Progress in Engineering Application and Technology Vol. 2 No. 2 (2021) 540–554
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PEAT

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Integration of IoT on Power Monitoring and Control of Electrical Load for Home Automation System

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DOI: https://doi.org/10.30880/peat.2021.02.02.053
Received 13 January 2021; Accepted 01 March 2021; Available online 02 December 2021

Abstract: From the beginning of human history, a variety of technologies have been invented to make daily human life easier while preserving comfort, and virtually all technology has been developed requiring electric power. Getting the fan and lamp switched on all the time is a waste of energy and money if the user fails or lazy to switch it off, particularly when he/she is out of their home. Today's development of IoT (Internet of Things) technologies will help to solve this issue. This project presents the design and implementation of the Arduino Uno, Arduino Mega along with the ESP8266 Wi-Fi module and 5 V relay which are based on the IoT concept. This system can be connected to the home electrical system so that the users can control and monitor the system by using their internet device anywhere and at any time via the Blynk platform. The system has also been equipped with sensors for control unit inputs so that users can control the switch in various ways, either online, by a sensor, or by a manual switch. ACS712 current sensors are used to allow users to monitor their electrical load power consumption at home. The construction of the prototype was carried out successfully based on the study and the designation that was made so that it can be observed how this system can operate. Current and power consumption data for each electrical load have been recorded and evaluated.

Keywords: Internet of Things (IoT), Arduino Uno, Arduino Mega, ESP8266 Wi-Fi, Sensors, Blynk Application

1. Introduction

Electricity is one of the greatest gifts that science has bestowed on mankind. For all nation-building activities, it has been a critical resource that keeps the wheels of the countries on progress and economic prospers [1]. Electricity is generated at power plants and moves through a complex system, sometimes called the grid of electricity substations, transformers, and power lines that connect electricity producers and consumers [2]. Domestic customers are supplied with 230 volts of single-phase power while the

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three-phase supplies for large properties, commercial buildings, and small factories may also be supplied with 400 volts [3].

As electricity demand emerges, the world is struggling to produce a wide range of technology-based that aimed to promote everyday life. The greatest achievement in technology is the creation of many devices such as mobile phones and computers that have caused many people to rely on technology to communicate, and store information [4]. The introduction of these technologies has also led to the introduction of the internet which has become a platform used by many apps to ease other people's quality of life and nowadays we are familiarizing with the words “IoT” which stands for the Internet of Things.

Even home appliances have intelligent features, but they still must be operated by switches classically. Such systems can sometimes be a challenge since people today want something easy to manage and fast. Besides, many consumers are unaware of how much power a specific device uses, which allows them to use energy as much as they like which leads to a waste of energy and an increase in electricity bills. As the smart home system evolved, various wireless technologies designed to enable remote information sharing, sensing, and management, such as Bluetooth, Wi-Fi, and mobile networks [4]. Even over great distances the user can monitor and manage their home gate, various appliances, and turn on/off the television without any human intervention [4].

This paper presents the designation project which is a low-cost and scalable solution based on the concept of the Internet of Things (IoT). It allows the user to turn off lights and other electronic items even when are in bed and going to sleep or outside at the party. Besides, allowing users to track their power use via online to handle power usage more smartly. The construction of the system is explained. Verification of hardware and data collection for all power consumption for each load will be clarified.

1.1 Internet of Things (IoT)

According to McKinsey, IoT can be defined as “sensors and actuators embedded in physical objects are linked through wired and wireless networks, often using the same Internet Protocol (IP) that connects the Internet” [6]. It also can be described as a connection between different types of items, such as smart telephones, personal computers and tablets, sensors, software, and other technologies through the internet that leads to a new kind of communication between things and people, and between things and at the same time share data with other devices and systems [4].

Looking back on history in 1999, during Kevin Ashton's work at Procter & Gamble, he invented the actual word "The Internet of Things" [6]. The IoT was first born as the title of an Ashton presentation. Ashton, which has worked to improve the supply chain, wanted the management to draw attention to the new exciting RFID (radio frequency identification; tags with data bits which can be transmitted through the WLAN) technology. Because the internet was the newest phenomenon of 1999 and it was something important, he called his presentation as the “Internet of Things presentation” [6].

As the technology evolved, the evolution of the internet becomes more advanced not only getting data from sensors but also transferring information and communications [5]. For the public, IoT now appears to be a combination of intelligent home devices, wearables, and industrial IoT. But, the truth, it can have a much broader scope. Once the world is connected, the IoT transforms nearly all main segments from homes to hospitals and from vehicles to towns [6].

1.2 Smart Home

The introduction of information technology in the last quarter of the century has started up opportunities to share knowledge, possibilities still being explored between people and devices, systems, and networks in and outside of the home. At the end of the 20th century, the previously unknown idea of a smart home was emergence [7].

There are several ways to describe a smart home automation system. One of the concepts is a home with an automated system consisting of sensors and device controllers that allow individuals to control electrical appliances smartly and automatically within a home environment to provide a comfortable, smart, energy-efficient, and secure system to improve the quality of life of their inhabitants [8] and [9].

Smart home network infrastructure can be divided into two major groups, wiring systems, and wireless systems. The main energy supply connected directly to the computer with the cable control system to allow or disable the data to the devices, while in a wireless network, the sender and receiver must be included. Wireless networking networks include microwave and infrared (IR), radio frequency (RF), wireless internet access, and Bluetooth [5].

2. Methodology

The designation and construction process of completing the project is explained in this section. The designation process involves the selection of suitable prototype components, workflow system, hardware designation, and how the system functions. The inclusion of a flowchart and block diagram makes the operation of this system more understandable. The hardware construction was driven by the layout of the designation as well as the wiring diagram that has been developed.

2.1 Materials

- MA-01 IoT Magic Kit - ESP8266

  MA-01 IoT Magic Kit-ESP8266 act as the main microcontroller which is embedded into a system for the control of a unique function in a device. This kit is provided with complete source code, however, the modification process must still be done on the pin configuration used in the SD card embedded in this kit. IoT Magic Kit is primarily constructed with the microcontroller of Arduino Mega (Atmega2560 IC) and ESP8266 module. The Blynk device connects to the internet, which is one of the greatest phone applications of IoT [10]. Arduino ESP8266 Wireless Internet, which has been prepared, is a low-cost Wi-Fi chip with complete TCP / IP (Transmission Control Protocol/Internet Protocol) capabilities, and the wonderful thing about that small board is fitted with an MCU (Micro Controller Unit), which enables I / O digital pins to be controlled with a simple, almost pseudo-code, such as programming language, and then provides Internet Wi-Fi connectivity for any microcontroller [11].

- Arduino Uno

  For the power monitoring system to work well, Arduino Uno has been used. This Arduino Uno acts as a second microcontroller that is used specifically for the ACS712 current sensor. Arduino Uno is a microcontroller board based on an 8-bit ATmega328P microcontroller and consists of components such as crystal oscillator, serial communication, voltage regulator. They are used to support the microcontroller. Besides, Arduino Uno has 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analog input pins, a USB link, A power barrel jack, an ICSP header, and a reset button [12].

- Blynk

  Blynk is a platform for controlling Arduino, Raspberry Pi, and others via IOS and Android devices. It is a common IoT software that allows monitoring the hardware of tiny circuits, capture sensor data, create custom-designed dashboards, and save the data in the Blynk cloud automatically [13]. It is a digital dashboard where can easily drag and drop widgets to create a graphical interface for the project.

2.2 Proposed System

The workflow of the system can be divided into two parts since this project has been designed for two systems which are for power monitoring and control system.

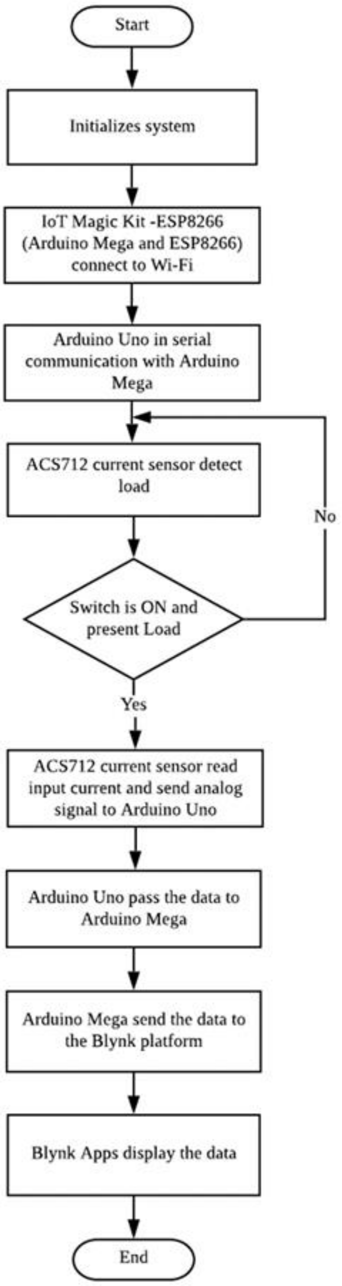

Figure 1: Flowchart of the power monitoring system

Figure 1 shows a flowchart of the power monitoring system. The system begins to operate when the IoT Magic Kit (Arduino Mega and ESP8266) is connected to the Wi-Fi which allows the interface between the Blynk and microcontroller to take place. The connection between Arduino Mega and Arduino Uno through a serial communication method also simultaneously created that allows information to be sent and receive. Arduino Uno has been installed acts as a second microcontroller that will read the input given by the current sensor. ACS712 current sensor is installed to monitor the electrical loads by detecting the presence of the load connected to it. When the sensor detects the presence of current in a load, it will send an analog signal to Arduino Uno then Arduino Uno will pass the data to Arduino Mega. The data received will be sent to the Blynk for display, allowing the user to see the amount of power used.

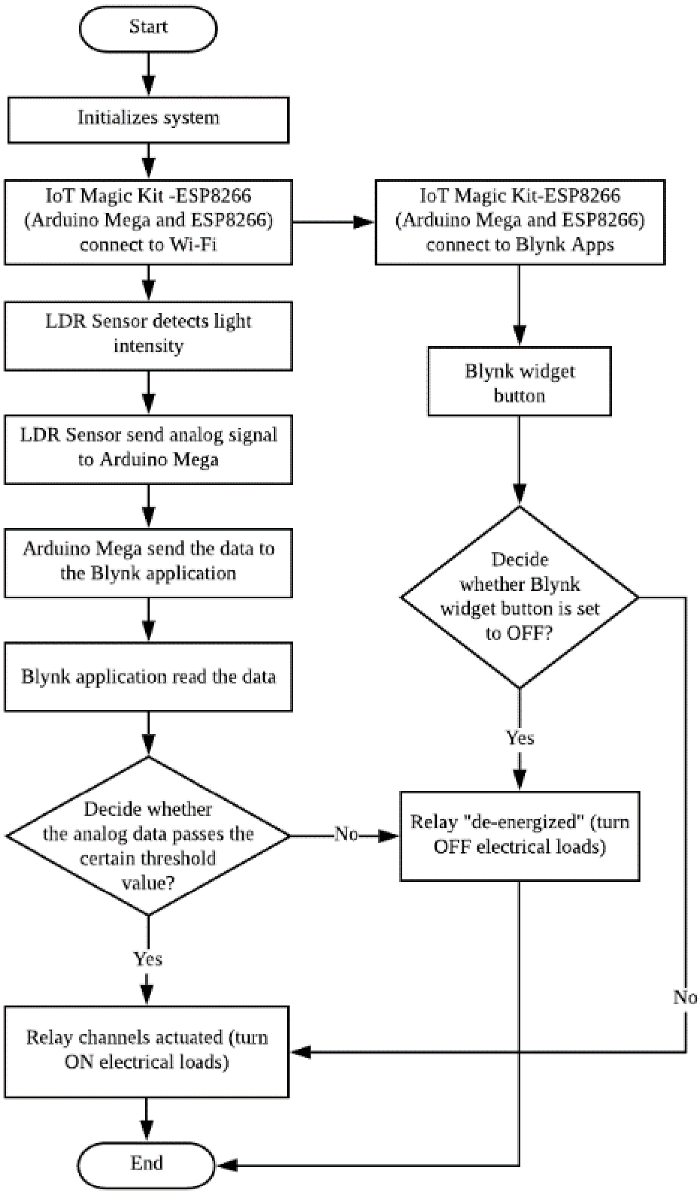

Figure 2: Flowchart of the control system

Figure 2 shows the flowchart of the control system. The system begins to operate when the IoT Magic Kit (Arduino Mega and ESP8266) is connected to the Wi-Fi which allows the interface between the Blynk and microcontroller to take place. The loads can be controlled either by using sensors or by the Blynk widget buttons. For the LDR sensor, it will detect the presence of light intensity. LDR sensor acts as input and sends an analog signal to Arduino Mega to act. Arduino Mega continued the process by sending data to the Blynk platform and allowed the data to be read. If the data able to pass the certain threshold value which has been set, it will allow the relay channels to be triggered, which indirectly activates the load connected to it. For the widget button in the Blynk application, the OFF button will de-energize the relay, and the load will not operate while the ON button will energize the relay and will turn the load ON.

2.3 Block Diagram

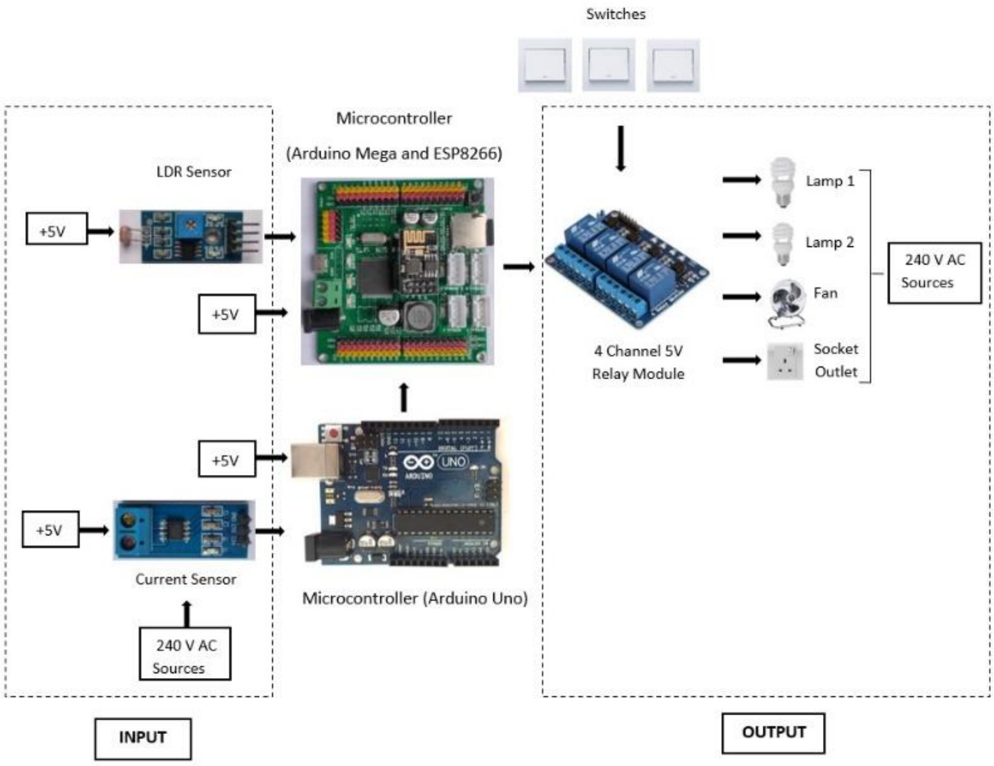

Figure 3: Block diagram of the project

Figure 3 shows the block diagram of the project. This system can be divided into several parts which are input, controller, and output. The input part consists of sensors while the output part consists of the 4 channel 5 V relay and electrical loads. There are two microcontrollers used, which are Arduino Mega (IoT Magic Kit) as the main microcontroller and Arduino Uno as the second microcontroller. Arduino Mega and Arduino Uno will be connected via the serial communication method. There are two types of sensors used which are the LDR sensor and ACS712 current sensor. The presence of an LDR sensor allows the load such as the lamp to be controlled through various means. LDR sensor modules serve as load activators by detecting and sending the input to the main microcontroller (Arduino Mega). ACS712 current sensor is positioned between the load and the supply to measure the current of the load. The measured information is transmitted to the second microcontroller (Arduino Uno) then Arduino Uno will send the information to the main microcontroller (Arduino Mega) for further monitoring system computation. The 4 channel 5 V relay module is placed between the load and the main microcontroller (Arduino Mega) used for controlling the electronic component. Blynk application is used as the platform of IoT to control hardware remotely, data stored and displayed from sensing equipment.

2.4 Schematic Diagram

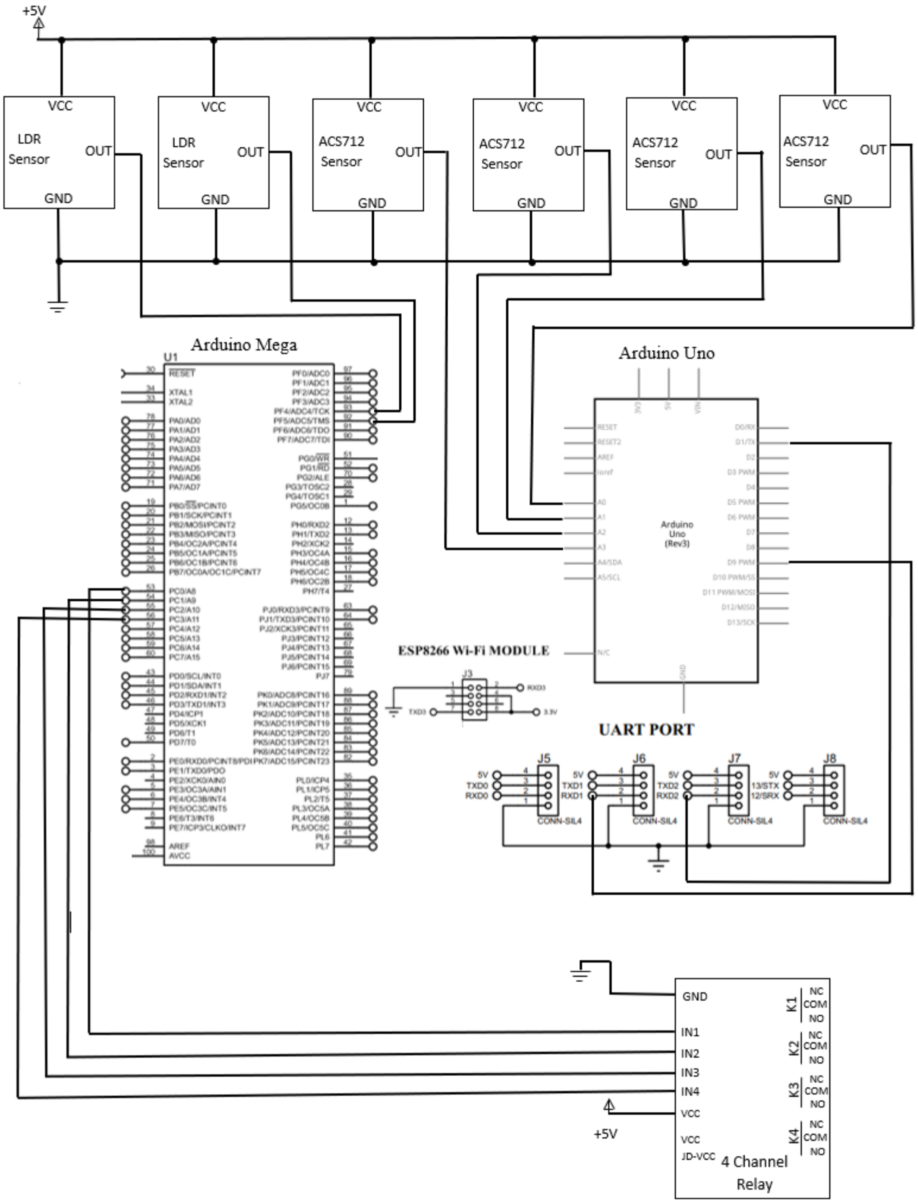

Figure 4: Schematic diagram of the system

Figure 4 shows the schematic diagram of the system. The major components on the circuit, starting from the main microcontroller which is Arduino Mega (IoT Magic Kit), consist of both analog and digital input pins that permit electrical connection with the circuit. In this microcontroller, two analog input pins consisting of A4 and A5 are used. These analog input pins will be connected to the LDR sensors. The UART port in this IoT Magic Kit will also be used to enable the serial communication method between the two Arduino to occur. The pin RXD1 at the UART port will be connected to pin 9 (PWM) of Arduino Uno while the RXD2 pin will be connected to pin 1 (TX) of Arduino Uno. The PC0, PC1, PC2, and PC3 digital pins are linked to a 5 V Relay 4 channel for control of Arduino and enable the users to use the Blynk. For the ACS712 current sensor connection, the input pins A0, A1, A2, and A3 of the second microcontroller which is Arduino Uno are used. There is no need to set up a wiring connection for the ESP8266 module because the IoT Magic Kit is already equipped and has a connection with the ESP8266 Wi-Fi module, one explicitly built for online usage and has a link to the Blynk application.

2.5 Designation Layout

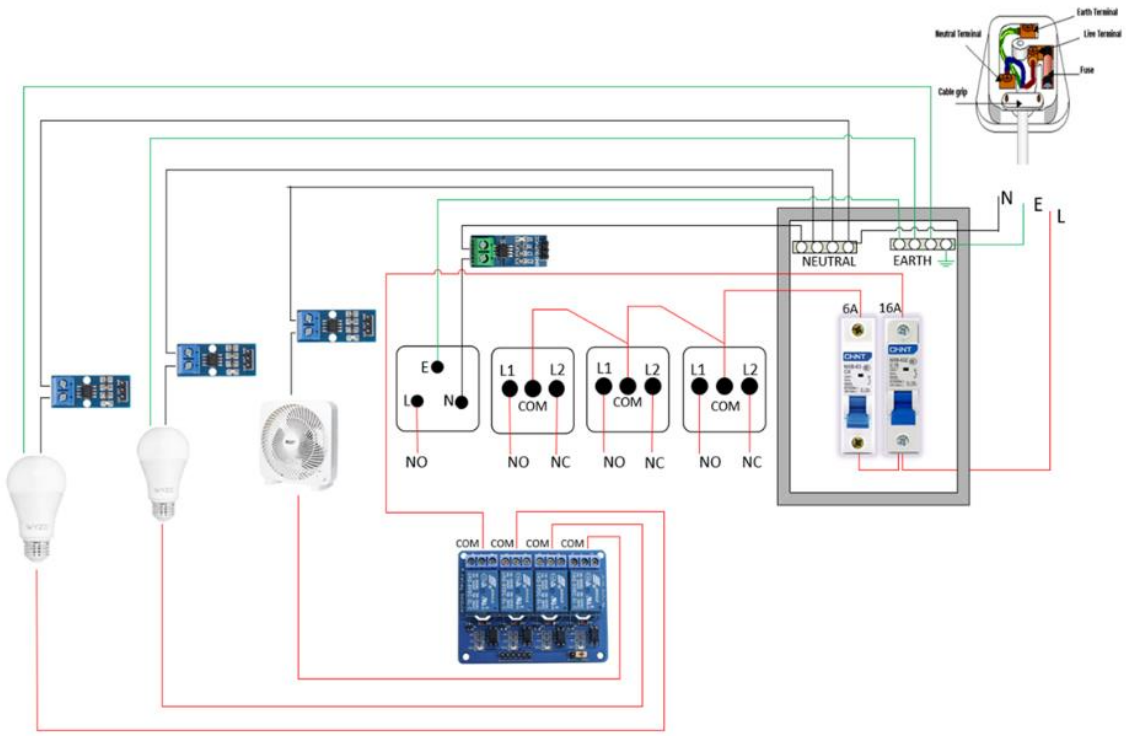

Figure 5: Project designation layout

Figure 5 shows the project designation layout. This prototype works when the live wire of the 3 pins 13 Ampere plug is connected to the MCB (Miniature Circuit Breaker) which allows the voltage supply to go through this circuit (240 V AC) to switch this prototype ON. Two MCB ratings are used for safety and protection purposes in the event of any fault. The 6A MCB is used for lighting circuits while the socket with relatively high power was attached to the 16A MCB.

Live wire connection from 6 A MCB will directly be connected to the command of switch 1 gang 2 way while L1 and L2 are linked to the normally opened (NO) and normally closed (NC) of relays. This connection allows the switch to control the load manually. The relay command connection is linked to the load that allows the load to be controlled using the Blynk. Three switches are used to control the light and fan. For the 13 Amp socket outlet, the live wire which links from 16A MCB connected directly to the command port on the 5 V relay, while the normally opened (NO) port on the relay is connected directly to the live port on the 13 Amp socket outlet. The remainder of the port, as neutral, will be connected to the neutral found in the DB box and the earth port will also be connected to the ground for safety measures.

Loads such as lights and fans can be controlled by two methods, either manually or online, but for a 13 Amp socket outlet, it can only be controlled online through the Blynk application. To allow the current and power values of each load to be monitored, the ACS172 current sensor is mounted on a neutral load connection, this is a safety measure to prevents accidents. This is because the connection to the live wire has a high possibility of an explosion. Two different ratings of current sensors are used according to their respective power loads. The current sensor used for the fan and the lamp load is 5 A, while 30 A for the 13 Amp socket-outlet.

2.6 Wiring Diagram

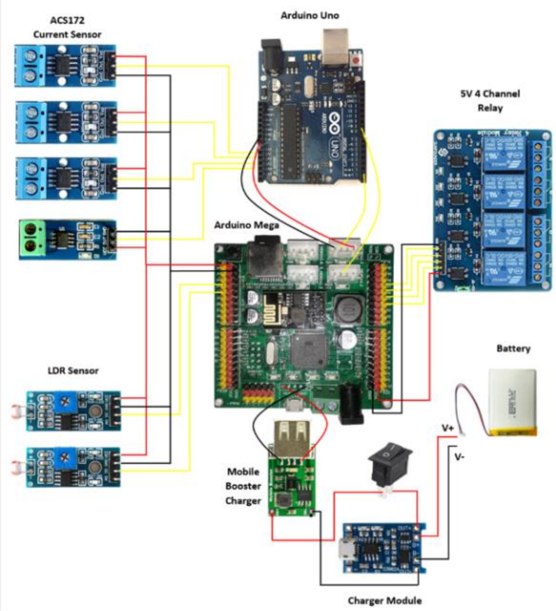

Figure 6: Wiring diagram of the project

Figure 6 shows the wiring diagram of the project. This wiring diagram consists of Arduino Uno, IoT Magic Kit (Arduino Atmega and ESP8266 Wi-Fi), ACS712 current sensors, LDR sensors, and also 5 V 4 channel relay. The connection could be seen starting with the connection of the LDR sensors to the Arduino Mega that serves as the main microcontroller in this system. As for the ACS712 current sensors, it is connected to Arduino Uno which acts as the second microcontroller and this microcontroller has a connection with the Arduino Mega via serial communication method. Each sensor is supplied with 5V sources while the main microcontroller has been supplied by using a Lipo battery which is a rechargeable battery. The input of the 4 channel 5 V relay is connected to the output of the main microcontroller (Arduino Mega) to allows the microcontroller to control the relay and enable the control system of the project.

3. Results and Discussion

This section discusses the hardware implementation. All data relating to the objectives of this project, such as the interface between the Blynk application used for the monitor and the control system, also have been documented and explained.

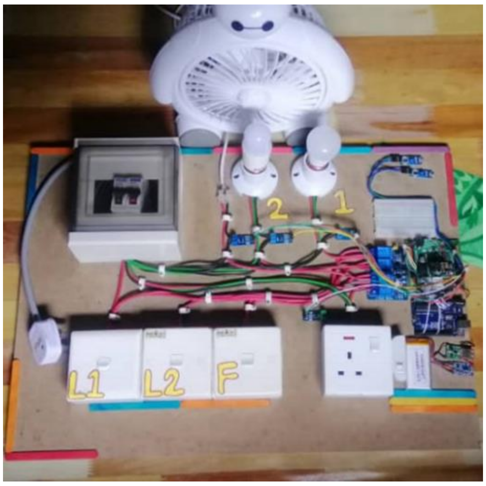

Figure 7: Hardware implementation

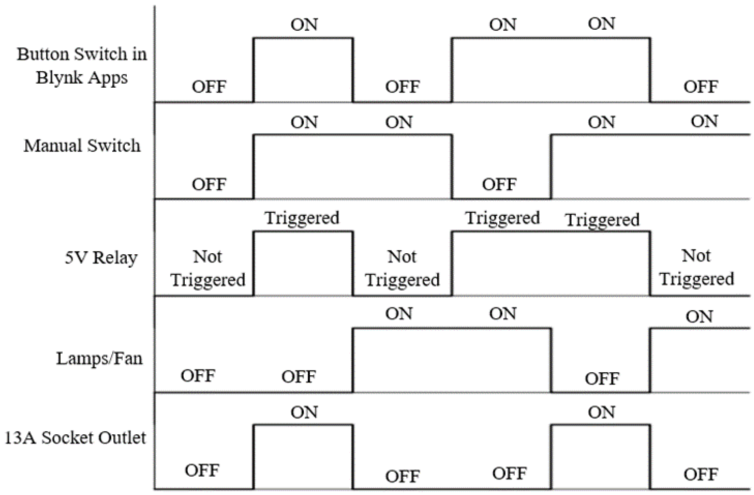

Figure 8: Waveform for the control system for housing electrical load

Figure 7 shows hardware that has been successfully built while Figure 8 shows the waveforms result for the control system. The test of the control system was performed in several situations to ensure and verify its functionality. For the case both the manual switches and the widget buttons in the Blynk Apps were switched OFF, there were no electrical load functions since none of the switches were triggered. When both the manual switches and the widget buttons were switched ON, the result showed that lamp 1, lamp 2, and fan were off, but the socket-outlet was ON. This implies that both switches, specifically manual and widget buttons, cannot be activated simultaneously to turn ON the loads such as lamps and fans. Both switches were necessary for the socket-outlet to function. Besides, when the widget button was ON, the relay will be triggered since the relay has a connection to the microcontroller. For the case when the manual switches were ON and the widget buttons were OFF, the waveform showed that the fan and lamps were ON while the socket-outlet was OFF since the relay was not triggered. When the manual switches were OFF and the widget buttons were ON, the waveform indicates that the fan and the lamps were switched ON since the relays were triggered but unfortunately, the socket-outlet was still switched OFF since the manual switch was switched OFF.

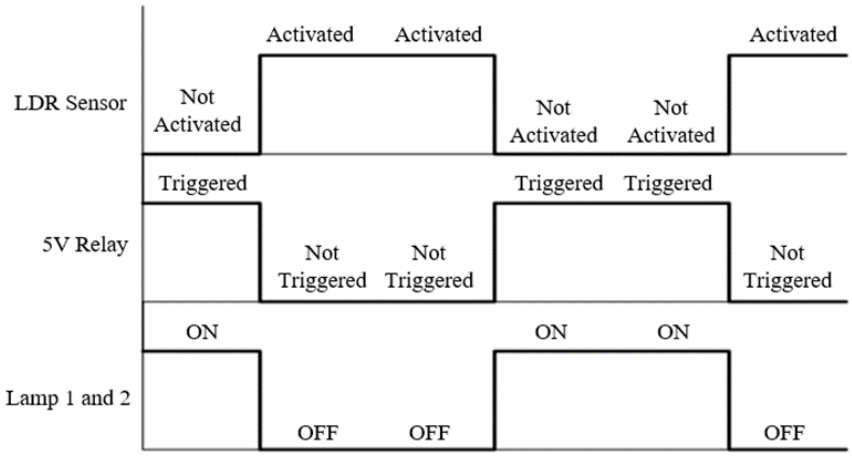

Figure 9: Waveform for the control system by the sensor for housing electrical loads

Figure 9 shows the waveforms result for the control system by the sensor. The LDR sensor was used to detect light intensity and works on the "Photo Conductivity" principle. In other words, the resistance of the LDR falls when the light falls on the surface of the LDR. The LDR sensor was activated when it detects the presence of light. As the light was sensed, it produces a low reading of the resistance value. The relay will not be triggered if it does not meet the preset threshold value set in the Blynk application. Thus, the loads were OFF.

Figure 10: The current used by lamp 1

Figure 10 presents the value of current when lamp 1 was ON was 0.01 A as shown in the Blynk application and the value measured by the clamp meter was 0.02 A. The reading obtained from a clamp meter shows that the value was almost to the values read by the Blynk application. A slightly different value may due to the offset value of the current sensor. It was verified that the system and Blynk can function properly. The rated power by lamp 1 was 3.00 W.

Figure 11: The current used by lamp 2

Figure 11 presents the value of current when lamp 2 was ON was 0.04 A as shown in the Blynk application and the value measured by the clamp meter was 0.043 A and when rounded will get a value of 0.04 A. The reading obtained using a clamp meter was the same as the value read by the Blynk application. Recorded data was acceptable. The rated power for lamp 2 was 10.00 W.

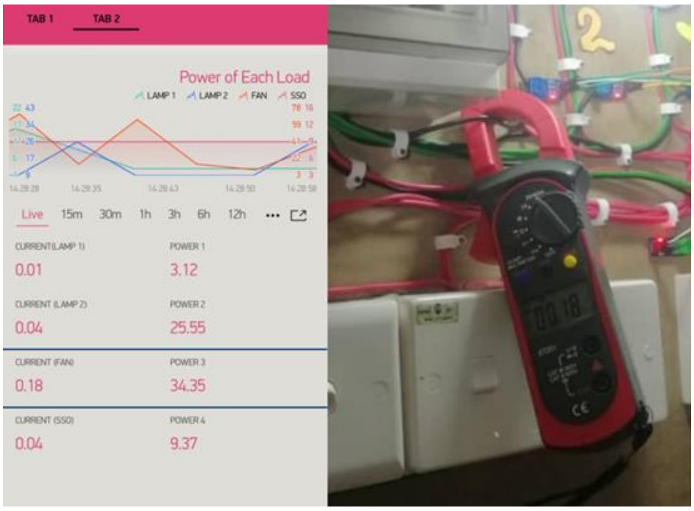

Figure 12: The current used by the fan

As shown in Figure 12, the value of current while the fan was ON was 0.18 A and the value measured by the clamp meter was 0.18 A. This implies that the system performs well. The reading obtained using a clamp meter was the same as the value read by the Blynk application.

Figure 13: The current used by socket with the load

As shown in Figure 13, the value of current while the socket with load was ON was 0.04 A and the value measured by the clamp meter was 0.04 A. The reading obtained using a clamp meter was the same as the value read by the Blynk application. This implies that the system performs well.

Figure 14: Power consumption per load

For power consumption, the user can observe the value in the Blynk application either through the value that has been displayed or in the form of a graph. In the form of a graph, the X-axis indicates the time while the Y-axis indicates the power used. Figure 14 shows the power consumption by the four electrical loads at a time. The graph recorded was at 2.22 pm. For the electrical load lamp 1, the main focus should be on the green line. There was a fluctuating movement in the power used from time to time since, in reality, there was indeed such an occurrence for the use of alternating current. However, the Blynk application was still able to record reading for power used by lamp 1 at 3.12 W at 14:22:26. The power rating for lamp 1 was 3.00 W and this value was closed to the value on the Blynk application graph. Besides, the blue line represents the power consumption by lamp 2. As observed, the graph produced was linear. The power used by lamp 2 was 9.00 W. The power rating for lamp 2 was 10.00 W and this value was closed to the value on the Blynk application graph. For the fan load, the power consumption was represented by the orange line. The graph shown was uneven. Although fluctuations occur and sometimes the value was high but this situation was very short-lived and will continue to change. The Blynk application was still able to produce a reading that was closed to the actual reading which was 40.00 W at 14:22:33. Next, the red line in the graph reflects the socket with the load power usage. The power consumption displayed on the graph was linear and does not fluctuate at the reading of 9.00 W each time. It makes it easy to take measurements. The power used by the socket was very small since the load used on the socket was a phone charger.

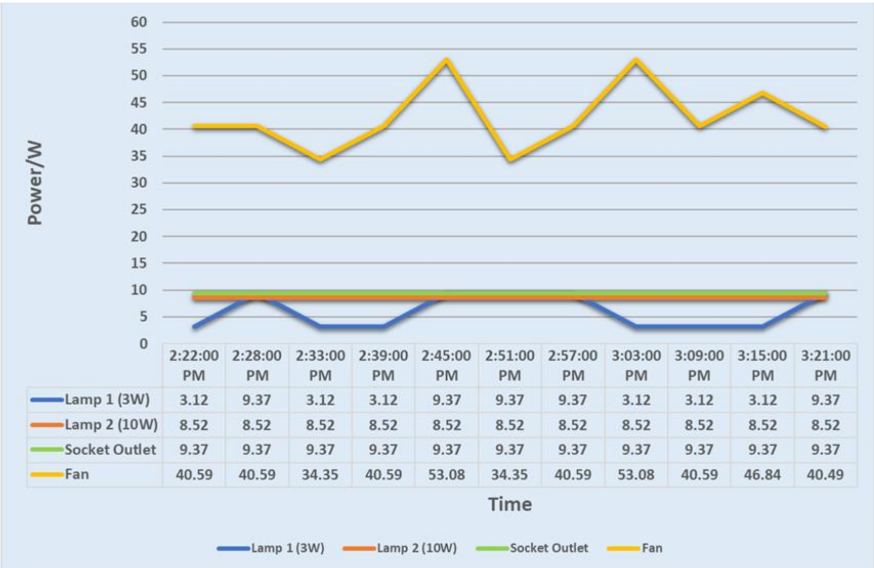

Figure 15: Amount of power consumption per load

Figure 15 shows the amount of power consumption by each electrical load used. The graph shows the movement of the power recorded by the Blynk application for lamp 1 fluctuates between 3.12 W and 9.37 W. Since, in reality, this occurrence was unavoidable due to certain factors, the readings still reasonable because it has a value that closes to the actual value which was 3.12 W. For lamp 2, the amount of power consumption graph was linear since the reading on the current values was linear. Lamp 2 also does not use a huge amount of power which was only 8.52 W. Small variations of the actual value may be attributable to the power loss and electrical noise present in these components. The socket with the load also produced a constant graph at 9.37 W. There may be changes in the value but the value was too small even when rounded, it would get the same value across all readings so the graph generated was linear. The power used by the socket for an hour was also low as the load attached to the socket was a phone charger. Recorded data was close to the actual value. Thus, it shows Blynk application can perform its function well to monitor the power consumption by the loads.

Several factors may have an effect on the measurements recorded. The first may be attributable to the offset value found in the ACS712 current sensor. Moreover, another contribution to the problem was possible because the electronic component was sensitive, the current sensor used may be more sensitive to detect current readings with each load. Besides, it may also be caused by the power loss and electrical noise present in these components.

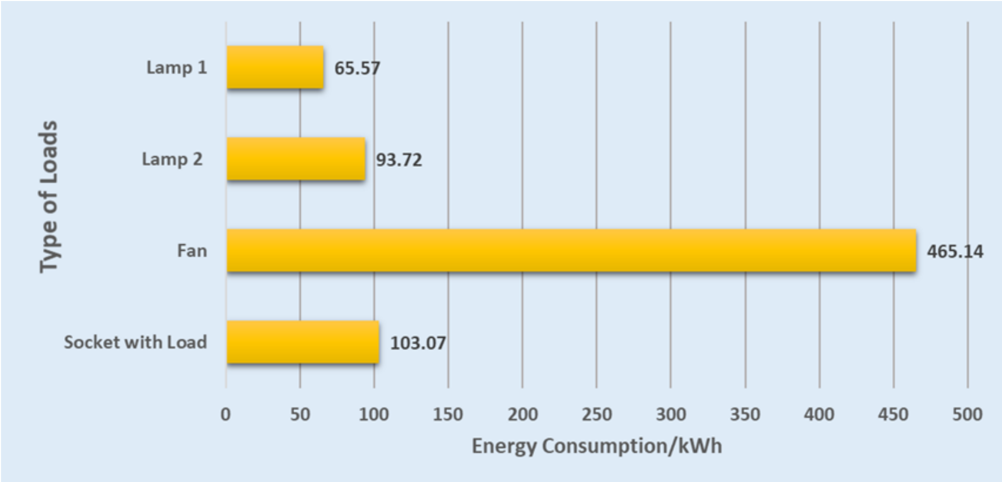

Figure 16: Energy consumption per load

Figure 16 shows the energy consumption by each load. The housing electrical load consists of lamp 1, lamp2, fan, and socket with the load. To obtain the energy consumption used by each load, the previously recorded power values have been added together and allow to compare which load uses the highest and lowest power. Fan load recorded the highest usage which was 465.14 kWh based on the graph provided, while lower reading was recorded by lamp 1 which was 65.57 kWh.

4. Conclusion

In conclusion, this project has successfully achieved the objectives and the data performance of the whole system was recorded and evaluated. This project can be a solution to the energy consumption crisis nowadays. Knowing the amount of energy used every day makes consumers more aware and more interested in implementing energy management or energy efficiency which the concept that has been issued by Suruhanjaya Tenaga.

Improvements to this project can be made first in terms of the use of the microcontroller. The IoT Magic Kit provided strengths and weaknesses. If users want to use it for an electrical load control system, the IoT Magic Kit is very suitable for further use. This is because of its features, which come with the Arduino Mega and the ESP8266, which is designed specifically for controlling and accessing the internet. But if users want to use it for a power monitoring system, this IoT Magic Kit is not suitable because it can only provide raw data. The source code presented is complex and difficult to alter according to what the user needs. Next, it is possible to upgrade the Wi-Fi module for ESP8266 to ESP32, which was the most powerful compared to ESP8266, since it includes more GPIOs with multiple features, faster Wi-Fi, and Bluetooth support. Apart from that, improvement can be done in this system by adding features to Blynk Apps that allow power to be measured for energy-saving purposes such as notification to users when they need to minimize energy usage or a system that automatically switches OFF load usage when the energy used exceeds and is too high.

Acknowledgment

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

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