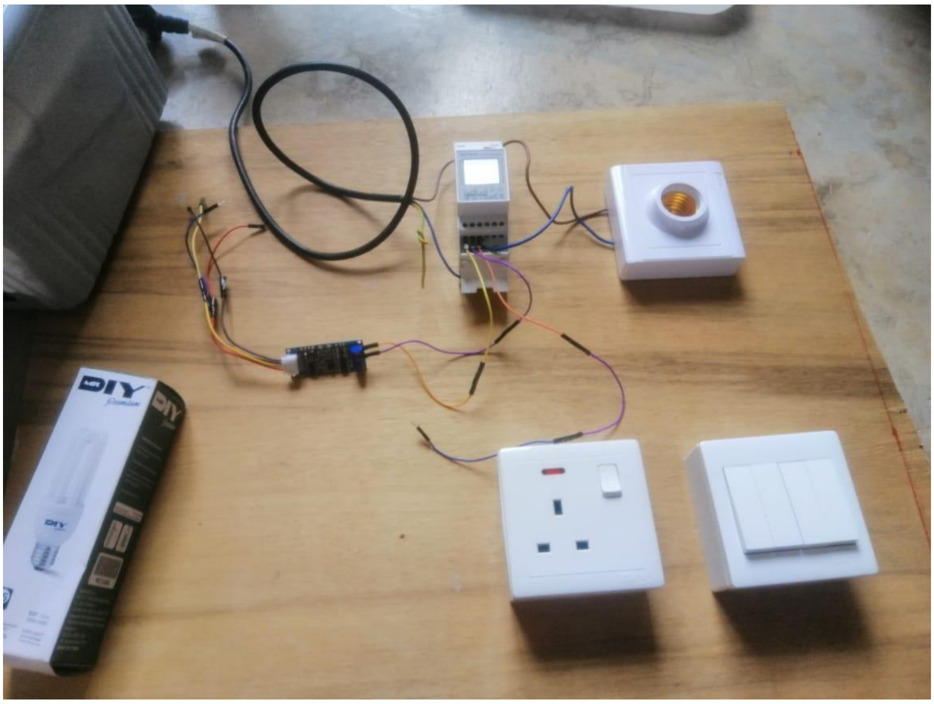

Figure 3.6 Electrical component placement setting

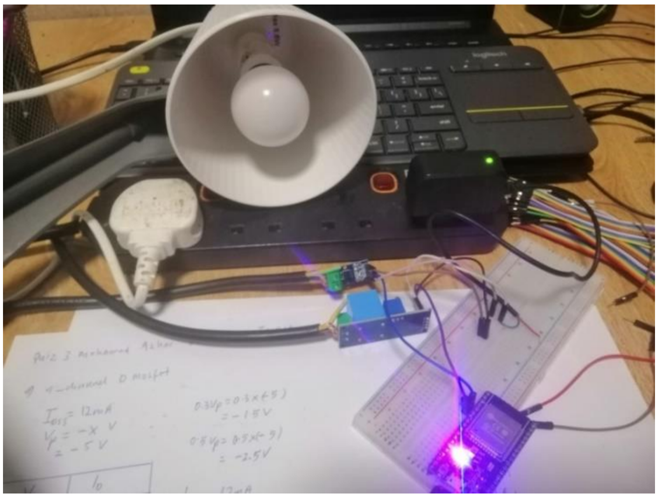

Figure 3.7 Sensor and microcontroller testing phase

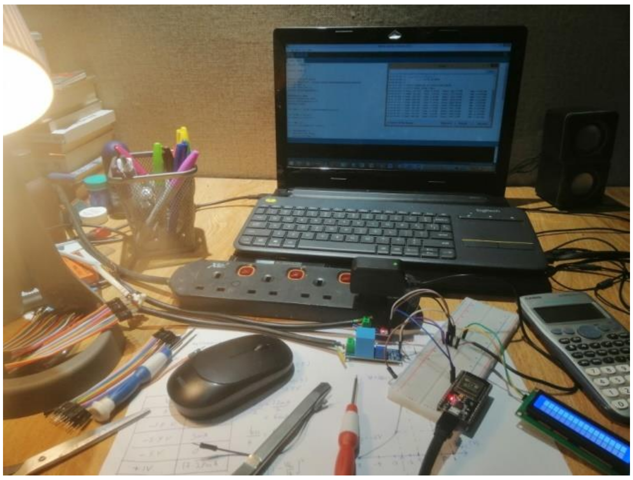

Figure 3.8 Electronic components testing and programming phase

At this beginning phase, ESP32 only connected to the voltage and current sensor to measure the parameters from the bulb. The reading successfully measured, obtained and sent to the microcontroller. But, the sensor has few limitation; low accuracy and low ampere rating. These sensors are not suitable to be used to measure high ampere electrical appliances.

3.2.5 Graphic User Interface Design

To completing the term of "IoT-BASED" in smart energy meter, user and utilities provider can access the parameter and monthly bill from the energy meter, thus GUI must be designed to display all desired electrical parameters that have been measured and processed by the microcontroller.

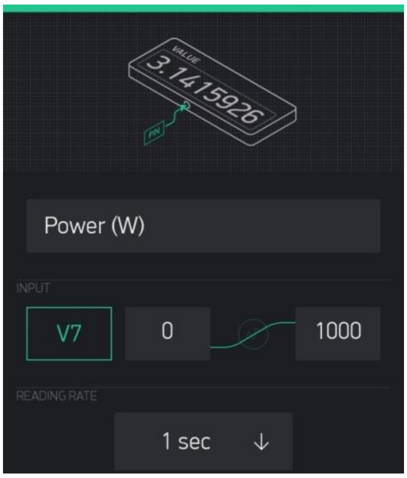

Figure 3.9 Setting widget display for Power

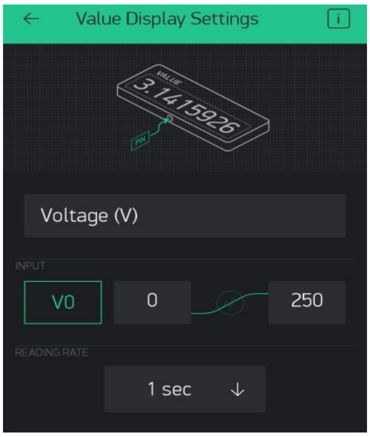

Figure 3.10 Setting widget display for Voltage

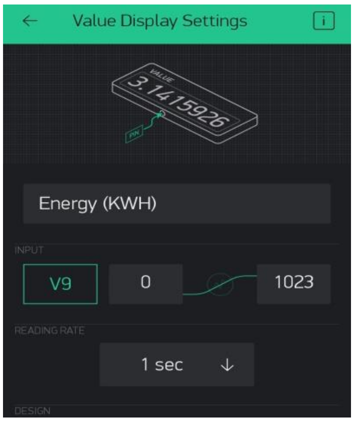

Figure 3.11 Setting widget display for Energy

In the GUI in Blynk Application, it should display electrical parameters such as voltage, current, power and energy. We have to design and set the display widget in the Blynk first. Thus, five widgets needed to display that four parameters and one for monthly bill. In Blynk, widgets are free as long it not exceeded the free coins quota. If we want to use widget to display more info and parameter, we have to purchase more coin, but it is enough to display only important one.

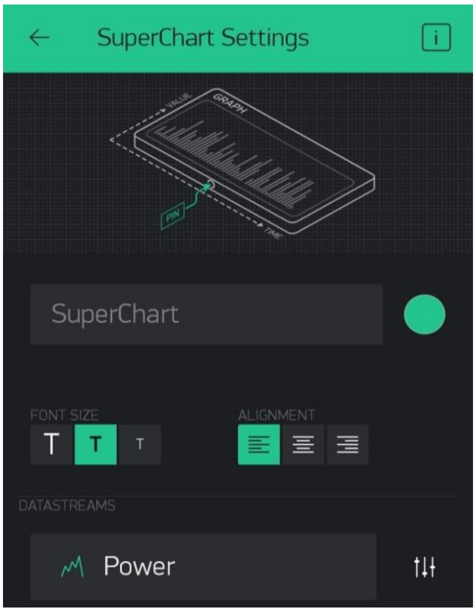

Figure 3.12 Superchart setting to display Power in graph

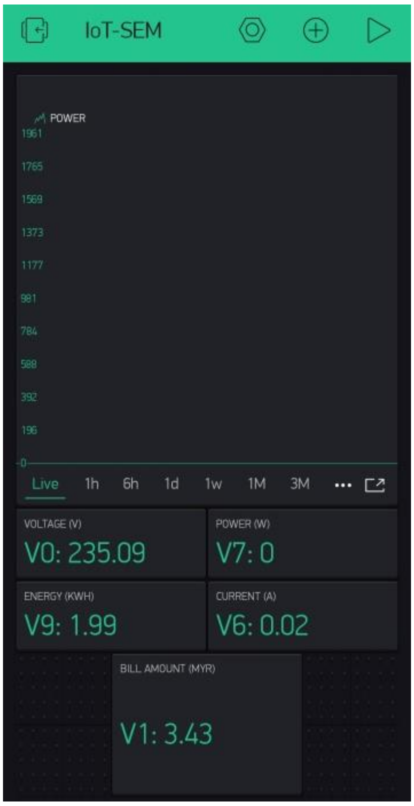

Figure 3.13 Final GUI Display Design

The setting for each widget must set to the virtual pin, which allow uplink and downlink communication. The address of data type that sent to Blynk set to V0, V1, V3 and more. This data type will be set in programming, so the measure reading from Modbus communication will be sent to this data type address. The GUI only display what data has been sent to the certain address.

3.2.6 Testing and Verifying Phase

In this phase, SDM230 Digital meter has replacing the voltage and current sensor. SDM230 is built with Modbus communication. This digital energy meter is able to send more than 20 electrical parameters by use this communication to the microcontroller. It also has good accuracy on the current and voltage which is 0.5% and 100A ampere rating.

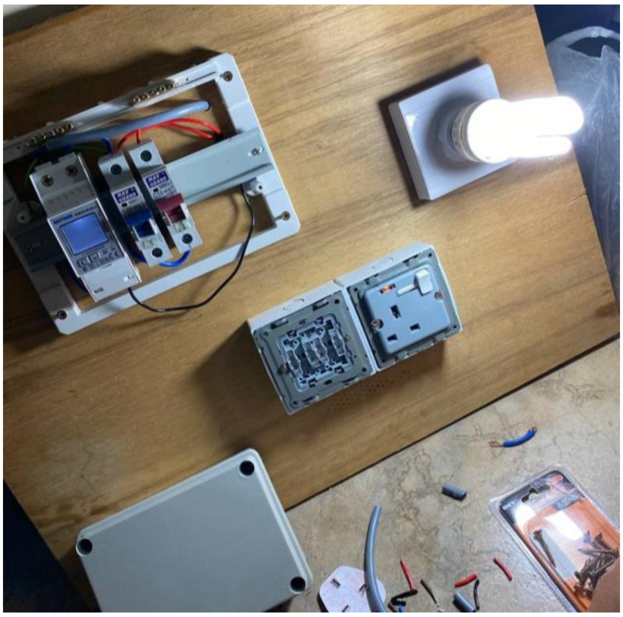

Figure 3.14 Testing phase with SDM230 Energy Meter

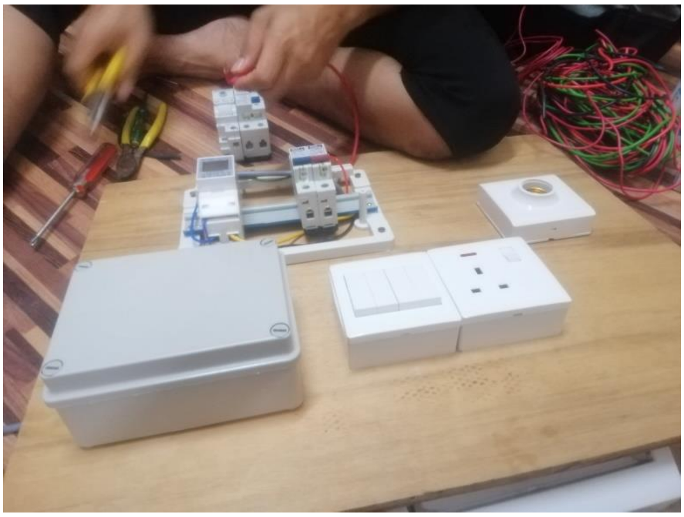

Figure 3.15 Installing main switch, ELCB and MCB

Figure 3.14 and 3.15 show the fabrication and installing single phase wiring circuits on the plywood as represent the real environment in home wiring circuit.

3.2.7 Performance evaluation and final product

The final testing and validation phase is using this final prototype. Before this, only one bulb were tested, and it is too hard to measure the changes since the LED Bulb has low power consumption, only 12W. By adding 2 power bulb, we can obtain slightly changes in power, energy and bill consumption. The read and log more consumption, electrical water heater and iron clothes are used since they have high power rating, 1900W to 2200 W. After connected water heater to the three pin socket, smart energy meter able to measure the exactly reading in that range and sent the data to be display in Blynk, and also on the LCD.

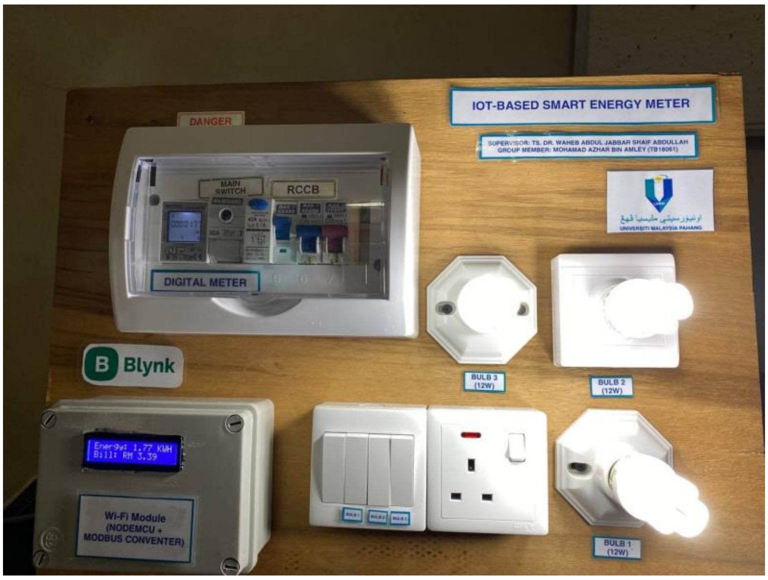

Figure 3.16 Testing and validation with 3 bulbs

Figure 3.17 Testing with electrical water heater

During this phase, the IoT-based smart energy meter ran for 50 hours and successfully obtain, process and sending the data. All the connection, both electrical and electronic part are safe. The final prototype as shown below, there is DB box unit contain the SDM230 energy meter, main switch, ELCB and MCB. There are three LED bulb mount and to be measured. For any external electrical appliances can be connected to the three pin socket.

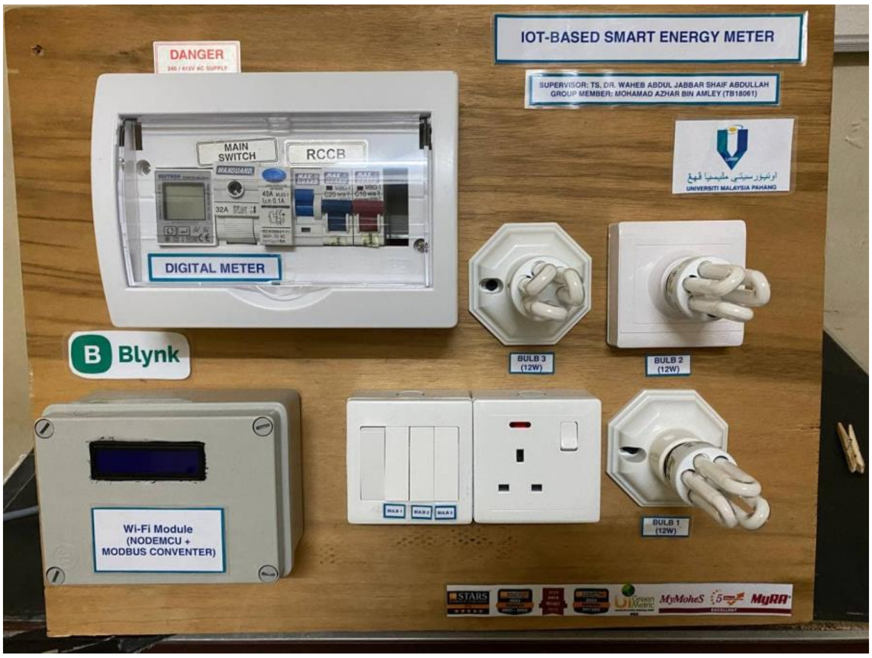

Figure 3.18 Final Prototype

Figure 3.18 above show the final prototype of IoT-based smart energy meter with demonstration electrical parts. The prototype consists of electronic parts (microcontroller and Modbus to serial communication converter), also the electrical parts, bulbs, switches, and safety units in the DB Box.

3.3 Purpose of the Material

3.3.1 SDM230 Digital Meter

The SDM230 is a single phase energy meter used in this project. It designed for residential, utility, and industrial applications. The unit able to measure a wide range of parameters, and has a Modbus communication port for remote monitoring. With bi-directional energy measurement, this meter is ideal for solar PV energy metering and domestic usage since it has ampere rating of 100A. This digital energy meter is able to measure below parameters:

Figure 3.19 The SDM230 unit

Figure 3.19, shows the digital energy meter unit that able to measure phase to neutral voltage, current, fundamental frequency, power factor, energy, power and others electrical parameters. In table 3.1 shows the range of the value can be measured by this type of digital energy meter, up tp 99999.99 Kwh, this can be reset on the digital meter itself when the value counts to the limit. Also, this model has the best accurate reading compare to others existing digital meter in the market, as shown in table 3.2.

Table 3.1 Energy Measurements

Parameter	**Range**
Active energy	0 - 99999.99 kWh
Reactive energy	0 -99999.99 kV Arh
Total active energy	0 - 99999.99 kWh
Total reactive energy	0 - 99999.99 kV Arh

Table 3.2 Accuracy parameters measurement of SDM230

Parameter	**Range**
Voltage (V)	0·5%
Phase Current (A)	0·5%
Frequency (F)	0·2%
Active power (W)	±1% (maximum range)

3.3.2 ESP32 Microcontroller

The ESP32 is a latest powerful microcontroller that has ESP8266 AS THE predecessor, includes a CPU. However, due to the multitasking required to update the Wi-Fi stack, the majority of applications employ a separate microcontroller for data processing, sensor interfacing, and digital I/O. You may not need to utilize an additional microcontroller with the ESP32. The ESP32 will operate at frequencies ranging from 160MHz to 240MHz on breakout boards and modules. That is an excellent rate for anything requiring a microcontroller with networking capabilities. Figure 3.21 shows the 36 I/O pins

Figure 3.20 Espressif Microcontroller ESP32

TCP/IP, the complete 802.11 b/g/n/e/i WLAN MAC protocol, and the Wi-Fi Direct specification are all implemented on the ESP32. This means that when used in station (client) mode, the ESP 32 can communicate with the vast majority of Wi-Fi routers available. Additionally, it is capable of establishing an 802.11 b/g/n/e/i access point. Additionally, the ESP32 supports Wi-Fi Direct. Wi-Fi-Direct is an excellent choice for peer-to-peer connections that do not require an access point. Wi-Fi-Direct is easier to configure and provides significantly faster data transfer speeds than Bluetooth. This could be used to configure ESP32-based projects using a phone or tablet equipped with Wi-Fi direct.

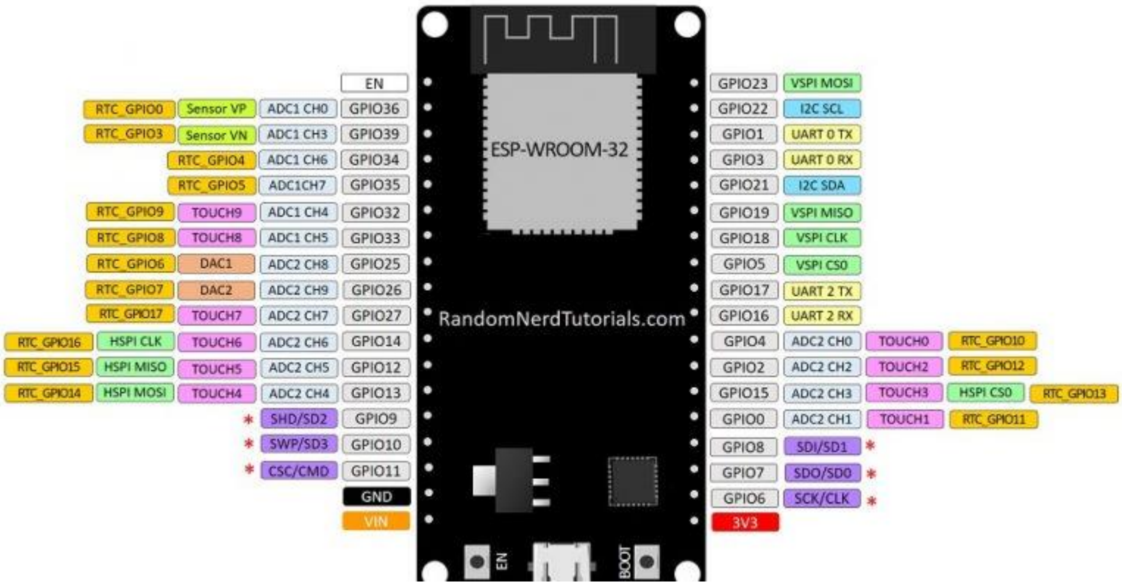

Figure 3.21 The 36 I/O pins in ESP32

The ESP32 is powerful with the hardware features. Due to the high-speed two core processors and multiple integrated peripherals, it is expected to eventually replace microcontrollers in linked products. The Wi-Fi, Bluetooth Classic, and BLE capabilities make it an excellent choice for connecting anything. Even if a project does not originally require a particular functionality, it might be added as needed. The integrated hardware accelerator enables secure code storage and secure Internet connectivity through TLS (SSL).Table 3.3 shows Data Sheet of ESP32.

Table 3.3 Data Sheet of ESP32

Microprocessor	**Tensilica Xtensa LX6**
Maximum Operating Frequency	240MHz
Operating Voltage	3.3V
Analog Input Pins	12-bit, 18 Channel
DAC Pins	8-bit, 2 Channel
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
SRAM	520 KB
Wi-Fi	802.11 b/g/n

3.3.3 RS485 TO TLL UART

The TTL-485-2 is a bidirectional RS485 to TTL convert that converts two-wire RS485 to 5V DC TTL-compatible levels and vice versa. This RS485 to TTL converter supports multi-drop RS485 networks and is capable of communicating with up to 128 RS485 devices in a single loop.

Figure 3.22 RS485 to TTL converter

Figure 3.22 below shows converter unit. It operates between -40^{o}F and 185^{o}F (-40^{o}C and 85^{o}C) and includes 600W surge protection and 15kV static protection. This industrial TTL to RS485 converter / adapter is supplied by an external 5V DC regulated power supply (included); it features data direction auto-turnaround, which enables the RS485 transceiver automatically when data is present on the TTL side. As a result, no software drivers or flow control are required, making the system extremely reliable and simply plug-and-play.

3.3.4 12C LCD Crystal Display

LCD 16x2 refers to a Liquid Crystal Display that utilises a plane panel display technology and is often seen on computer monitors and televisions, smartphones, tablets, and other mobile devices. While both LCD and CRT displays appear identical, their functionality is rather different. Rather than electrons diffracting at a glass panel, a liquid crystal display utilises a backlight to illuminate each pixel in a rectangular network. In this project, LCD is used to display energy consumption and monthly electricity bill on the module junction box (offline display).

Figure 3.23 I2C LCD Display

In figure 3.23, shows the LCD unit used to display all electrical parameters it will mount on the Wi-Fi module junction box that will display same parameters in the SDM230's screen LCD and Blynk Application.

3.3.5 5V Power Supply

A 5V DC power supply is used in this project for the electronic component that gives direct current voltage to power the LCD, Microcontroller and RS485 to TTL converter. An 240V AC input is rectified and filtered to produce a 5 DC voltage, which is then applied to a regulator circuit, generating a constant 5 V DC output voltage. Since the product is placed in domestic houses, battery is not efficient to be used as the power supply because it has short life span, not enough power rating.

Figure 3.24 5V power supply adapter (2A)

Figure 3.24 above show unit of power supply used to supply all the electronic components in smart energy meter that has voltage input of 5V. By using direct AC power supply input and converted to DC voltage output, the electronic part can be powered up continuously as long the switch is on and the supply is available. The power supply used in this project has 2A ampere rating which is enough to power up all the electronic part since they only consume below than 50mA for each component.

3.3.6 LED Bulb and 2 gang 1 way switch

LED Bulbs are used this project as home appliances and AC Loads. These bulb will be switched off and on to measure the electrical parameters flow on it. There are three bulbs connected from the main supply, and each of them is come with the one switch. LED Bulbs used in this project has 10W-13W power rating.

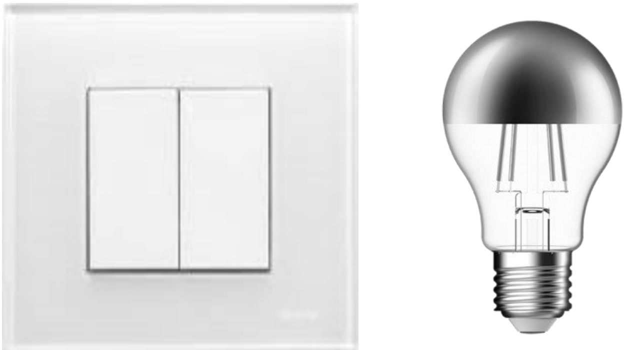

Figure 3.25 Two gang switch and bulb

Figure 3.25 above shows the switch that used to control on-off the LED Bulb, it mount on the plywood, that make the demonstration process easier, since we want to observe the change in energy and power consumption.

3.3.7 Three pin socket

Three pin sockets are used in this project to make sure this design prototype is same as actual home that has three pin sockets. Any equipment, home appliances or electronic devices can be plugged in into this socket, so then the energy meter would detects the electrical parameters that flow into it.

Figure 3.26 A three pins socket plug in

Figure 3.26 shows the pin socket used to be connected with any home appliances such as refrigerator, television, water heater or clothes iron.

3.3.8 Main Switch

The main switch, alternatively called a distribution board, divides the electrical power supplied to a building into subsidiary circuits and provides a safety fuse for each circuit. When a circuit is overloaded, the primary switch's fuse is blown. This efficiently cuts off electricity to the circuit and prevents a fire caused by the overload. Without the primary switch, an overload would cause the wire to heat up, melt the insulation, and finally cause a fire.

Figure 3.27 Main Switch Unit

Figure 3.27 below shows the main switch that used in this project has 30A fuse as the safety feature in demonstration phase.

3.3.9 Earth Leakage Circuit Breaker

An Earth Leakage Circuit Breaker is an electrical safety device that is used to detect and interrupt current flowing to earth from an installation. If the voltage on the equipment body increases due to a breakdown of the insulation or due to phase contact with metal parts, resulting in a differential between the earth and the body load voltage, the hazard of electric shock exists.

Figure 3.28 ELCB Device

Figure 3.28 below shows the ELCB device that used in this project as the safety feature in demonstration phase. This voltage differential generates an electric current in the metal framework of the load, which passes through the relay loop and to ground. When the voltage across the appliance or equipment's metallic body surpasses 50 V, the flowing current via the relay loop may move the relay contact, cutting off the supply current and preventing any severe electric shock.

3.3.10 Miniature Circuit-Breaker

A miniature circuit breaker's principal role is to protect an installation or appliance against persistent overloading and short-circuit faults, but it will also guard against earth faults if the earth fault loop impedance is sufficiently low. The miniature circuit-breaker can also be employed as an isolating switch or for local control switching as a supplementary function.

Figure 3.29 20A MCB Device

Figure 3.29 below shows the MCB device unit that used in this as the safety feature in demonstration phase. Miniature circuit breakers typically incorporate both overload and short-circuit current tripping mechanisms, with the overload typically being a thermal device and the short circuit typically being a magnetic device. A trip-free mechanism is incorporated to prevent the contacts from being held closed in the presence of a fault, and the thermal element prevents the circuit from rapidly reclosing while a fault persists.

3.4 Software Development

3.4.1 Proteus

Proteus is a simulation and design software used in this project. The Labcenter Electronics Company created this instrument for electrical and electronic circuit design. It also has a 2D CAD drawing capability. The tagline "From idea to execution" is well-deserved. This is a software package that includes schematic, simulation, and PCB architecture. ISIS is a programme that allows the users to build schematics and simulate circuits in real time.

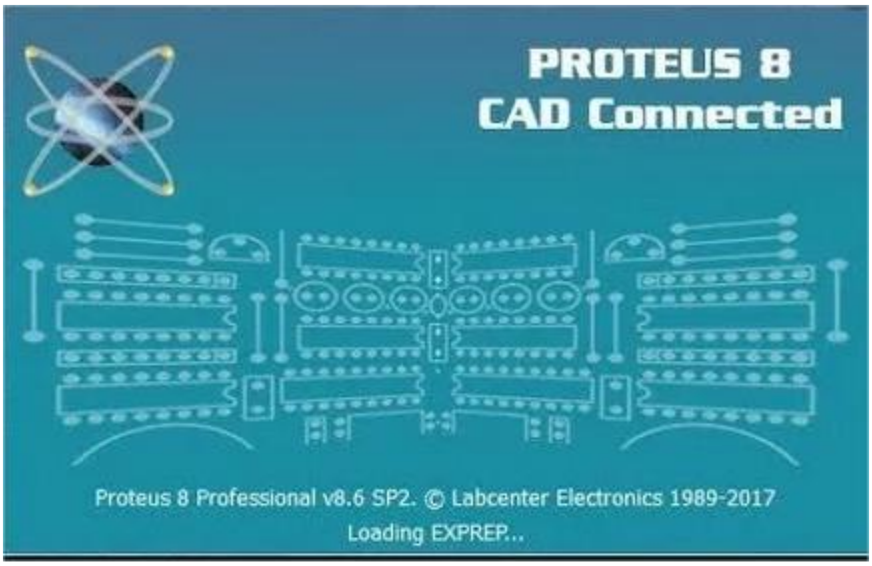

Figure 3.30 Logo and interface of Proteus

Figure 3.30 above shows the Proteus Opening Logo. The simulation allows for human interaction during the simulation, allowing for real-time simulation. ARES is then used to design PCBs. It has the ability to display the output in a 3D view of the built PCB, including modules.

3.4.2 Arduino IDE

Arduino IDE is an open-source programme created by Arduino.cc that is used to write, compile, and upload code to practically all Arduino Modules. It is official Arduino software that makes code compilation so straightforward that even a non-technical person may get their feet wet with the learning process.

Figure 3.31 Arduino IDE Software

Figure 3.31 above, shows Arduino Logo Software. Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Micro, and many other Arduino modules are available. On the board of each of them is a microcontroller that has been programmed and accepts data in the form of code. The core code, also known as a sketch, written on the IDE platform will eventually generate a Hex File, which will be copied and uploaded to the board's controller.

3.5 System Architecture of IoT-Based Smart Energy Meter

The System Architecture of IoT-Based Smart Energy Meter designed as below; which AC Loads are needed to measure and log their electrical consumption. SDM230 is connected to the load as the digital energy meter that sending the parameters to the ESP32 by using MODBUS RTU to TTL communication.

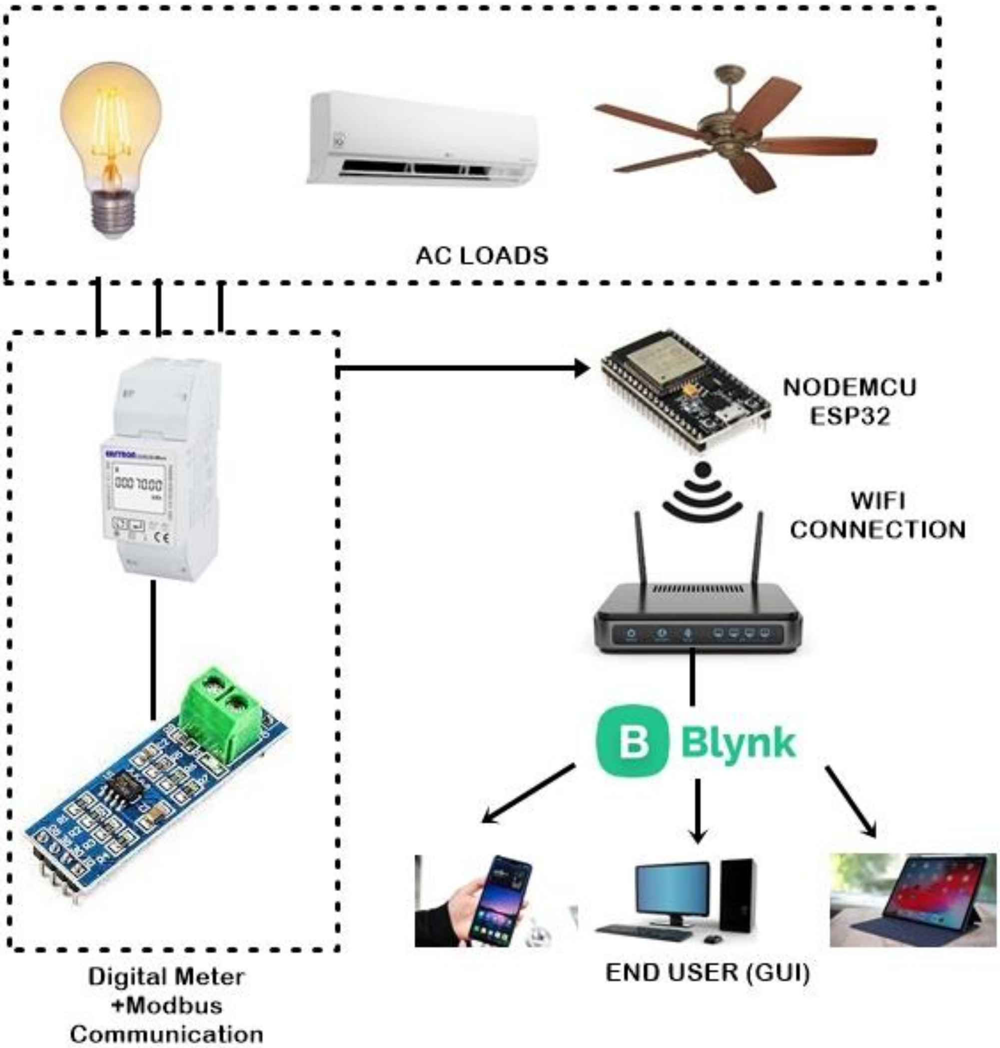

Figure 3.32 System Architecture of IoT-based smart energy meter

Figure 3.32 above show the system architecture design contains of few blocks, AC Loads, digital energy meter unit and converter, Wi-Fi MCU unit and the Blynk server block.

3.6 Flowchart of IoT-Based Smart Energy Meter

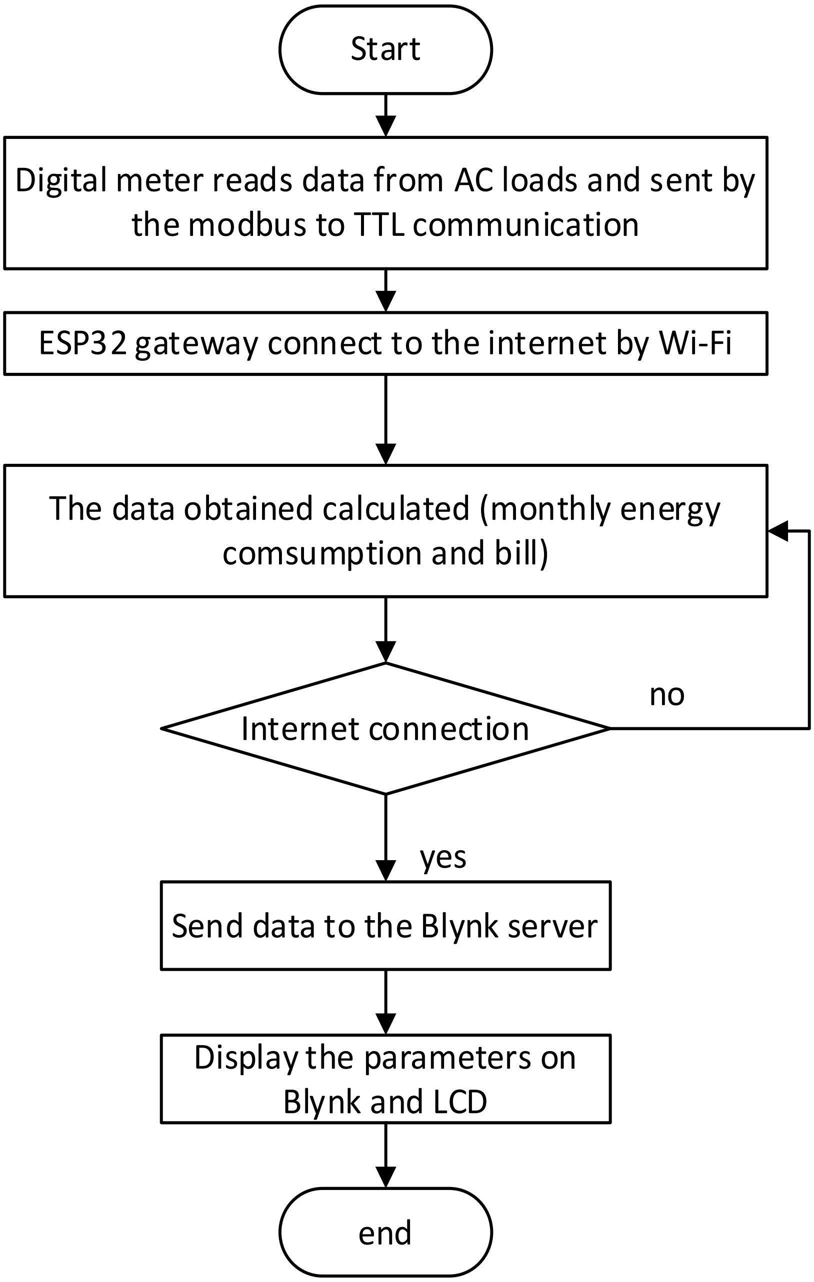

Figure 3.33 Flowchart of the System

The flow of this IoT-based smart energy meter as shown in figure 3.33, when the electrical appliances is switched on, the SDM230 digital meter will measure the electrical parameters of the loads; voltage, current, power and energy. This energy meter will keep logging the reading as long the user did not reset the digital meter. After the readings were obtained, it will be transferred to the microcontroller by using Modbus RTU protocol that converted to the TTL, serial communication. At the same time, in this programme code there four parameters will be sent to the microcontroller. To calculate the monthly consumption, TNB tariff rate has been programmed in the ESP32, that calculate the energy consumption transferred by the digital energy meter.

By that, there one additional data will be sent to the server which is monthly bills. To able sending data to the Blynk server, the ESP32 must be connected to the to any Wi-Fi connection. These data will be sent to the Blynk Server and ready to be displayed on the Graphic User Interface in Blynk Application, in the same time, parameters such as energy and monthly bill also can be displayed on the LCD.

3.7 Summary

To conclude this chapter, all the method that selected and used to design, fabricate and implement in this project, has been explained in detail. The flowchart of the project, system flowchart and system architecture were explained. The process of designing the IoT-based smart energy meter also explained where involving designing the circuits, connecting the loads in single phase wiring, GUI design, and also the programming coding. To validate, the testing and verifying phase were done to measure the system's efficiency and lastly the evaluation on the performance in real environment.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the outcomes from the testing, validation of this project will be discussed accordingly with the problem and solution. The calculation on theoretical and testing will be compared to validate the success of this project.

4.2 Result

To validate and testing the accuracy, functionality of this IoT-based smart energy meter, we have to connection on phase electrical circuits to represent loads that used in domestics houses such as bulb and kettle. These loads are connected after the SDM Modbus energy meter and this loads will be switched off and on to measure the parameters reading; voltage, current, power, energy.

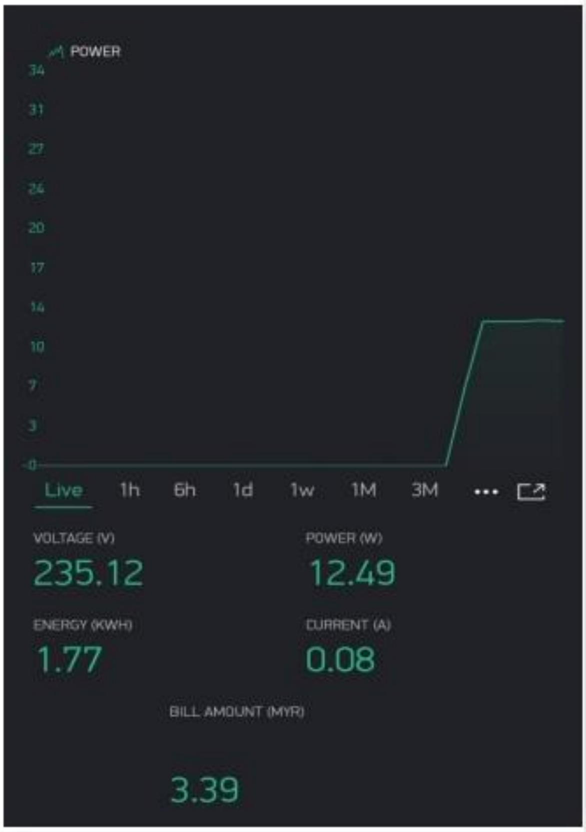

Figure 4.1 When 1 bulb is switched on and the display on Blynk

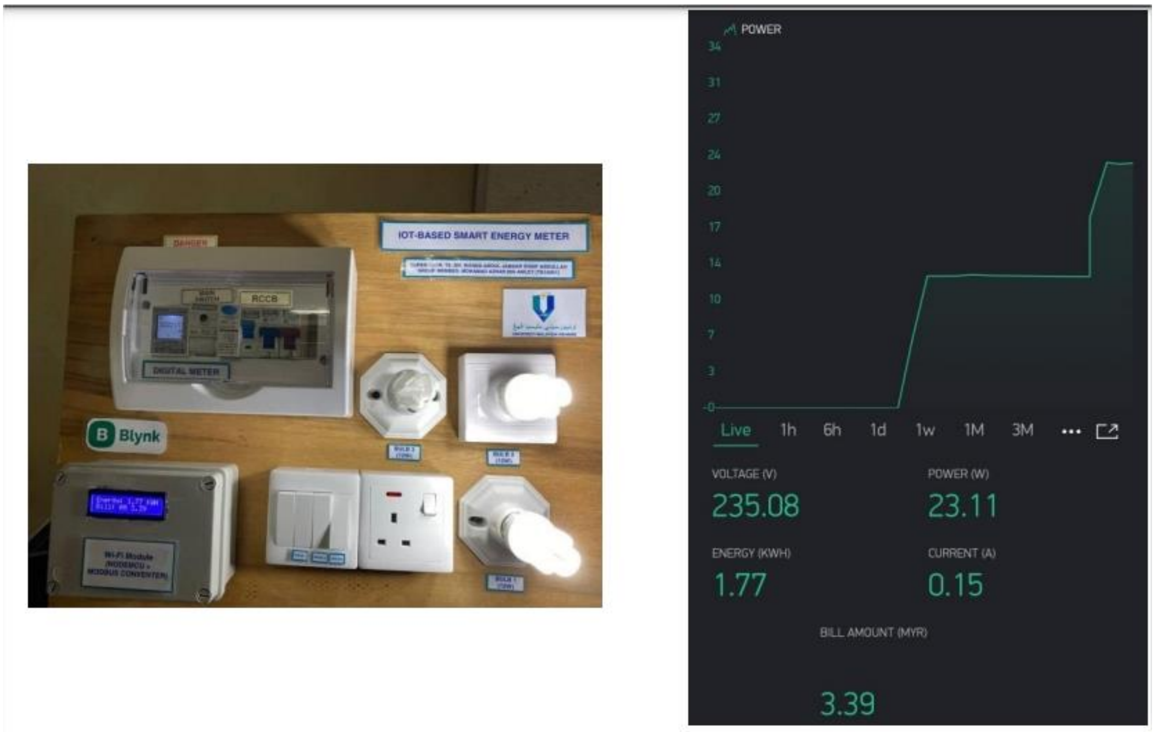

Figure 4.2 When 2 bulbs are switched on and the display on Blynk

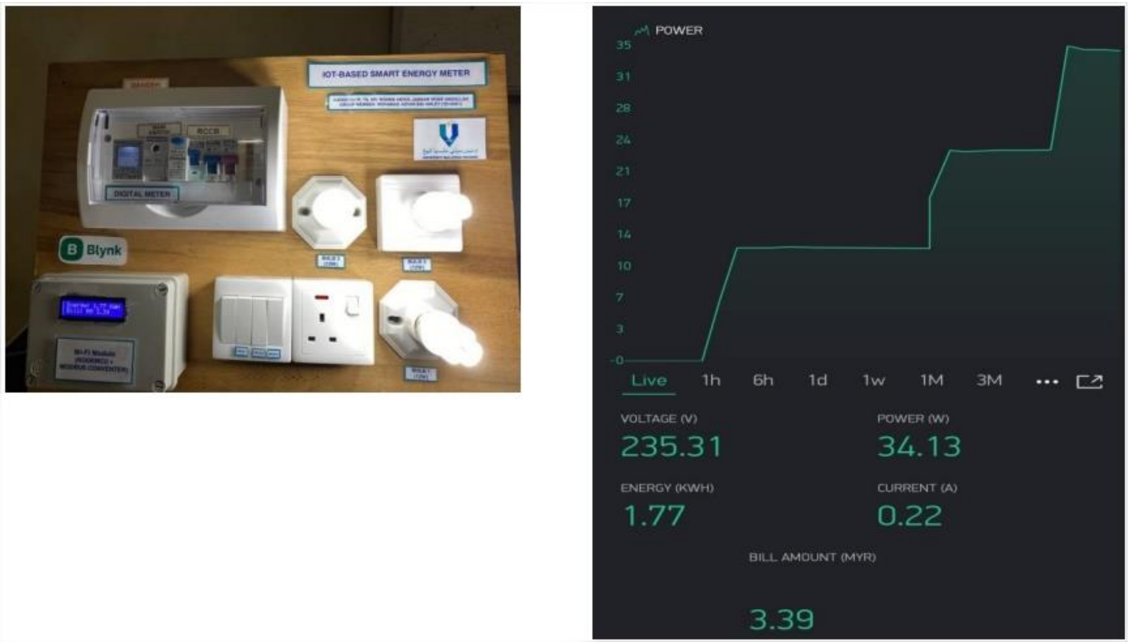

Figure 4.3 When 3 bulbs are switched on and the display on Blynk

From figure 4.1, we can see the demonstration when 1 bulb switched of, the graph power show increment of 12.49 W which the bulb used is LED has rated power of 12W to 13W. When another bulb switched on, the power consumption increased as showed in figure 4.2, 23.11W. When three bulbs switched on as in figure 4.3, the power display in the Blynk app increased to 34.13W. That's means, in that time, the power consumption of three bulbs is 23.11W.

The obtained value from the digital meter will be processed by the microcontroller and to be sent to Blynk server for each 1 second time interval. The change on the energy consumption also sent in 1 second time interval, but it is hard to see the changes in a short time, since it is represent in Kilowatt hour and the load just consume below than 20 Watt.

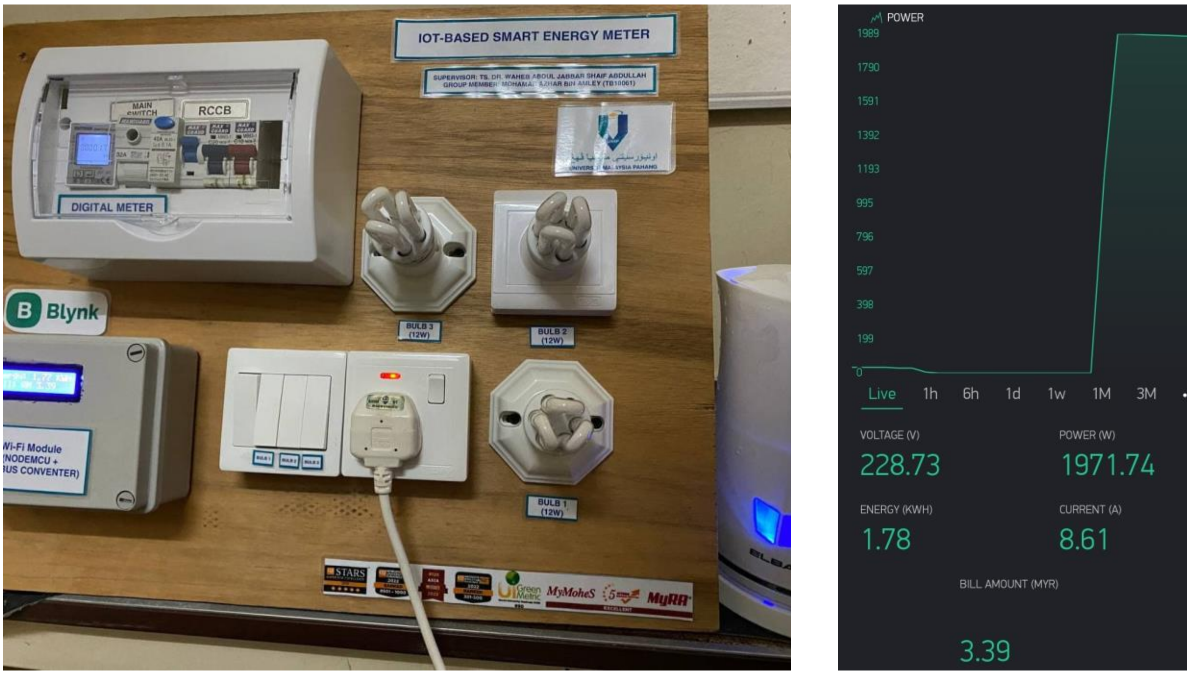

Figure 4.4 Demonstration with high power load (1900W- 2200W)

To measure the changes in energy (KWh), we must use high current or power loads such as clothes iron or water heater. In this demonstration, 1900W water heater was used to measure the energy changes. In figure 4.4, we can see the huge different number of power and current consumption when water heater is connected; which 1971 Watt and 8.61A measured from the digital energy meter.

4.3 SDM230 Digital Energy Meter Performance

SDM 230 series is digital energy meter that selected in this project. This digital energy meter used instead of voltage sensor and current sensor, since it has a better accuracy rate, high in durability and has a MODBUS communication. This type of energy meter rated with 100A which it can measure 24kW in a time, suitable for domestic usage. In addition, it has MID Certified which is approved and can be used safely. It also comes with two module din rain to make it easier to be mounted in any common DB box.

Besides that, it comes with clearly backlit display, which user can monitor and do a setting in the display (time, baud rate, setting password, resetting after a month, and many more). What more important, the ability of this energy meter to measure and monitor active and reactive energy, to make sure the final calculated bill is accurate based on the energy consumption.

Figure 4.5 DB Box used in demonstration

Figure 4.5 above shows this energy meter was placed in the DB box before the main switch. Basically in IoT-based smart has three displays, on the energy meter itself, can display all the parameters except monthly bill, since it calculated in ESP32. Second, display on the Wi-Fi module junction box, the energy and monthly bill displayed on I2C 16X2 LCD Display. These two displays are available offline, and for online display, user and utilities provider both can monitor their consumption in Blynk Application.

During the testing and validation phase, this type of energy meter showing good performance in order measuring and sending data to ESP32. All parameters measured by this energy meter can be transmitted microcontroller by using MODBUS RTU and to serial communication in ESP32. The desired parameters are Voltage, Current, Power and Energy being received from the communication. This SDM230 has 0.5% accuracy percentage, and the testing phase had been made to validate its performance and accuracy

4.4 Blynk Time Interval Function

During the validating and testing phase, we found out that, every time the system switched on, the data only recorder and display once in Blynk GUI, by that, real-time monitoring are disable. To overcome this problem, the time interval in programming code should be set to select desired time of transferring data to the Blynk Application Server.

```
myTimerEvent();

timer.setInterval(1000L, myTimerEvent);
```

Figure 4.6 Programming code for time interval

In order to enable the real-time data monitoring, the data should be transferred between 10 seconds or below. In figure 4.6, 1000L means the packet data will transfer for each one second, this packet data contains below than 10 desired parameters; to be displayed in Blynk. However, the electric provider can set the refresh rate, for each one hour or 24 hours, or one month.

4.5 Energy Consumption Tariff Calculation

This section presents results of testing and validating IoT based smart energy meter using practical prototype as shown in figure 3.18. The convention energy meter won't tell the user about their monthly bill consumption except the utilities provider. But, this IOT-SEM will tell the user all about their usage. During this testing phase, they are three bulbs connected and mount on plywood with the real home wiring and a three pin socket also installed.

This testing phase was running about three days and the calculation is done to measure the theoretical monthly bill compared to the value calculated and displayed by the microcontroller. All three bulbs were running three days or 72 hours and the total consumption of the energy is 0.083 kWh.

TARIFF CATEGORY	CURRENT RATES (1 JUNE 2011)	NEW RATES (1 JANUARY 2014)
Tariff A - Domestic Tariff		
For the first 200 kWh (1 - 200 kWh) per month	21.80 sen/kWh	21.80 sen/kWh
For the next 100 kWh (201 - 300 kWh) per month	33.40 sen/kWh	33.40 sen/kWh
For the next 100 kWh (301 - 400 kWh) per month	40.00 sen/kWh	51.60 sen/kWh
For the first 100kWh (401 - 500 kWh) per month	40.20 sen/kWh	
For the next 100 kWh (501 - 600 kWh) per month	41.60 sen/kWh	
For the next 100 kWh (601 - 700 kWh) per month	42.60 sen/kWh	54.60 sen/kWh
For the next 100 kWh (701 - 800 kWh) per month	43.70 sen/kWh	
For the next 100 kWh (801 - 900 kWh) per month	45.30 sen/kWh	
For the next kWh (901 kWh onwards) per month	45.40 sen/kWh	57.10 sen/kWh
The minimum monthly charge is RM3.00		

Figure 4.7 TNB Tariff for domestic usage
Source: https://www.tnb.com.my/residential/pricing-tariffs

Figure 4.7 shows TNB Tariff rating used in this system, since we are using single phase wiring for demonstration. The programming code are set according to the tariff and the price. However, if this IoT-based smart energy meter used in three phase wiring, we have to modify the programming code, and also change another digital energy meter that’s support three phase parameter measurements.

$$Bill\_Charges = Energy \times Rates \qquad 4.1$$

$$Bill\_Charges = 0.083KWH \times RM0.2180$$

$$Bill\_Charges = RM0.02$$

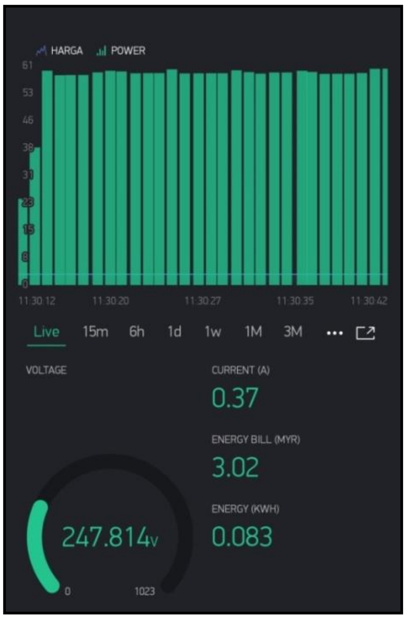

Figure 4.8 GUI in Blynk Application display the measured and calculated parameters

Since the minimum value is of charged bill is RM 3, then the total bill would be RM 3.02. Same as shown in the GUI application on Blynk of IoT-based smart energy meter. Based on figure 4.4, after the water heater plugged into the socket, there is increment on the power and energy consumption 1.77KwH increased from previous reading without water heater as a loads make the monthly bill showing RM3.39, RM 3 is initial charges.

$$Bill\_Charges = Energy \times Rates \qquad 4.2$$
$$Bill\_Charges = 1.77KWH \times RM0.2180$$
$$Bill\_Charges = RM0.39$$

4.6 Parameters Error Calculation

To validate the reading, home appliances are used; and had been connected to the single phase wiring circuits 240 AC voltage. The results are recorded and calculated as below shown in table 4.1, 4.2 and 4.3. The parameter were collected are Voltage, Ampere current, and Power.

$$\%Error = \frac{|displayed - measured|}{measured} \times 100\% \qquad 4.2$$

Equation 4.1 shows the percentage error formula used to calculate and compare the reading between IoT-based smart energy meter and Digital Multi Meter.

Table 4.1 Voltage Percentage Error

Home appliances	Rated power (W)	Displayed voltage (V)	Measured voltage (V)	Percentage error (%)
Led bulb	13	234.3	234.0	0
Table fan	60	232.6	234.5	0.81
Water kettle	1900	232.7	233.3	0.25
Clothes iron	700	235.2	233.3	0.81

Table 4.2 Current Percentage Error

Home appliances	Rated power (W)	Displayed Current (A)	Measured current (A)	Percentage error (%)
Led bulb	13	0.08	0.08	0
Table fan	60	0.266	0.270	1.48
Water kettle	1900	8.61	8.63	0.23
Clothes iron	700	2.99	3.01	0.66

From table 4.1, percentage error for voltage has been calculated, where 0% for LED bulb, 0.81% table fan, 0.25% water kettle and 0.81% clothes iron. These data show below than 1% percentage error for voltage measuring when these AC loads were connected. Meanwhile, in table 4.2, same as voltage, LED bulb recorded 0% in percentage error. For table fan, it recorded 1.4%, water kettle 0.23% and clothes iron 0.66%. These value is still showing good performance and accuracy.

Table 4.3 Power Percentage Error

Home appliances	Rated power (W)	Displayed power (W)	Measured power (W)	Percentage error (%)
Led bulb	13	12.44	12.44	0
Table fan	60	63.00	62.00	1.6
Water kettle	1900	1972	1974	0.1

Clothes iron	700	721	721	0

$$P = V \times I \times \cos\phi \qquad 4.3$$

Equation 4.4 above shows the formula to calculate power in single phase AC voltage. From table 4.3, we can see the percentage error calculated are 1.6% for table fan and 0.1% for water kettle, and 0% percentage error for LED blub. From these reading, we can validate that SDM230 digital energy meter has an good performance and accurate.

4.7 Summary

To sum up this chapter, the result has been obtained from the testing phase of this system, has been shown, which the data successfully transferred from the SDM230 digital energy meter by MODBUS RTU, to the microcontroller, and being processed, sent to Blynk server through Wi-Fi and displayed on the GUI Blynk Application. This prototype had been validated by using serial monitor, digital multi meter and LCD display. The MODBUS digital meter working properly in order to measure all the electrical parameter desired. The problem occurred during the testing phase such as sensor problem and the real time monitoring have been overcomed.

CHAPTER 5

CONCLUSION

5.1 Conclusion

IOT-based energy meter is a cost effective, more practical and a safe way to save energy. IOT-based energy meter is a cost effective, more practical and a safe way to save energy. This smart energy meter is able disseminate real-time information to both consumer and utility thus; overcome the limitations of the conventional energy meters. This has made this system different with other existing smart energy meter since most of they are not capable to transfer real time data because the limitation of the wireless communication they used.

Smart energy meter integrated Wi-Fi technology and Modbus communication for monitoring energy consumption and expected bill information over the Blynk IoT Platform using an integrated GUI has been successfully fabricated. By showing real-time data parameter on Blynk Application, user able to monitor their own energy consumption in one second refresh rate.

The developed smart meter in a real environment is successfully deployed in a real environment and its functionality was verified and performance has been analysed. This system's digital energy meter below than 0.5% accuracy among the exiting digital energy meter and its performance tested, has a low energy consumption sending data system and high durability

5.2 Recommendation on the system's Improvement

Few recommendations for improving the system:

- Add backup power supply the electronic parts such as Li-Po battery.
- Integrate with IoT home automation system for more energy saving, since the system only for monitoring. With this integration, user able to control switching their home appliance trough internet and application.
- Add more wireless communications instead of only Wi-Fi, such as Bluetooth, GSM, SIGFOX AND LoRa.
- Enable GSM features in the microcontroller, so it can automatically send monthly bill SMS each month to the user even though the user did not have internet connection.
- Add safety features that enable user turn of and on the IoT-based smart energy meter,

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APPENDIX A GANN CHART SDP1

NO	ACTIVITY		WEEK												
			1	2	3	4	5	6	7	8	9	10	11	12	13
1	BRIEFING ABOUT PROJECT	PLANNING													
		ACTUAL													
2	SELECT MEMBER FOR GROUP	PLANNING													
		ACTUAL													
4	PROJECT TITLE DISTRIBUTION	PLANNING													
		ACTUAL													
5	PROJECT INTRODUCTION PRESENTATION	PLANNING													
		ACTUAL													
6	IDENTIFY EQUIPMENT	PLANNING													
		ACTUAL													
7	STUDY ABOUT EQUIPMENT	PLANNING													
		ACTUAL													
8	DRAFT SIMPLE DIAGRAM	PLANNING													
		ACTUAL													
9	COLLECT INFORMATION FOR PRESENTATION	PLANNING													
		ACTUAL													
10	UPDATE CONTENT PRESENTATION	PLANNING													
		ACTUAL													
11	CHAPTER 1-3 PRESENTATION	PLANNING													
		ACTUAL													
12	SUBMIT REPORT CHAPTER 1-3	PLANNING													
		ACTUAL													

Table 5.1 The Gann Chart For SDP 1

	PLANNING
	ACTUAL

APPENDIX B GANN CHART SDP2

NO	ACTIVITY		WEEK													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	TASK DISTRIBUTION	PLANNING														
		ACTUAL														
2	COMPONENT SELECTION AND PIRCHASE	PLANNING														
		ACTUAL														
4	TESTING ON COMPONENT	PLANNING														
		ACTUAL														
5	FABRICATION HARDWARE	PLANNING														
		ACTUAL														
6	WRITE C++ PROGRAME	PLANNING														
		ACTUAL														
7	CONNECTIING CIRCUITS	PLANNING														
		ACTUAL														
8	TESTING AND VALIDATION	PLANNING														
		ACTUAL														
9	OPTIMAZTION AND ENHANCEMENT	PLANNING														
		ACTUAL														
10	RESULT OBSERVATION	PLANNING														
		ACTUAL														
11	TECHNICAL REPORT WRITING AND DEMONSTRATION	PLANNING														
		ACTUAL														
12	FINAL PRESENTATION	PLANNING														
		ACTUAL														

Table 5.2 The Gann Chart For SDP 2

	PLANNING
	ACTUAL

APPENDIX C COST ANALYSIS

No.	Item	Quantity	Price (RM)
Electronic Parts			
1	ESP32 Microcontroller	1	19.80
2	SDM230 Digital meter	1	168.00
3	RS485 TO TTL	1	11.70
4	PCB BOARD	1	4.90
5	POWER SUPPLY	1	11.90
6	JUNCTION BOX	1	4.30
		Total (RM)	**220.6**
Electrical Parts			
7	BULB	3	11.00
8	BULB SOCKET	3	10.00
9	DB BOX	1	22.00
10	WIRE 2 METER	1	10.00
11	MCB	2	22.00
		Total (RM)	**75.00**
		Total (RM)	**295.60**

Table 5.3 Cost Analysis for the components

APPENDIX D PROGRAMMING CODE

```
   // SDP Final Year Project
   // Title: IoT-Based Smart Energy Meter
   // Name: Mohamad Azhar Bin Amley


   // Please Include SDM Meter, Blynk and I2C Library before
compiling
   #include <SDM.h>
   #include <SDM_Config_User.h>
   #include <Wire.h>
   #include <LiquidCrystal_I2C.h>
   #include <Blynk.h>
   #define BLYNK_PRINT Serial
   #include <WiFi.h>
   #include <WiFiClient.h>
   #include <BlynkSimpleEsp32.h>
   #include "SDM.h"
//import SDM library

   HardwareSerial SerialSDM(1);
//Pin for serial commuication(pins 16 & 17)
   SDM sdm(SerialSDM, 2400);
   LiquidCrystal_I2C lcd(0x27, 16, 2);

   float voltage,current,power,frequency,energy,billamount;

   //===============Wifi and Blynk Configuration=========//
   char auth[] = "HvD9eQFzPTVtQTKh79Mf2nJiYat6GP6u";
//Paste Blynk token here
   char ssid[] = "novacc2";
//Write Wi-Fi's name here
   char pass[] = "azzs12345";
//Write Wi-Fi's pasword here
   //====================================================//


   void sdm_get(void);
   bool triggerBlynkConnect = false;
   bool isFirstConnect = true; // Keep this flag not to re-sync on
every reconnection
   BlynkTimer timer;


   void myTimerEvent()
   {
     if (WiFi.status() != WL_CONNECTED)
     {
       Serial.println(F("WiFi not connected"));

       Blynk.connectWiFi(ssid, pass);
     }
     else
```

```
    {
      Serial.println(F("WiFi in connected"));
    }

    if (!Blynk.connected() && WiFi.status() == WL_CONNECTED)
    {
      if (Blynk.connect())
      {
        Serial.println(F("Blynk reconnected"));
      }
      else
      {
        Serial.println(F("Blynk not reconnected"));
      }
    }
    else
    {
      Serial.println(F("Blynk connected"));
    }

    if (Blynk.connected() && WiFi.status() == WL_CONNECTED)
    {
      //=====SENDING DATA TO BLYNK'S SERVER==========//
      // !!WARNING: DO NOT SEND MORE THAN 10 VALUES PER SECOND!!
//

      sdm_get();
      Blynk.virtualWrite(V0, voltage);
      Blynk.virtualWrite(V6, current);
      Blynk.virtualWrite(V1, billamount);
      Blynk.virtualWrite(V7, power);
      Blynk.virtualWrite(V8, frequency);
      Blynk.virtualWrite(V9, energy);

      //=====================================//

    }
  }

  BLYNK_CONNECTED()
  {
    triggerBlynkConnect = true;

    Serial.println(F("Blynk Connected!"));
    Serial.println(F("local ip"));
    Serial.println(WiFi.localIP());

    if (isFirstConnect)
    {
      Blynk.syncAll();

      isFirstConnect = false;
    }
  }
```

```
   void setup()

   {

     Serial.begin(9600);
     sdm.begin();
     Blynk.config(auth);
     Blynk.connectWiFi(ssid, pass);
     energy = sdm.readVal(SDM230_TOTAL_ACTIVE_ENERGY  );

   //=========================================Calculation Tariff
Bill==================================//

     if (energy <= 200)
//First 200 units
       billamount = 3+ (energy * 0.218);

     else
     if (energy <= 300)
//Next 100 units
       billamount = 3+ 200 * 0.218 + (energy - 200) * 0.334;

     else
     if (energy <= 600)
//Next 300 units
       billamount = 3+ 200 * 0.218 + 100 * 0.334 + (energy - 300) *
0.516;

     else
     if (energy <= 900)
//Next 300 units
       billamount =3+ 200 * 0.218 + 100 * 0.334 + 300 * 0.516 +
(energy - 500) * 0.546;

     else
     if (energy > 900)
//Above than 900 units
       billamount =3+ 200 * 0.218 + 100 * 0.334 + 300 * 0.516 + 300
* 0.546 + (energy - 900) * 0.571;


   //====DISPLAY ON 16X2 LCD=============//

     lcd.init();
     lcd.backlight();
     lcd.setCursor(0,0);
     lcd.print("Energy: ");
     lcd.print(energy,2);
     lcd.print(" KWH");
     lcd.setCursor(0,1);
     lcd.print("Bill: RM ");
     lcd.print(billamount);

    //=======================================//
```

```
    if (WiFi.status() == WL_CONNECTED)
    {
      if (Blynk.connect())
      {
        triggerBlynkConnect = true;
      }
      else
      {
        triggerBlynkConnect = false;
      }
    }

    myTimerEvent();
    timer.setInterval(1000L, myTimerEvent);       //Timer to send
data to blynk's server (referesh and send data every 1 second)
  }

  void loop() {

    if (Blynk.connected())
    {
      Blynk.run(); // Initiates Blynk Server
    }
    else
    {
      triggerBlynkConnect = false;
    }

    timer.run(); // Initiates BlynkTimer
  }


  //======Read Value Function From SDM==============//
  void sdm_get()
  {
    char bufout[10];
    sprintf(bufout, "%c[1;0H", 27);
    Serial.print(bufout);

    Serial.print("Voltage:   ");
    voltage = sdm.readVal(SDM230_VOLTAGE);
    Serial.print(voltage, 2);                               //
serial display voltage
    Serial.println("V");

    delay(50);

    Serial.print("Current:   ");
    current = sdm.readVal(SDM230_CURRENT);
    Serial.print(current, 2);
//serial display current
    Serial.println("A");

    delay(50);
```

```
     Serial.print("Power:     ");
     power = sdm.readVal(SDM230_POWER);
     Serial.print(power, 2);
//serial display power
     Serial.println("W");

     delay(50);

     Serial.print("Frequency: ");
     frequency = sdm.readVal(SDM230_FREQUENCY);
     Serial.print(frequency, 2);
//serial display frequency
     Serial.println("Hz");

     delay(50);

     Serial.print("Total Active Energy: ");
     energy = sdm.readVal(SDM230_TOTAL_ACTIVE_ENERGY  );
     Serial.print(energy, 2);
//serial display total active energy
     Serial.println("kWh");

   //=============Calculation Tariff Bill===========//
     if (energy <= 200)
//First 200 units
       billamount = 3+ (energy * 0.218);

     else
     if (energy <= 300)
//Next 100 units
       billamount = 3+ 200 * 0.218 + (energy - 200) * 0.334;

     else
     if (energy <= 600)
//Next 300 units
       billamount = 3+ 200 * 0.218 + 100 * 0.334 + (energy - 300) * 
0.516;

     else
     if (energy <= 900)
//Next 300 units
       billamount =3+ 200 * 0.218 + 100 * 0.334 + 300 * 0.516 + 
(energy - 500) * 0.546;

     else
     if (energy > 900)
//Above than 900 units
       billamount =3+ 200 * 0.218 + 100 * 0.334 + 300 * 0.516 + 300 
* 0.546 + (energy -900) * 0.571;

   //=========================================//

   }
```

APPENDIX E SDP2 PROGRESS