Faculty of Electrical Technology and Engineering

INTEGRATION OF SMART ENERGY METERING SYSTEM FOR RESIDENTIAL HOUSE VIA IOT

IZATULNAJEHAH BINTI OSMAN

Bachelor of Electrical Engineering Technology (Industrial Power) with Honours

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INTEGRATION OF SMART ENERGY METERING SYSTEM FOR RESIDENTIAL HOUSE VIA IOT

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DEDICATION

To my beloved mother, Saidah Binti Sahari, and
father, Osman Bin Mohamad Yusof, and
To dearest friend, Muhammad Fakrul Bin Anuar

ABSTRACT

The Internet of Things (IoT) offers a promising way to monitor and manage energy consumption through the integration of smart energy metering systems for residential homes. Homeowners find it difficult to efficiently monitor their energy usage with traditional energy metres because they require manual readings. The deployment of a smart energy metering system that makes use of IoT technology is suggested in this research in order to allow real-time monitoring, data analysis, and remote control of energy use in residential homes. The proposed system consists of smart energy metres installed in homes that gather real-time data on energy usage and send it via IoT communication protocols to a central data management platform. The central platform analyses and examines the data to produce insights into patterns of energy consumption, spot abnormalities, and give homeowners useful advice for maximising energy use. Additionally, the system offers homeowners a user-friendly interface accessible from computers or mobile devices that allows them to remotely control and manage their energy usage. Smart energy metering system integration through IoT has a lot of promise to improve residential buildings' sustainability, lower expenses, and promote energy efficiency. The technological considerations, advantages, and difficulties of implementing such a system are covered in this research, along with some information on possible residential applications.

ABSTRAK

Internet Pelbagai Benda (IoT) menawarkan cara yang menjanjikan untuk memantau dan menguruskan penggunaan tenaga melalui penyatuan sistem pemeteran tenaga pintar untuk kediaman kediaman. Pemilik rumah sukar untuk memantau penggunaan tenaga mereka dengan cekap dengan meter tenaga tradisional kerana mereka memerlukan pembacaan manual. Penggunaan sistem pemeteran tenaga pintar yang menggunakan teknologi IoT disarankan dalam penyelidikan ini untuk memungkinkan pemantauan masa nyata, analisis data, dan kawalan jauh penggunaan tenaga di rumah kediaman. Sistem yang dicadangkan terdiri daripada meter tenaga pintar yang dipasang di rumah yang mengumpulkan data masa nyata mengenai penggunaan tenaga dan menghantarnya melalui protokol komunikasi IoT ke platform pengurusan data pusat. Platform pusat menganalisis dan meneliti data untuk menghasilkan pandangan mengenai corak penggunaan tenaga, kelainan spot, dan memberi nasihat berguna kepada pemilik rumah untuk memaksimumkan penggunaan tenaga. Selain itu, sistem ini menawarkan pemilik rumah antara muka yang mesra pengguna yang dapat diakses dari komputer atau peranti mudah alih yang membolehkan mereka mengawal dan mengurus penggunaan tenaga mereka dari jauh. Integrasi sistem pemeteran tenaga pintar melalui IoT mempunyai banyak janji untuk meningkatkan kelestarian bangunan kediaman, perbelanjaan yang lebih rendah, dan meningkatkan kecekapan tenaga. Pertimbangan teknologi, kelebihan, dan kesulitan dalam melaksanakan sistem seperti ini diliputi dalam penyelidikan ini, bersama dengan beberapa maklumat mengenai kemungkinan aplikasi kediaman.

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CHAPTER 1

INTRODUCTION

1.1 Background

A smart energy metering system is an essential component in determining the functioning of the electricity grid, allowing users to get better, more efficient services. Modern developments in energy monitoring and management have led to the development of smart energy meters. They are technological gadgets that continuously track and record how much water, gas, or electricity is being used. Smart energy meters, in contrast to conventional analogue ones, provide effective monitoring and control of energy usage by allowing two-way communication between the utility company and the customer.

The population is now growing faster than ever. Residential areas and enterprises require a lot of current for this reason. To conserve energy from household electric meter devices, numerous solutions have already been developed. The energy meter gadget used to fit inside the users' premises. Humans recorded the consumption rate and updated it in the system. This system was very reliant on the operator. For the purpose of gathering information, the operator wet it to the users' locations. It's a pretty challenging process. The suggested system is utilised to automatically measure the current consumption rate in order to avoid this circumstance. With the help of IoT, this system is utilised to gather the current consumption number and send the user an alarm message. The IoT idea enables remote measurement and management of physical equipment over an already established network connection, establishing direct contact between the physical world and computer systems. Accurate results and financial gain are the end results of the IoT technology. Since its inception, this technology has advanced and is now utilising this idea. Everybody's life depends on electricity. In the modern world, people would be unable to survive without electricity. This system's purpose is to gather information from the user's location and use it to calculate the user's bill. The measured value will be saved on the server and utilised to calculate the amount as well. Accurately measuring current consumption units is done by this system. This method eliminates human involvement. On the LCD screen, the suggested system shows the real-time statistics on current consumption. The consumed units can be checked and the threshold unit level can be provided via a webpage using a Wi-Fi modem [1].

The purpose of this research is to cut energy costs by improving the likelihood that consumption will be reduced using data from analysed Smart Meters. Traditional meters involve a significant energy and labour waste when they are used. There is a general need for the power utilities to investigate a new development for the benefit of the consumers as well as themselves as the electricity usage of the household is known on a monthly basis by conventional meters. However, the study decides to try to replace the electricity meter in the individual households by minimising the negative effects experienced by the user [3].

1.2 Addressing Security Challenges Through Integration of Smart Metering System

Security challenges are huge social issues for consumers. One of the main factors causing security challenges is the electronic devices consist of millions of pieces of low-cost measurement components that are installed physically in risky places which have potential worth to cybercriminals. The vulnerability allows the hacker access to your meter by allowing them to steal your personal information, like your name, address, and energy usage history. However, it is essential to understand the parts of electrical equipment that have been installed through to the smart energy meter to manage these concerns. In order to improve consumer safety and security, smart metering systems can be integrated through IoT initiatives. The integration of smart energy meters based on IoT allows the customers to observe and monitor their data on energy consumption through their mobile phones. Meanwhile, the integration of smart metering systems via IoT project can aid in tracking unit consumption, projected cost, line voltage, current, energy power, and power factor. Ultimately, by providing more secure data on energy usage for consumers, the integration of smart energy metering systems via IoT can be effective and valuable measurement devices in the struggle against security concerns.

1.3 Problem Statement

Real-time energy monitoring to implement a system that allows for real-time monitoring of energy usage in residential buildings. In order to give accurate and current information on energy usage, the system should collect data from numerous energy metres that are installed in various parts of the house. Provide homeowners with a user-friendly interface that allows remote access and control of their energy metering equipment. The system should include mobile applications or web portals that let users keep track of their energy use, establish preferences for conserving energy, and get warnings or alerts when there are odd patterns of consumption or possible energy waste.

1.4 Project Objective

The main aim of this project is to propose monitoring and tracking power usage for verification and allowing users to quickly review data on energy consumption. Specifically, the objectives are as follows:

a) To develop smart energy meter using a smart system that makes accessible to view data.

b) To design an IOT system that uses Blynk Apps to display data connected from a smart meter.

c) To monitor energy consumption for the consumer.

1.5 Scope of Project

The scope of this project are as follows:

a) Displaying the meter readings will enable the consumer to manage their electricity consumption and will also be useful for invoicing or payment purposes.

b) The development of a user-friendly mobile or online application can enable homeowners to track their energy usage in real-time, view historical data, establish targets for their usage, and get alerts or notifications about usage patterns.

c) A smart energy meter circuit will need to be built as part of the project. Real-time data on energy use, including details on electrical use, voltage swings, and power quality, will be provided by this metre.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The Internet of Things (IoT) is an innovative approach for managing and monitoring energy consumption in various contexts, and the integration of a smart energy metering system is one example of this. The real-time gathering, analysis, and control of energy data is made possible by this system's use of IoT technology, which boosts sustainability, cost savings, and energy efficiency. IoT-enabled smart meters that can connect with a central hub or a cloud-based platform replace conventional energy meters in a smart energy metering system. Due to the sensors and communication modules that these smart meters have, they can measure and transmit data on energy consumption on a regular basis. To process and conduct analysis on the data, it is safely sent over the internet to a coordinated server. Energy metering IoT integration enables real-time monitoring of energy use, providing consumers with accurate and up-to-date information about their energy usage trends. Customers are therefore better able to make energy-related decisions, identify areas where energy is being squandered or utilized excessively, and take the required steps to maximize energy efficiency for this project.

2.2 Power Energy Consumption

Power consumption is the total quantity of energy used by a certain household. Power usage is a crucial component of the provision of electricity. People need to understand the importance of conserving energy. The energy patterns have been gradually changing as a result of regular electrical use. Weather circumstances and excessive power use by residents, such as the addition of appliances in individual residences and a casual attitude towards usage, such as failing to turn off the lights or the television when not in use, can both contribute to these variations in consumption patterns. These elements might have more of an effect on the final user. Most individuals are ignoring energy and its savings because of how much electricity is provided by energy companies. Consumption is becoming less significant in utilities' attitudes. By raising people's understanding of the effects of their present level of consumption, the energy utilities should encourage participation from the public in lowering energy implications and promoting the Smart Meters technology [3].

Significant reductions in power usage and emissions could result in even greater reductions in energy usage. Recommendations and estimations based on energy usage trends are needed for energy-efficient household management. The future generation of smart metres can incorporate energy and sensor systems, as well as smart devices and smart meters [4].

2.3 Smart Energy Meter

The smart meter provides detailed information on consumption to reduce electricity bills and also increases knowledge about the status of the electricity grid, which improves its performance and the quality of service for customers.

Smart Meter are electronic measurement tools that utilities use to transmit data for consumer billing and managing their electrical infrastructure. Due to the demand for increasingly complex rates and detailed billing data requirements, this technology was initially deployed to commercial and industrial customers. The utility's biggest customers were the first to employ electronic metres, and over time, this practise progressively spread to all consumers. Reduced technological costs and more stringent billing criteria for all clients enabled this migration. AMI (advanced metering infrastructure) is the term used to describe the setup of electronic metres with two-way communications technology for information, monitoring, and control. The primary function of the smart metre is to monitor energy use and transmit pertinent data for invoicing to the Distribution Service Operator (DSO), also known as the Energy Service Provider (ESP) [5].

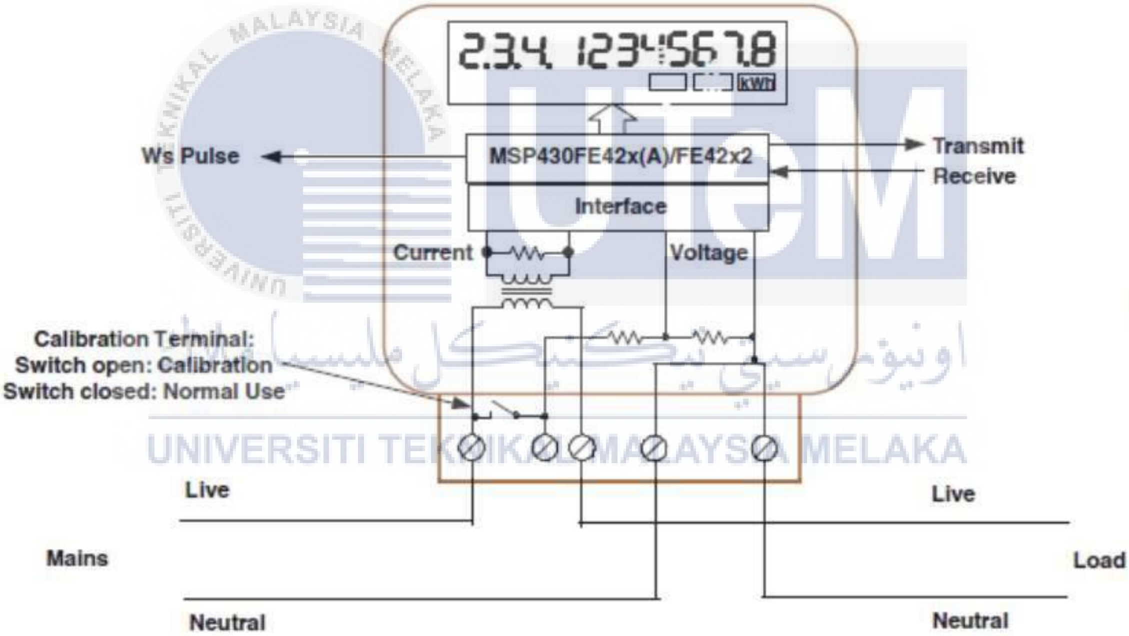

Figure 2.1 Smart Energy Meter

2.4 Liquid Crystal Display

A flat panel display, electronic visual display, or video display that makes use of the liquid crystals' ability to modulate light is known as a liquid-crystal display (LCD). Direct light emission is not possible from liquid crystals. There are LCDs that can show random pictures, like pre-programmed words and numbers. Thus, it is able to obtain information via the display [5].

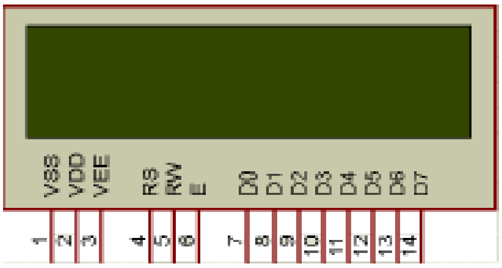

Figure 2.2 LCD

2.5 Current Sensor

The electrical current for the devices where the current must be measured is through measurement using a current sensor. Depending on the type of device—an analogue or a digital one—this sensor produces a signal. Additionally, the current sensors in this instance are used to gauge the current flowing through various appliances, such a fan and a light bulb [6].

Figure 2.3 Current Sensor

2.6 Measurement of Voltage, Current, Energy Power, and Power Factor to The Load

Through some coding in the Arduino library, we were able to obtain values for voltage sensitivity, energy, and power factor after we had obtained data for both current and voltage in addition to the real power reading [7].

2.6.1 Voltage to Load Sensitivity

Voltage to Load Sensitivity is significant because it allows you to gauge how far you are from the grid. If you plug in a heavy load, the voltage will shift significantly due to the great sensitivity of the grid. There won't be much of a change in voltage when plugging in a big load if the grid is close by because the sensitivity is low [7].

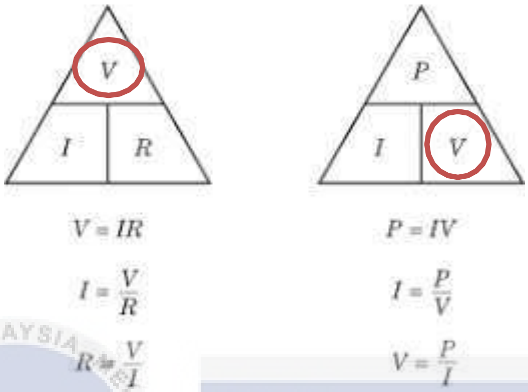

Figure 2.4 Voltage Formula

2.6.2 Current

The number of appliances that can be connected to a particular energy meter depends on the current rating. A domestic load must be considered while designing an energy metering system, or it must be strong enough to handle commercial energy demand [7].

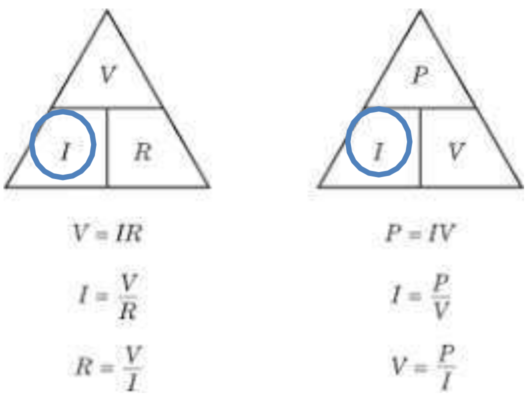

Figure 2.5 Current Formula

2.6.3 Energy Power

Considering the limited time we have to deliver the demo, we measured energy in kilowatt-minutes rather than KWh for the purposes of presentation. KWh results are quite small amounts. Every minute, an average of energy is calculated [7].

$$E_{(kWh)} = \frac{P_{(W)} \times T_{(hrs)}}{1,000}$$

$$P = \frac{W}{t}$$

$$P = IV \qquad P = I^2R \qquad P = \frac{V^2}{R}$$

P = Power
V = Potential Difference (Voltage)
I = Current
R = Resistance
W = Work done
t = time taken for the work to be done

Figure 2.6 Energy Power Formula

2.6.4 Power Factor

Due to its impact on both the economic cost of energy consumption and the required power quality by the grid, the power factor in electrical power systems is of utmost importance. Due to increased installation current needs, larger industrial equipment sizes, larger conductor wiring that can withstand higher currents, and more voltage regulators for the equipment, low power factor has an impact on both electrical consumers and suppliers [8].

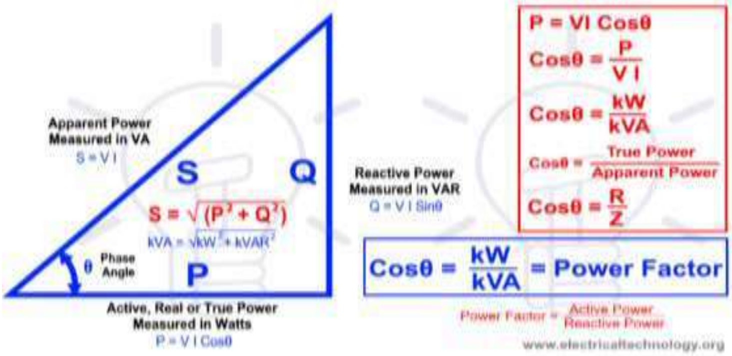

Figure 2.7 Power Factor Formula

2.7 Prior Project

2.7.1 Design of IoT Based Smart Energy Meter For Home Appliances

The advancement of communication technology is accelerating daily. As a result of the advancement of communication technology, every product is made using smart processes. Since the last ten years, the majority of electric gadgets are operated by remote control. With the aid of sensors, the Internet of Things (IoT) connects numerous devices quickly. No human involvement is necessary for the autonomous operation of any connected devices. Humans' only responsibilities are to remotely oversee and operate connected equipment. The Internet of Things is also used by electric meters. This essay discusses smart meter technology. The primary function of this system is to automatically count the LED light's current consumption units, calculate the amount, and display messages on the user's website and smartphone. The user receives a warning message from this system when the current consumption unit exceeds the set limit [1].

2.7.2 An IOT Based Smart Metering Development For Energy Management System

Due to the rising global energy demand, it is imperative that suitable metering infrastructure be installed in buildings to avoid energy waste. With the use of smart grid technologies, a smart metre can be used to track consumers' electricity usage. Appropriate energy demand management is necessary for allocating the resources that are already available. For energy demand management, a variety of techniques have been used in recent years to precisely estimate future energy needs. As long as a competence with end user is carried out, a large system has a potential value to implement energy saving as well as new services linked to energy services. The monitoring system at the utilities decides how gadgets with substantial advantages connect, while communication with the household frequently suggests specific implementation strategies for a network of smart metres that is properly customer-focused. This research also focuses on the assessment of energy use. This paper measures energy in units and provides product arrangements for LabVIEW software to build energy consumption bills and apply them. For real-time remote monitoring of the metering infrastructure, an IOT-based platform has been developed. Additionally, data visualisation is done on websites, and data packet loss is looked into while parameters are being remotely monitored [2].

2.7.3 Smart Metering For Smart Electricity Consumption

The use of various appliances in homes has raised the need for power in recent years. Many rich and emerging countries are concerned about this because of the sudden surge in demand for electricity. Consumers or individuals must monitor their daily energy use in their homes. Therefore, it is crucial that humans manage and conserve these resources. This study focuses on data from smart metres that can be used to distribute electricity to consumers in an intelligent and effective manner. The fundamental flaw in formerly prevalent traditional meters is that they don't give users any information, something that the Smart Meter does. With the use of a smart meter, consumers may learn how much electricity is being used by the equipment in their homes. By conducting a case study on several families, this project aims to monitor and analyse electricity consumption using data from Smart Meters. Data from smart meters shows how consumers use devices in addition to saving electricity. As power consumption rises daily, there should be a greater emphasis placed on understanding consumption patterns, necessitating measurement and study of usage across time. In undeveloped countries, many common people and power utilities are still unaware of the technologies used in smart electricity meters. Installing these meters is therefore essential for reducing energy use. The goal of this study is to reduce energy consumption by better understanding customer behaviour and how it relates to electricity spot prices [3].

2.7.4 Smart Technologies For Energy Consumption Management

The purpose of this project is to categorise and describe the smart technologies and solutions that are currently being utilised to manage energy usage. It emphasises the beneficial effects of technology on the environment, with a focus on climate change, renewable energy, and energy efficiency. In order to improve energy management and have an impact on energy consumers' demand-side response, the article analyses the green technologies used in energy generation and storage and thinks about the Internet of Things (IoT) concept that enabled using incredibly fast information flows from the generator to the consumer and back. Additionally, it describes upcoming photovoltaic (PV) panels, storage devices, and battery-based smart energy systems. Finally, it addresses the value of peer-to-peer (P2P) energy and information exchange, virtual power plants, and many other cutting-edge components of the upcoming smart grids that will facilitate and expedite the shift to a low-carbon economy and electric transportation [4].

2.7.5 Design and Implementation of an Energy Meter System For Optimized Cost using Internet of Things (IoT) Technology Administration

One of the most important things that adversely affects the economics and way of life in all nations is the observable rise in the price of electricity bills. This is brought on by the wasteful energy consumption, which costs consumers money. Furthermore, a major issue could arise between the consumer and the electrical distribution firms due to the high cost of electricity brought on by excessive usage. This issue is made worse by the lack of an energy usage monitoring system. As a result, it became vital to create an energy monitoring strategy that can compute daily usage and display it to clients so they can easily understand their energy consumption. This study uses internet of things (IoT) technologies to build and deploy an energy meter system for reduced cost. Customers are being warned to take precautions to limit the increase in electricity prices. The TINKERCAD programme is used to simulate this system, and the Arduino Integrated Development Environment (IDE) was used for system programming. Additionally, the system has been implemented, tested, and the necessary outcomes have been successfully analysed. The system has worked effectively and is satisfactory. It is also easy to use, straightforward, and efficient [5].

2.7.6 Simulation of Smart Meter Using Proteus Software For Smart Grid

The standard electricity transmission and distribution network can be upgraded into an interactive service network or a smart grid in response to the rising energy demand and consumption. One of the suggested solutions for the smart grid is smart meters. In order to achieve real-time data collecting, meter reading analysis, real-time monitoring and decision-making, etc., wireless smart metering is a crucial component of the smart grid. This project aims to build and implement a ZigBee-based smart power meter for reading power consumption and transmitting this data to the utility server for processing power data using new wireless communication technologies. Wireless transmissions use the ZigBee protocol. The implementation of smart meters based on budget-set energy usage. In this system, a power monitoring technique is employed. In this method, it is feasible to control the power system's energy usage, which lowers overall consumption and expenses. The user can also turn ON and turn OFF the specific appliances depending on the amount of power needed, which is a novel element of the power theft idea [6].

2.7.7 IoT Based Smart Energy Meter

Researchers presented a real-time, low-cost IOT-based energy management system in this work. It is designed to be a component of a distributed system that provides the ability to control the entire power plant and measures the major power system quantities. An integrated web server is able to interface devices for load displacement and collect statistics on power consumption and power quality. Fast data access is one of the device's key features, and both local and remote access are made possible by the smart meter's digital connection capabilities. This makes it feasible to control how much electricity our electrical gadgets use as well as monitor how much power our appliances use financially. Overall energy usage and expenses were decreased as a consequence of the power system. Method for reducing energy consumption in smart grids utilising smart. This outlined about how the need for energy-saving measures with appropriate building metering infrastructure is growing due to the increased demand for energy globally. Real-time pricing is the goal of this endeavour. This solution saves money and is environmentally beneficial. Electro-mechanical meter technology is currently being gradually replaced by electronics energy measurement. The suggested technique can be used to show the money that the devices draw in addition to the load energy use reading in Watts. Every user will be able to access the data from anywhere in the world. One website that uses MathWorks MATLAB analytics to display device information in a more extensive analysis, both in description and visualisation, is ubidots.com [9].

2.7.8 Design of A Smart Energy Meter

Technology has altered the world of today in ways that humans first brought about in the physical world. The flexibility to connect our real world to an automated dream world is made possible by the Internet of things. The world can be automated by connecting items to each other through the internet. This paper describes the construction of a smart energy metre design that uses an Internet of

Things-based monitoring and control system. This study suggests a system that reduces errors, which are a key contributor to energy-related corruption, and removes labour by automatically adjusting metre readings and bill production. The lack of a verification facility has led to a desire for transparency in the field of energy estimation. This system's central controlling unit is a NODE MCU built on an ESP-32. The microprocessor of the energy meter is interfaced with the ACS712 current sensor and ZMPT101B voltage sensor. Calculated readings of voltage, current, power used, quantity produced, and associated cost are shown on a 16*2 LCD display module and through our mobile application. The load power is managed via a relay. The Blynk smartphone app, which is connected to the Internet of Things, is used to monitor load through the use of mechanical relays, current and voltage sensors, and an interface. All of the sensor's readings are transmitted to Blynk cloud storage via the ESP32 Wi-Fi module. We are constructing an energy metre that can gauge the voltage of the electrical supply and the amount of electricity used by our household. Here we can see the live real-time reading by metre on the LCD attached with our gear and can also see this over the cloud using the Blynk app. We are able to view the voltage in real time as well as the overall electricity use for the current day, last month, and last year. Consumers can also easily track how much power they use, turn on and off multiple houses from anywhere in the world, and the electricity board can use our API (application programming interface) to automate the process of manually taking readings of electricity consumption. After that, customers can conveniently pay their bills online [10].

2.7.9 Implementation of Smart Metering Based on Internet of Things

Communication technologies and information are always changing to meet client demands while maintaining energy efficiency. Customers now expect fast data delivery, precise energy monitoring, and excellent customer support. The most successful approach is a smart grid system that combines a variety of affordable communication technologies with a bidirectional electrical section that allows utility companies and consumers to communicate information about electrical energy usage for remote monitoring. The

Internet of Things (IoT) idea is used in this work to monitor energy use using an Arduino Uno board and Ethernet. With this proposed system, human participation in electricity saving is eliminated. By using their device's IP address, consumers can access information on their energy consumption. the client code is uploaded to verify client details such URL, content, connection, and disconnect from the server. This proposed system delivers dependable and accurate information on electrical energy management system (EMS) using Internet of things (IoT) [11].

2.7.10 Smart Energy Metering and Control System

A tool for tracking electricity use and consumption is an energy meter. In order to calculate current, voltage, and power, meters often use real-time or nearly real-time sensor data. Using instantaneous power computation, the primary goal of this work was to design a single-phase smart energy meter. Electric power consumption by electrical appliances can be measured with this equipment. Monitoring the amount of electricity consumed by using the power system's current and voltage signals is one of the objectives. Arduino is used to sample and analyse voltage and current signals. The gadget has an integrated WiFi control switching function that allows users to remotely turn on and off the appliances at any moment using PMU-named Android platform software. To test the different circuit parameters, such as current voltage, power factor (PF), real power consumption, and reactive power, an Arduino code has been written. Additionally, a sensitivity measurement module is included in the system, and the results are routinely shown. An integrated smartphone application is created and used to operate the different appliances. An energy metering system with WiFi capability can be used to remotely operate the appliances [7].

CHAPTER 3

METHODOLOGY

3.1 Introduction

The Integration of a Smart Energy Metering System For Residential Houses proposes an efficient and thorough method of analysis for evaluating data regarding the energy usage of houses. This project requires certain components, including a 240 VAC power supply, a 4x20 LCD, an Arduino Uno, a Current Sensor, an LED Bulb, a rectifier, a resistor, a DC Motor, and Virtual Terminal. The IoT concept functions as the framework of the methodological approach used in this project. The method approach is based on the quantitive measurement type and attempts to create an analytical model to evaluate and analyze energy usage, including current, voltage, energy power, frequency, and power factor in houses using smart energy metering systems. Before constructing the hardware circuit, the Proteus software is used to simulate the schematic circuit and display it to the users.

3.2 Block Diagram

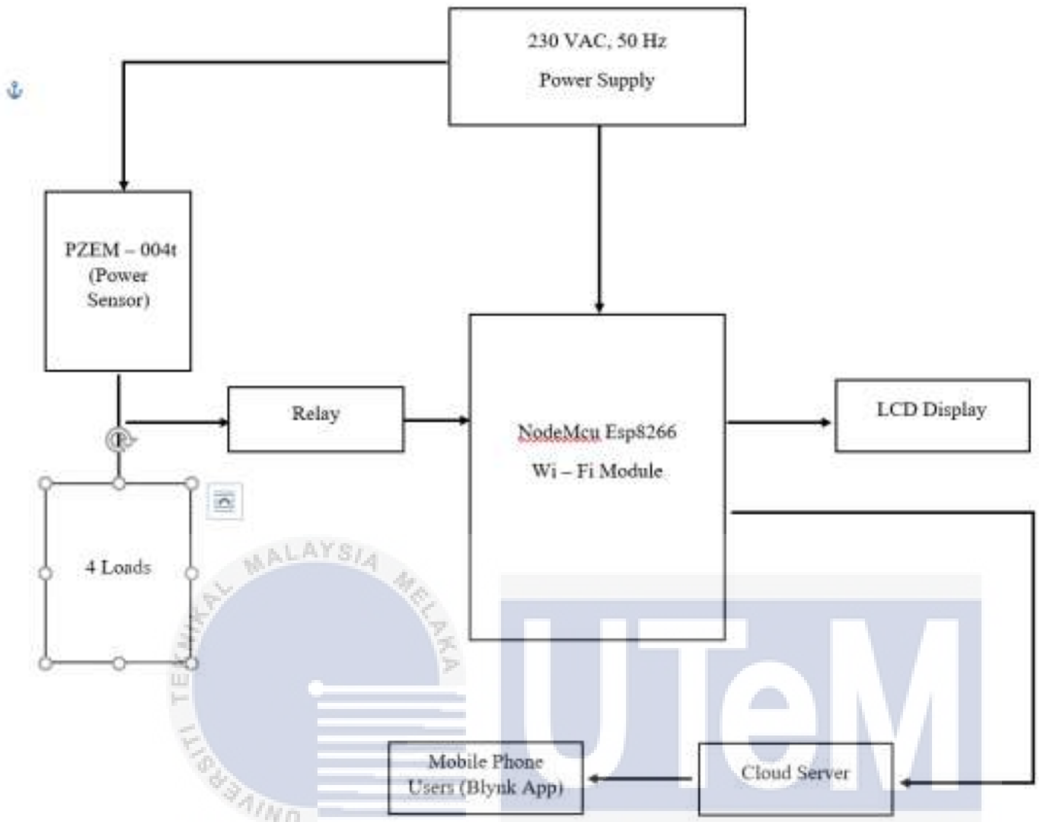

Figure 3.1 Block Diagram of The Smart Energy Metering System

The system will begin from the supply block, as shown in the block diagram. The IoT integration of the smart energy metering system for residential homes is powered by the supply block. The supply block travels via the NodeMcu ESP8266, Power Sensors, and Loads blocks. The supply travels from the Power Sensors and Loads blocks through the Relay block and onto the NodeMcu ESP8266 block. Following the coding on the NodeMcu ESP8266 block, the LCD display block shows the energy consumption, including the applied voltage, circuit current, energy power, energy cost, and power factor. It will pass through the NodeMcu ESP8266 (Wi- Fi) Module . The energy usage data is then displayed on the mobile phone users (Blynk App) block from the NodeMcu ESP8266 (Wi-Fi)

Module block via the Cloud Server block. The block diagram approach was essential for this project's successful system.

3.3 Flowchart

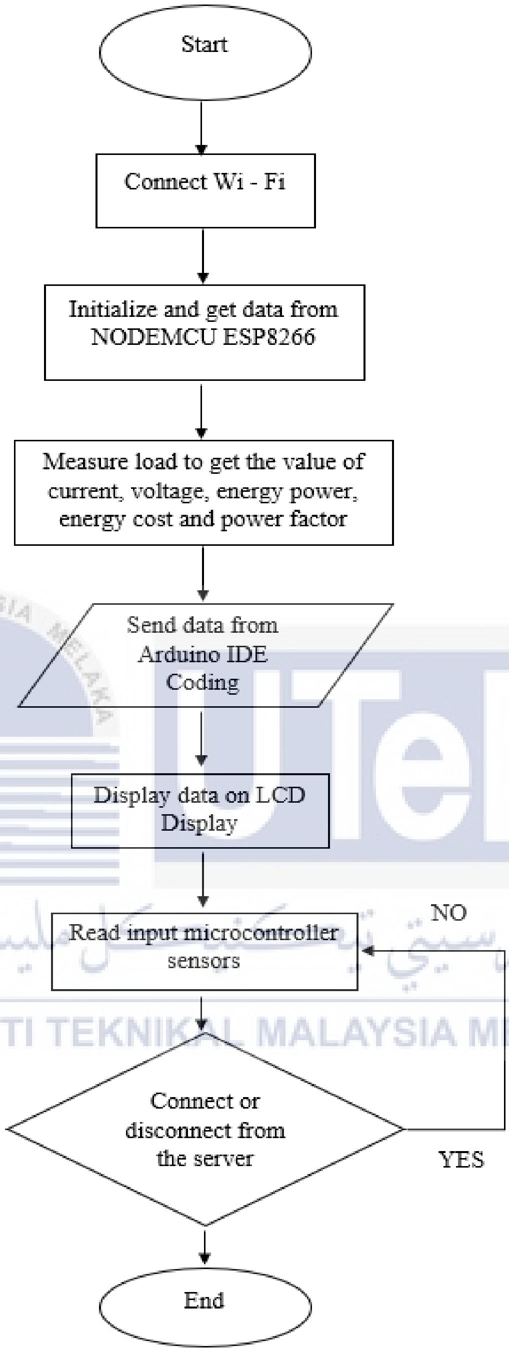

Figure 3.2 Flowchart of The Smart Energy Metering System

This flowchart provides a guide to demonstrate how the process works in this system. The system first begins with the incoming voltage. It has a 230V input voltage and a 50HZ frequency. Circuit current and applied voltage are measured using the power sensors. Send the data to the NodeMcu ESP8266 so it may run the inserted code to measure the loads' voltage, current, energy, energy cost, and power factor. The data is then sent to the NodeMcu ESP8266, which connects via Wi-Fi and displays the data similarly to an LCD display using the "Blynk App." If the connection is successful, the "Blynk App" and LCD display show the energy consumption for the applied voltage, circuit current, energy power, energy cost, and power factor. The microcontroller sensors' input is used for NodeMcu ESP8266 and Arduino IDE coding. The conclusion occurs. However, if the server connection abruptly disconnects, the LCD display will only display the data related to energy usage.

3.4 Design Requirements For Simulation

As stated previously, the project is created using Proteus 7. Figure 3.3 illustrates the complete circuit for our endeavour. This circuit has been segmented into a few sections for the sake of clarity. The component parts are:

- Power Supply
- Arduino Uno
- LCD Display
- Rectifier
- Resistor
- Current Sensor
- LED Bulb
- DC Motor
- Virtual Terminal

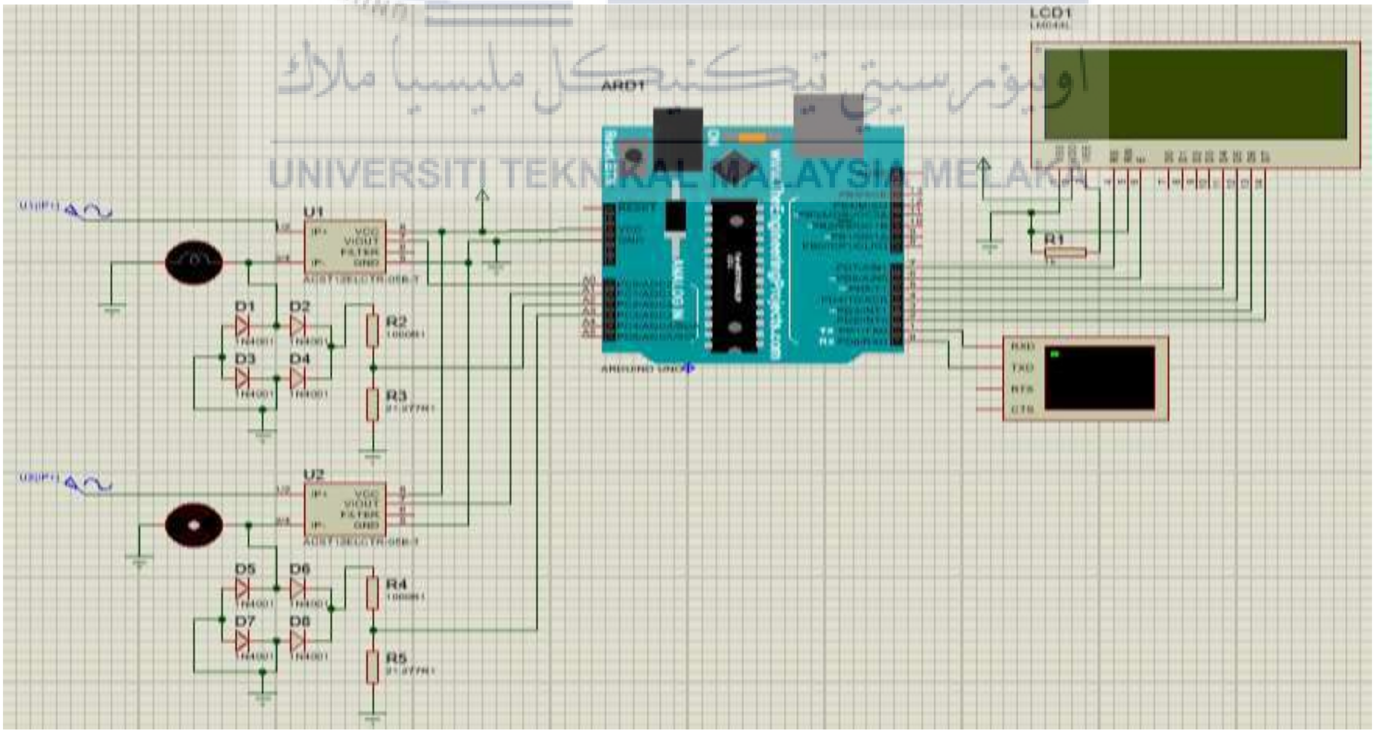

Figure 3.3 Schematic Circuit Diagram of Smart Energy Metering System

3.4.1 Power Supply

This project used a sine generator to generate an AC supply at 230VAC and 50Hz.

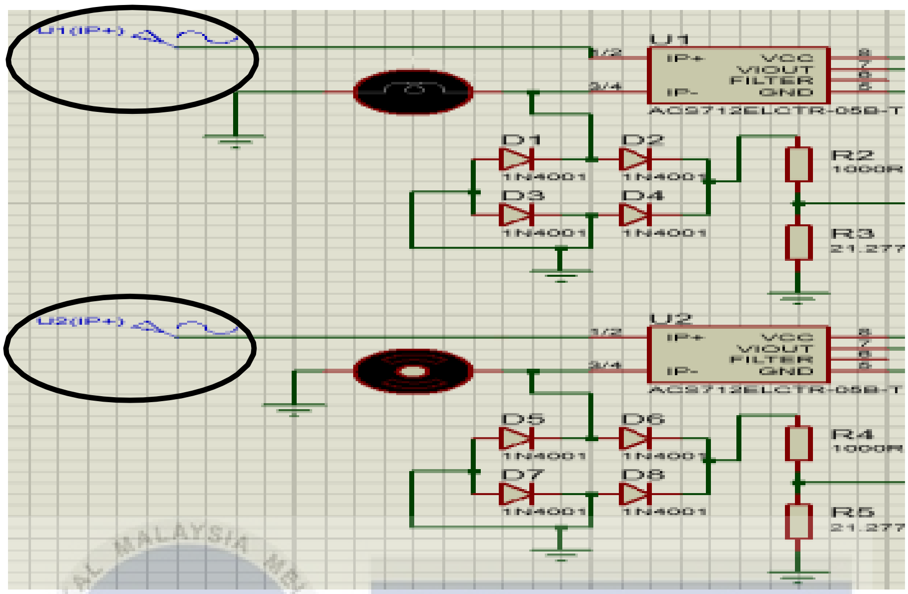

Figure 3.4 Power Supply, Current Sensor, Rectifier, Resistor and Load

3.4.2 Arduino Uno

Throughout this project, we measured the energy consumption by using a "Arduino Uno" to measure voltage, current, power, frequency, and power factor. To compare the load between the motor and LED bulb, which have consumed the most energy consumption, in order to display the value of voltage, current, energy power, frequency, and power factor. The Arduino must gather data from the circuit and transfer it to the LCD Display and current sensor in order to do all of these functions.

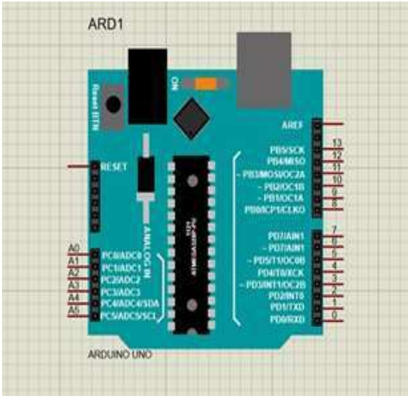

Figure 3.5 Arduino Uno

The coding section will cover the measuring and evaluation procedures. In this section we'll mainly go through the software connections. The Arduino's various pins are connected as follows :

- ❖ Pin VCC : Connected to the output of the VCC Current Sensor. This pin used to supply the Arduino Uno.
- ❖ Pin GND : Connected to the output of the GND Current Sensor. This pin used for the grounding protection of the entire circuit.
- ❖ Pin A0 and A1 : Connected to the output of the VIOUT (volatge and current) Current Sensor. This pins used to measure the voltage and current values.
- ❖ Pin A2 and A3 : Connected to the resistor of (R2, R3) and (R4,R5) . This pins used to supply the required voltage and limit the circuit's current flow.
- ❖ Pin 2 – 7 : The LCD Display is connected to these pins. It is used to manage and display the data value for energy usage.
- ❖ Pin 0 : Connected to the RXD input. This pin used to transmit and receive lines of the system.

- ❖ Pin 1 : Connected to the TXD output. This pin used to transmit and receive lines of the system.

3.4.3 LCD Display

The Arduino is coupled with a 20x4 LCD. It is used to display the energy consumption values for voltage, current, energy power, frequency, and power factor. The ground and R1's input are connected to the LCD's VSS pin. The terminal label is wired up to the LCD's VDD pin. The output of R1 is coupled to the VEE pin of the LCD. The Arduino's Pin 7 is connected to the LCD's RS pin. The LCD's RW pin is connected to the R1's input. The Arduino's Pin 6 is connected to the LCD's E Pin. Thus, the pins 2-5 of the Arduino are connected to the LCD's D4 to D7 pins. The VSS and R1 pins of the LCD are grounded, while the VDD pin is supplied with 5V through the terminal label.

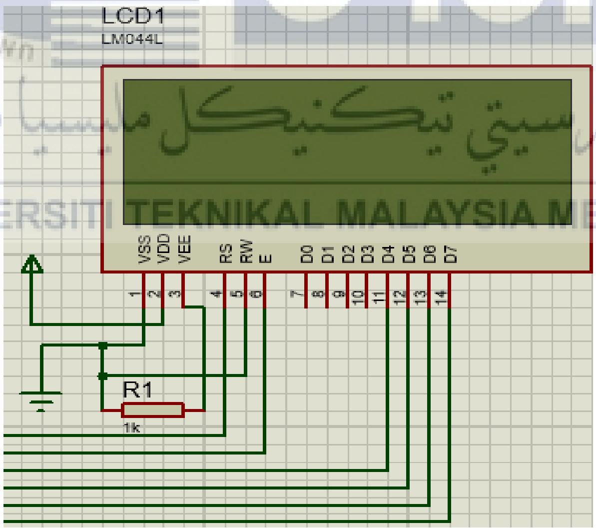

Figure 3.6 LCD Display

3.4.4 Rectifier

The eight rectifiers are utilised. The input of the current sensor is connected to each of the four rectifiers. The input of the current sensor, the output of the load (an LED bulb), and the connections to R2 and R3 of the resistor are connected for D1, D2, D3, and D4 of the rectifier. The rectifier is connected to the output of the load (DC Motor), the input of the current sensor, and the R4 and R5 of the resistor for D5, D6, D7, and D8. Depending on the direction of the applied voltage, rectifier diodes behave as though current flows (ahead direction) or does not flow (reverse direction). The diode works to correct the AC voltage by enabling use of this feature. In this schematic circuit, every rectifier is grounded.

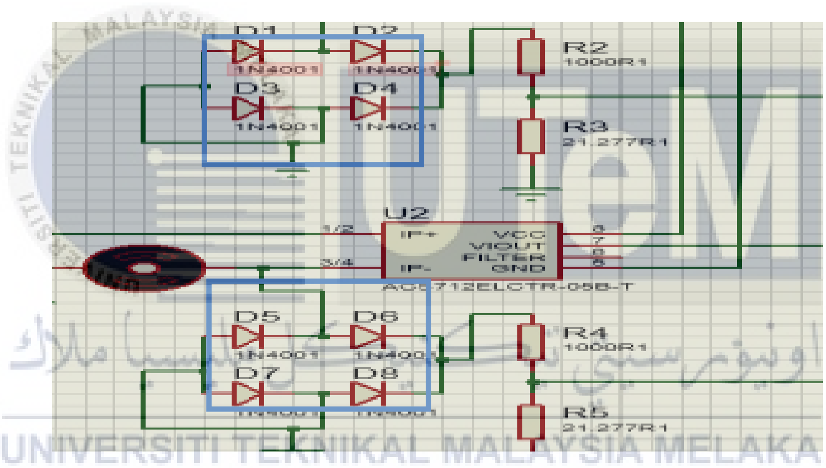

Figure 3.7 Rectifier

3.4.5 Resistor

There are four resistors included. The Arduino's pin A2 is connected to the R2 and R3 via a wire. The rectifiers of D1, D2, D3, and D4 are also connected to the R2 and R3. The R4 and R5 are connected to the Arduino's pin A3. The rectifiers of D5, D6, D7, and D8 are also connected to the R4 and R5. These resistors operate to supply the required voltage and control the current flow in the circuit. This schematic circuit's resistors are all grounded.

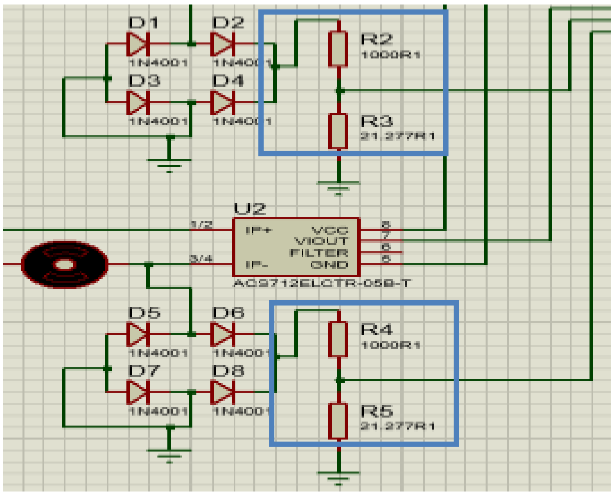

Figure 3.8 Resistor

3.4.6 Current Sensor

A current sensor is a device that detects electric current in a connection and produces a signal according to that current. A digital output or an analogue voltage or current could be the generated signal. There are two current sensors. For the first (U1) and second (U2), the input of current sensor (IP+) are connected to the sine generator that generate the supply of 230 VAC and 50 Hz. For U1, the input of current sensor (IP-) are connected to the input of the load (LED Bulb) then connected through the rectifiers of (D1, D2, D3 and D4). For U2, the input of current sensor (IP-) are connected to the input of the load (Motor) then connected through the rectifiers of (D5, D6, D7 and D8). The pin VCC of output current sensors are connected to the VCC pin of Arduino and Terminal Label. The pin GND of output current sensors are connected to the pin GND of Arduino and through the grounding. The pin VIOUT of output current sensors are connected to the pin A1 and A0 Of Arduino.

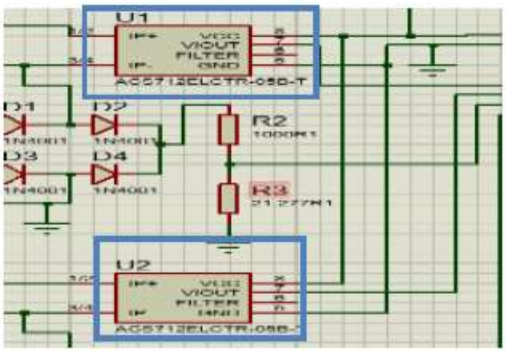

Figure 3.9 Current Sensor

3.4.7 LED Bulb (Load)

For this project, we utilized the two various types of loads. LED Bulb are one of them. Through rectifiers (D1, D2, D3, and D4), the input of the LED bulb is connected to the input (IP-) of the current sensor (U1). The ground is connected to the LED bulb's output. Outlets normally provide high voltage, alternating current electricity, but LED's operate on low voltage, direct current electricity. An LED driver's primary function is to convert this higher voltage alternating current into the low voltage direct current energy that LED's are made to withstand.

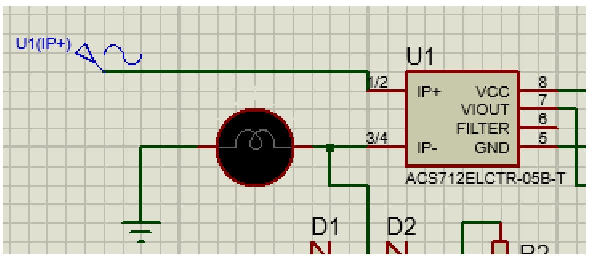

Figure 3.10 LED Bulb

3.4.8 DC Motor (Load)

DC Motor also one of the loads. Through rectifiers (D5, D6, D7, and D8), the input of the Motor is connected to the input (IP-) of the current sensor (U2). The ground is connected to the DC Motor's output. This DC Motor is used to measure the voltage, current, energy power, and power factor values for the comparison of other loads.

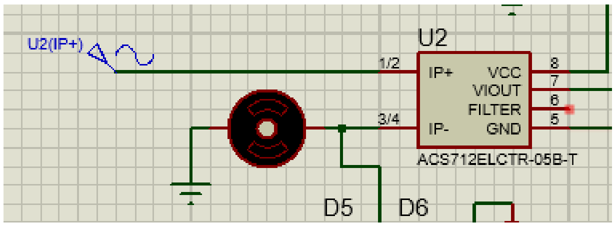

Figure 3.11 DC Motor

3.4.9 Virtual Terminal

For this project, we have used a software-based interface called a Virtual Terminal in Proteus Simulation enables designers to digitally interact with their circuits and systems. Designers can enter and output data from their circuits and systems due to its conduct simulating that of a real terminal. The pin A0 of the Arduino are connected to the output TXD of the virtual terminal to transmit the data. The pin A1 of the Arduino are connected to the input RXD of the virtual terminal to receive the data.

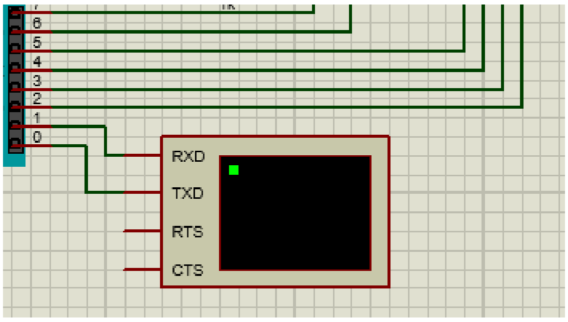

Figure 3.12 Virtual Terminal

3.5 Design Requirements For Prototype Design

As stated previously, the project circuit is created using Fritzing. Figure 3.13 illustrates the complete circuit for our endeavour. This circuit has been segmented into a few sections for the sake of clarity. The component parts are:

- Power Supply (Plug Top)
- NodeMCU ESP8266
- ELCB
- LCD Display
- Power Sensor (PZEM – 004T)
- Indicator Light (240V)
- AC Blower Fan (240V)
- Toggle Switch Push Button
- 13A Socket Plug
- Blynk App

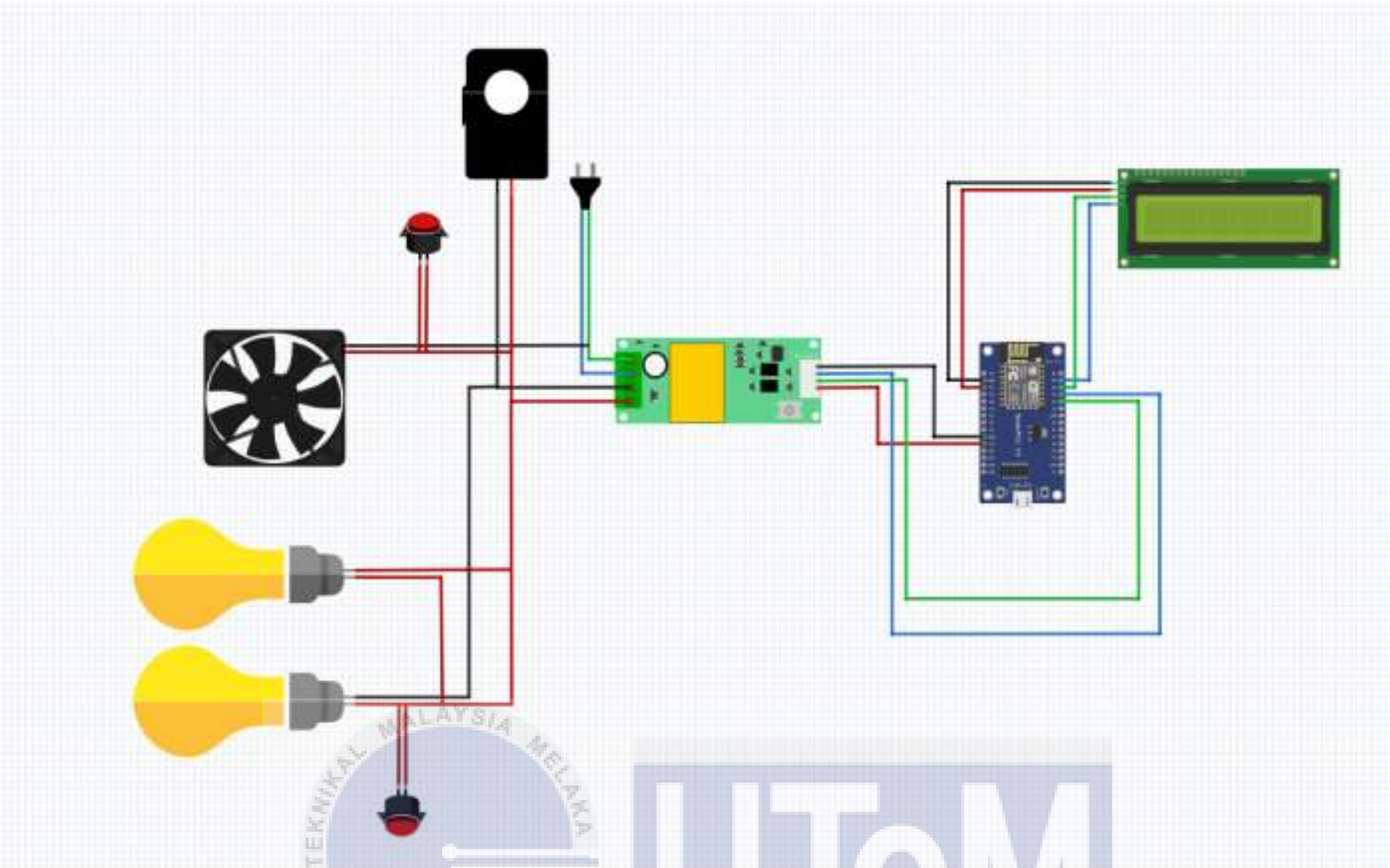

Figure 3.13 Hardware Schematic Circuit Diagram of Smart Energy Metering System

Figure 3.14 Hardware Prototype Design of Smart Energy Metering System

3.5.1 Power Supply (Plug Top)

This hardware prototype project used a single phase power supply 240VAC.

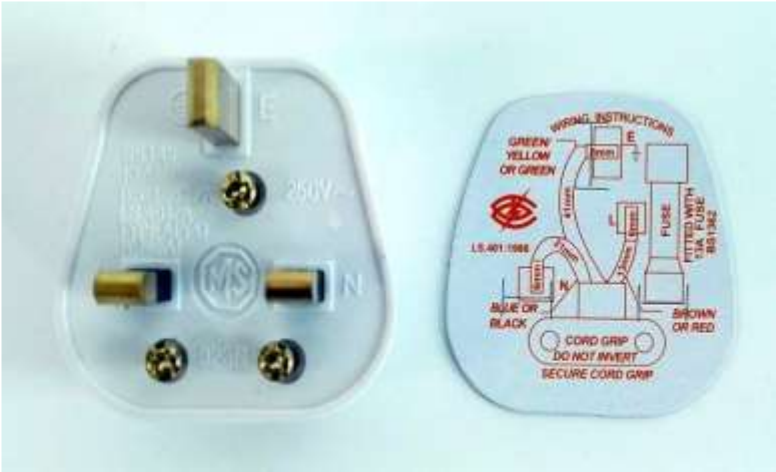

Figure 3.15 Power Supply (Plug Top)

3.5.2 NodeMcu ESP8266

Throughout this hardware prototype project, we measured the energy consumption by using a "NodeMcu ESP8266" to measure voltage, current, energy power, energy cost, and power factor. To compare the load between the indicator light, blower fan, and hairdryer which have consumed the most energy consumption, in order to display the value of voltage, current, energy power, energy cost, and power factor. To perform all of these functions, the NodeMcu ESP8266 needs to collect data from the hardware prototype circuit and send it to the Blynk App, the LCD Display, and the power sensor.

The coding section will cover the measuring and evaluation procedures. In this section we'll mainly go through the hardware connections. The Arduino's various pins are connected as follows :

- Pin 3V : Connected to the output of the 5V Power Sensor. This pin used to supply the NodeMcu ESP8266.
- Pin GND : Connected to the output of the GND Power Sensor. This pin used for the grounding protection of the entire circuit.
- Pin D3 : Connected to the input of the TX pin Power Sensor. This pin is used to transmit data to the NodeMcu ESP8266 on the measured value of energy usage.
- Pin D4 : Connected to the input of the RX pin Power Sensor. This pin is used to transmit data to the NodeMcu ESP8266 on the measured value of energy usage.
- Pin VCC : The LCD Display is connected to VV pin of the NodeMcu ESP8266. It is utilised to supply electricity and display the energy consumption data value.
- Pin GND : Connected to the Gnd pin of the NodeMcu ESP8266. This pin used for the grounding protection of the entire circuit.
- Pin SDA : Connected to the D2 pin of the LCD display. It is used to manage and display the data value for energy usage.
- Pin SCL : Connected to the D1 pin of the LCD display. It is used to manage and display the data value for energy usage.

Figure 3.16 NodeMcu ESP8266

3.5.3 ELCB

With an automatic shut-off upon detection of leakage, earth leakage circuit breakers are used in applications to prevent electrical shock and electrical fires caused by a short circuit or overload in the control panel. This ELCB is utilised in the hardware prototype project to connect via the plug top in order to supply power to the hardware prototype circuit.

Figure 3.17 ELCB

3.5.4 LCD Display

The NodeMcu ESP8266 is coupled with a 20x4 LCD I2C. It is used to display the energy consumption values for voltage, current, energy power, energy cost, and power factor. The ground input are connected to the LCD's GND pin. The terminal label of VV at NodeMcu ESP8266 is wired up to the LCD's VCC pin. The D1 pin is where LCD SDA connections are made. LCD SCL pins are connected to the D2 pin, and the terminal label provides 5V to the VV pin.

Figure 3.18 LCD Display

3.5.5 Power Sensor (PZEM – 004T)

The PZEM-004T was developed to monitor voltage, current, power, and energy consumption, among other electrical parameters in an AC circuit. It is frequently used to track device power consumption, assess electrical system performance, and interface with microcontrollers for data logging and analysis. In order to install the PZEM-004T, it is usually connected in parallel to measure voltage and in series to measure current with the load for the output of this power sensor. The NodeMcu ESP8266 is connected to the power sensor's TX pin through pin D3 and RX pin through pin D4 for the power sensor's input. The NodeMcu ESP8266's GND pin is linked to the GND pin, and the power sensor's 5V pin is where the 3V is connected.

Figure 3.19 Power Sensor (PZEM – 004T)

3.5.6 Indicator Light (240VAC)

For this project, we utilized the three various types of loads. Indicator light are one of them. The output of the cable connector that connects to the toggle switch push button is where the live and neutral connections for the indicator light are connected. The output of the power sensor is connected to the input of the power supply for the indicator light.

Figure 3.20 Indicator Light

3.5.7 AC Blower Fan (240V)

AC blower fan also one of the loads. Live and neutral connections for the AC blower fan are connected at the output of the cable connector that joins to the toggle switch push button. An AC blower fan's power supply input is connected to the power sensor's output. This AC blower fan is used to measure the voltage, current, energy power, energy cost, and power factor values for the comparison of other loads.

Figure 3.21 AC Blower Fan

3.5.8 Toggle Switch Push Button

A mechanical switch with two settings is called a toggle switch; it can normally be in either the "on" or "off" state. Until the other position is manually selected, it remains in its current position. Toggle switches are utilised in this hardware prototype project to turn on and off the indicator light and the AC lower fan. If the hardware prototype circuit has a power supply, the switches additionally act as component protection. Two toggle switch push buttons are linked to the AC blower fan and the indicator light, respectively.

Figure 3.22 Toggle Switch Push Button

3.5.9 13A Socket Plug

A power plug made specifically to fit into a 13-ampere electrical socket is commonly referred to as a 13A socket plug. In nations where the British standard is used, the word "13A" is frequently used to refer to the maximum current rating for which the plug is intended. The 13A socket plug will be fitted for this hardware prototype project in order to plug in hairdryer pins, which is the third load that will be utilised for evaluating energy consumption. The output cable connection connects the 13A socket plug's live and neutral cables, while the power sensor connects the socket plug's input. Three Pins: A plug typically contains three pins, which are rectangular prongs. These are the following:

- Live (L): The conductor that carries current
- Neutral (N): The current's path of return
- Earth (E): The safety grounding link

Figure 3.23 13A Socket Plug

3.5.10 Blynk App

Creating mobile applications for managing and keeping an eye on Internet of Things (IoT) devices is made possible with the well-known Blynk platform. Select an energy monitoring module that can measure for energy consumption voltage, current, energy power, power factor, and energy cost, such as the PZEM-004T or something comparable. Utilise an ESP8266 microcontroller to communicate with the energy monitoring module and establish an internet connection. As directed by the datasheet or instructions included with the module, connect the energy monitoring module to the microcontroller. For the microcontroller platform you are using, install the Blynk library. The Blynk libraries for ESP8266 are available in the corresponding libraries. Launch the Blynk app on your mobile device and start an entirely new project. You will receive an authentication token from Blynk.To display energy-related information in your Blynk project, add the relevant widgets. SuperChart, Gauge, and Value Display are examples of common widgets.Using the Blynk library, write a programme for your microcontroller.

The data from the energy monitoring module should be read by this programme and sent to the Blynk server. Transfer the code to the ESP8266. The widgets you added to your project should show real-time energy consumption data when you open the Blynk app.

Figure 3.24 Blynk App

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

The simulation results and analysis of the IoT integration of the smart energy metering system for houses are presented in this chapter. We constructed the schematic circuit diagram and conducted the simulation for this project using Proteus Software 8.13. This enabled us to measure the energy consumption data, including the applied voltage, circuit current, energy power, and power factor.

The hardware results and analysis of the IoT integration of the smart energy metering system for houses are presented in this chapter. We design the circuit diagram for this project using Fritzing and constructed the hardware. This enabled us to measure the energy consumption data, including the applied voltage, circuit current, energy power, power factor, and energy cost by using Blynk App.

4.2 Simulation Results and Analysis

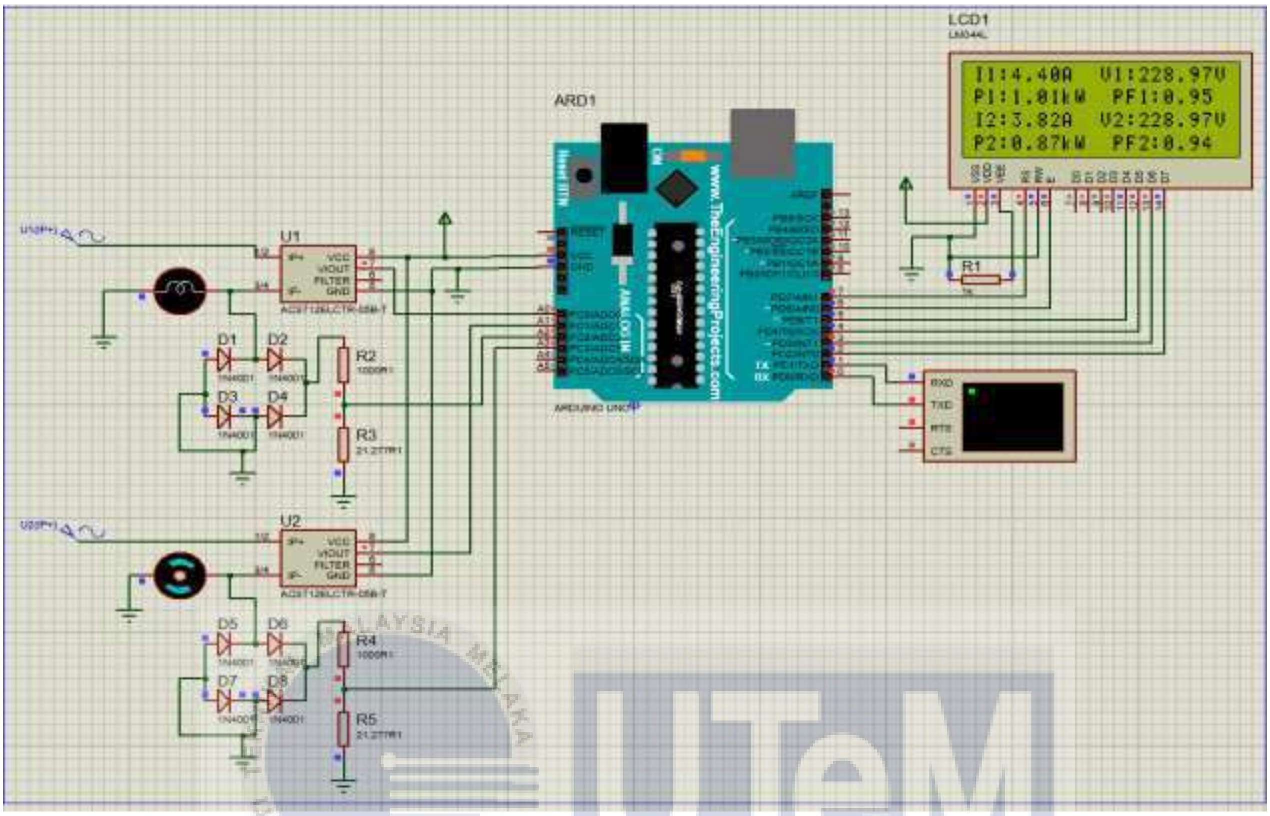

Figure 4.1 Simulation Results and Analysis For Normal Load

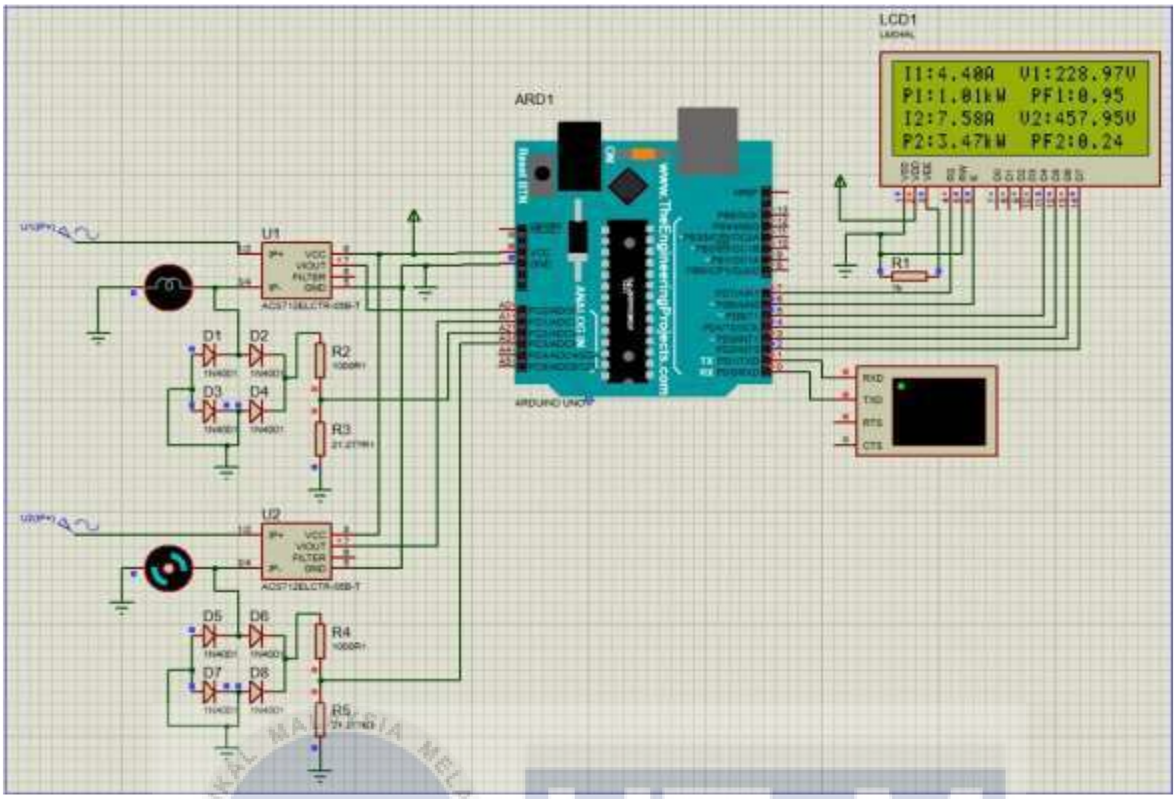

Figure 4.2 Simulation Results and Analysis For Overload

4.3 Measurements of Volatge, Current, Energy Power, and Power Factor Based On Simulation Results and Analysis

Table 4.3 Measurements For Voltage, Current, Energy Power, and Power Factor (Normal Load)

Load	Voltage	Current	Energy Power (kW)	Power Factor
LED Bulb	228.97 V	4.40 A	1.01 kW	0.95
DC Motor	228.97 V	3.82A	0.87 kW	0.94

The LED Bulb consumes more energy than the DC Motor, as seen in Figures 4.1 and 4.3. Maintain the same voltage. Energy power is different from current. The load current increases in direct proportion to energy consumption.

Table 4.4 Measurements For Voltage, Current, Energy Power, and Power Factor (Overload)

Load	Voltage	Current	Energy Power (kW)	Power Factor
LED Bulb	228.97 V	4.40 A	1.01 kW	0.95
DC Motor	457.95 V	7.58 A	3.47 kW	0.24

When we increased the load, the system for this project would indicate that it had become overloaded based on Figures 4.2 and 4.4. So, utilising the integrated smart energy metering system, we can detect the overload. Then, as the current's load rises, the energy's power rises as well, and the power factor decreases. Due to the overload, the line voltage will also shift, becoming a three-phase power supply.

4.4 Discussion of Simulation Results and Analysis

The proposed schematic circuit design is simulated in Figure 3.3, and Figure 4.1 displays the simulation's findings. The current sensors monitored the measuring circuit current and voltage once the meter had been powered on. Following the programmed procedure, the Arduino was used to calculate the signals from the sensors. Results were displayed on the LCD display that was supplied by the power supply (Sine Generator) based on the data processed regarding voltage, current, energy power, and power factor. Prior to connecting the loads to the the single-phase power supply (Sine Generator). The current sensor of the Hall Effect must be attached for the voltage measurement in order to obtain the current produced by the load. The Arduino's built-in ADC (analogue to digital converter) was then used to convert the analogue signal from the voltage and current sensors directly to digital. Results of the circuit current, applied voltage, energy power ratings, and power factor were displayed on the LCD display.

4.5 Hardware Results and Analysis

Figure 4.5 Hardware Results and Analysis For Normal Load of Blower Fan

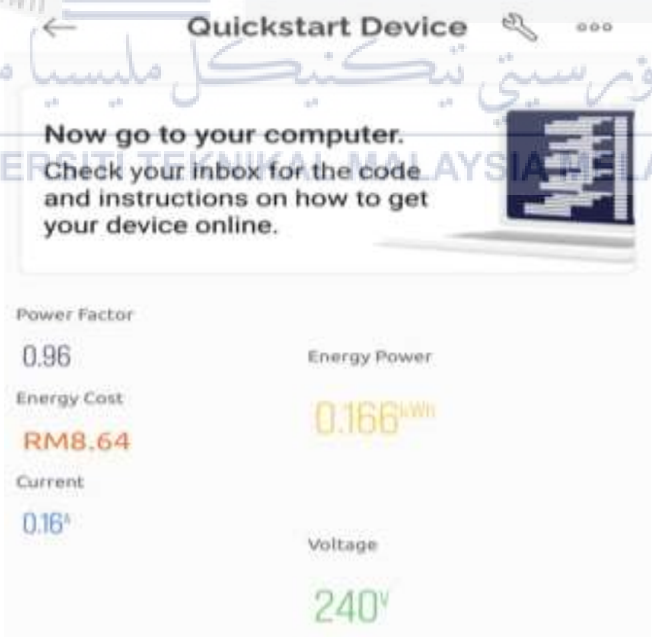

Figure 4.6 Hardware Results and Analysis For Normal Load of Indicator Lamp and Blower Fan

Figure 4.7 Hardware Results and Analysis For Overload of Indicator Lamp

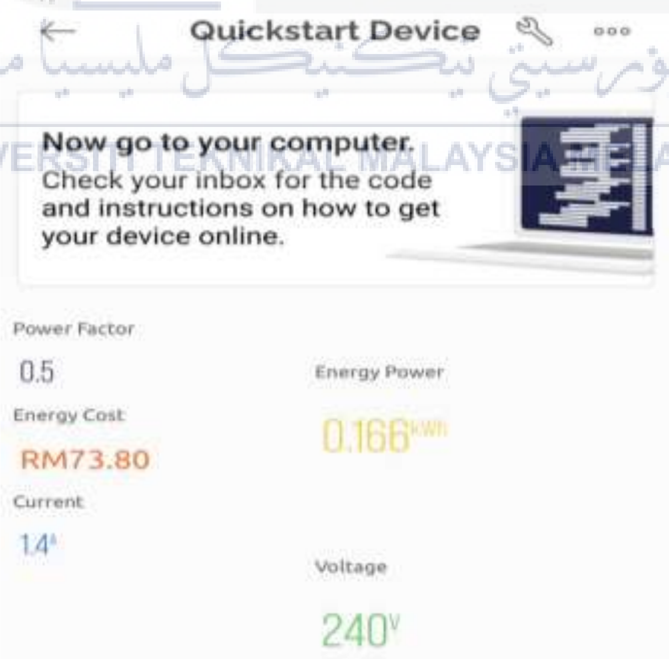

Figure 4.8 Hardware Results and Analysis For Overload of Hairdryer

Figure 4.9 Hardware Results and Analysis For Overload of Charging Phone (Type C)

Figure 4.10 Hardware Results and Analysis For Overload of Indicator Lamp, Blower Fan, and Hairdryer

4.6 Measurements of Volatge, Current, Energy Power, Energy Cost, and Power Factor Based On Hardware Results and Analysis

Table 4.10 Measurements For Voltage, Current, Energy Power, Energy Cost, and Power Factor (Normal Load)

Load	Voltage (V)	Current (A)	Energy Power (kWh)	Power Factor	Energy Cost (RM)
Blower Fan	240	0.14	0.164	0.96	7.46
Indicator Lamp + Blower Fan	240	0.16	0.166	0.96	8.64

The Indicator Lamp and Blower Fan consumes more energy than the Blower Fan, as seen in Figures 4.5 and 4.6. Maintain the same voltage. Energy power is different from current. The load current increases in direct proportion to energy consumption. Increasing load current also results in higher energy costs.

Table 4.11 Measurements For Voltage, Current, Energy Power, Energy Cost, and Power Factor (Overload)

Load	Voltage (V)	Current (A)	Energy Power (kWh)	Power Factor	Energy Cost (RM)
Indicator Lamp	240	0.04	0.164	0.36	2.28
Hairdryer	240	1.40	0.166	0.50	73.80
Charging Phone (Type C)	240	0.10	0.208	0.49	5.34
Indicator Lamp + Blower Fan + Hairdryer	240	1.53	0.168	0.54	80.99

When we increased the load, the system for this project would indicate that it had become overloaded based on Figures 4.7, 4.8. 4.9, and 4.10. So, utilising the integrated smart energy metering system, we can detect the overload. Then, as the current's load rises, the energy's power rises as well, and the power factor decreases. Due to the overload, the line voltage will also decreases. Other than that, increasing load current also results in higher energy costs.

4.7 Discussion of Hardware Results and Analysis

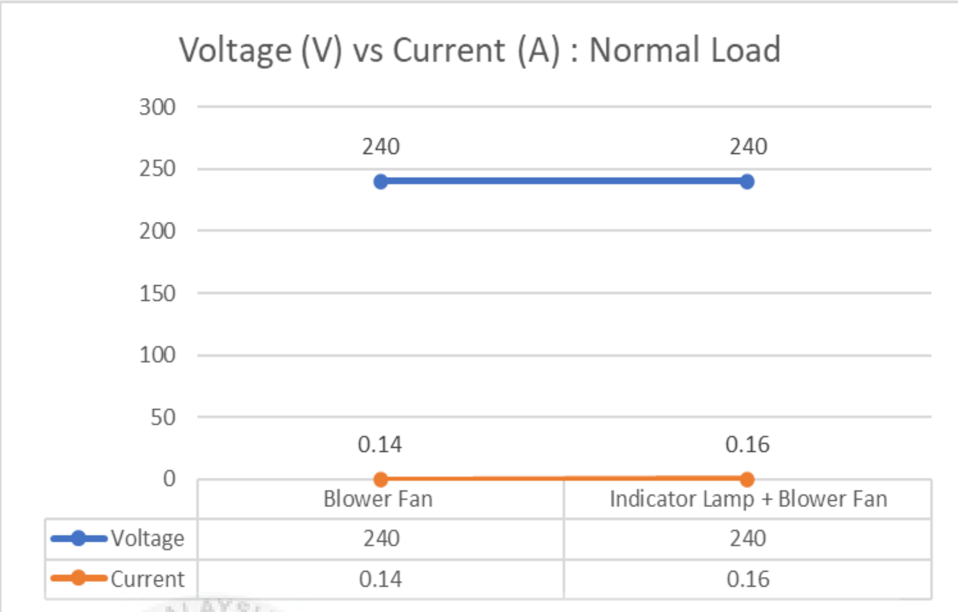

Figure 4.12 Graph Voltage (V) vs Current (A) For Normal Load

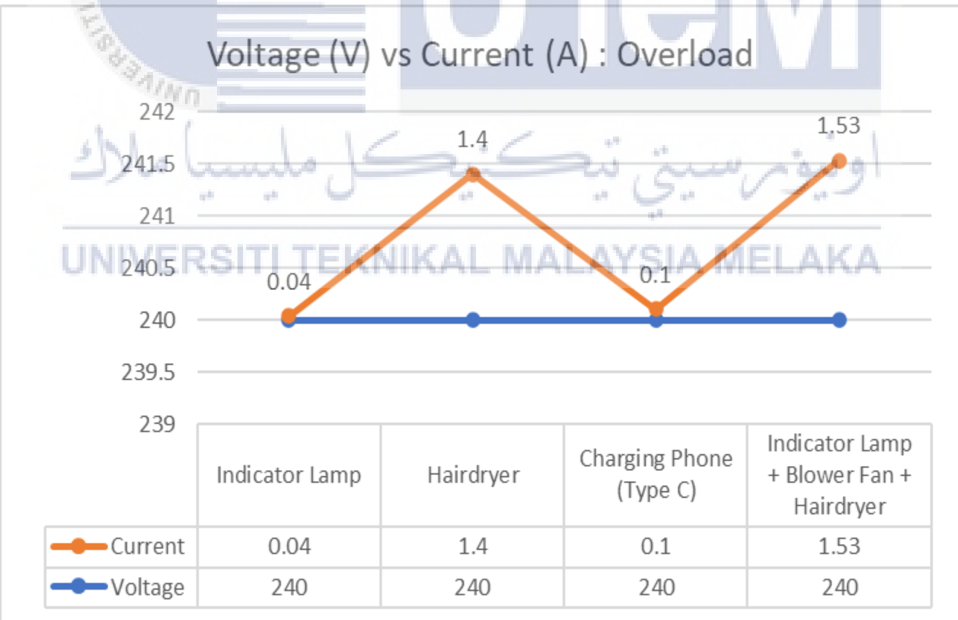

Figure 4.13 Graph Voltage (V) vs Current (A) For Overload

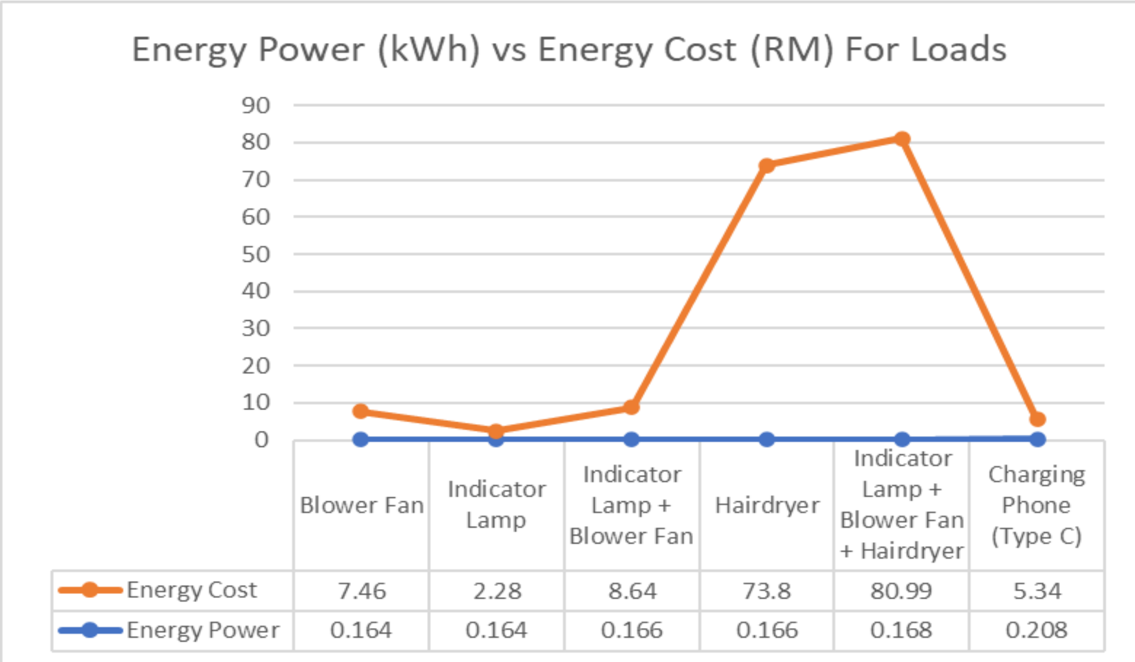

Figure 4.14 Graph Energy Power (kWh) vs Energy Cost (RM)

The proposed hardware circuit diagram and prototype design are constructed in Figure 3.13 and Figure 3.14. Following the power supply's activation, the power sensor measured the circuit current and voltage. The power sensor's signals were calculated by the NodeMcu ESP8266 using the preprogrammed process. The data regarding voltage, current, energy power, power factor, and energy cost were processed, and based on Figures 4.5, 4.6, 4.7, 4.8, 4.9, and 4.10 the findings were displayed on the Blynk App and LCD display that was powered by the power supply. Before attaching the single-phase power supply to the loads. To determine the current generated by the load, the power sensor needs to be connected for the voltage measurement. The Blynk App and LCD display showed the results of the circuit current, applied voltage, energy power ratings, power factor, and energy cost.

Several factors, including energy consumption, performance, accuracy, and system dependability for both results and analysis, are compared between the hardware and simulation results. Based on the schematic circuit design that was created using Proteus Software for the simulation. LED bulb and DC motor are the two different types of loads that are represented by this schematic circuit layout. LED bulbs use more energy (kW) and current (A) than DC motors under typical load conditions. In addition, in the event of an overload, a DC motor will use more energy power (kW) and current (A) than an LED bulb, resulting in a low power factor of 0.24. The line voltage will also convert to a three-phase power supply. To determine the energy usage for this schematic circuit design, while used two current sensors. Apart from that, then utilised Fritzing software to construct the circuit diagram for the prototype hardware, which was then used to design the hardware's wiring and connections. It used four distinct types of loads to measure this hardware prototype's energy consumption. In comparison to the indicator lamp and blower fan, the blower fan uses less energy power (kWh) and current (A) under normal load conditions. Indicator lamps and blowers fans have greater energy costs (RM) than blowers fans. For overload condition, the most consumes current (A) are indicator lamp, blower and hairdryer which is 1.53A. For charging phone (Type C) consumes more energy power (kWh) which is 0.208 kWh. The measured energy usage for the prototype hardware design using one power sensor, aside from that. The reason why the data energy consumption for simulation results and prototype hardware design are different because of the accurate models of energy use should be used in simulations. Check to see if the hardware components behave as predicted given the simulated energy usage. For the hardware results to determine how much energy the deployed hardware actually uses. This covers the energy consumed by any additional parts, communication modules, and smart meters.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Future developments in energy management are made possible by the incorporation of smart energy metering. Smart meters can make it easier to integrate these decentralised energy generation systems into the grid as renewable energy sources like solar panels and wind turbines gain popularity. Homeowners may optimise their use of renewable energy and even sell extra energy back to the grid by tracking energy production and consumption in real-time. This encourages sustainability and lessens reliance on fossil fuels. While establishing in place a smart energy metering system based on the Internet of Things (IoT), it is crucial to handle specific issues and factors. The acquisition of precise data on energy consumption increases privacy considerations, thus privacy and data security should be your top priorities. Sensitive user data must be shielded from unauthorised access and cyber-attacks by effective security measures. A seamless integration and the avoidance of vendor lock-in depend on the compatibility and standardisation of various IoT platforms and smart metering systems. A variety of advantages, including real-time monitoring, remote control, demand-response programmes, and potential for future energy management, are provided by the integration of smart energy metering systems for residential homes via the IoT. These systems encourage energy efficiency, sustainability, and cost savings while helping to create a more dependable and smarter energy infrastructure by arming homeowners with specific information about their energy consumption.

5.2 Future Works

The Internet of Things (IoT) can be used to integrate a smart energy metering system for residential homes, which has the potential to improve energy efficiency, save expenses, and encourage sustainable living. We have investigated the possible advantages and difficulties of putting such a system into place during this study. The main conclusions and understandings from this project open the door to a more knowledgeable and effective approach to energy management in home settings. It is imperative to recognise the obstacles and factors involved in the process of integration. To guarantee that sensitive data is protected, privacy and security issues need to be taken seriously. To facilitate smooth communication across various platforms and devices, interoperability standards should also be developed. To improve the technology and make it more usable and accessible for a wider variety of homeowners, ongoing research and development initiatives are needed. Investigate cutting-edge data analytics methods to extract more meaningful information from the gathered energy usage data. Machine learning algorithms may be used in this to forecast usage trends, spot abnormalities, and provide tailored energy-saving advice. Other than that, increase the system's capacity to interface with solar panels and other renewable energy sources. This would further lessen reliance on conventional power sources by enabling homes to monitor and optimise the use of renewable energy. Ensure that the interfaces created for homes to engage with the Smart Energy Metering System are clear and easy to use. To improve the user experience, this might include voice-activated gadgets, smartphone applications, or other cutting-edge designs. In summary, the energy industry has a revolutionary opportunity with the integration of an IoT-based smart energy metering system for residential homes. We can realise the full potential of this technology and help create a more sustainable and energy-efficient future for residential communities by tackling the issues that have been highlighted and concentrating on future research topics.

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