DESIGN AND DEVELOPMENT OF INTERNET OF THINGS (IoT) BASED SYSTEM FOR MONITORING ENERGY CONSUMPTION

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LIST OF ABBREVIATIONS

AC	Alternating Current
ACS	Current Sensor
ADC	Analogue to Digital Converter
AO	Analogue Digital Pin
API	Application Programming Interface
CC	Common Contact
CT	Current Transformer
D	Digital Pin
GND	Ground
GPIO	General Purpose Input Output
GSM	Global System for Mobile Communication
HEMS	Home Energy Management System
HVAC	Heating, Ventilating, and Air Conditioning
IoT	Internet of Things
Irms	Root Mean Square Current
LCD	Liquid Crystal Display
LED	Light Emitting Diode
NC	Normally Close
NO	Normally Open
NodeMCU	Node Microcontroller Unit
PIR	Passive Infrared Sensor
PWM	Pulse Width Module

RF	Radio Frequency
RMS	Root Mean Square
RTC	Real Time Clock
SCT	Non-Invasive AC Current Sensor
TM	Telekom Malaysia
TTL	Transistor - Transistor Logic
VCC	Voltage at common Collector

ABSTRAK

Internet of Things (IoT) adalah teknologi yang sangat canggih yang boleh digunakan untuk pelbagai aplikasi yang memberi manfaat kepada manusia. Pada masa ini, dengan pertumbuhan teknologi, penggunaan elektrik adalah agak tinggi. Untuk mengelakkan pembaziran tenaga elektrik, kita mesti memantau dan mengawal tenaga ini supaya tiada pembaziran berlaku. Memandangkan lebih banyak peralatan elektrik digunakan di rumah pada masa kini, kami menjalankan eksperimen di rumah untuk memantau dan menguruskan tenaga elektrik yang digunakan supaya ia tidak disia-siakan secara berlebihan. Oleh itu, kami mereka bentuk dan membangunkan sistem berasaskan Internet of Things (IoT) untuk memantau penggunaan tenaga kediaman. Komponen utama reka bentuk ialah mikropengawal ESP8266, penderia arus SCT013-000, penderia gerakan dan geganti. Ketepatan bacaan pengukuran boleh diterima, dengan ralat kurang daripada 5%. Dalam eksperimen ini, peralatan elektrik dibahagikan kepada dua kategori: beban berjadual dan tidak berjadual, dan data dikumpul selama dua bulan, April dan Mei. Selepas menggunakan sistem rumah tenaga pada beban berjadual, kita dapat melihat bahawa penggunaan tenaga Mei adalah jauh lebih rendah daripada April, iaitu 0.9130KWj dan 1.5332KWj, masing-masing. Di samping itu, perumahan telah direka untuk menampung setiap komponen elektrik, dan analisis tekanan telah dijalankan.

ABSTRACT

The Internet of Things (IoT) is a highly advanced technology that may be utilised for various applications that benefit human existence. Currently, with the growth of technology, electricity consumption is relatively high. To prevent the waste of electrical energy, we must monitor and regulate this energy so that no waste occurs. Since more electrical equipment is used in the home nowadays, we conducted experiments in the home to monitor and manage the electrical energy used so that it is not squandered excessively. We, therefore, design and develop an Internet of Things (IoT) based system for monitoring residential energy consumption. The design's primary components are the ESP8266 microcontroller, SCT013-000 current sensor, motion sensor, and relay. The measurement reading accuracy was acceptable, with an error of less than 5%. In this experiment, the electrical appliances fall into two categories: scheduled and unscheduled load, and data is collected for two months, April and May. After applying an energy home system to a scheduled load, we can see that May's energy consumption is substantially lower than April's, which is 0.9130KWh and 1.5332KWh, respectively. In addition, the housing was designed to accommodate every electrical component, and stress analysis was conduct.

CHAPTER 1

INTRODUCTION

1.1 Brief overview of the overall structure of the project

Monitoring and managing power using cloud-based Internet of Things (IoT) is the goal of this study. There are a number of components that will be used to build the Smart Home design, such as an Arduino microcontroller, an Internet module and an AC current sensor and a voltage meter. The energy consumption data is monitored and processed on a device, then transferred to a secure cloud service, where data can be further processed. formatted, and sent to the server that is used for data storage. This power monitoring system is expected in offering of guidelines for more efficient use of electric power.

Increased energy consumption has an impact on CO_2 emissions. CO_2 emissions released from power plants, industry, residential, and other sectors that are released into the atmosphere in a certain amount have an impact on global warming. Energy savings and energy efficiency improvements can help to reduce global warming. Energy efficiency is now important and most developing in many countries. The importance of energy efficiency as a policy objective is linked to commercial, industrial competitiveness and energy security benefits, as well as an increase in environmental benefits such as reducing CO_2 emissions.

Using typical energy efficiency methods, new commercial buildings can save 20–30 % on their energy use on average and as much as 40 % depending on the building type and the region. Because of the increased efficiencies, smaller, less expensive heating, ventilation, and air conditioning (HVAC) equipment may be installed, allowing for these reductions to be achieved with negative life-cycle costs. With these upgrades, a building's carbon footprint is reduced by an average of 16 % while also saving money and energy (Suruhanjaya Tenaga (Energy Commission), 2017).

Energy efficiency can be achieved by the development of novel control systems and services, such as developed networked technologies, to build smart environments that are also able to monitor third-party energy wastes and achieve high levels of efficiency.

Nowadays, IoT is highly developed in technology that can be used to monitor electrical energy consumption. IoT is a physical, cyber system or network of networks that consists of many objects/things and sensors/actuators that are networked in a very large internet network and are used to transmit data generated by sensors/things. Data will be collected, exchanged, and analyzed to obtain valuable through IoT.

Monitoring and managing power using the cloud based IoT is the goal of this study. There are several components that will be used to build the Smart Home design, such as an Arduino microcontroller, an Internet module and an alternating current (AC) sensor and a voltage meter. The energy consumption data is monitored and processed on a device, then transferred to a secure cloud service, where data can be further processed. Formatted and sent to the server that is used for data storage. This power monitoring system is expected to offer guidelines for the more efficient use of electric power.

1.2 Problem statement

Nowadays, the population and industry are increasing rapidly, thus the high demand for energy, especially electrical energy, which needs to be controlled to reduce energy waste. Many research activities have been done to monitor and control power consumption by using various IoT applications. However, certain applications have weaknesses in data transmission and are not cost-effective. Therefore, this research study is to focus on developing a system that can monitor and control in an economical and efficient way.

1.3 Objectives

The general objective of this research is to design and development of IoT-based system for home energy consumption. The specific objectives are :

1. To develop a system that can monitor and control energy consumption.
2. To measure/evaluate the effectiveness of electricity usage by monitoring and controlling power using cloud based IoT network.
3. To develop energy management systems to reduce waste.

1.4 Outline the scope of the project.

This research is conducting an experiment about monitoring and controlling energy consumption by using IoT based system. Based on Figure 1.1, it shows design architecture of IoT system. There are several components and apparatuses are needed to setup in this experiment which ESP8266 microcontroller, relay, Non-Invasive AC current sensor (SCT), passive infrared sensor (PIR), Internet module and device. The software use in this experiment is Arduino IDE and use C++ coding. Then connect this system to the household appliance and run the experiment and record/collect the data. The parameter that will be measure is current (A), voltage (V), and Power (P). Then after collect all the data, analysis will be done.

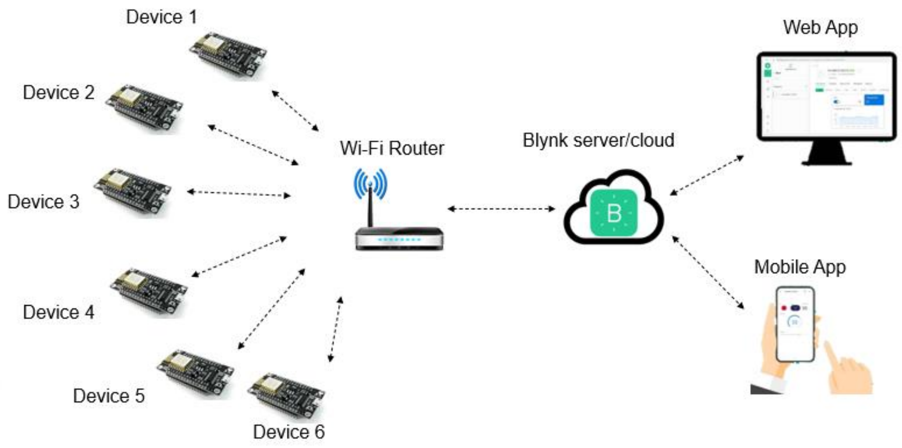


Figure 1.1 shows the system architecture

CHAPTER 2

LITERATURE REVIEW

2.1 Home Energy Management

The increasing demand for electricity has presented new opportunities for a home energy management system (HEMSs) that can reduce energy usage. Besides, this system also becoming important because it related to the global warming and energy shortage. This system assists to decrease the demand for electricity, especially during peak load times (Pau et al., 2017) . To cut emissions of greenhouse gases, HEMS should be examined because they make it possible to control a home's electricity supply automatically (Aman et al., 2013). This system routinely generates consumption patterns that are ideal by considering several criteria, including energy costs, concerns about the environment, load profiles, and the level of comfort experienced by consumers (Shareef et al., 2018).

The IoT includes a wide range of devices and technologies that can be used in conjunction with smart sensors, sophisticated metering infrastructures, and smart home appliances. As a result of this expanding tendency, HEMSs are now being deployed, paving the path for future smart grids (Zafar et al., 2020). The smart controller is the most important component of the HEMS system. It offers functions for system management, such as logging, monitoring, and control of various aspects of the system. The intelligent controller is responsible for gathering real-time data on electricity usage from schedulable and non-schedulable appliances to put into effect the most effective demand management strategies.

Home appliances End users are given the ability to programme their home appliances through demand-response systems, which allows them to reduce their energy use while maintaining a comfortable level of living. The loads generated by home appliances can be classified as either non-schedulable or schedulable. The loads known as non-schedulable loads are those that cannot be moved in response to signals from the utility. These are often things like refrigerators, printers, TVs, microwaves, laptops, and the like, and consumers can change them. Those loads that can be turned on or off at any moment are referred to as schedulable loads. These may include things like lights, air conditioners, heaters, irons, electric vehicle chargers, and other such items (Zhou et al., 2016). One can further divide schedulable loads by classifying them as either interruptible or non-interruptible loads. Non-interruptible loads are subject to a 'hold-time,' which refers to a specified amount of time of operation that must pass before the loads can be switched off (Asare-Bediako et al., 2012).

2.2 Design of the Internet of Things system

There are many methods that were purposed in this system. To monitor the energy, they need a stable device that can prevent the error in result.

Thakare et al., (2017) research about implementation of an energy Monitoring and control device based on IoT. In this paper, the microcontroller and sensor are used is Arduino Nano, RTC DS3231, Nokia 5110 display, ESP8266, LM 2596, and SCT013-030. Current data obtained are process to calculate the voltage and energy consumption of room and each electrical device by using different mode. From this paper, the user can easily monitor the power consumption as well as the bill on daily basis. But there are a few limitations by using this method which is the current sensor measure from 0 to 30A. Thus, the accuracy would fall if the current value was low. Besides, by assuming the voltage 230V in the power consumption calculation, it also will decrease the accuracy. This is because based on the observation, the voltage reading fluctuated from 228V to 235V.

Hartman et al., (2018) research on Energy Monitoring and Control Using IoT System. The purpose of this study is to investigate, construct, test, and ultimately put into operation on a global scale and energy monitoring and control system that makes use of IoT technologies. It also covers everything from start to the end, including a mobile app, a cloud-based database, application programming interface (API) development, and hardware development. The purpose is to identify energy waste that may occur during the daily operation of electrical appliances for air conditioners and conventional overhead lights. This model was built with Raspberry Pi, relay, SCT, Analog-to-Digital-Converter (ADS1115) zero wireless. These intelligent IoT devices make it possible to collect data on the energy usage of each individual unit and store it in a database hosted in the cloud, where it can then be evaluated and published for the sake of energy conservation and analysis. During the process of implementation in Costa Rica, the researcher encountered various difficulties because of low Wi-Fi bandwidth, old networking technologies, frequent power interruptions, and a short Wi-Fi network range.

Chooruang & Meekul, (2019) development of an IoT Energy Monitoring System This researcher's goal is to create and implement an inexpensive IoT energy monitoring system that may be used in a wide variety of contexts. Microcontrollers and sensors such as Raspberry pi 3B, PZEM-004T, SCT, SD3004 electric energy measurement chip, and ESP8266 Wemos D1 mini microcontroller are utilised in the design in order to retrieve data from sensor nodes and transmit it to a server over the internet. The results of the experiments demonstrated that the newly created system for monitoring energy consumption is capable of accurately recording the voltage, current, active power, and accumulated power consumption.

Hoque & Davidson, (2019) investigate into the planning and building of a smart home security system that is based on the IoT. An IoT enabled smart home security system will be presented in this study, along with a low-cost architecture that is built on RF-based communication within a home. The components that make up these systems include an Elegoo Mega 2560 microcontroller board, a Raspberry pi 2, an RF receiver-transmitter pair operating at 433 Hz, a magnetic reed switch, an android phone, or a representational state transfer (REST) API. Using a 433 Hz radio frequency (RF) signal does have some drawbacks, one of which is that it can cause interference. This is since a great number of home appliances communicate with one another using RF signals, and there may be more than one RF trying to send or receive at the same time. Interference occurs on the 433 Hz RF frequency because many home devices use RF signals to communicate. At any given time, there may be more than one RF receiver trying to send signals to the Raspberry Pi, or it may be picking up signals that it was not intended to receive. Additionally, there may be multiple RF receivers trying to send signals to the Raspberry Pi at the same time.

Gupta & Chhabra, (2016) investigation into the IoT as it relates to the building of smart homes with power and security management. This researcher presents this design system in a method that is both user-friendly and mobile. It will reduce power consumption while simultaneously increasing usage through intelligent real-time tracking and monitoring of electrical devices and the safety of the home. These systems consist of Ethernet based Intel Galileo 2nd Generation, temperature sensor, smoke sensor, PIR and relay module. The objective of this research is to reduce household electricity consumption while also maintaining home security by allowing users to control device switching via speech or an Android application. Homeowners can save money on their electricity costs and keep an eye on their home security with the ability to regulate the switching of various devices.

Marques & Pitarma, (2017) research on monitoring energy consumption systems to improve energy consumption efficiency. Increasing productivity is one of the goals of this study, which intends to design and construct an automatic system that will allow for the monitoring and control of electrical equipment that is connected to the Internet via Wi-Fi and is referred to as iPlugs. The system is made up of a low-cost energy monitoring system that is based on the Internet of Things and was developed using Arduino UNO, ESP8266 module, current sensor (ACS712), a Hall-effect, SRD-VDC-SL-C relay, and voltage sensor. All of these components were connected together using a relay. To storing monitoring data and making it accessible on a web portal in real-time. This system can monitor the power usage of the devices and measure the power utilised by the equipment in addition to the voltage from the mains.

Prasetyo et al., (2019) research on smart home power electric monitoring and control in Indonesia. The research aims to monitor and power control using cloud-based IoT to get effectiveness in electricity and reduce the cost of energy use at home. The research output is still in the design stage, and the tool has not yet been developed and implemented.

David et al., (2019) research on Decrease of Power Consumption Utilizing IoT. Energy consumption in India was quite high from 2015 to 2016. Electricity consumption in India reached 6.76 GW in 2015 and rose to 12.28 GW in 2016. The aim of this research is to overcome the challenges that the previous system was experiencing and help reduce electricity usage in a cost-effective and make the system simpler. Arduino, SCT-013-000, burden resistor, and capacitor were used to construct the IoT. This method gives a vitality screen right on the breadboard that may be used to determine how much electrical vitality is utilised at home, based on the measurement of the current with a voltage received fixed 220V. Overcomes the challenges of the current system by adding a smartphone app and sensor linked through the cloud by IoT that is watched by the consumer 24 hours a day, seven days a week, anywhere in the world.

Nasar et al., (2019) investigate into the development of a straightforward real-time energy analytics model for smart buildings that make use of open IoT technologies. The purpose of this research is to devise a method that is accurate, does not require a lot of money, and can be used to examine energy swings and noteworthy patterns. This article's design architecture can be broken down into three primary sections: the acquisition layer, the transit layer, and the application layer. The acquisition layer consists of sensors which are PZEM004T, and a microcontroller which is ESP8266. PZEM004T be able to measure sensing voltage, current, active power, total energy, frequency, and power factor. The result of the experiments revealed that data on electrical energy usage could be collected in near-real-time, and power anomalies and patterns may be identified.

Gowda et al., (2017) design IoT-based smart energy meter. The research presents a smart energy measurement system using IoT and Arduino. This paper was to overcome the existing problem, which is to eliminate errors from the third part between consumer and services provider. In this system, the Arduino is selected as a microcontroller because it consumes less power, saves energy and is faster. The design consists of Arduino ATMEGA Uno 328, Max 232, Global System for Mobile Communications (GSM), relay, Wi-Fi module ESP8266, driver circuit (MOC3011), and signal condition (P817). The advantage of this research is the user was noticed if electrical consumption exceeds the limit, and data and prices on electricity consumption are displayed on a web page.

Prashant Hiwale et al., (2018) research on IoT based smart energy monitoring. This paper aims to propose a system design to eliminate the involvement of humans in electrical maintenance, providing automated load energy reading and reducing power waste. Arduino Nano, Arduino Nano, ESP8266, liquid crystal display (LCD), buzzer, power supply, and ACS712 are used in this paper. The ACS712 measures the power utilised by the load and sends the output in analogue form to the Arduino board at the analogue pin. Arduino has an inbuilt analogue to digital converter. Then the digital output is displayed on an LCD. The ESP8266 is what is utilised to establish a connection between the internet and the monitoring hardware system. Graphically, the amount of electricity that was consumed by the load can be seen in the cloud viz, which is part of the ThingSpeak cloud.

Al-Kuwari et al., (2018) research on Smart home automation using IoT-based sensing and monitoring platform. This system makes use of the EmonCMS platform for the purposes of data collection and visualisation, as well as remote control of various appliances and gadgets in the home. The EmonCMS platform has a high degree of adaptability and is simple to use. The NodeMCU-ESP8266 microcontroller board is utilised in the operation of the system. This board enables real-time data sensing and processing, as well as uploading and downloading to and from the EmonCMS cloud server.

Joseph et al., (2020) research on the development of IoT based energy consumption monitoring and device control system. This system is controlled by an Atmega328 microcontroller and is supported by ESP8226, LCD, current sensor, relay, and power supply. The results of the experiment indicate that the proposed system is an excellent method for monitoring power consumption and sending the measurements through IoT. This method significantly overcomes the numerous challenges that are associated with the conventional technique of monitoring energy consumption. This model can work automatically in a very effective manner with no need for humans and at a very low cost. It also has the capacity to do so. In addition, it is possible to monitor, control, and bill for the energy usage of individual appliances as well as the overall system. This system is also capable of computing the overall energy use and producing billing information, which is then automatically distributed to customers.

Muralidhara et al., (2020) research on internet of things based smart energy meter for monitoring device level consumption of energy. The purpose of this article is to make a proposal for the design and implementation of an Internet of Things (IoT) enabled, minimalistic, cost-effective, and efficient smart energy meter. This meter will assist users in collecting information on the energy usage of any electrical item. The system is connected to the device before it is connected to the AC power supply. The energy consumption of the device can be measured with the help of the ACS712. This consumption data is updated in the ThingSpeak channel every two minutes after being transmitted from the Arduino to the Wi-Fi module ESP8266 and sent every two minutes. The user can access this information.

MacHesoa et al., (2021) research on the design of energy monitoring systems for traditional factories. A low-cost Arduino microcontroller, a non-invasive split-core current transformer, a relay module, and a voltage transformer are the foundational components of this design. The system can accurately record Root Mean Square (RMS) voltage and current, as well as actual and perceived power, power factor, and energy. The advantage of this system is that it saves money on energy, minimizes carbon emissions and environmental impact, and improves profit margin.

Stusek et al., (2017) research on the measurement within the context of the smart grid ecosystem, utilizing a platform for non-invasive electricity on the IoT. The design is based on measurements taken from a current transformer. It functions appropriately for values of alternating current up to 30 A. It may also be extended to 100 A, which considerably increases the impact when applied to use-cases, including smart grids. The employed Arduino board is responsible for the processing of the data that was measured. The current measurements can either be shown on a connected LCD panel or supplied to an application that was written for a webserver. The system indicates a non-zero value even in the case of an empty load due to noise in Analogue to Digital Converter (ADC) Arduino, and this will decrease the accuracy of the whole system.

Kshirsagar & Kshirsagar, (2021) research on the smart energy meter. The systems contain Arduino Uno, ESP8266, SCT, and LCD as the main component. Initially, a split-core transformer is used to measure the current, and then the data is transferred to an Arduino. After that, the data is sent over a Wi-Fi connection to the base station where it is stored. The benefit of utilising this technique is because give an accurate depiction of the present use of a home and, through the use of data, gives an estimate of the amount of power consumed, as well as ways to cut back on that consumption.

Malik & Kamarudin, (2020) investigate the use of a mobile phone as an energy metre. This project is being carried out to establish a monitoring system for electricity consumption that is capable of being controlled by an internet-of-things-based protocol. This system will enable customers to monitor their own electricity consumption based on the real-time and automatic reading of electricity metres located at single-load electrical appliances. A microcontroller known as NodeMCU ESP32 was utilised during the building process of this device. This circuit establishes a connection between the Blynk application and the AC Current Sensor SCT-013-000 as well as the micro detector ZMPT101B Voltage sensors. This system provides consumers with the ability to enhance their user behaviour in terms of energy consumption by making efforts to better control power demand and minimise carbon emissions. This is made possible by the system.

Karthikeyan & Bhuvaneswari, (2017) research on an IoT based real-time monitoring solution for household energy metres. The suggested system in this research is shown to be cost-effective because it only requires a minor upgrade to be performed on the currently installed metres rather than their entire replacement. In addition, it is not only lightweight but also compact, and it can be used for controlling and communicating. As a result of the experimental study, it was discovered that from the data that was obtained, it is possible to determine the pattern of consumption as well as faultiness that is present in the system that is already in place.

Based on the overall result, the Arduino Uno is widely used as a microcontroller because it is cost-effective, easy to obtain, and easy to configure with various programming languages. Besides Arduino, there is ESP8266 (NodeMCU). This microcontroller is one that is also often used because it is directly equipped with Wi-Fi Module (Gede et al., 2020). Arduino and NodeMCU are highly recommended for conducting research related to energy management. But now, there are new NodeMCU that can be used in IoT projects which is ESP8266. There are several other microcontrollers, such as Raspberry Pi, MSP-430F6736, ARM, and Intel Galileo, but the costs may be incurred.

Besides, sensors used in electrical energy monitoring systems using IoT technology are also very diverse, depending on measurement parameters and needs such as voltage using voltage sensors, current using SCT sensors, active power, accumulative power consumption, and so on. The sensor used to measure energy also requires the help of several electronic modules installed on the microcontroller, such as relay, LDR, PIR, LCD, real time clock (RTC), transistor, resistor, capacitor, buzzer, power supply, and others.

CHAPTER 3

METHODOLOGY

3.1 Proposed method

The proposed system model for monitor and control energy consumption in household application. There are several electrical appliances was used to monitor, and control such as refrigerator, air-conditioning, washer machine and light. Based on Figure 3.1, it shows the design of architecture. This system consists of three part which is acquisition, transport, and application layer. The acquisition layer is a hardware component that consist of a sensor, and microcontroller that can be used to control the program to perform the experiment by collecting and transferring electrical data through a local area network called the transport layer and will pass the data to an application layer. Telekom Malaysia (TM) Wi-Fi is used as local area network and send the data to Blynk Application. The data will display the trend of electrical consumption and can be control by using this application. The input data in this system is a current (A), then it will be calculate based on real time to obtain the energy consumption. Based on Figure 3.2 shows the system model.

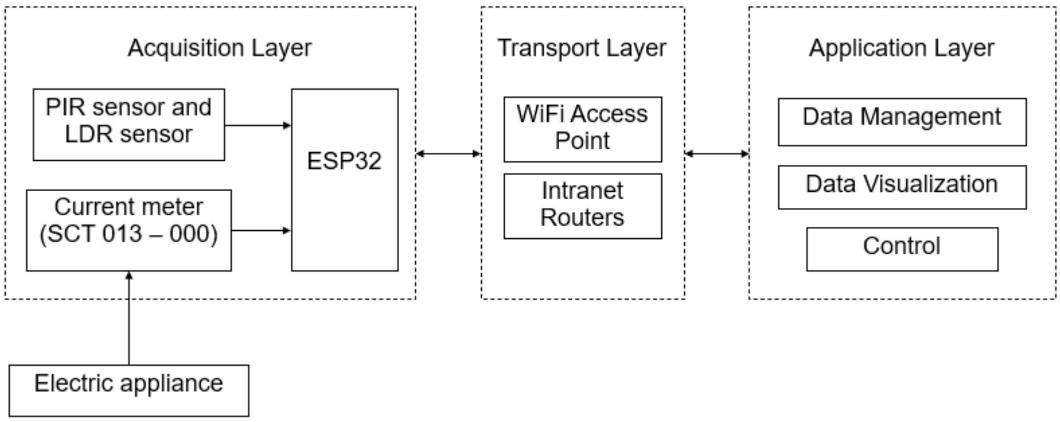


Figure 3.1 Design of architecture

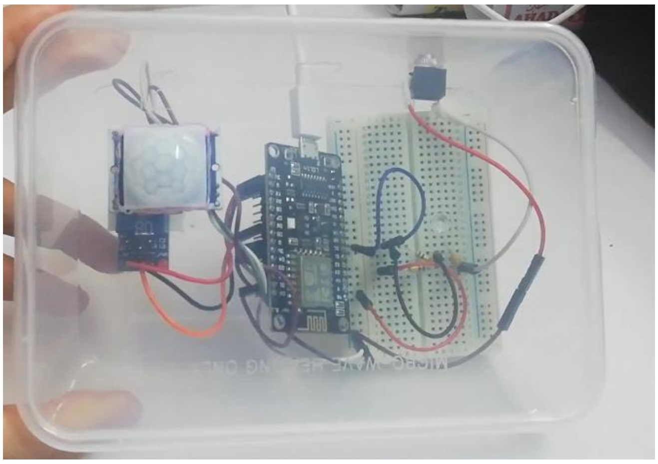


Figure 3.2 System Model

The project takes two months to run the experiment and collect the data. For first month the system only use monitoring system to collect the data without applying control system then the data will be compared to the data in second months which applying control system but not all electrical appliances will be install this system. In this project, six electrical appliances were selected, and can divided into two group which is non-schedulable and schedulable load as shown in Table 3.1.

A Non – schedulable load cannot be moved in response to signals from the utility, which means that once the load is turned on, the load cannot turn off immediately. It must wait until the load completes the process, for example, refrigerator, washer machine, and heater. On the other hand, the schedulable load is the load that can be turned on or off at any moment, for example, light and fan. For this case, the air conditioner is one of the schedulable load categories. But it has a problem when do an electrical circuit to become automatic so for this case we put air-conditioner as non – schedulable load.

Table 3.1 List of Schedulable load and non-Schedulable load

Monitoring system	
Non-schedulable load	Air-conditioning
	Refrigerator
	Washer Machine
	Heater

Monitoring & controlling system	
Schedulable load	Light 1
	Light 2

3.2 Acquisition Layer

The main component in acquisition layer is microcontroller and ESP8266 is selected. However, there is another component that connected to the ESP8266 to measure the input, and control the output which is current sensor, PIR, and relay. The ESP8266 measures the current values in real-time and sends them wirelessly to the server.

3.2.1 Microcontroller

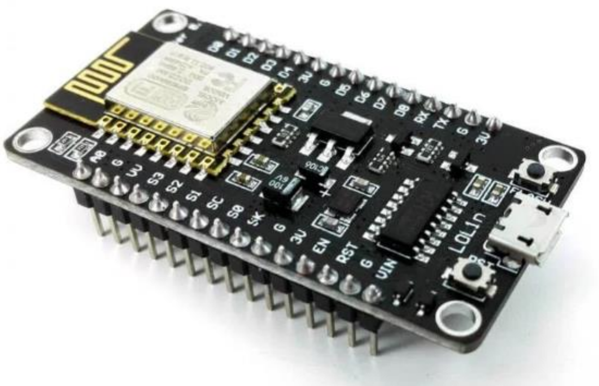


Figure 3.3 ESP8266

Table 3.2 Specification of ESP8266 (NodeMCU ESP8266 Pinout, Specifications, Features & Datasheet, 2020)

Item	Value
Microcontroller	Tensilica 32-bit RISC CPU XTensa LX106
Operating voltage	3.0 ~ 3.6V
Operating Current	Average value: 80mA
Operating temperature range	-40º ~ 125º
Ambient Temperature Range	Normal Temperature

Package Size	49mm*24.5mm*13mm
Mass	20g
General Purpose Input/Output (GPIO)	17
Pulse-width modulation (PWM)	8 Channels
Digital I/O Pins (DIO)	16
Analog Input Pins (AIO)	1
ADC	10-bit
SPI/ I2C/I2S/ UART	2/1/2/2
Flash Memory	4 MB
SRAM	64KB
Clock Speed	80MHz

3.2.2 Current Sensor

The Split Core Current Transformer sensor SCT-013-000 has been used in this system. It can sense a maximum current of 100A and provides an output voltage of 1V peak to peak for this current as shown in Table 3.3 the specification of current sensor. This voltage corresponds to the peak value of the current. After this, the voltage produced is sent through the ADC input of the microcontroller ESP8266. This voltage is measured relative to the microcontroller supply voltage, which is 3.3V in ESP8266, and the reference voltage is the maximum count of 10 bits which is 1024. Figure 3.4 shows the SCT-013-000 and external circuit.

The voltage fed to the microcontroller already has a constant bias applied to it. However, this bias is instantly eliminated by a software filter, which means that it may be ignored while the calibration regular is being calculated.

$$Calibration\ constant = \frac{\text{Rated input(rms)}}{\text{Rated output (V)}} \quad \text{..(1)}$$

The mains voltage considered for this section is the standard voltage in Malaysia which is 240V. The root mean square current (Irms), is computed using Equation (5).

$$Irms = count \times constant \quad (2)$$

Where,

$$counts = \frac{input\ pin\ voltage}{3.3V} \times 1024 \quad (3)$$

$$constant = Calibration\ constant \times \frac{3.3V}{1024} \quad (4)$$

By substitute this equation (2) and (3) into (4) we get :

$$Irms = input\ pin\ voltage \times calibration\ constant \quad (5)$$

Then the instantaneous power, and total energy consumption will calculate by using equation (6) and (7).

$$P = V \times Irms \quad (6)$$

$$E = E + P\left(\frac{Current_{time} - Last_{time}}{3600000}\right) \quad (7)$$

Table 3.3 specification of SCT-013-000 (Non-Invasive AC Current Sensor Split Core 100A)

Parameter	**Value**
Rated input(rms)	100 A
Maximum Input	120A
Rated output (V)	1V
Accuracy	± 1%
Linearity	≤ 0.2
Weight	50 g
Work temperature	-25℃ ~ +70℃

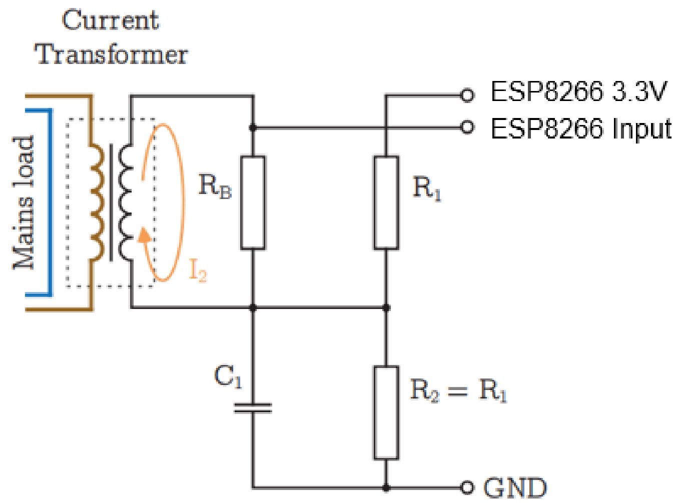


Figure 3.4 Current sensor and external circuit

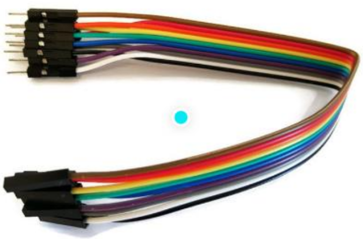
3.2.3 List of components

This system has more components such as a relay, PIR sensor, extension socket, etc. Table 3.4 shows the overall component and functionality.

Table 3.4 List of components

Components	Functions
ESP8266 	Microcontroller
SCT-013-000	Current sensor can be clamped around the supply line of an electrical load to measure current is passing through it.

	
Relay 	An electromechanical relay is a switching system. In this project, the relay will turn on or off the load depending on the signal from a microcontroller.
Capacitor 50 pF 	Store electrical energy
Resistor 100 KΩ 	Reduce the voltage coming out from SCT013-000 to ESP8266 and prevent ESP8266 from burn.
Extension socket	To measure the current using SCT013, it needs to clamp around a single wire. Adding the extension socket is the best way. Then the measurement is only taken from the extension socket and connected to electrical appliances.

	
Passive infrared sensor 	PIR is an electronic sensor that measures infrared light radiating from objects in its field of view. In this project, PIR will sense the presence of a human.
3.55mm Female connector audio Jack 	To connect male connector from current sensor.
2.1A Adaptor Dual USB 1.0 A 	Used as a power supply to the ESP8266.
Female/Male Wire 	To connect the circuit to another component.

3.2.4 Electrical Circuit

There are two types of circuits in this project: a monitoring system and a monitoring and controlling system. First, Figure 3.5 shows the monitoring circuit. This circuit contains some components: SCT 013-000, ESP8266, capacitor and resistor and extension socket. Then, based on Figure 3.6 shows the electrical circuit for monitoring and controlling. This circuit contains all the monitoring system components but added a few components, such as a PIR sensor and relay. But this circuit did not have an extension socket because the electrical appliances we want to use are connected directly to the main wire. The Table 3.5 shows the explanation of the system connection.

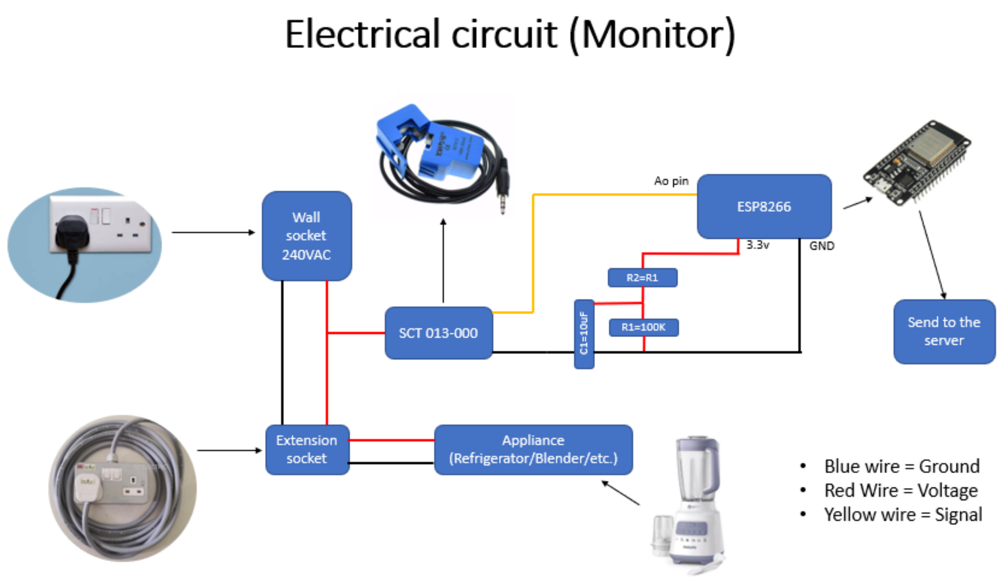


Figure 3.5 Monitoring circuit

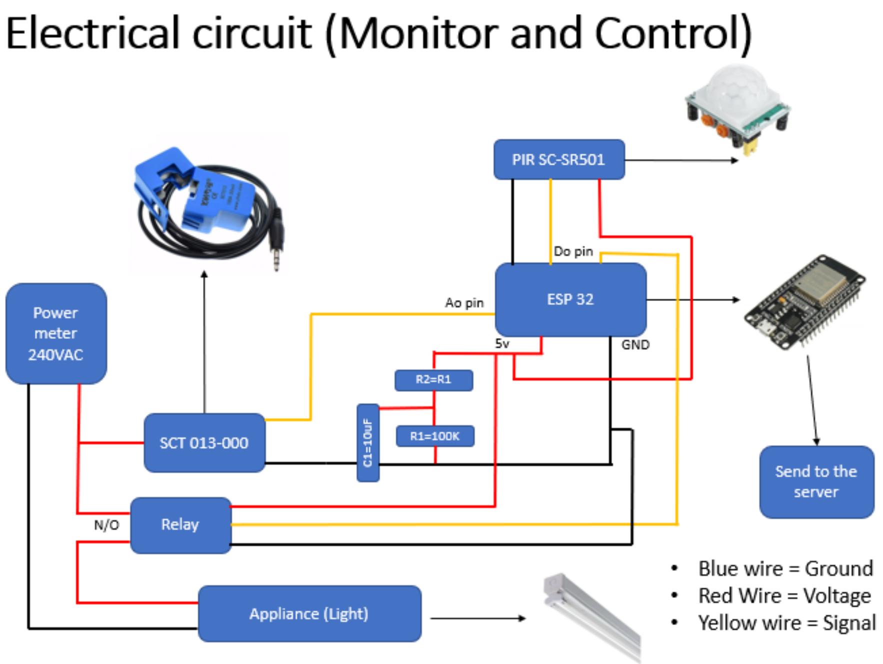


Figure 3.6 Monitoring and Controlling

Table 3.5 Explanation of connection

Component	GPIO
SCT013-000	This sensor contains two wire which is voltage and ground wire. The voltage wire will directly connect to the analogue pin (AO) whereas, the ground wire is connected to the resistor (100kΩ) and capacitor (50 pF) before it is connected to the ground pin (GND).
Relay	This relay has six pins which are voltage, ground, signal, normally open (NO), normally close (NC) and common contact (CC). The voltage, ground and signal pin connect directly to voltage output (VCC), GND, and digital pins (D1) respectively. For other pins connected to the life (L) wire on load, in this project, only use CC and NO pins.
Pir Sensor	Pir sensor has three pins which are voltage, ground, and signal. The voltage and ground pin from the sensor connects directly to the Vcc and GND pin. The signal pins will connect to D0.

3.3 Transportation Layer

The data must be transported from the acquisition layer to the application layer, which requires the transport layer. To complete this task, we used my Unifi TM home Wi-Fi network. This system needs two network segments, the first of which is where the ESP8266 is connected to Wi-Fi before reaching the server at the application layer. Therefore, the network may have some segments and different physical layers.

3.4 Application Layer

All the information data from the acquisition layer will process and display in the Application layer. In the application layer, we can see the current, power and energy consumption data in detail for each electrical appliance. The Blynk application is used to perform this experiment.

Blynk is one IoT platform that enables the creation of interfaces to manage and monitor the project from iPhone Operating System (IOS), android mobile or web application. Using Blynk, you can connect your devices to the cloud, analyse real-time and historical data, and remotely control and monitor your devices from anywhere on the planet. Besides, the Blynk cloud has multiple layers of security. Every data sent through Blynk is encrypted and secure because it uses a local Blynk server, and each device has its own Auth token and a Product Id.

The data from the acquisition layer will flow through a DataStream using the Blynk protocol, and every value is automatically time-stamped and stored in the Blynk Cloud database. The data can be stored as raw data or will be averaged based on the setup and will be recorded based on real-time. Based on Figure 3.7, shows a network in Blynk architecture.

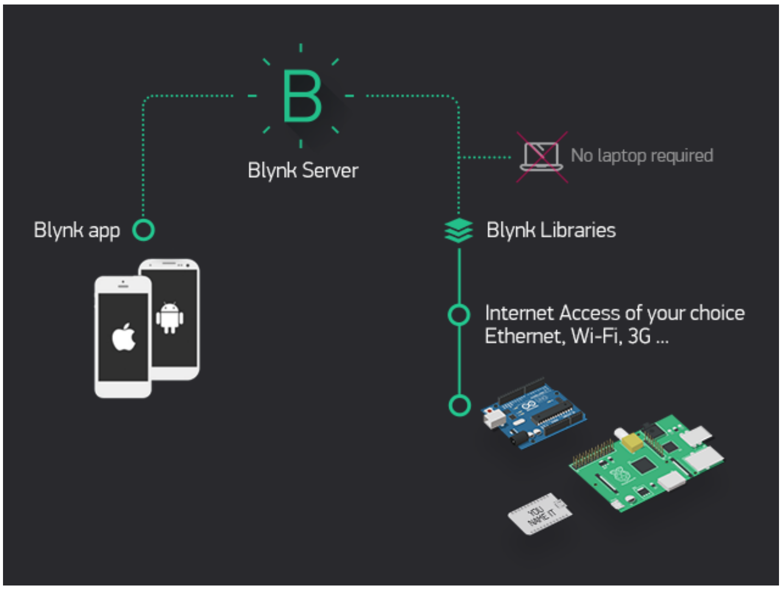


Figure 3.7 Blynk architecture (Blynk Documentation)

3.4.1 Blynk Setup

The most important in the Blynk is the device template. It makes it easy to work with multiple devices that perform the same function, for example, in this project. In this research, six devices are used and divided into two groups explained before. Thus, two templates are used, which are schedulable load and non-schedulable load. To create this, we start with template ID, datastreams and web and mobile app dashboard. Table 3.5 show the explanation of that function. For the non-schedulable load template, six types of widgets were created for one appliance. In contrast, in the schedulable load template, there is an additional widget, a button, as shown in Table 3.6. This button will control to turn on/off the light. Based on Figures 3.8 and 3.9, we can see the dashboard for this project.

Table 3.6 Explanation of some function in Blynk

Item	Description
Template ID	Template ID is an identifier of every template which should have a specific code on the device. Besides, another identifier is included in the template ID, Auth Token generated by Blynk Cloud.
Datastreams	Datastreams is a channel that transfers data between the device and Blynk Cloud. In datastreams, we need to declare all the data types to make it process correctly because Blynk Cloud should know what type the data is being transferred
Web and Mobile app dashboards	In this area, it is easy to control and monitor the device because these dashboards are made from building blocks or widgets. Many types of widgets can use to perform the task, and data from datastreams will appear when using widgets.