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Electricity Usage Monitoring Based on Internet of Things

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Abstract: Electricity monitoring systems have long been used in industrial scenarios such as process scheduling and distribution. This monitoring system needs to be developed for domestic use such as in homes and shops. In recent times, the electricity demand has increased in households with the use of different appliances. The advent of technologies such as the Internet of Things (IoT) has made real-time data acquisition and analysis possible. This project is designed to control and monitor household electricity consumption based on current parameter via smartphones using the ESP8266 Wi-Fi module as a communication protocol and the Blynk application as a private server. The used Wi-Fi module provides notification through the Blynk application. The system uses an Arduino Mega2560 microcontroller to control all devices in this project. For monitoring the energy usage, a current sensor type Split Core Current Transformer (SCT013) was used. From the experimental results, it is confirmed that the system can monitor the whole house's electrical usage easily. With this system in place, end-users are provided with proper awareness and able to plan their home's electrical consumption pattern effectively.

Keywords: Internet of Things (IoT), Wireless Fidelity (Wi-Fi), Split Core Current Transformer (SCT013)

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1. INTRODUCTION

Since the 19th century, measurement of electricity consumption has been done using mechanical and electronic meters [1]. This meter was designed years ago with a measurement of kWh. After that, there are innovations in meter technology with the addition of voltage, current, and power factor measurements. This meter plays an important role in measuring the use of electricity in the household.

Nowadays, the use of smart meters has been widely commercialized especially in developing countries and Malaysia is no exception [2]. One of the main benefits of using smart meters is smart meters deliver information to users for more details on the electrical consumption, and the electricity supplier monitors customers and the billing system. Apart from that, the smart meter can spare measure electricity use two-way communication between the smart meters with suppliers.

Several objectives are set in the early stage of this project. It is to ensure that all purposes of the project can be achieved after completing the project. The objectives are; i) To design a circuit that can display the usage cost for each electricity consumption, ii) To monitor units consumed and transmit the units as well as cost charged over IoT to the end-user, iii) To give a notification to the end-user if usage exceeds the limit. To achieve the said objectives, this project studies and reviews previous papers and research to get the relevant methods. This project uses an Arduino microcontroller as the heart of the system. The Arduino responds with a given 5 volts and keeps on counting the supply and then calculates the power consumed and also the cost. This data will continue to be stored in the website application so that the end-user can monitor every day and can calculate the cost of electricity consumption. The ESP8266 Wi-Fi module was used as a link between the Arduino board and IoT applications. To measure current, this project uses the current sensor type Spilt Current Transformer (SCT013). It is designed for easy handling for its users as no modification on the existing electrical distribution board is needed. Apart from that, an important part of this project is writing programming using Arduino IDE software for Arduino board devices.

2. LITERATURE REVIEW

2.1 Existing Systems

Power consumption is the amount of electrical power used in a house. Electricity consumption is an important aspect of the electricity supply. End users should be aware that wasting electricity will be detrimental in the future. By using electricity every day, the pattern of electrical energy will change. Weather factors also play an important role in changing the use of electricity for example when the weather is hot, end-users will install air conditioners at high temperatures. In addition, the indifference of the end-user is also one of the factors of high electricity consumption, for example not switching off the lights or television when not watching it. Because the power supplied by the energy company is not limited, most end users do not monitor each usage. Energy utilities should play a major role in advancing smart meter technology and should make people participate in reducing energy consequences by creating awareness about the impact of their current level of consumption [3-5].

Research by [6] presented a system of metering as well as billing in India that uses an electromechanical and digital smart meter. One of the main reasons for this project was made because the existing system is slow and inaccurate in reading the use of electricity. Accuracy in slag electrical energy reading is considered. This paper also discusses smart grid and smart meter and advanced metering infrastructure briefly. A possible solution is a Wireless Energy Meter which can send its data via wireless communication to a Personal Computer (PC) or a remote device where monitoring and analysis of the data [7-11]. Here various wireless communication used in smart meter technology is described and the comparison of four different technology is given.

Most modern homes have a technological and innovative environment. It consists of equipment handling, safety, and monitoring of electricity usage. These factors have allowed the integration of homes with IoT environments in what is known as smart homes [12]. In this paper, a smart IoT sensor of electricity consumption in a smart home is capable of analyzing energy consumption using a mobile device over a wireless connection. Smart meters are designed using a cyber-physical system based on the ESP32 microcontroller where the Embedded Web application is run which shows the electrical consumption of the electrical device. The current sensor type ACS712 was used in this project. This technological IoT smart device aims to help to detect the phantom consumption of electrical energy in a smart home environment to promote energy-saving [13-17].

Works by [18] aimed to explain the digitization of the use of load energy through the internet. This project is designed to reduce human involvement in electrical maintenance. End-users can monitor the use of electricity in watts from the website. For hardware devices, this project uses the Arduino Nano board as the main device. ESP8266 Wi-Fi module as a device that connects Arduino board with IoT system. Current sensor type ACS712 was used to measure the value of pliers current used. As for the software, it uses the ThinkSpeak application to analyze energy consumption to provide a more detailed description and visualization of energy consumption statistics. The IoT concept provides the basic infrastructure and opportunities to form a connection between the physical world and computer-based systems [19-21].

2.2 Research Gap

From observations and research on literature review, the main limitations of the existing electricity meters are not being able to display the usage cost in real-time. Due to this, end-users difficult to monitor usage costs. Apart from that, some of the existing systems cannot provide notifications to end-users.

3. METHODOLOGY

An electricity monitoring system is one of the design systems that use IoT to help end-users monitor their electricity usage. The system works when this prototype is connected to the distribution board (DB) of the end-user's house. This section discusses the project methodology approach to develop this prototype, the project description on the system process flow together with the system block diagram, and the system operation.

3.1 Block Diagram

The Electricity Usage Monitoring based on IoT can be easily described in two-part. The first part being the hardware part and the second one being the programming together with the Blynk application. Figure 1 shows a block diagram for this project. The block diagram shows the whole system connection in a real situation. The current sensor measures the input/output current source at DB. After that, the ADS1115 gets the analog signal data from the current sensor and converts it into a digital signal before transfer the data to Arduino Mega2560. Then the microcontroller processes the current value to convert Ringgit Malaysia (RM). Next, ESP8266 sends data to the Blynk application. A notification is sent to the end-user. The LCD shows current and power values and buzzers ring for each notification. The power supply to this project is taken from USB plug supply 5V.

3.2 Flow Chart

Figure 2 shows the flow chart for the whole system in this project. The system starts by finding the internet network that has been set up in the programming. Once the internet network has been connected to the ESP8266, the buzzer will sound, and the system is ready for use. Users need to enter the cost limit value in RM to be set to control the current electricity consumption. Once the cost limit value has been entered, the system will continue to operate according to the programming that has been set. Each electrical usage will be counted, and the cost limit value will be decreased proportionately. If the limit value has reached or is less than RM10, a notification will be sent to inform the usage is high. After that, if the limit has reached RM0, another notification will be sent informing that the electrical usage has exceeded the set limit. The system will stop until a new limit is re-entered.

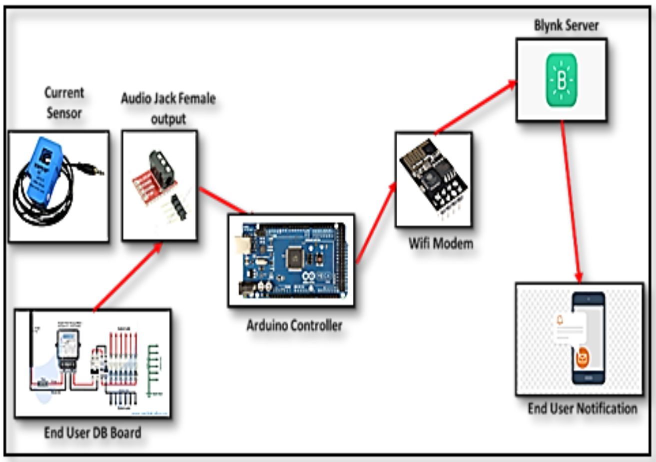

Figure 1. Block Diagram of the system

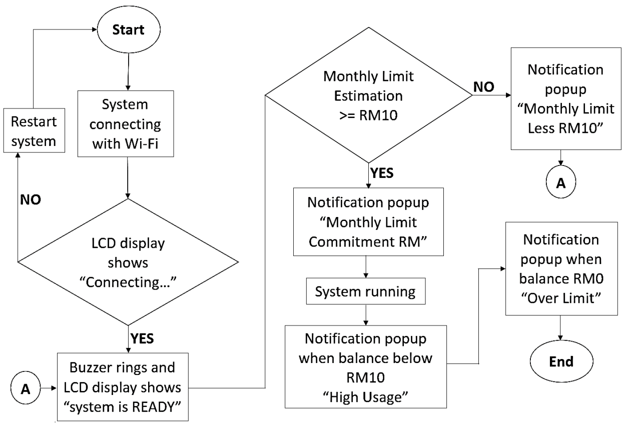

Figure 2. Flow Chart system

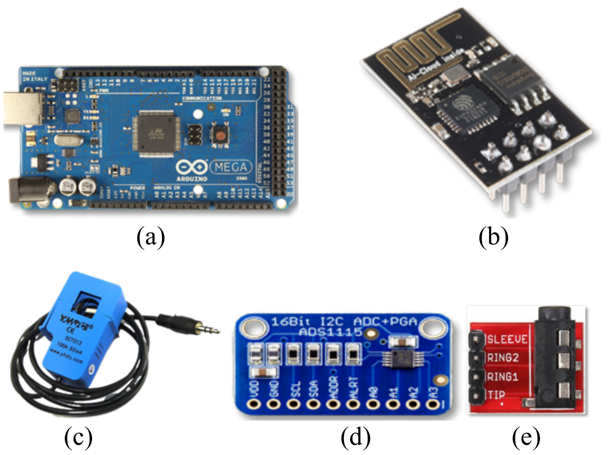

Figure 3. (a) Arduino Mega2560 (b) ESP8266 (c) Split Core Current Transformer (SCT013) (d) ADS1115 (e) Audio Jack Breakout Board

3.3 Hardware

3.3.1 Arduino Mega2560

Figure 3(a) shows the Arduino Mega2560 board as the main controller of this system. It has 54 pins digital input/output, of which 14 pins can be used as Pulse Width Modulation (PWM) output, 16 analog inputs, 16 MHz crystal oscillator, USB connection, one power jack, one ICSP head cover, and reset button.

3.3.2 ESP8266

Figure 3(b) shows the ESP8266 Wi-Fi module device. The ESP8266 Wi-Fi is a low-cost module. ESP 8266 Wi-Fi module is a system-on-a-chip with capabilities for the 2.4 GHz range [9]. This device is used to collect and send data from the microcontroller to the IoT cloud server. By using Wi-Fi, users can monitor electricity consumption and can set a limit for electricity consumption at home.

3.3.3 Split Core Current Transformer (SCT013)

The current sensor type SCT013 is shown in Figure 3(c). This device is easy to operate by the user. This device is already built in the load resistance. This sensor is also capable of measuring direct current from 1A to 30A. The current flowing through this current sensor will produce a magnetic field, which the ring-core converts into a proportional voltage. To use this SCT013 Sensor requires an Audio jack (female) as an intermediate with the ADS1115 because the SCT013 sensor output uses an Audio Jack (male). The current sensor sends an analog signal to the ADS1115 and converts it to a digital signal to Arduino Atmega2560. The typical output error is ± 3% and operates from 4.5 to 5.5V. Therefore, this project uses 5V as the main supply.

3.3.4 Analog to Digital Converter (ADS1115)

Figure 3(d) shows the ADS1115 module device. ADS1115 is an analog to digital converter module. This device comes with a 16-bit resolution. It is a low-power device and operates at a voltage range of 2V to 5.5V. Therefore, this project uses 3V as the main supply. In this project, this device is used to convert analog data from the current sensor SCT013 and send digital data to the Arduino Atmega2560.

3.3.5 Audio Jack Breakout Board

Audio jack female type TRRS is used as an intermediary with ADS1115. TRRS stands for 'Tip, Ring, Ring, and Sleeve'. Only 'Tip' and 'Sleeve' pinouts are used and connected to ADS1115. Figure 3(e) shows TRRS 3.5 mm Jack Breakout Board module device.

3.4 Schematic Diagram

Figure 4 shows connections between all hardware components used in this project. The insets show the pinouts used for each hardware component.

3.5 Programming

To achieve the objectives of this project, programming needs to be made so that this prototype can function according to the flow chart system that has been designed. The programming language is C and Arduino IDE 1.8.13 version was used in the software development. The algorithm starts reading and analyzing incoming data from the current sensor. Then, the analysis result is sent via Wi-Fi module ESP8266. After that, the Blynk application receives data from the Wi-Fi module and sends a notification to the end-user. To ensure that the value of the electrical current reading is the same as issued by the current sensor, a parameter is set in the program. More information related to the programming is described elsewhere [22-25].

4. RESULTS AND DISCUSSIONS

4.1 Circuit Wiring

The wiring is made according to the design schematic diagram on the methodology. Each wiring is tested before it is used in this project. Each wiring includes an Arduino Mega2560 device, ESP8266, ADS1115, current sensor SCT013, audio jack breakout board, LCD, and a buzzer. The wiring on the stripboard is neater and more orderly. With the wiring on the stripboard, it makes it easier for any testing that is done on the end-user distribution board. Figure 5 shows the stripboard that has been prepared.

4.2 Blynk Interface

Figure 6 shows the Blynk interface that has been set for this project. It shows some of the parameters that have been selected as the current (Ampere), power (kW), monthly limit, balance, notification, and graph to see any changes in real-time.

4.3 Calibration

To ensure the current sensor is in good condition and usable, calibration was done. The calibration was done using the current comparison method between Amp Meter and current sensor SCT013. The type of Amp Meter used is the Kyoritsu model KEW2200R with a serial number E8115238. Before this Amp Meter was used as a benchmark, it was also calibrated by TNB Petaling Jaya Forecasting Services Laboratory. This calibration is performed five times to ensure the current sensor is in good condition.

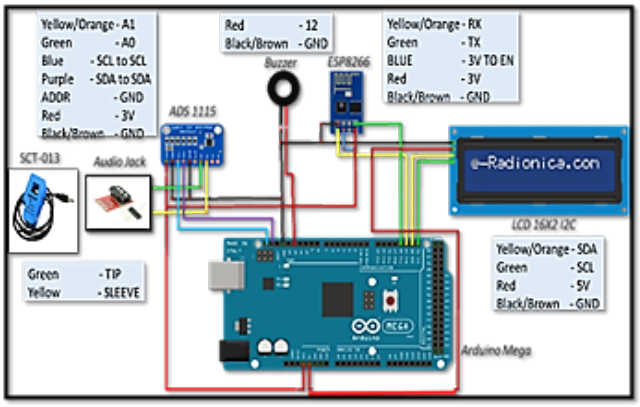

Figure 4: Schematic Diagram

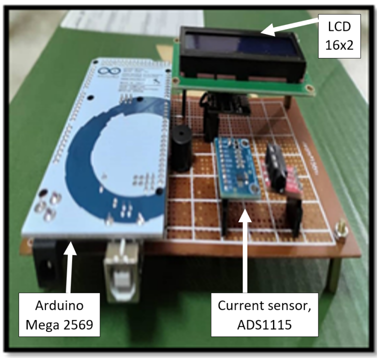

Figure 5. Wiring on stripboard

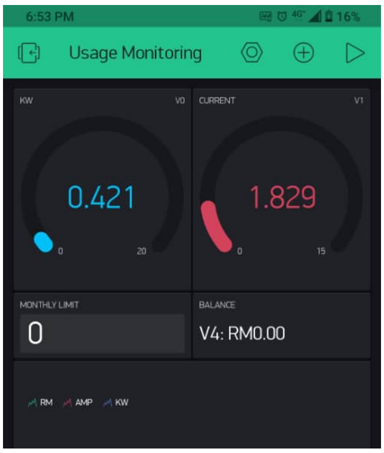

Figure 6. Blynk Interface

Of the five calibrations, each data was taken, and a table (as shown in Table 1) was made to facilitate the evaluation. After that, the data from Table 1 were plotted as a graph of standard deviation between Amp Meter and current sensor SCT013. From the graph, the standard deviation for the Amp meter is 0.02 while the standard deviation for SCT013 is 0.01 as shown in Figure 7. This indicates that the current sensor is in a good condition.

Table 1. Calibration data

NUMBER CALIBRATION	AMP METER (A)	SCT013 (A)
1.	2.24	2.21
2.	2.24	2.20
3.	2.25	2.20
4.	2.28	2.21
5.	2.25	2.22
AVG	2.25	2.20

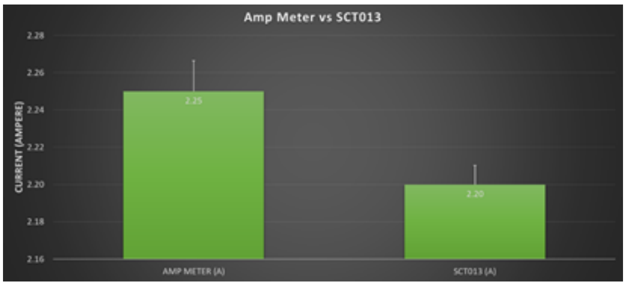

Figure 7. Standard Deviation Graph

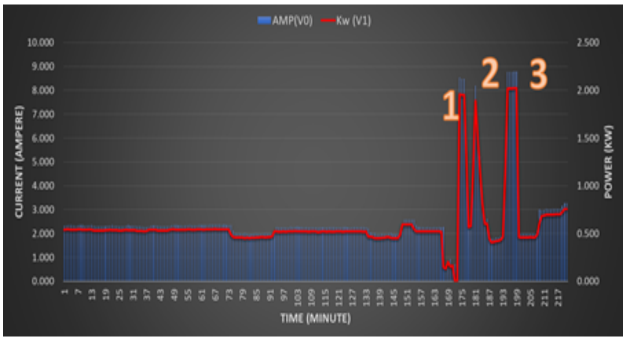

Figure 8. Energy Usage

4.4 Data Analysis

One of the design specifications of this project is to measure each electricity consumption in real-time. The beginning of the graph shows the usage approaching the horizontal line. To ensure that this prototype can be used in real-time, three tests have been done as shown in Figures 8. The first peak due to the water heater was turned on. For the second peak, the oven was turned on. And the last peak occurs when the air-conditioning was turned on. This data confirms that the prototype can function in real-time.

4.5 LCD Display and Blynk Notification

At the beginning of the system is turned on, the LCD shows "connecting". It shows that the system is looking for Wi-Fi that has been programmed in the system. After the system is connected with Wi-Fi, the LCD shows "System is READY" and the buzzer also gives a beep sound.

This system can be monitored anywhere using the Blynk application. This is one of the design specifications set in this system. The system has also been programmed that can inform every change in electrical energy consumption. For example, the user will enter a limit value for a month of electricity consumption and if the end-user enters a limit value of less than RM10, a notification will be sent through the Blynk application. Meanwhile, if the end-user enters a limit value exceeding RM10, a notification will be sent and show the value entered.

The system has set a benchmark to ensure that each electrical usage is monitored constantly. This allows the end-user to monitor their electrical usage. If the end user's electricity consumption reaches the set benchmark, a notification is sent to inform the high usage. If the electrical usage exceeds the monthly limit completely, a notification is sent to the end-user to inform the over the limit.

5. CONCLUSION

Based on the observations made in this project, the following conclusion can be drawn. Every design specification has been achieved according to each setting. End-user can see their usage and energy consumption in real-time. This project could help end-user to monitor and control their energy usage. This system can provide a notification to end-user in real-time. After monitoring the result, this project has a high potential to manage every electricity usage very well. Every single minute and hours end-user can be monitoring by this system according to the Blynk application via a smartphone anywhere.

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