SMART ENERGY METER (SEM) BASED ON INTERNET OF THINGS (IOT)

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

Faculty of Electronic and Computer Engineering
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DECLARATION

I declare that this report entitled "SMART ENERGY METER (SEM) BASED ON INTERNET OF THINGS (IOT)" is the result of my own work except for quotes as cited in the references.

Signature :

Author : NUR ATIQAH BINTI ABD RAZAK

Date : 23 JUNE 2021

APPROVAL

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

Signature :

Supervisor Name : IR DR. RIDZA AZRI BIN RAMLEE

Date : 23 JUNE 2021

DEDICATION

The project entitled is “SMART ENERGY METER BASED ON INTERNET oF THINGS (IoT)” is given blessed by Allah S.W.T with the knowledge, strength, and blessing for completing the report. I dedicate this project work to my beloved family, my beloved fiancé who always support and encourage me through my degree journey, my beloved lecturers who do not stop giving knowledge, especially my supervisor, Ir. Dr. Ridza Azri Bin Ramlee because without him early inspiration, coaching and enthusiasm none of this would have happened.

ABSTRACT

Electricity meters are a device that measures the amount of electric consumption at every households. Smart Energy Meter is the project that can help the consumers to monitor billing and manage their data electric consumption easily by using the great development in the field of Internet and technologies. The bill amount can be checked by the users anytime and anywhere. This project also can monitor the pattern of the data electric consumption such as energy consumption on the types of lamp to give awareness to the consumers to save energy. Therefore, this project is able to read the data energy consumption and manage the data in the cloud by using the Internet of Things platform, it also can collect and analysed real-time electric consumption. A microcontroller of energy meters was proposed this system consists of a digital energy meters, NodeMCU ESP8266 (microcontroller), current sensor, and WIFI module that built in the ESP8266. ESP8266 receives the measured data from the sensor and sends calculated data to the IoT part they used a platform called Blynk. This project will help many consumers to reduce their electric consumption and can save the data of the electric consumption in the cloud for future references. For achieving all the objectives of the Bachelor Project, all experiments should be done carefully and linked with reference to the scope of the project.

ABSTRAK

Meter elektrik adalah alat yang mengukur jumlah penggunaan elektrik di setiap premis. Tenaga meter pintar adalah projek yang dapat membantu pengguna memantau penagihan dan menguruskan penggunaan elektrik data mereka dengan mudah dengan menggunakan teknologi yang semakin moden dalam bidang Internet. Jumlah bil dapat diperiksa oleh pengguna pada bila masa dan di mana sahaja. Projek ini juga dapat memantau corak data penggunaan tenaga salahnya adalah penggunaan tenaga terhadap jenis lampu untuk memberi kesedaran kepada pengguna untuk menjimatkan tenaga. Oleh itu, projek ini dapat membaca data penggunaan tenaga dan menguruskan data di dalam web dengan menggunakan kaedah Internet of Things, ia juga dapat mengumpulkan dan menganalisis penggunaan tenaga masa nyata. Projek ini akan membantu banyak pengguna untuk mengurangkan penggunaan tenaga mereka dan dapat menyimpan data penggunaan tenaga di awan untuk rujukan di masa hadapan.

ACKNOWLEDGEMENTS

In the name of Allah, the most beneficent and merciful. It is the deepest gratitude from the Almighty that gives me the strength and ability to done my final year project report. Due to COVID-19 there were many troubles but a very special thanks to my project supervisor, Ir Dr. Ridza Azri Bin Ramlee, who patiently helped me and coordinate my project, particularly in the writing of this report. A most thanks to my family and my fiancé for their efforts to support me in the process of making this project a successful. Other than that, I would like to thanks all my friends who helped me with my end of the final year project.

Thank You.

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LIST OF SYMBOLS AND ABBREVIATIONS

D, d	-	Diameter
F	-	Force
g	-	Gravity = 9.81 m/s
I	-	Moment of inertia
1	-	Length
m	-	Mass
N	-	Rotational velocity
P	-	Pressure
Q	-	Volumetric flow-rate
r	-	Radius
T	-	Torque
Re	-	Reynold number
V	-	Velocity
w	-	Angular velocity
x	-	Displacement
z	-	Height
q	-	Angle

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

For this chapter, the project's introduction, background, problem statement, objective, and scope of the project will be discussed. This project focuses on designing and invents a Smart Energy Meter Based on Internet of Things (IoT). This project proposed to innovate the digital meter energy to smart energy meter that can automatically calculate and save the data in the cloud server based on the Internet of Things (IoT).

1.2 Background

Nowadays, the concept of the Internet of things (IoT) is the most popular communication protocol technology. The Internet of Things environment would allow users to manage, monitor, and enhance types of electronic and electrical equipment using the Internet. Internet of Things network technology also can be interpreted commonly as the link between computers, devices, and humans. Basically, the goal IoT is intended to improve the accessibility of the first edition of the Internet and make it more useful. Furthermore, users of IoT can share both the human-provided data contained in databases systems and also the information given by things in the real world [1]. This network system can be controlled and monitored the equipment or projects that connected to the communications protocols for providing better services through intelligent data processing and analysis to various applications. Therefore, mostly the process of data transfers needs to be done with the help of sensors in the Internet of Things systems. Sensors are an important part to convert raw physical data to digital signals and transfer the data to the microcontroller systems. Other than that, this network system also can operate and process in the real-time framework. Thus, the Internet of Things network will perform the collection, transmission, and analysis of the data on energy consumption between users and the utility's service quick and easy process.

In 2020, the demands of electrical energy for transport, industry, and also for national, rapidly rising in Malaysia. This is due to the large population and increased demand mainly from manufacturing, domestic industries, and commercial. While electricity is an essential source of national growth, the increased electric energy has resulted in high electricity flows, which have a negative impact on Malaysia's municipal growth. In doing so, the Malaysian Government has agreed to reduce greenhouse gas emissions by up to 40% by applying the concept of sustainable energy use and development [2]. This because fossil fuels in general is causes of contributing to carbon (CO_2) and greenhouse gas levels emissions [3]. Hence, the bad impact of global warms on the increased use of fossil fuel resources. Therefore, the efficient uses of energy consumption can help to secure energy sustainability for the next generations.

Tenaga Nasional Berhad (TNB) is the electricity company that supplies electricity to each consumer's premises. It is the multinational power company and the only power company in Peninsular Malaysia. The electricity supplies from the system were divided by 2 parts which is generation and distribution. Generation is the portion of a power plant in which renewable and non-renewable energy generates electricity. There are few sources of renewable energy which is solar, biomass, wind and hydro. Biomass, hydropower and solar are among Malaysia's most important renewables. The electricity generated from renewable energy will increase to 169% by 2040[4] .

Non-renewable energy in Malaysia mostly depends on natural gas, oil, and coal for power generation. In 2015, the World Energy Council reported that natural gas, oil, and coal, accounted for 23.85%, 29.20%, and 32.94% respectively to the global energy consumption. Next, distribution part consist of current transformer (CT) and substation. The function of substation is to distribute the electricity into kilowatt energy meter for each buildings and households. These where the project that will be implement.

Energy meter billing is an important part of energy distribution. In the beginning phase of domestic technology, the electricity supply is totally dependent on conventional meters. Thus, these energy meters play an important role in measurement process of electrical energy consumption in buildings and consumers house. Researchers have found that the traditional metering system is undesirable[5]. One of the reasons which are inaccurate, slow, expensive, and lack of flexibility as well as reliability.

Figure 1.1 shows the traditional energy meter that has been used since the late 19th century. The traditional energy meter will exchange the data between electronic devices in a computerized environment for the production and distribution of electricity. In most traditional energy meters, aluminum discs are used to determine energy consumptions.

Figure 1.1: Traditional Energy Meter

Smart energy meter are an eco-friendly energy meter that is used to measure electrical energy in kWh (kilowatt-hours). Smart energy meter is invent based on IoT system which is the data of energy consumption can be read by the sensors. Storage will save the data of electricity consumed every half an hour in the cloud storage based on IoT platform. The data is automatically calculated and transmitted to the cloud-based on the Internet of Things (IoT) then will be displayed through the smartphone application. From the application, consumers can notice the records intake data of energy consumption in real-time. The consumers be able to monitor and notify the bill in order to analyze the energy consumption pattern and make decisions on how to save the energy.

1.3 Problem Statement

Recently, the number of electricity consumers is increasing rapidly including in Malaysia. Due to that, the consumption patterns lead to increasing demand for energy. Since most of the energy supply comes from fossil fuels, the resource is reducing which can increase the cost of energy. The burning of fossil fuels has also increased the concentration of carbon dioxide in the environment, when the carbon dioxide (co_2) came into the atmosphere that can contribute to global warming.

Due to burned the fossil fuel that a phenomenon which will cause global climate change by increase the temperature or earth, which may modifies the weather balances and ecosystems. Thus, it is also can increase the greenhouse gases in atmosphere and heightening the greenhouse effect. Other than that, the effect of global warming is the glacier and ice are melting massively at the poles. Thus, the sea level was increases at a rate that never known before. Overconsumption is the main reasons of this problem and in order to reduce global warming, smart energy meter can monitor the data energy consumption by the consumers and will give awareness from causing unnecessary energy to be wasted.

Researcher from [6] one of the most important inputs in urbanization, development, and modernisation is energy. Many emerging countries are becoming more energy-intensive as a result of rapid urbanization and population increase. Among the various sectors, the residential and commercial sector is one of the most energy-intensive, contributing for over 14% of overall energy consumption in 2016[6] In different areas of the world, the building sector consumes between 20% and 60% of total energy. [6], [7] Many countries continue to create more electricity using conventional power generation, such as gas and coal, which release greenhouse gases, in order to meet the growing energy demand[3]. Based on the Intergovernmental Panel on Climate Change (IPCC) [6], The global temperature is rising rapidly, due to higher energy consumption in buildings.

As a consequence, energy conservation strategies in the building sector must be defined in order to minimize both energy consumption and emissions. This is critical for achieving the long-term goal of reducing carbon emissions. In most office buildings, energy is used for heating, cooling, lighting, computers, printers, and others[8]. Habib et. [9] examined energy use in industrial facilities and discovered that lighting consumed for 13% of overall energy consumption. Overall, energy consumption in the industrial, residential, and service sectors increased by 0.4%, 0.1%, and 0.9%, respectively, over the world.

One of these proposal is also to replace high energy consumption of light with energy efficient light. The replacement of energy inefficient bulbs with energy efficient bulbs is one of the several strategies for reducing energy consumption. For example, replacing of Incandescent Bulbs with energy-efficient lamps such LED will decreases lighting energy and helps to save energy in the buildings. Researchers [10]have indicated that lighting is a major part of overall power consumption in the country. According to the Swedish Energy Agency report, the lighting contribution in the Sweden is almost 23% of overall power consumption.

Figure 1.2, According to data, lighting consumes 33% of developed sectorial energy resources and contributes to carbon emissions[11]. With such a large amount of energy use and high carbon emission, lighting efficiency should be increased. Thus from an environmental sustainability point of view, the usage of monitoring energy devices such as smart energy meter is beneficial.

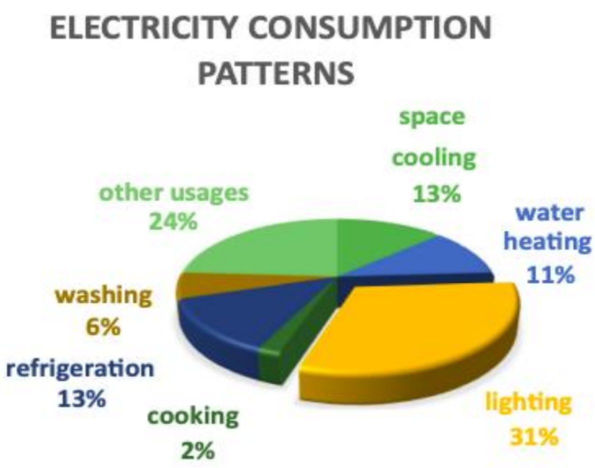

Figure 1.2: Sectorial Electricity Consumption Pattern[11]

1.4 Objective

The Purpose of this project is to design the Smart Energy Meter based on IoT system that able to save the data into the cloud. The objective of this project are :

1. To monitor data of energy consumption in kWh (kilowatt-hours) from Smart Energy Meter.
2. To save the data of energy consumption in the cloud server based on IoT.
3. To analyze the data energy consumption for 3 types of lamps by using Blynk platform.

1.5 Scope of Project

This project is to monitor the data of energy consumption by using smartphone applications based on the Internet of Things (IoT). Smart energy meter can read the amount of energy consumption. Next, the current sensor means for sensing the current flowing at least one of the wires and signaling an electronic trip unit of microcontroller NodeMCU ESP8266. The function of current sensor ACS712 is to measure the current, then transfer the data to the NodeMCU ESP8266 Microcontroller to calculate the data according the coding system.

NodeMCU ESP8266 is a microcontroller that calculate current from the current sensor. The data will save after the calculation into the cloud server and transmit to end-user by using the Wi-Fi module which is also built in the NodeMCU ESP8266 since its low-cost integrated wireless communication module that can be used for innovations in end-point IoT. Then, the signal will be sent to the application in the smartphone if both devices are connected with the Internet.

To monitor and analyses the real-time data energy consumption over the internet, it use the Blynk Application platform to create the interface application based on the Internet of Things (IoT). The data will be analyses by using graph in interval of 1 hours. The graph will represent in power, voltage, current, daily usage, monthly, and amount of usage in Ringgit Malaysia (RM).

1.6 Thesis Outline

Chapter 1 Begins with the project's abstract, background study, problem statement, objective, and scope of the project will be discussed.

Chapter 2 Presents a review of the literature that will discuss about some information related to this project and will be cover basic theories with a principle for a better understanding about this smart energy meter.

Chapter 3 This chapter will be a brief discussion on the methodology and how to innovate smart meter energy based on a review of the literature from chapter two. It will give detailed explanations of the methodology and it will be divided into several sections.

Chapter 4 This chapter discusses the actions taken to achieve the aim of the project. Other than that, to see how the project is being implemented. Each good result and selection made when the project is applied will be discuss in details for each state until the project is successful.

Chapter 5 In this chapter, after the analysis was done, the results were concluded for future research to improve. Finally, recommendations have been made to be used in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The study of the literature review will discuss some information and the different methods of Smart Energy Meter.

2.2 Power Generation

By 2020, Malaysia is heading towards an industrialized nation and net energy importer with demand for electricity that influenced by population growth. It is regarding the future energy resources options because of power generation. The electrical power generation in Malaysia was control by 3 major power producers which is Tenaga Nasional Berhad (TNB) , Sabah Electricity Sdn. Bhd. (SESB) and Sarawak Electricity Supply Corp.(SESCO) [2].

During the period 1994 to 2015, more than 90% of electricity generation in peninsular Malaysia used fossil fuels. In 2015, coal provided up to 41.1% of energy generation while gas accounted for 46.3% (Energy Balance 2016). The outline at the moment, along with the decline national fossil fuel reserves will lead to an increase in Malaysia in importing fossil fuels to the highest market prices and will bear the risk of purchasing energy resources in foreign markets. This is because the reduction of fossil fuels in Malaysia can threaten the development of the country. therefore, it is very important to overcome the country's dependence on fossil fuels.

Basically, the power generation concerns are centered on the security of the fossil fuel of power supply in the power plant. In the power generation the largest percentage is to produced natural gas and coal. However, the trends of current shows that the gas generation is decrease and the energy supply was extended to its limits. Besides, coal is primarily supplied from foreign sources, and it mainly imported from South Africa, Australia and Indonesia. According to UNITEN procedure for the National Conference on Energy Security back 2012 shown that the amount of imported coal increased steadily by 11.9 million tons in 2009 to 19.2 million tons in 2011 [12].

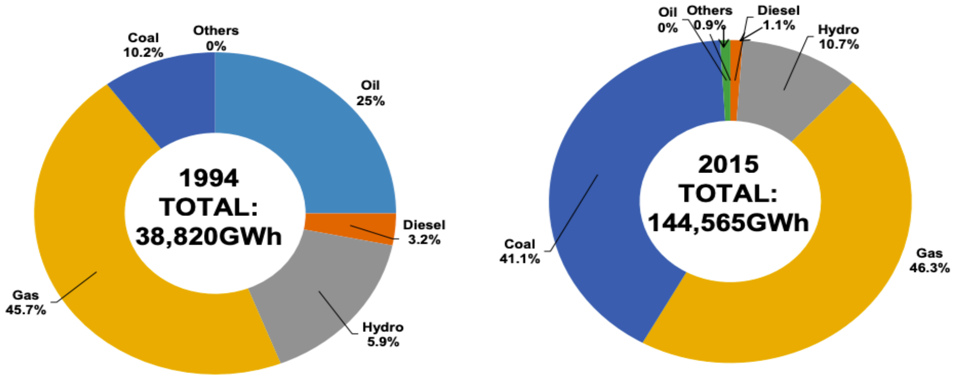

Figure 2.1: Source (Energy Balance 2016) [13]

2.3 Types of Power Generation

The power generation source that existing in Malaysia is divided into 5 types which are oil, coal, natural gas, hydro, and others like solar and biomass. In the coming years, coal should rapidly replace by natural gas in power generation. The efforts were carried out to reduce the heavy dependence on natural gas in the power generation mix by expanding the use of coal.

The result shows in Table 2.1 [14], the total generation mix share of coal was increased from 8.8% in 2000 to 21.8% in 2005 and the natural gas was reduced from 77.0% to 70.2%. Therefore, the share of normal gas within the power generation fuel mix will be decreased from 74% in 2002 to 45% in 2030, whereas the share of coal will increment to 50% in 2030 [14].

Table 2.1: Fuel mix in electricity, 2000-2010[14]

Year	% of total					Total (GWh)
	Oil	Coal	Gas	Hydro	Others	
2000	4.2	8.8	77.0	10.0	0.0	69,280
2005	2.2	21.8	70.2	5.5	0.3	94,299
2010	0.2	36.5	55.9	5.6	1.8	137,909

2.4 Policies Implementation

Malaysia National Energy Policy has introduced 3 principles Fundamental energy objectives to guide the future development of the energy sector. These objectives are :-

The Supply Objective guarantee the provision of sufficient, secure and profitable energy supply services by establishing local energy supply for both non-renewable and renewable energy sources, using low-cost options and a variety of supplies from within and outside Malaysia [15] . It aimed for a power generation mix of oil, gas, hydropower and coal in energy use. Thoroughly, the local resources for these fuels used to improve security of power generation. The electricity sector has shown the greatest success in dependence on fuel oil has been reduced [15].

The Utilizations Objective for promote efficient use of energy and discourage waste and inefficient of energy consumption patterns. The government's primary approach to achieving this aimed to depend largely on the energy industry and consumers to work efficient in the energy utilization and consumption of energy through the execution of awareness programs [15]. The demand of management initiatives for utilities, in particular through tariff incentives, have had some effects on efficient energy utilization and consumption. Co-generation plants are also encouraged to promote an efficient way that generating thermal energy and electricity from each energy source.

The Environmental Objective to reduce negative effects of energy production, transportation, conversion, utilization and energy consumption on the environment. The environmental objective is under severe strain from the accelerated growth of energy demand in Malaysia. Power generation has a strong effect on every level of environmental impact assessment such as utilizations of energy resources, power supply, and energy demand levels. In order to overcome that problem, The Ministry of Energy, Green Technology and Water (KeTTHA) the government in promoting renewable energy and the efficient use of energy as an energy source [12], [15].

New roles and responsibilities have been added to KeTTHA for planning, policies, and program development of green technology by showing the government's determination to lead a new initiative in addresses global issues such as environmental pollution, global warming, and reduction of natural resources[12], [15].

2.5 History of Kilowatt Meter

In 1881, Thomas Alva Edison who introduced the electric meter was patented by using the electromechanically impact of current. It formed an electrolytic cell in which the measured copper strip was installed specifically at the start of the billing period. The meters have been calibrated to generate bills. Edison also produced a motor type meter but chose the chemical meter due to his interest in chemistry[16]. Figure 2.2 below shown the components in the electrochemical meter that patented by Thomas Alva Edison.

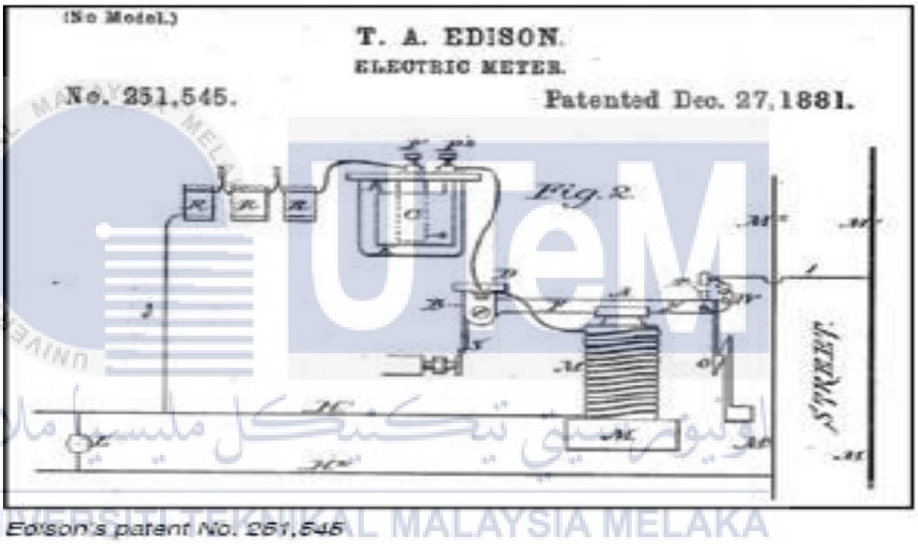

Figure 2.2: Edison's patent Electric Meter[16]

Around 1930, the Hungarian Ottó Titusz Bláthy are inventor of the induction electric meter and co-inventor of the transformer. Through the invention of the dynamo (Anyos Jedlik in 1861, Werner von Siemens in 1867), it was possible to produce electricity in significant quantities[16]. Rather than consistency in nature, meters were built by separate vendors (or sometimes multiple variations of the same models) until the mid-1930s.

In the late 1930s, considerable improvement was needed to solve a problem that became apparent after the construction of meters in the outdoors rural areas. This was resolved by replacing stainless steel magnets with electromagnet from Alnico, which did a very decent job of maintaining their effectiveness. By placing its chrome-plated steel magnets heavily on copper, Westinghouse implemented a different approach and continued this practice until 1954 [16].

Over the next years, there have been many improvements: reduction in weight and dimensions, load range extension, compensation for power factor changes, voltage and temperature, friction removal by replacing the pivoting bearings with ball rollers, and later by magnet and double jewel bearings. Bearings and long-term stability improved by improved brake magnets, removing and registering bearing oil. In the early 20th century, The measuring systems was arranged on one, two or three discs for develop three phase induction meters [16]. Today components with complex functions are based in digital signal processing on the latest electronic technology, most of them algorithms are performed in firmware.

2.6 Types of Kilowatt Meter

Energy meters or kilowatt hours meters are categorized into several of criteria, for example: an analogue or digital display; method of measurement point: grid, secondary transmission; main and local distribution; end applications: residential, industrial and commercial; and technical: three phases, single phase, and precision class meters. The three principal meters types are electromechanical induction, electronic energy and smart meters [17].

1) Electromechanical Induction
2) Electronic Energy Meters
3) Smart Energy Meters

2.6.1 Electromechanical Induction

The electromechanical meter induction model is a single phase induction type. It consists of a revolving aluminum disk placed between two electromagnets on a shaft. Hence, this electromagnet called as shunt magnet. The rotational speed of the disc is proportional to electricity, and the counter mechanism and gears are used to combine this power. However, this type of meter is created quickly and the precision is much lower due to cracks and other external fields. In the other hand, a big issue with these counter forms is that they are vulnerable to abuse. These are frequently used in domestic and commercial applications [17], [18].

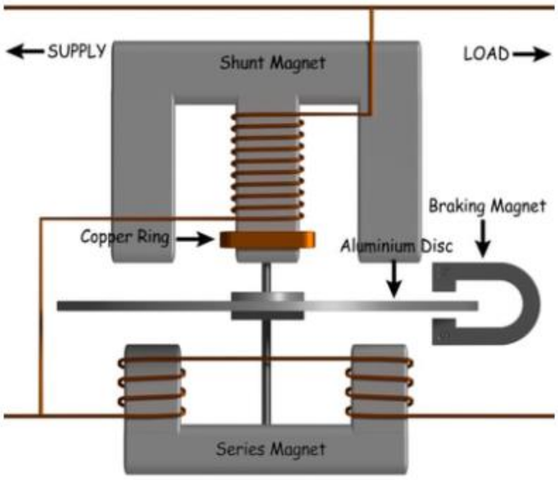

Figure 2.3: Electromechanical Induction Watt Hour Meter[19]

2.6.2 Electronic Energy Meter

Electronic Energy Meter are reasonably precise and effective measurement system types comparison to traditional mechanical meters. Hence, it uses insufficient power and begins calculating when it is attached to load instantaneously. These meters may be digital or analogue. Power is transformed in analogue meters to relative frequency or pulse frequency and it integrated into counters. Therefore, in digital electric meter capacity, a high-end processor is directly tested. Power is incorporated into logical circuits to receive energy as well as to monitor and calibrate. It is then translated to pulse rate or frequency [17]. Figure 2.4 shown electronic energy meter which might be in digital or analog system that also known as "Static Energy Meter".

Figure 2.4: Electronic Energy Meters[20]

2.6.3 Smart Energy Meter

Smart Energy Meter is an innovative metering technology that includes read, process and send data to consumers using smart meters. Basically, this smart energy meter is to monitors electricity consumption, transfers supply to consumers remotely, and thereby manages the maximum consumption of electricity. Next, for increased efficiency, the smart metering device employs an advanced metering infrastructure of technologies for great implementation [17].

Moreover, this system is efficient to communicate in dual directions and it also can send the data of energy consumption to the utilities company and consumers. These smart energy meters will reduce the necessity to go visit the consumer's households while taking or reading the monthly bill.

In these smart meters, modems are used to facilitate communication systems like telephones, cordless, fiber optic cables, and power lines. Moreover, the another advantages of smart meters is to completely prevent tampering with the energy meter when it's possible to use electricity illegally [17]. Figure 2.5 below shown the smart energy meters used in Europe that has capability to reduce load, connect and disconnect remotely also can interface to water and gas meters.

Figure 2.5: Smart Energy Meters[21]

2.7 Current Sensor

Nowadays, current information is increasingly essential for digital monitoring or control purposes in digital form. This necessarily requires the acquisition of an analog-to-digital converter's output signal from a specific current sensing technique. Specific dc and ac current sensors are needed by the automotive, electrical and chemical industries for measuring power and energy, as well as in a variety of other applications. The study in [22] provides a brief overview of common methods of measuring electric current before going in depth further into relatively new types of current sensors. Hall Effect sensors with field power systems, are examples of these.

2.7.1 Magnetic Field Sensors

1) Hall Effect Sensor

The Hall Effect Sensor is one of the most common magnetic field sensors. This sensor is based on the Hall Effect, which was discovered by Edwin Hall in 1879 [23]. Based on Figure 2.6, he discovered that when a current ***I*** flows through a thin sheet of conductive material penetrated by a magnetic flux density ***B***, a voltage ***v*** perpendicular to both the current and field is produced [22], [23].

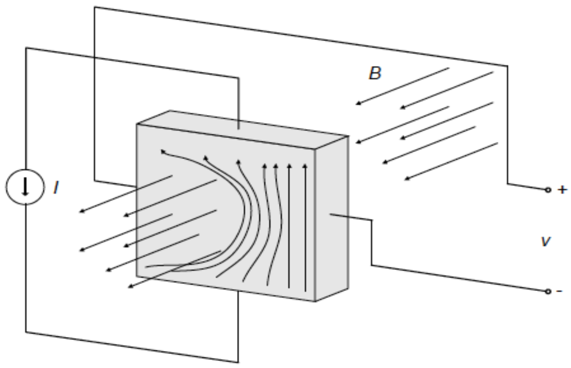

Figure 2.6: Lorentz Law Principle[24]

According to the Lorentz law, an external Magnetic Field *B* is applied by a fluxing current *I* through a thin layer of conducting material. As a rule, the number of conductive carriers is higher at one side of the layer, resulting in a voltage potential *v* that is equal to the magnetic field *B*[24].

$$v = \frac{IB}{nqd}, \quad (1)$$

where q is the charge of the current carrier, n is the carrier density, and d is the layer thickness. This equation applies to materials that electrical conductivity is mediated by either positive or negative charge carriers[22], [23]. Hence, this is accurate for conductors, but a more complicated coherence occurs in semiconductors. Current emitters are used in some Hall Effect current sensors to maximize the measured field but do not fully cover the measured current[23]. In this case the danger of saturation is much lower. However, the direction of the measured conductor should be specified, and external fields and currents should be prevented by other means.

2.7.2 Brief Overview of ACS712 Current Sensor

Sensing and regulation of current flow is important in a wide range of applications, such as overcurrent safety circuits, battery chargers, switching power supplies, optical power meters, programmable current sources, and so on. One of the simplest methods of detecting current is that the voltage drop between the load and the ground is measured in small amounts (also called shunt resistance) and is in fact directly proportional to the current flowing. While this method is simple to use, it may not be very reliable since the shunt resistance value changes significantly with temperature, which is not constant due to Joule heating. Also, this simple technique does not provide isolation between the load and the current sense unit, which is desirable in applications involving high voltage loads.

2.7.3 Theory of ACS712 Current Sensor

The Allergo ACS712 current sensor is based on the Hall effect theorem, which was discovered by Dr. Edwin Hall in 1879[25]. When a current-carrying conductor is mounted in a magnetic field, a voltage is generated across its surfaces perpendicular to the current and magnetic field directions. It is shown in the Figure 2.7 below. A thin sheet of semiconductor material (referred to as a Hall element) carries a current (I) and is positioned in a magnetic field (B) that is perpendicular to the direction of current flow. Due to the Lorentz law, the current distribution around the Hall element is no longer uniform, and hence a potential difference is formed around its edges perpendicular to the current and field directions[25]. This voltage is known as Hall voltage, and its average value is a few microvolts. The magnitudes of I and B are directly proportional to the Hall voltage. So the measured hall voltage can be used for estimating the others if one (I and B) is known[25].

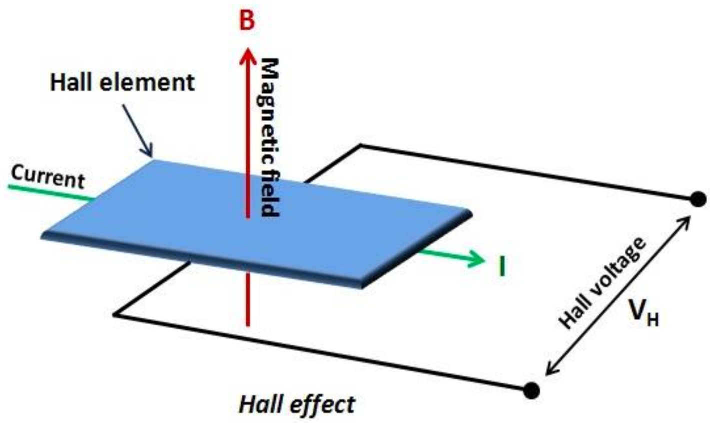

Figure 2.7: Principle of Hall effect [26]

The ACS712 is contained in a small SOIC8 surface mount[26], [27]. It is composed of an accurate, linear, low offset Hall sensor circuit with a copper-level route near the die surface. A magnetic field, measured by the integrated element Hall, is formed when current is delivered through the copper conductor. The magnetic field magnitude is directly proportional to the amount of the current through the conduction path which gives the output Hall voltage a linear relationship to the input conduction current. The induced hall voltages are stabilised by the built in signal conditioner and filter circuit, to be measured through a microcontroller ADC channel.

2.8 Internet of Things (IoT)

IoT is a system in the real world and sensor that measure connected to the cloud by wireless or wired network connections. The sensor also can connected with many types of communication protocol such as Wi-Fi, RFID and Bluetooth. The sensors can also have wide-space properties like GSM, GPRS, 3G, and LTE[17]. Generally, this system might consist of concentrators to send and receive real time data from the sensors or smart devices and also can include the message decoder to receive the data consisting the real time data that store the data on the cloud web.

IoT systems might include a perseverance components to store the real time data which can be used to store value data in the database system. IoT systems is to build and dispose designed Internet of Things applications and also can applies the sciences of large data, advance analytics, and cloud computing. Thus, the product is to redesigned for networking and low cost sensors, offering a demand opportunity for smart devices, a new generation of smart applications and a revolution of re-engineering business processes [28].

2.9 Electrical Measurement

The current flowing from the major source is AC (alternating current), Figure 2.8 shown which forms a sine wave there since the RMS (root mean square) value has to be measured[29]. Therefore, the formula to calculate the RMS value is to measure the peak to peak voltage first, then divide it by 2 to get the peak of voltage and multiply the peak voltage by 0.707.

$$Vrms = Peak\ Voltage*0.707 \quad (2)$$

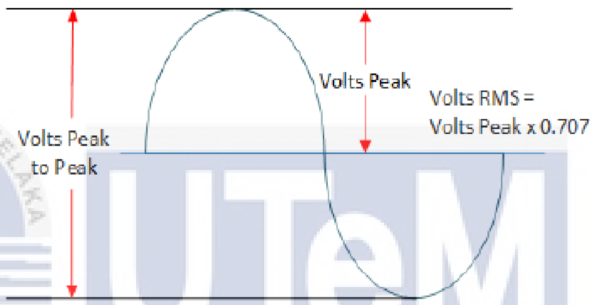

Figure 2.8: Calculation RMS of Current Sensor[29]

Otherwise, to get Irms value the Vrms need to multiply with the sensitivity value. Sensitivity value for current sensor ACS712 30A module is 66MV/A.

$$Irms = Vrms*sensitivity \quad (3)$$

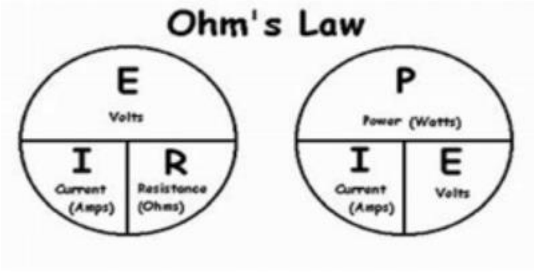

Figure 2.9: Formula of Ohm's Law[29]

From figure 2.9 above shown the formula of Ohm's Law, to calculate the power can use which is *P=IV*. The unit of power is watt or kW.

$$Power = current \ x \ voltage \quad (4)$$

In order to calculate energy consumption of energy meter the power calculated by time in hours. The energy was calculated in kilowatt hours (kWh)

$$Energy = power \ x \ time \quad (5)$$

The tariff of energy usually was calculate in unit 1000 unit per 1kW and the tariff per unit was set by utilities[29]. Hence, to get the total bill of energy consumption need to multiply hour with tariff per unit set and divide by unit consumed.

$$Tarif/hour = units \ consumed \ / \ hour \ x \ tariff \ in \ ringgit \ Malaysia \ (MYR) \quad (6)$$

2.10 Previous Research

[30]**Darshan Iyer N, Dr. KA Radhakrishna Rao M Tech. student, Dept. of ECE ,PES College of Engineering, Mandya, Karnataka, India, " IoT Based Energy Meter Reading, Theft Detection and Disconnection using PLC modem and Power optimization" , Vol. 4, Issue 7, July 2015.**

In this research paper was describes the microcontroller PIC18F46k22 is based on the concept and application of a smart meters using the IoT concept. The proposed system design eliminates human implication in the maintenance of billing electricity. The customer has to get the utilization of electricity on time, just in case they cannot pay, the transmission of electricity are often disabled independent from the cloud host. The user can monitor the facility consumption of the units from an internet page by providing the IP address of the device. When the counter tampering takes place inside the energy meter, the theft detection unit connected to the energy meter will notify the commercial side and can send theft detection data through the PLC modem and it will be displayed on the corporate side within the terminal window. The Wi-Fi unit performs the IoT operation by sending the energy meter data to an internet page accessible via the IP address.

[31]**Indra, Win & Morad, Fatimah & Mohd Yusof, Norfadzlia & Che Aziz, siti asma. (2018). GSM-Based Smart Energy Meter with Arduino Uno. International Journal of Applied Engineering Research. 13.**

This research paper designed the Smart Energy Meter that users can monitor their energy consumption bill at anytime, anywhere via Short Message Services (SMS) by using mobile phone. The interface between the energy meter and the Global System for Mobile Communication (GSM) is Arduino Uno which that is the main controller in their project. Moreover, the GSM module was connects with energy meter to the mobile phone of users. The DS1307 Real Time Clock (RTC) was used to calculate the real time and store the usage in the EEPROM. The program was developed in C language with Arduino syntax in Arduino IDE. The proposed system has demonstrated its ability to check current usage (bill), notify, restore usage (bill) successfully when it reaches the limit, only by accessing GSM mobile phones.

[32]**Z. Sultan, et al. has made a research about GSM based smart wireless controlled digital energy meter and had been published in 6th IEEE International Conference on Engineering Technologies and Applied Sciences (ICETAS), 2019.**

In this paper, researcher was proposed smart meter that is offered with an automated prepaid billing system is a mechanism that makes electricity billing easy to use. The smart meter was includes an energy meter, a Global System for mobile Communication (GSM) modem, a microcontroller (PIC18F452), and 16 X 2 LCD is used to display data that transmit from microcontroller[30]. However, by using GSM module the costing of sending invoice by SMS to consumers quite expensive rather than using Wi-Fi module and it also need to fixed the GSM number.

2.11 Summary of Previous Research

According to the previous research, the most of the energy meters based on IoT designed by different authors. Table 2.2 shows a list of devices used in others projects.

Table 2.2: List of Related Work

Related Work [Reference]	**Application**	**Microcontroller**	**Monitoring System**
Z. Sultan, et al [29]	GSM based smart wireless controlled digital energy meter	PIC18F452	LCD Display
Indra, et al [28]	GSM-Based Smart Energy Meter with Arduino Uno	Arduino Uno	Short Message Services By Mobile Phone
Darshan Iyer N, et al [27]	IoT Based Energy Meter Reading, Theft Detection and Disconnection using PLC modem and Power optimization	PIC18F46k22	Web Page and LCD

2.12 Microcontroller

This system was design the smart meter with the microcontroller PIC18F452 which is discussed in [30], [32] that connect different modules and sensors, so that can communicate with each other. It is seen in their work that an EEPROM (Electrically Erasable Programmable Read Only Memory) is linked to a microcontroller as it is a non-volatile memory. memory that is often used to store small amounts of data in electronic devices.

Moreover, this microcontroller was embedded with RTC (Real Time Clocking) to keep status of the current time. However, this microcontroller only uses 8-bits which is has slow duty cycles and it has 40 pins with five input/output ports that a lot of pins that not to used.

Therefore, when compared with PIC 18 controllers. This proposed project using NodeMCU ESP8266 is very simple microcontroller. In most cases, NodeMCU ESP8266 uses built-in library features, and most significantly, all base programmed are accessible such as built in Wi-Fi module. Furthermore, in terms of price the module is extremely inexpensive. As a result, it is possible to replace new technology equipment with a low-cost solution for storing data to the cloud and provide monitoring systems[33], [34].

2.13 Monitoring System

According to Z. Sultan et al. in 2019, was proposed 16 X 2 LCD discussed in [32] is used to display the data that provided by microcontroller. The LCD panel is an interactive monitor module which contains a variety of applications. 16*2 view indicates that 16 characters per line can be shown, and there are 2 such lines [32], [35]. Each character in this LCD is shown in a 5*7 pixel matrix[35]. Otherwise, the monitoring system in [30]was used webpage and LCD which is it can monitor in two way condition.

However, while use webpage it takes a lot of time to create anything that even resembles a webpage. Moreover, webpage also can be hacked on contains of a viruses and the other reason that webpage not so convenient is cannot bring laptop or pc anywhere anytime. For the LCD also has a limitation such as it not easy to access at everywhere and anytime and it also have a limited viewing because of the aspect ratio and resolution are fixed. Therefore, this project proposed for using Blynk application to display the data on the smartphone based on IoT. Hence, it will make consumers more easy to access and monitor the energy consumption.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter will be discussed on methodology about the flow of how the project work and how to create a prototype of smart meter energy based on IoT according to literature review from the chapter two. It will give a detail explanations about the methodology and will divided into several sections.

3.2 Process Flow Chart

The flow chart in Figure 3.1 shown starts with the power supply from the energy meter (kWh), The current sensor will detect the current from the load that connected with Distribution Board (DB). When the current sensor successfully reads the data from the load, current sensor will initialized with NodeMCU. Then, NodeMCU will calculate the data according to the programming Arduino IDE. Next, the data will be transfer by Wi-Fi that also built in at the same microcontroller in order to create wireless communication between the device and customers.

Besides, after all the data has been read the data will be analyses based on the energy consumption of the lamps. Smart energy meter can shows the power in watts, billing data shows the cost of the load electric consumption and the total power that will show watts of load. The power usage will be analyses daily and monthly then it will calculated into Malaysia Ringgit (MYR) that will display in application. Therefore, The consumers can easily manage and monitor their energy consumption all over the place.

For the analysis, the types of lamps energy consumption will be analyses in an hours. A part of that 3 types of lamps will be chosen, which is incandescent light bulb, fluorescent lamp and LED (Light Emitting Diode) light bulb to test their total energy consumption and efficiency. The interface for this project is to innovate the Blynk application based on the IoT system and the data will be display on the smartphone. But if there have any error or problem with this system, must go back through every step to troubleshooting the problem. Lastly, when the project is successfully integrated it can be said the project is done.

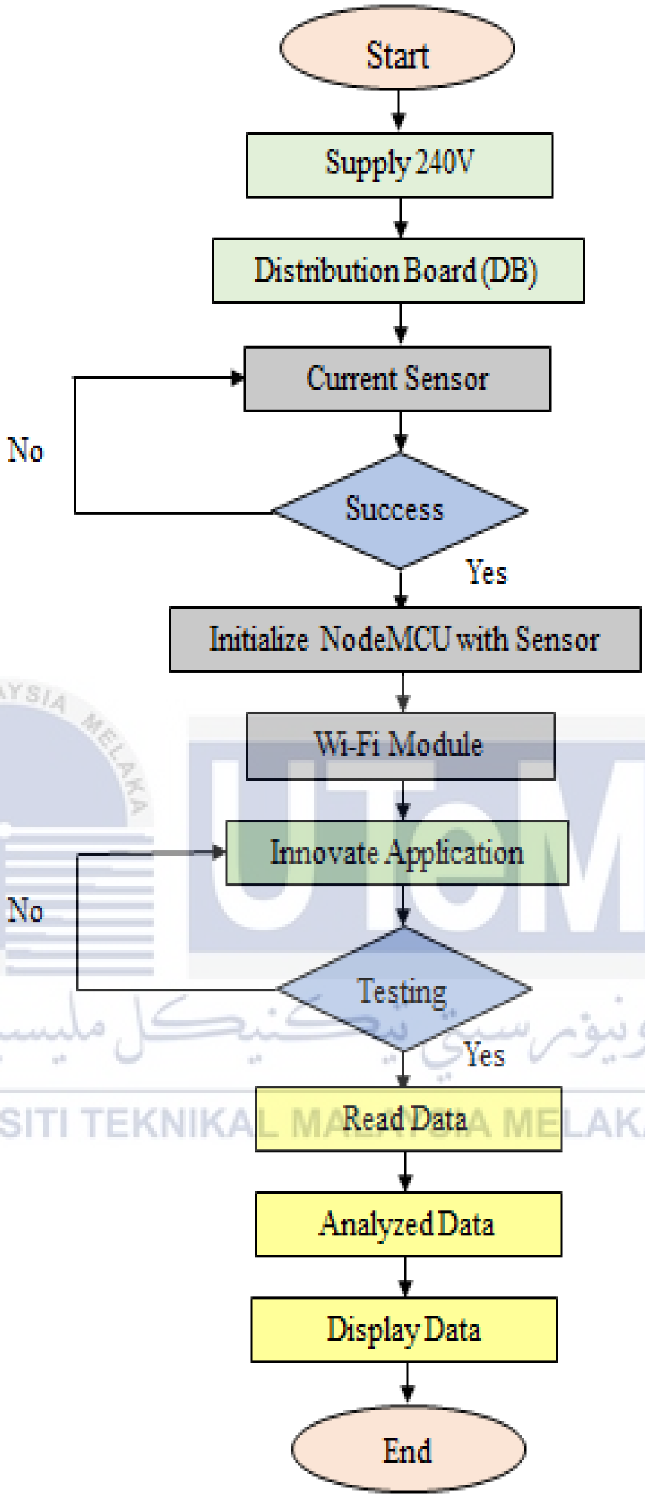

Figure 3.1: Flow Chart

3.3 Component

Smart energy meter need several component required to complete this project. The main purpose of this project are to monitor the energy consumption types of lamp, it is because lighting also consumes much energy so that this project can analyses which lamps is more energy efficiency. Below is all the component that used and the total cost of this project are in table 3.1:

Table 3.1: Cost of Project

No	Component	Quantity	Price
1.	NodeMCU ESP8266	1	RM 22.00
2.	Current Sensor ACS712 30A	1	RM 13.00
3.	UV PCB Board	1	RM 15.00
4.	Male to Female Jumper Wires	40	RM 2.90
5.	Lamp Holder	1	RM 6.50
6.	USB Cable	1	RM 10.00
7.	Plactic Box	1	RM 5.00
8.	40 pin Single Row Female Pin Header	1	RM 1.20
9.	PVC Casing Box	1	RM 14.15
10.	2 Gang 13A Wall Plug Socket	1	RM 9.97
11.	ELCB and MCB	1	RM 44.50
12.	Type G 13A Plug	1	RM 2.50
Total Cost = RM 146.72			

3.3.1 NodeMCU ESP8266

Figure 3.2 shown the NodeMCU is an open source Internet of Things network. It includes firmware based on the ESP8266 Wi-Fi SOC from Espressif Systems, as well as hardware based on the ESP-12 board. By design, the name "Node MCU" applies to the firmware instead of the development kits . Since NodeMCU is an open-source framework, its hardware architecture is available for editing, modifying, and development. The ESP8266 Wi-Fi-enabled chip is included in the NodeMCU Dev Kit/board. The ESP8266 is a low-cost Wi-Fi chip developed by Espressif Systems that uses the TCP/IP protocol and it easy to configure.

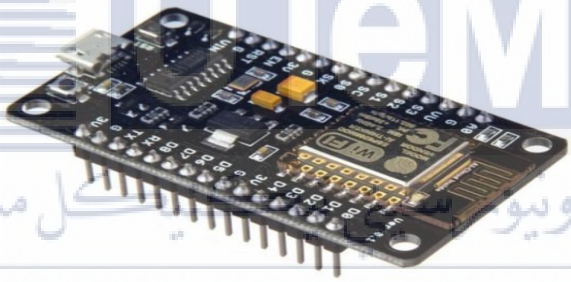

Figure 3.2: NodeMCU ESP8266

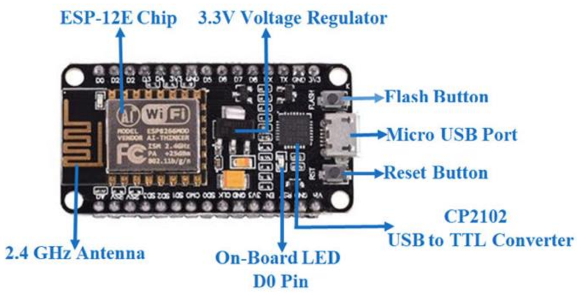

Figure 3.3: Features of NodeMCU ESP8266

3.3.2 Currenr Sensor ACS712

The Allegro® ACS712 offers cost-effective and reliable solutions for AC or DC current sensing in automotive, commercial and connectivity systems. The kit of devices makes it easy for the consumer to implement. The system is not for automotive purposes. The unit consists of a reliable, low offset, linear hall circuit with a copper route near the die surface. The applied current flows through this copper route creates a magnetic field which is transformed into equivalent voltage by the Hall IC. The precision of the system is optimized by strongly observing the magnetic signal to the Hall transducer. The low offset, stabilized BiCMOS Hall IC, programmed for precision after shipping, offers an accurate, proportional voltage.

Therefore, as a growing current flows across the primary copper route (from pins 1 and 2 to pins 3 and 4), a path used for current sampling, the system output has a positive pitch (>VIOUT(Q). This conductive route has a normal internal resistance of 1, 2 mΩ that offering low power loss. Figure 3.4 and 3.5 shown the Current Sensor ACS712 and the pin diagram that available in an 8-lead SOIC package.

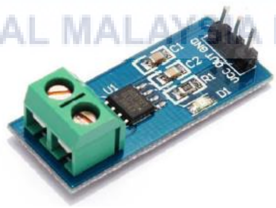

Figure 3.4: Current Sensor

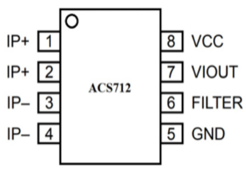

Figure 3.5: Current Sensor Pin Diagram

3.3.3 Breadboard

Figure 3.6 shows a breadboard is a block for prototyping electronics. Generally, it was literally a breadboard, a polished piece of wood used to cut bread. In the 1970s, the solder less breadboard (also known as a patch board, a terminal board) became available and today the term "breadboard" is commonly used to refer to them. Because the seamless breadboard requires no welding, it is reusable. This makes it easy to use for creating temporary prototypes and experimenting with circuit design. For this reason, built-in breadboards are also extremely popular with students and in tech education.

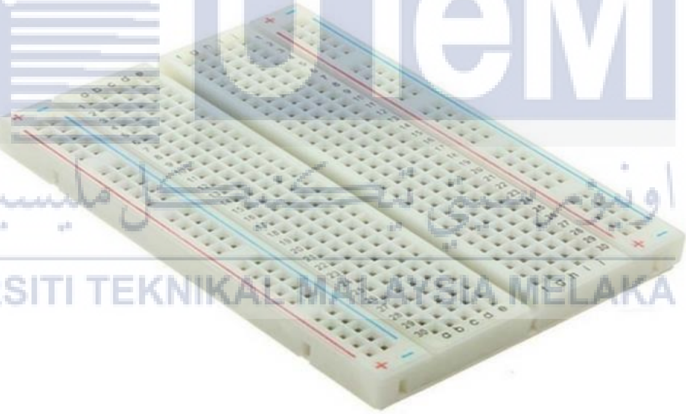

Figure 3.6: Breadboard

3.3.4 USB Cable and Jumper Wire

The USB cable in this project as the method to upload my coding to the NodeMCU board. Next, Jumper wire is an electrical wire in a cable with a connector or wire with pin at each of the end which is used to interconnect the components on the breadboard as well as prototype without soldering. There are different types of connecting cables. In this project, the jumper wire is used to connect each component in the transmitter and receiver to the circuit that can work. Other than that, male to female, male to male and female to female jumper wires are used to connect the pin between NodeMCU and current sensor so that the information can be transferred.

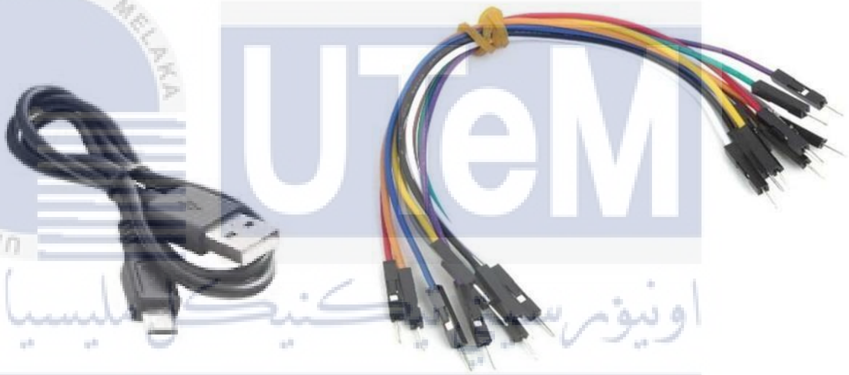

Figure 3.7: USB cable and Jumper wires

3.4 Hardware Development

In this section will discussed about how the hardware of smart energy meter was setup. There were several part in this hardware development which power supply, control system and lamp tester. The most important part in this project is control system.

3.4.1 Power Supply

13A Type G plug is used in this project, Figure 3.8 shown the wiring of the plug that consist of 2 wires which is black is Neutral and Red is Live. Then, the plug is connected with Earth Leakage Circuit Breaker (ELCB) and specific Miniature Circuit Breaker (MCB). For safety purposes the ELCB was used in this project because to avoid over current from the main supply.

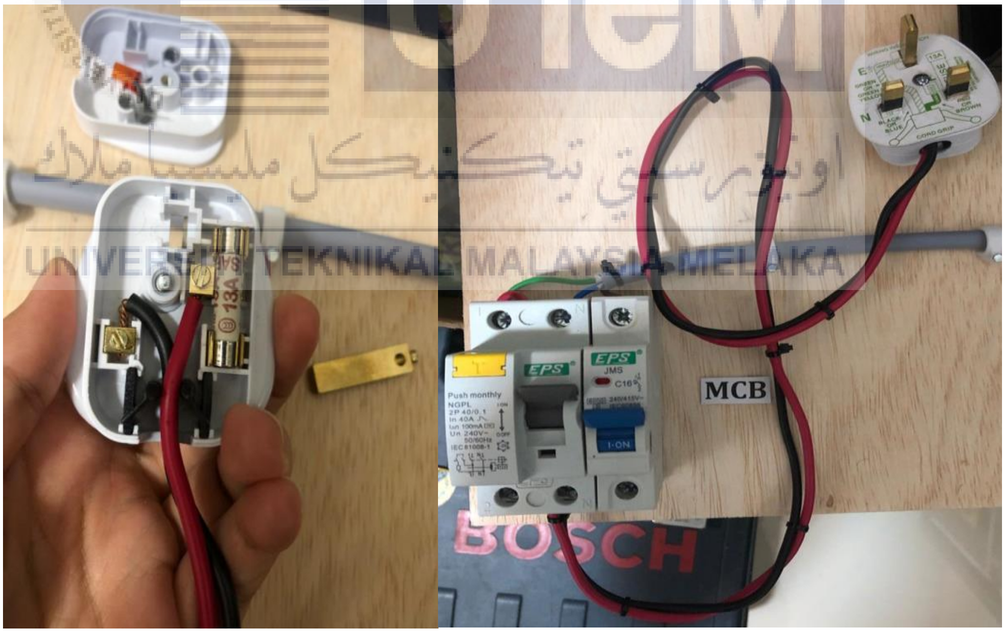

Figure 3.8: 13A Type G Plug and MCB Connection

3.4.2 Lamp Tester

Based on Figure 3.9 and 3.10, from the power supply live and neutral wires must be connected with both 13A sockets. Then, the fluorescent lamp was connected with one of the 13A socket for testing. Meanwhile, for the other socket is connect with copper screw lamp holder type.

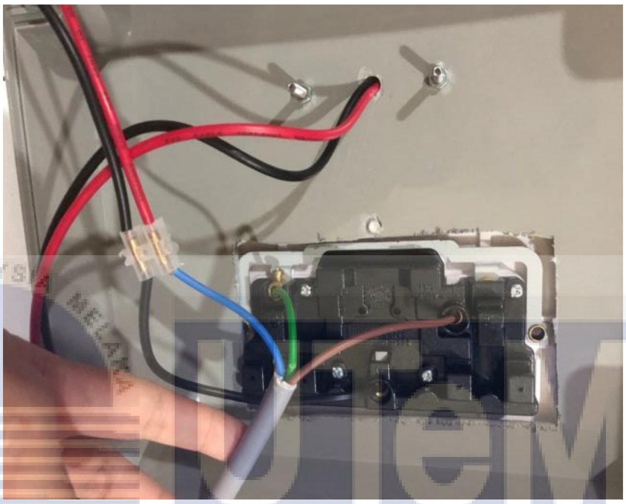

Figure 3.9: Wiring 13A Socket

Figure 3.10: 13A Socket and Lamp Holder

3.4.3 Control System

Control system is the most important part in this smart energy meter project. This is because it consist of NodeMCU and Current Sensor ACS712 30A. Figure 3.11 shown the connection between NodeMCU and the current sensor. Next, for the input of current sensor have 3 pin which is ground, output, and VCC. The VCC pin was connected with 3V of the NodeMCU, the ground of current sensor connect to the ground NodeMCU and lastly the output of the sensor connect to the A0 of NodeMCU which is also called as analog input pin. Meanwhile, positive and negative current sensor output will connect with series connection at live of power supply to read the current from lamp.

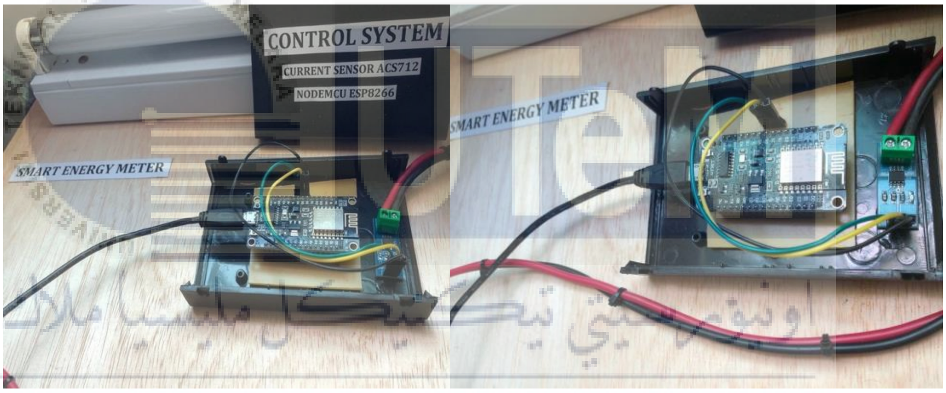

Figure 3.11: NodeMCU and Current Sensor ACS712

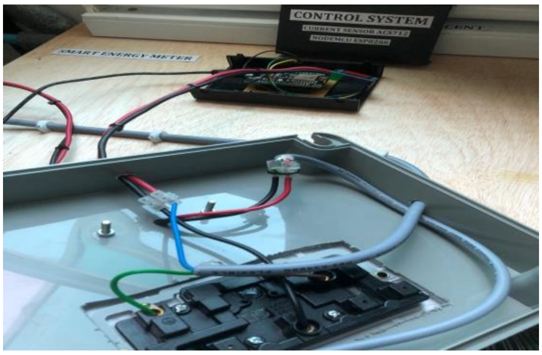

Figure 3.12: Wiring of Current Sensor ACS712

3.5 Software

3.5.1 Arduino IDE

The Arduino Integrated Development Environment or Arduino Software (IDE) is software for writing code to the NodeMCU microcontroller. Therefore, The NodeMCU Development Board can be easily programmed with Arduino IDE since it is easy to use. In order to program this project, the Arduino IDE, a USB cable, and the NodeMCU board itself are all that is needed.

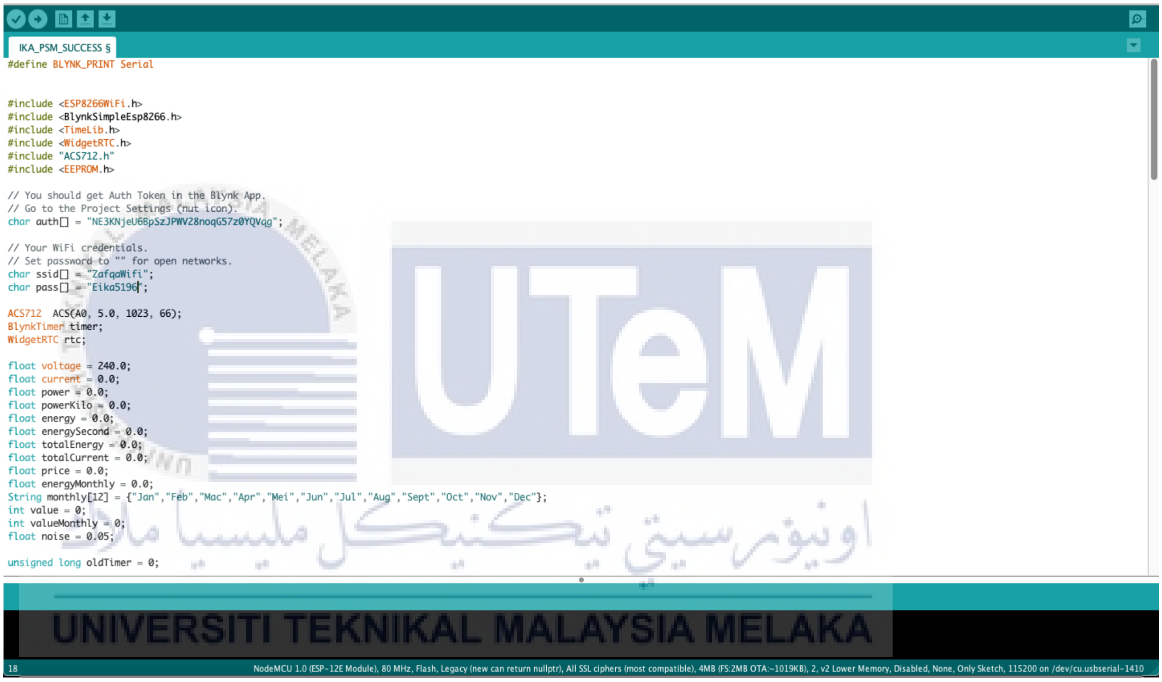

Figure 3.13: Arduino IDE Interface

3.5.2 Cloud Server IoT Platform

Figure 3.14 shown the Blynk IoT Platform is used in the development of this system to display the data transferred from the Wi-Fi in microcontroller of this project. On the dashboard, users can check the current in ampere, billing data shows the cost of the energy consumption and the power that will show watts of load by looking at the dashboard of this system through their mobile devices using the Internet. The energy consumption will calculated by the sensors and the sensors will trigger the NodeMCU to transfer the data to the dashboard via the Internet. In this process, Wi-Fi is required for data transmission.

Figure 3.14: Blynk Apps Interface

3.6 Software Development

3.6.1 Coding of Project

In this section will shows the coding for this project in programming the NodeMCU ESP8266. The main aim of writing this coding is to allow the NodeMCU to communicate with the current sensor in order to calculate the power and total energy consumption and display to the Blynk application.

3.6.2 Setting Up Blynk Application

Blynk is a smartphone application that works on Android and iOS smartphones that allows users to operate any IoT-based application. It enables to design user IoT application's graphical user interface. Here will display the smart energy meter on Blynk Application. Below is the step to setup the Blynk Application:

1. Download and install the Blynk apps on the smartphone.
2. Create a new project on the dashboard then select NodeMCU and Wifi connection.
3. Get the token from Blynk apps and choose the widget for the project and then assign the variable as per code then email the authentication code to the email that been registered.
4. Figure 3.15 shows the authentication code will send to mail. Copy the authentication code and used in the coding programming part.

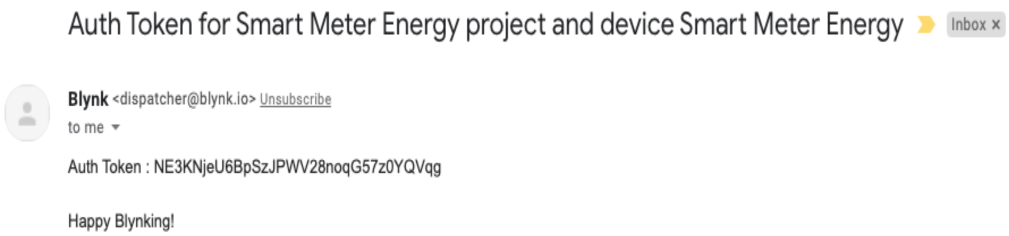

Figure 3.15: Authentication Token

3.6.3 Library Installation

This part explained that need to download the library before program the code in the Arduino IDE. First need to download NodeMCU library as a microcontroller which is ESP8266. Next, also need to download current sensor ACS712 library. The current sensor measures all of the current input channels, calculates a real average quantity for each, and then notifies the sketch that the measurements are ready to be read and processed. Lastly, Blynk is the most widely used Internet of Things platform for connecting any hardware to the cloud, creating apps to control it, and scaling up any deployed devices. With the Blynk Library, users may link over 400 hardware models to the Blynk Cloud.

3.6.4 Source Code of Smart Energy Meter

Figure 3.16 below shows, start with the necessary libraries for ESP8266 Board. Then, ACS712 is in charge of retrieving data from both sensors and calculating current and power values using NodeMCU. The software is integrated with the Blynk apps using BlynkSimpleEsp8266. The energy meter is designed, current sensor calibration factors are established for variant 30A with the sensitivity is 66mV. After that, the Blynk timer object is constructed to manage data transferring to the Blynk apps. Then, define the local Wi-Fi network's SSID and password, as well as the authentication code from the Blynk. Next, define all the variable of formula that used in this project and the values from the sensors are being retrieved & calculated. Using ACS712 the current, power, total energy, are being calculated. Furthermore, use Blynk.virtualWrite to send the data to Blynk based on the virtual pins set. The function of (millis(0) – oldTimer > 1000) is to run in 1 second for the loop and this going to read the value from sensor and calculate the max value and the min value. So, basically in that 1 second it going to store the min value of the current and the max value of the current . Lastly, to get the result it is the different between the max value and min value and all this calculation need to convert ADC value.

IKA_PSM_SUCCESS §

```
#define BLYNK_PRINT Serial


#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
#include <TimeLib.h>
#include <WidgetRTC.h>
#include "ACS712.h"
#include <EEPROM.h>

// You should get Auth Token in the Blynk App.
// Go to the Project Settings (nut icon).
char auth[] = "NE3KNjeU6BpSzJPWV28noqG57z0YQVqg";

// Your WiFi credentials.
// Set password to "" for open networks.
char ssid[] = "Narvin";
char pass[] = "rehan7361";

ACS712  ACS(A0, 5.0, 1023, 66);
BlynkTimer timer;
WidgetRTC rtc;

float voltage = 240.0;
float current = 0.0;
float power = 0.0;
float powerKilo = 0.0;
float energy = 0.0;
float energySecond = 0.0;
float totalEnergy = 0.0;
float totalCurrent = 0.0;
float price = 0.0;
float energyMonthly = 0.0;
String monthly[12] = {"Jan","Feb","Mac","Apr","Mei","Jun","Jul","Aug","Sept","Oct","Nov","Dec"};
int value = 0;
int valueMonthly = 0;
float noise = 0.055;

unsigned long oldTimer = 0;



float arrayCurrent[11];
int addr = 0;
int addrMonth = 10;

void myTimerEvent() {
  String currentTime = String(hour()) + ":" + minute() + ":" + second();
  String currentDate = String(day()) + "/" + month() + "/" + year();
  price = energyMonthly * 0.21807;

  if (current < noise) {
    Blynk.virtualWrite(V0, 0);
    Blynk.virtualWrite(V1, 0);
    Blynk.virtualWrite(V2, 0);
    Blynk.virtualWrite(V3, String(totalEnergy,5));
    Blynk.virtualWrite(V4, currentTime);
    Blynk.virtualWrite(V5, currentDate);
    Blynk.virtualWrite(V6, monthly[month()-1]);
    Blynk.virtualWrite(V7, String(energyMonthly,5));
    Blynk.virtualWrite(V8, String(price,5));
  } else {
    Blynk.virtualWrite(V0, String(voltage,2));
    Blynk.virtualWrite(V1, String(current,3));
    Blynk.virtualWrite(V2, String(power,3));
    Blynk.virtualWrite(V3, String(totalEnergy,5));
    Blynk.virtualWrite(V4, currentTime);
    Blynk.virtualWrite(V5, currentDate);
    Blynk.virtualWrite(V6, monthly[month()-1]);
    Blynk.virtualWrite(V7, String(energyMonthly,5));
    Blynk.virtualWrite(V8, String(price,5));
  }

}

BLYNK_CONNECTED() {
  rtc.begin();
}
```

```
void setup()
{
  // Debug console
  Serial.begin(9600);
  EEPROM.begin(512);  //Initialize EEPROM

  for (int i = 0; i < 11; i++) {
    arrayCurrent[i] = 0.0;
  }

  ACS.autoMidPoint();
  Serial.print("\n \n MidPoint: ");
  Serial.print(ACS.getMidPoint());
  Serial.print(". Noise mV: ");
  Serial.println(ACS.getNoisemV());

  Blynk.begin(auth, ssid, pass);
  timer.setInterval(1000L, myTimerEvent); // Setup a function to be called every second

//  value = EEPROM.read(addr);
//  Serial.println("Read value : " + String(value));
//  totalEnergy = (value * 1.0) / 100000.0;


  oldTimer = millis();

}

void loop()
{
  Blynk.run();
  timer.run(); // Initiates BlynkTimer

  // calculate parameter per seconds. 1000ms = 1s
  if (millis() - oldTimer > 1000) {
//    valueMonthly = EEPROM.read(month() + addrMonth);
//    Serial.println("Read valueMonthly : " + String(valueMonthly));


//    if (valueMonthly == 0){
//      energyMonthly = 0;
//    } else {
//      energyMonthly = (valueMonthly * 1.0) / 100000.0;
//    }


    arrayCurrent[10] = ACS.mA_AC() / 1000.0; // read sensor

    // average value
    for (int i = 0; i < 10; i++) {
      arrayCurrent[i] = arrayCurrent[i + 1];
      totalCurrent = totalCurrent + arrayCurrent[i];
    }
    current = totalCurrent / 10;
    totalCurrent = 0;

    if (current < noise) {

    } else {
      voltage = 240.0;
      power = (current * voltage); // calculate power in kW
      powerKilo = power / 1000.0; // convert watt to kilowatt

      energySecond = powerKilo * 1; // E = P x T ; T = 1 second
      energy = energySecond * 0.000277777777777778; // convert to kWh
      totalEnergy = totalEnergy + energy; // calculate total Energy
      energyMonthly = energyMonthly + energy; // calculate monthly Energy

      Serial.print("current: " + String(current,3));
      Serial.print(" | power: " + String(power,3));
      Serial.print(" | powerKilo: " + String(powerKilo,3));
      Serial.print(" | energySecond: " + String(energySecond,3));
      Serial.print(" | energy: " + String(energy,5));
      Serial.println(" | totalEnergy: " + String(totalEnergy,5));
      Serial.println(" | energyMonthly: " + String(energyMonthly,5));

//      int newdata = totalEnergy * 100000; // convert to integer number
//      int newMonthlyData = energyMonthly * 100000;


//       EEPROM.write(addr, newdata); // save into EEPROM
//       EEPROM.commit();
//       EEPROM.write(month() + addrMonth, newMonthlyData);
//       EEPROM.commit();
//       Serial.println("Written");
     }

     oldTimer = millis();
  }
}
```

Figure 3.16: Source code of Project

3.7 Block Diagram

Figure 3.17 shows the process of smart energy meter, from the power supply the electricity will flow to the energy meter. Then, the current sensor will read the current of load. All the data will transmit to the NodeMCU ESP8266 as a microcontroller to processing the data which can calculate automatically according to the coding that is program by using IDE Arduino software. Next, the data that has been process will be sent to the Wi-Fi that already built in at the NodeMCU and the signal of data will receive and store into the cloud. Lastly, the data will be display on the smartphone application based on IoT.

Figure 3.17: Block Diagram of Development of Smart Meter Energy

3.8 Schematic Design

The circuit design is shown in the figure 3.18 below. The NodeMCU ESP8266 as a main microcontroller was connecting with current sensor. There are three terminals on the current sensor. One terminal is grounded; second Connect VCC of sensor to 3.3V on NodeMCU, and the other is wired to the NodeMCU analog output terminal. This current sensor detects the current flowing through the wire and sends it to the NodeMCU. Then, linked to the Blynk application interfaces using NodeMCU.

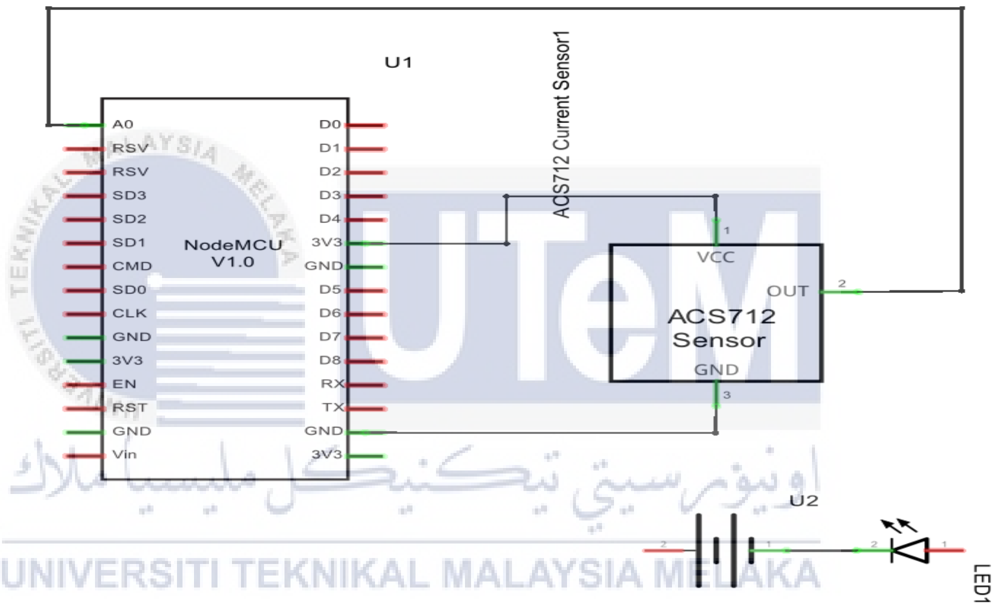

Figure 3.18: Schematic Diagram of Smart Energy Meter

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter will discuss about the action taken in order to reach the objective of the project. Other than that, to see how the project is implemented. Each successful results and selection made when the project is implemented will be explained in detail for each state until the project is successful.

4.2 Experiment Set Up

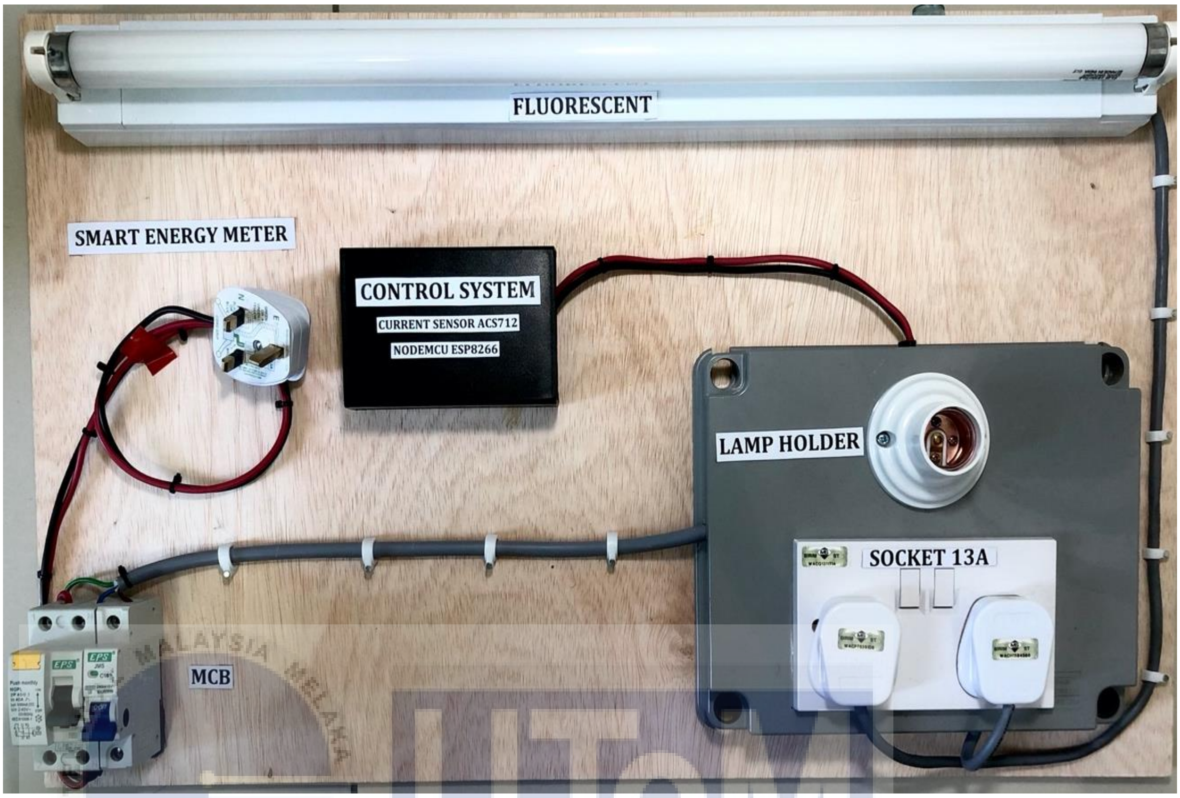

Figure 4.1: Smart Energy Meter Experimental Setup

4.3 Experiment Equipment

The tools that used to conduct this experiment are in Table 4.1.

Table 4.1: Equipment

No.	Equipment	Function
1	 Digital Clamp Multimeter	A digital clamp multimeter is test tools that having two jaws which open to allow clamping around an electrical conductor. This multimeter also can used to measure two or more electrical values principally voltage (volts), current (amps) and resistance (ohms). It is a standard diagnostic tool for technicians in the electrical/electronic industries.

4.4 Circuit Diagram

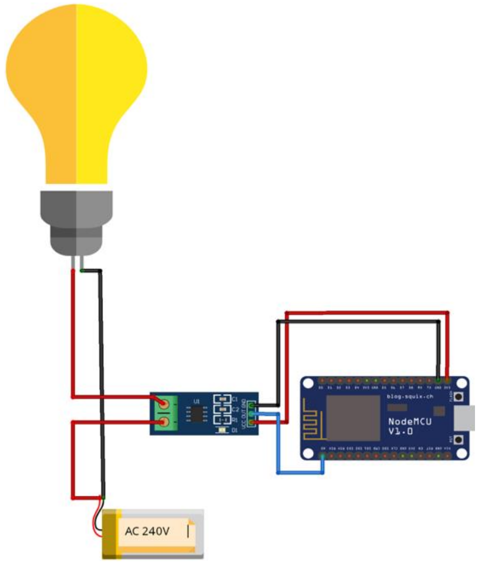

Figure 4.2: Circuit Diagram

As shown in Figure 4.2, this project used NodeMCU as microcontroller and current sensor. This ACS712 current sensor has 3 variant which is 185mV=5A module, 100mV= 20A & 66mV=30A module. Each variant shall be rated for a different current range value. This project using 30A with sensitivity of sensor 66mV. Next, for the connection of this project it starting with the current sensor ACS712 that have 3 pins which is ground, output, and VCC. The VCC pin was connected with the 3V of the NodeMCU and the ground of current sensor to the ground NodeMCU and the output pin to the A0 of NodeMCU. This A0 also called as analog input pin. Otherwise, the 2 pin terminal current sensor is IP+ and IP- which connected to the AC circuit. Hence, the current sensor will measure the current consumed by the AC load and the NodeMCU will measure this current, calculate the power with assuming the voltage is constant then send the power value to a cloud platform which is Blynk applications on smartphone.

4.5 Types of Lamp

The purpose of smart energy meter is to monitor and analyses the data of energy consumption. Therefore, for this project has analyses 3 types of lamp which to know their efficiency of energy consumption. The lamps that been chosen for this experiment is Incandescent lamp (IL), Fluorescent lamp (FL), and Light Emitting Diode (LED). These types of lamp are usually used for indoor lighting.

4.5.1 Incandescent Lamp

The incandescent lamp (IL) or bulb is an electric light source that operates on the concept of incandescence, which is the emission of light induced by heating the filament. The incandescent lamp glass enclosure is made up of a tungsten filament. Next, the filament is heated by an electric current, which causes it to light. Other than that, incandescent light bulbs typically have a stem or glass mount attached to the base that allows the electrical connections to pass through the envelope without leaking gas or air. The filament, its lead wires are supported by small wires inserted in the stem. Only 10% to 15% of the energy that goes into an incandescent filament is released as light and the remaining is released as heat [10]. In this project, the PS – 60 incandescent lamp with voltage 220 – 240V, power 60W, lamp current 0.29A, luminous flux 415 lm, and the nominal lifetime 1000hours are used.

4.5.2 Fluorescent Lamp

The fluorescent lamp (FL), bulb or tube is a low pressure mercury vapor gas discharge furniture that uses to create visible light. The light generated by a fluorescent tube is created by an electric current passing through mercury and inert gases in the tube. The gas in the tube emits ultraviolet light. This stimulates a layer of white phosphor coating inside the tube, causing it to produce visible light over its whole surface. It is important to highlight that reducing energy generation saves much more mercury than is contained in fluorescent lamps. Moreover, to deliver the same amount of illumination lighting, fluorescent lamps utilize 25%–35% of the energy are used by incandescent lamps. Thus, incandescent bulbs provide roughly 15 lumens per watt, but fluorescent lights may provide 50-100 lumens per watt. Besides, the FL also require ballast to control operational current and provide a high start-up voltage. Electronic ballasts improve conventional and upgraded electromagnetic ballasts by functioning at a high frequency that flicker and noise are reduced. This lamp power is 18W, lamp current 0.16A, lamp luminous flux 1050 lm, and the nominal lifetime 10000hours which last about 10 times longer than incandescent lamp.

4.5.3 Light Emitting Diode (LED)

LEDs lamp or bulb are basically diodes consisting of a tiny semiconductor that creates electromagnetic energy in the form of visible light or infrared light. The external part of the LED bulb is a plastic substance that covers the inside components completely. Specifically, the LED bulb is solid throughout, with no gas or vacuum chamber within it. Moreover, LED have rapidly improved in efficiency, affordability, and output. That improvement making them suitable for larger-scale lighting applications in homes, workplaces, and other environments. Next, because of the revolution that occurred for LED technology, LED lamps with a wide variety of efficiency and life spans are available. Thus, The specification of this lamp that state at the box which is range voltage for LED is 176-265V, the power is 18W, luminous flux 1800lm, and the nominal lifetime 25000 hours which much longer than incandescent and fluorescent lamp.

4.6 Incandescent Lamp Analysis

Table 4.2 shows the result of data that are recorded for current at incandescent lamp based on the smart energy meter set up with microcontroller NodeMCU and current sensor ACS712 30A. The total time taken output of this incandescent lamp was 60 minutes but for the results analysis was divided into 10 minutes.

Table 4.2: Experiment Test Result on Incandescent Lamp

Current (A)	0.286	0.283	0.282	0.281	0.285	0.282
Power (W)	68.64	67.92	67.68	67.44	68.4	67.68
Time (min)	10	20	30	40	50	60
Voltage (V)	240V					

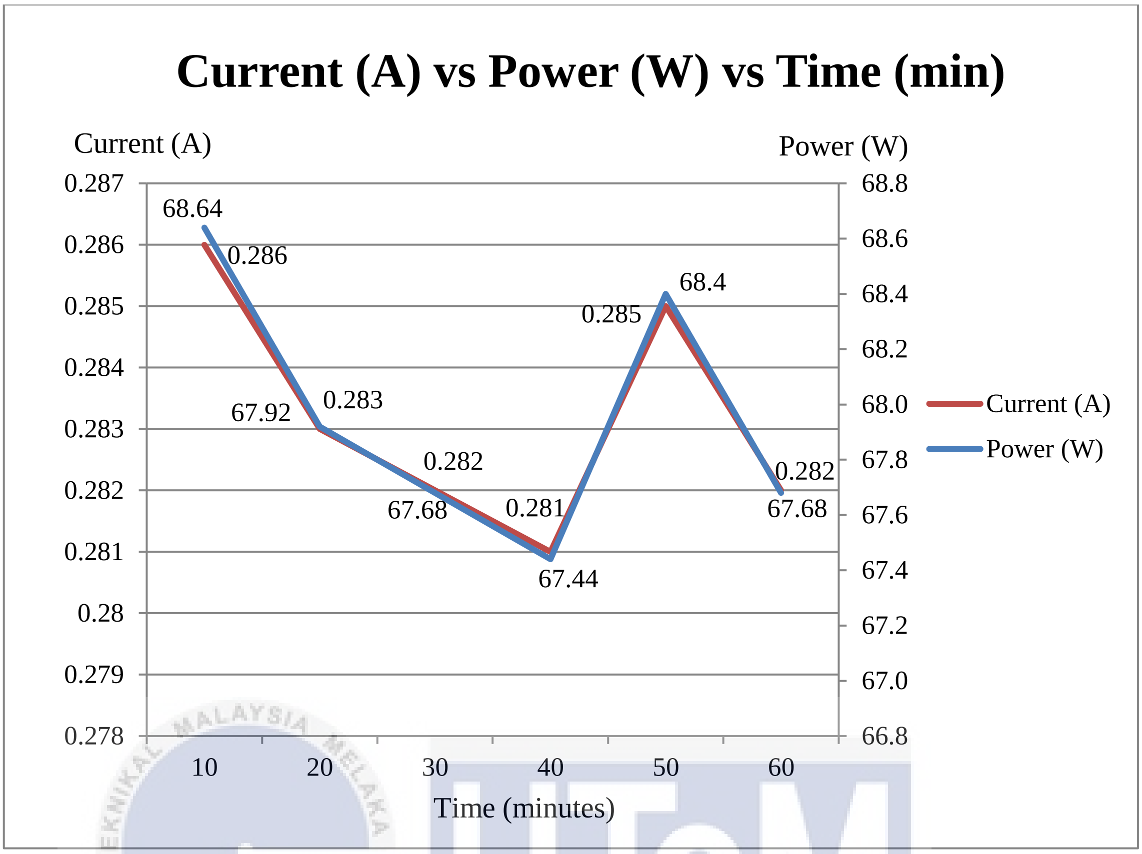

Figure 4.3: Current and Power Output of Incandescent Lamp

Based on Figure 4.3, shown the reading data current and power of Incandescent lamp at first 10 minute until 60 minutes. The maximum reading value for current is 0.286A while the minimum current is 0.281A. Therefore, current is quite stable with a little bit different. Next, the maximum reading for power is 68.64W and the minimum is 67.44W, from this graph shown the power is depend on the reading value of current.

4.7 Fluorescent Lamp Analysis

Table 4.3 shows the data analysis for the fluorescent lamp, the results of data that recorded is current and power based on smart energy meter set up with microcontroller NodeMCU and current sensor ACS712 30A. The total time taken output of this fluorescent lamp was 60 minutes but for the results analysis was divided into 10 minutes.

Table 4.3: Experiment Test Result on Fluorescent Lamp

Current (A)	0.15	0.14	0.11	0.17	0.12	0.11
Power (W)	36.33	32.26	26.35	40.18	28.08	25.44
Time (min)	10	20	30	40	50	60
Voltage (V)	240V					

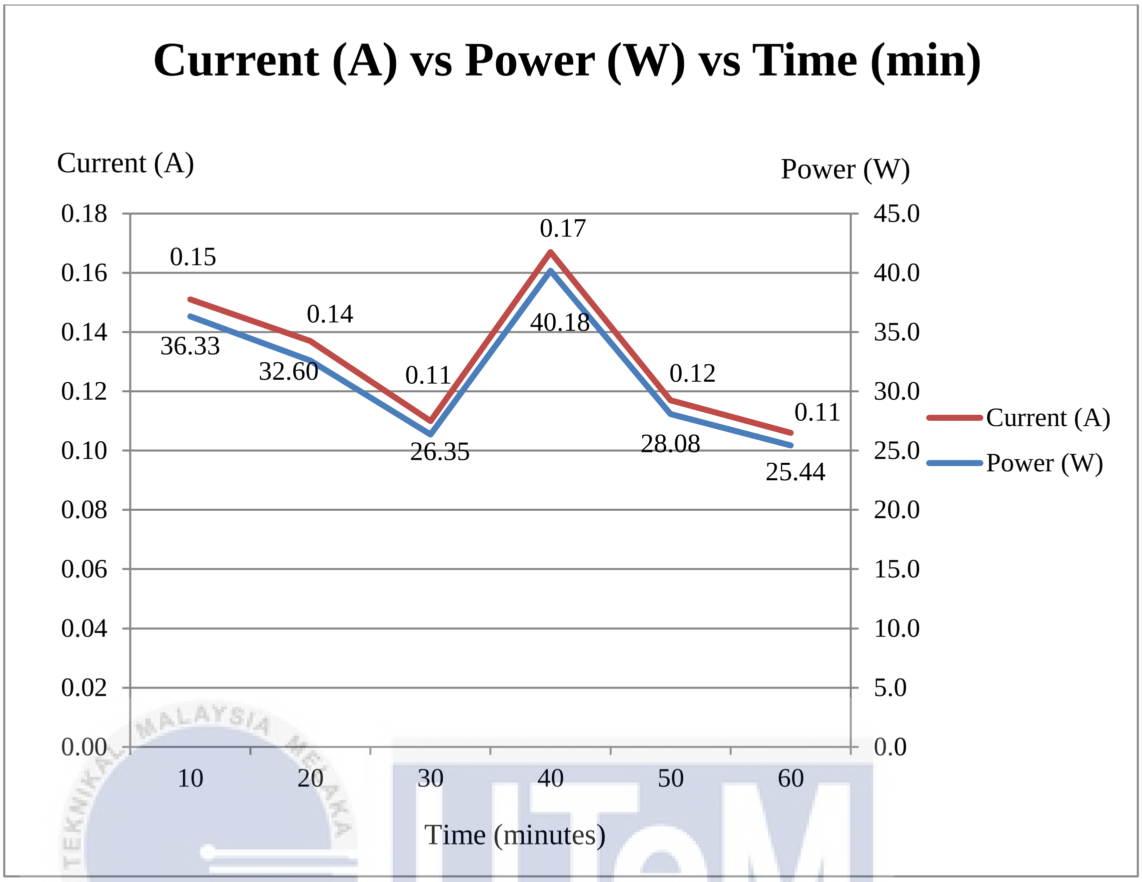

Figure 4.4: Current and Power Output of Fluorescent Lamp

Based on Figure 4.4, shown the reading data current and power of fluorescent lamp at first 10 minute until 60 minutes. The maximum reading value for current is 0.17A while the minimum current is 0.11A. Hence, current for fluorescent lamp is lower than incandescent lamp. Next, the maximum reading for power is 40.18W and the minimum is 25.44W from this graph shown the power is depend on the reading value of current.

4.8 Light Emitting Diode (LED) Analysis

Table 4.4 shows the data analysis for the LED lamp, the results of data that recorded is current and power based on smart energy meter set up with microcontroller NodeMCU and current sensor ACS712 30A. The total time taken output of this fluorescent lamp was 60 minutes but for the results analysis was divided into 10 minutes.

Table 4.4: Experiment Test Result on LED Lamp

Current (A)	0.08	0.06	0.08	0.08	0.06	0.07
Power (W)	19.20	14.42	19.20	14.42	14.42	16.80
Time (min)	10	20	30	40	50	60
Voltage (V)	240V					

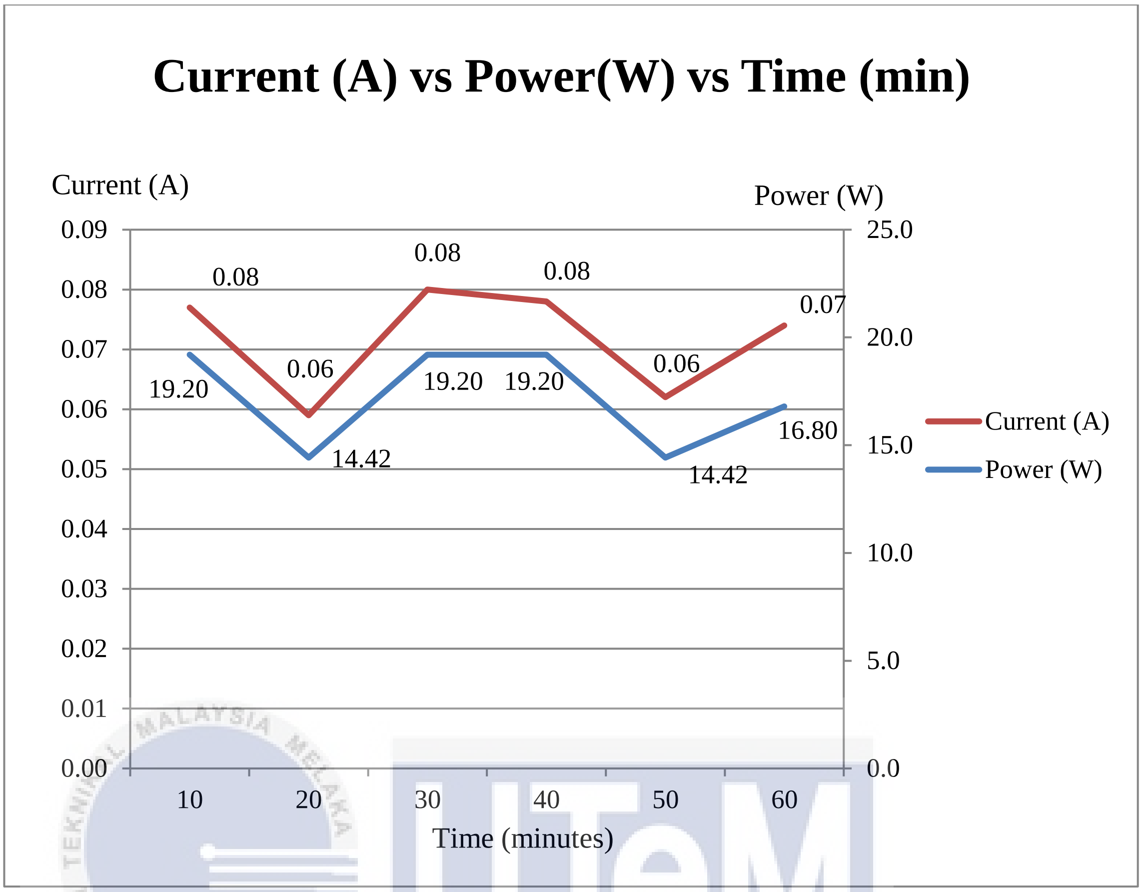

Figure 4.5: Current and Power Output of LED Lamp

Based on Figure 4.5, shown the reading data current and power of LED lamp at first 10 minute until 60 minutes. The maximum reading value for current is 0.08A while the minimum current is 0.06A. As a result, current is more stable with a little bit different. Next, the maximum reading for power is 19.20W and the minimum is 14.42W from this graph shown the power is depend on the reading value of current.

4.9 Comparison Data between Incandesent lamp, Fluorescent lamp, and LED lamp

The function of current sensor ACS712 30A in this Smart Energy Meter is to read the value of current at each 3 types of lamps that has been tested. Hence, the value of power will be calculated using the formula which is $P=IV$ that has been coded in the Arduino IDE. Meanwhile, the total energy consumption in kWh for each types of lamps also calculated, then the results shown in the Blynk applications.

4.9.1 Comparison Current Analysis

Based on the data that obtained in Figure 4.3, Figure 4.4 and Figure 4.5, the higher current that has been recorded from current sensor is from incandescent lamp. Meanwhile, the LED lamp recorded the lower current followed by fluorescent lamp. The various current values caused by the functioning principle of each lamp. An incandescent lamp is a type of traditional lamp that uses an electric current to heat a filament to a high temperature. In consequence, the higher current produces in this type of lamp. Next, in fluorescent tubes the small amount of mercury is mixed with inert gases to conduct the electrical current and also inductive ballast is used to reduce the current that passes through the tube. Contrastingly, an LED light bulb is a solid-state lighting (SSL) device that employs LEDs to create light. When an electric current that called electroluminescence flows through a semiconductor device, it creates visible light. The benefit of electroluminescence is flexibility, high visibility and also low consumption rate of current than other types of lamp. The data interpret as shown in Figure 4.6.

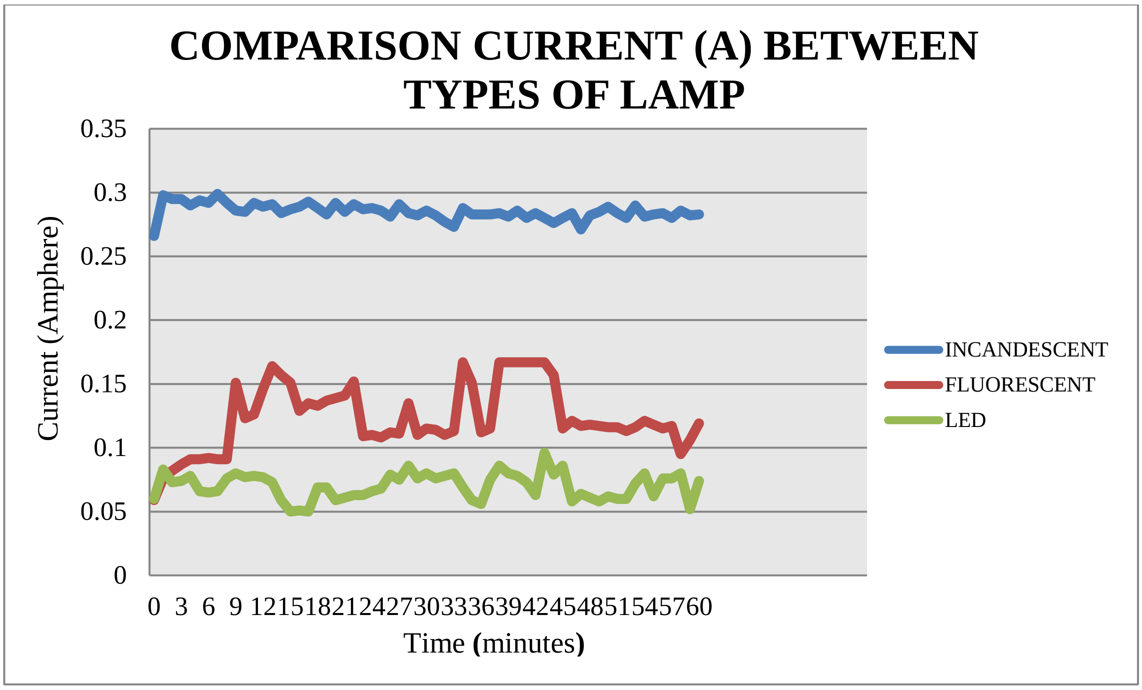

Figure 4.6: Comparison Current (A) Between Types of Lamp

4.9.2 Comparison of Total Energy in kWh

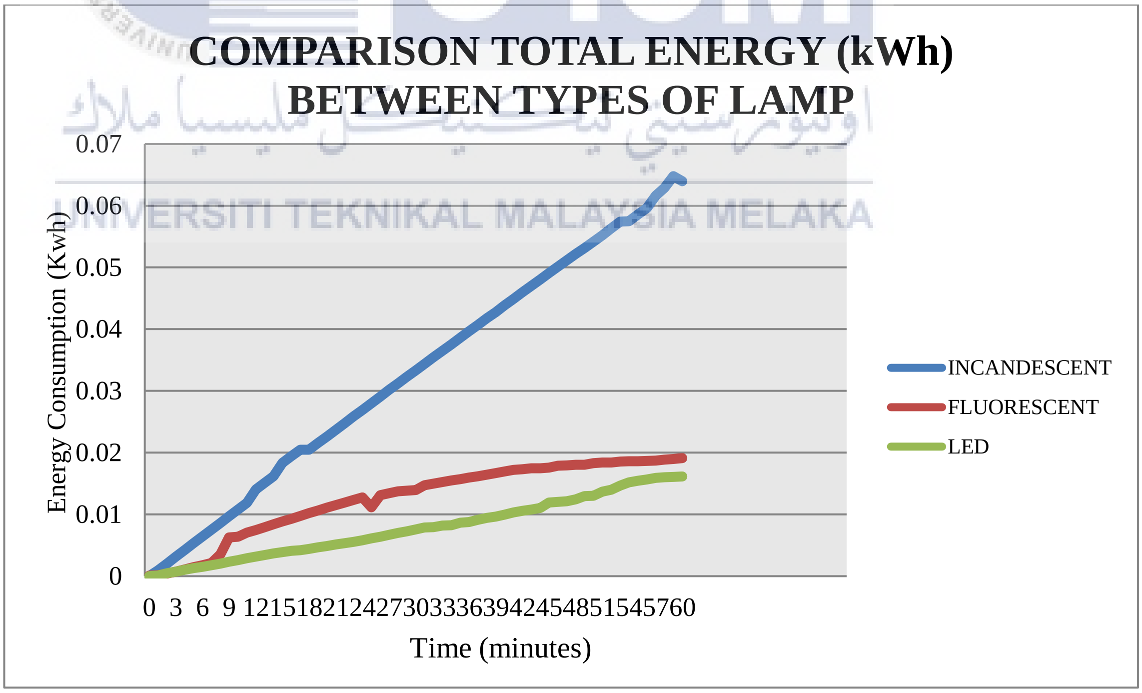

Figure 4.7: Comparison Total Energy (kWh) Between Types of Lamp

Based on the data that obtained from Figure 4.7, the total energy consumption depends on current produced by each lamp. The higher current produce affected the value of total energy consumption for 60 minutes. Therefore, Incandescent lamps consume more energy than fluorescent and LED. The maximum value of total energy for incandescent lamp is 0.06479kWh. While, the maximum value energy consumption for fluorescent lamp is 0.01912kWh. Other than that, LED shows less energy consumption than incandescent and fluorescent lamps with the total energy is 0.01615kWh. So, the LED has consumed energy about 15.53% - 75.07% less than fluorescent and incandescent lamps in 1 hour. Nevertheless, the data is followed the Ohm’s Law rule according to P=IV that shows current is inversely proportional to voltage.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Introduction

The project provided important experience in the design, development, and testing of a system with several hardware and software components. In this chapter, after the analysis was done, the results were concluded for future research to improve. Finally, recommendations have been made to be used in the future.

5.2 Conclusion

In this project, the data energy consumption (kWh) for each types of lamp was successfully monitor by using smart energy meter based on IoT. This research conducted about the current produced on types of lamp, power output and total energy consumption. Additionally, the cumulative energy consumption has been influenced by the current and power that have been recorded for 1 hour, and all data has been saved in the cloud server based on IoT using NodeMCU. Thus, using the results from the Blynk platform the research may determine that LED lights are significantly more energy efficient than equivalent incandescent bulbs, and they can be more efficient than fluorescent bulbs. In conclusion, the purpose of this project is to design the smart energy meter based on IoT that able monitor the data in Blynk application was successfully achieved.

5.3 Recommendation

There are some recommendations for understanding the configuration to set up smart energy meter based on Internet of Things (IoT). The type of current sensor unable to use if the current is higher than 30A and this is the weakness. For the next study, there are various improvements that may be made to the design of the smart energy meters and the current reading. The recommendations are:

I. The analysis is focused on current reading produced at the lamp. Therefore, it is recommended that in future research need to change of the current sensor that has more accuracy.

II. In this research, the current sensor unable to functioning more than 30A. Thus, it is recommended to use CT clamp sensor because got many variety of rated current.

III. For safety purposes, the CT clamp sensor has built-in protection and recommended to use for future project.

IV. In order to get the accurate value of voltage it is recommended to used voltage sensor ZMPT101B, because in this project the voltage value fixed to 240V in the coding.

V. Due to the analysis in this paper only reads current 3 types of lamp. For future research, next researcher can do the analysis on any appliances to diversify the results of smart energy meter.

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APPENDICES

Appendix A

ACS712 *Fully Integrated, Hall Effect-Based Linear Current Sensor with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor*

Description (continued)

loss. The thickness of the copper conductor allows survival of the device at up to 5× overcurrent conditions. The terminals of the conductive path are electrically isolated from the sensor leads (pins 5 through 8). This allows the ACS712 current sensor to be used in applications requiring electrical isolation without the use of opto-isolators or other costly isolation techniques.

The ACS712 is provided in a small, surface mount SOIC8 package. The leadframe is plated with 100% matte tin, which is compatible with standard lead (Pb) free printed circuit board assembly processes. Internally, the device is Pb-free, except for flip-chip high-temperature Pb-based solder balls, currently exempt from RoHS. The device is fully calibrated prior to shipment from the factory.

Selection Guide

Part Number	Packing*	T_A (°C)	Optimized Range, I_P (A)	Sensitivity, Sens (Typ) (mV/A)
ACS712ELCTR-05B-T	Tape and reel, 3000 pieces/reel	–40 to 85	±5	185
ACS712ELCTR-20A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±20	100
ACS712ELCTR-30A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±30	66

*Contact Allegro for additional packing options.

Absolute Maximum Ratings

Characteristic	Symbol	Notes	Rating	Units
Supply Voltage	V_{CC}		8	V
Reverse Supply Voltage	V_{RCC}		–0.1	V
Output Voltage	V_{IOUT}		8	V
Reverse Output Voltage	V_{RIOUT}		–0.1	V
Reinforced Isolation Voltage	V_{ISO}	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	2100	V
		Voltage applied to leadframe (Ip+ pins), based on IEC 60950	184	V_{peak}
Basic Isolation Voltage	$V_{ISO(bsc)}$	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	1500	V
		Voltage applied to leadframe (Ip+ pins), based on IEC 60950	354	V_{peak}
Output Current Source	$I_{IOUT(Source)}$		3	mA
Output Current Sink	$I_{IOUT(Sink)}$		10	mA
Overcurrent Transient Tolerance	I_P	1 pulse, 100 ms	100	A
Nominal Operating Ambient Temperature	T_A	Range E	–40 to 85	°C
Maximum Junction Temperature	$T_J(max)$		165	°C
Storage Temperature	T_{stg}		–65 to 170	°C

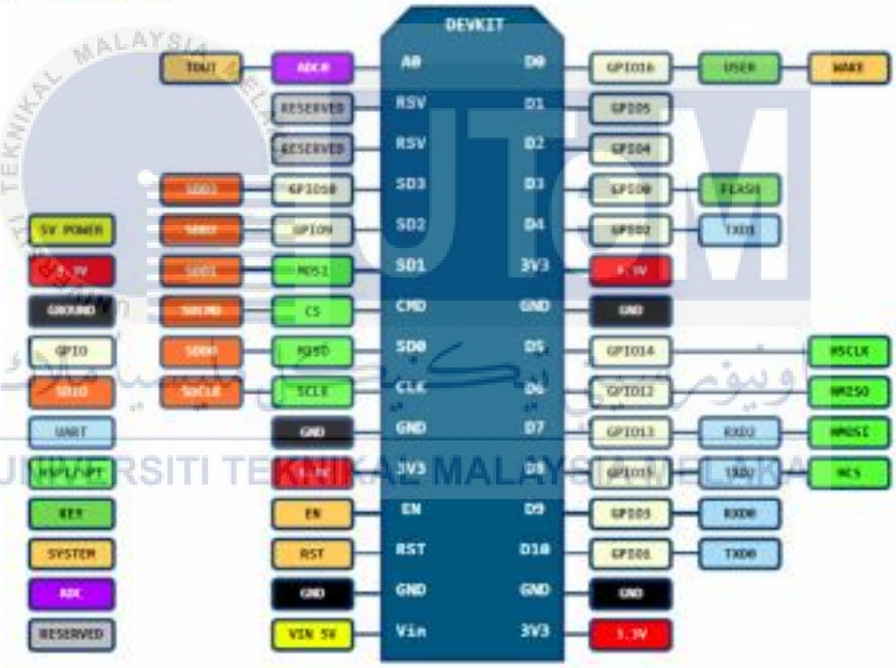
Parameter	Specification
Fire and Electric Shock	CAN/CSA-C22.2 No. 60950-1-03 UL 60950-1:2003 EN 60950-1:2001

Appendix B

1. Specification:

- Voltage:3.3V.
- Wi-Fi Direct (P2P), soft-AP.
- Current consumption: 10uA~170mA.
- Flash memory attachable: 16MB max (512K normal).
- Integrated TCP/IP protocol stack.
- Processor: Tensilica L106 32-bit.
- Processor speed: 80~160MHz.
- RAM: 32K + 80K.
- GPIOs: 17 (multiplexed with other functions).
- Analog to Digital: 1 input with 1024 step resolution.
- +19.5dBm output power in 802.11b mode
- 802.11 support: b/g/n.
- Maximum concurrent TCP connections: 5.

2. Pin Definition:



D0(GPIO16) can only be used as gpio read/write, no interrupt supported, no pwm/i2c/ow supported.

3. Using Arduino IDE

3 | www.handsontec.com