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Original Article

Energy Monitoring System Design and Analysis with the Internet of Things on the Blynk Platform

Yuslinda Wati Mohamad Yusof[1], Abdul Hafez Mohamed[2], Murizah Kassim[3]

[1,2,3]*School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia*
[3]*Institute for Big Data Analytic and Artificial Intelligence (IBDAAI), Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia*

[3]*Corresponding Author : murizah@uitm.edu.my*

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Abstract - *The Internet of Things technology system has been designed in many concepts to be accessed within a long-range using Wireless Fidelity communication, including energy monitoring. The concept of energy monitoring is today due to a lot of spending time using electrical appliances such as laptops, chargers, and personal computers, especially young users like students. Most students spend most of their time playing games, listening to music, and watching movies on their laptops. Due to this, energy monitoring and analysis are important as a guide to students on their spent energy. This research helps them to reduce their monthly electricity bills and reduce their energy usage. The objective of this research is to design an energy monitoring system using Arduino as a microcontroller. The system uses Wi-Fi communication which interacts with this system. The hardware comprises energy sensors for recording and analysing energy usage in daily life. This research aims at an implemented system that automates and records the daily energy of appliance usage. Daily data collection for 2 weeks data was collected, and 421 samples were recorded based on 6 hours of data collected during the day and night. The results show that nighttime energy usage is 68% higher than daytime. A real-time energy recording on a Blynk platform has been designed and accessed on mobile. A positive correlation increase for Current (A) appears highly determined by Voltages (V) with a reading of 0.0247, and Current (A) and Power (W) appears highly correlated to each other with a reading of 0.9791. This research is significant for accessing the real-time energy for electricity based on daily usage via Android apps. It benefits the consumers by monitoring energy usage and knowing how to save energy efficiently. This research is also significant for building facilities for monitoring energy usage based on the user's capacity.*

Keywords - *Energy monitoring, System design, Internet of things, Blynk, Energy capacity.*

1. Introduction

Recent technological advances today are mostly smart devices. Smart devices are electronic devices connected to other devices on networks and are composing different types of usage and different sizes depending on their application. Various smart devices available in the market today can be accessed either via Bluetooth, Wi-Fi, voice detector, graphical user interface (GUI), Android, and others. The arrival of technology like the IoT further enhances the development of smart devices [1, 2,27]. The IoT itself is easy to develop, and the presence of this technology's goal is to help facilitate human life. People can control at their fingertips like GUI on Android apps or voice activation using IoT concepts which are monitored with smart devices. Many types of research have been done on the monitoring system and IoT that presented an easy and diversified idea of the automation concept of IoT sensing and monitoring systems in broader areas have been developed today like smart homes [3], Electric Powered[4, 5], Data Communications [6], Society security[7, 8], agriculture[9-11] and many more. EmonCMS is an open-source web server that was chosen as the platform that collects information from the sensor using the IoT and utilizes the cloud server [12]. The gathered data can be monitored, recorded, processed, and used to control home equipment. In combination with the ESP2866, the NodeMCU has been used as the controller, which captures, processes, and then loads sensor information into the EmonCMS web server [13]. The NodeMCU can also read and control data on the server—this comprehensive IoT-based system of intelligent home monitoring and automation [14, 15].

Recently, many researchers on building energy consumption analysis on smart building systems and equipment automation based on the wireless sensors network and by using the IoT technology have been developed [34]. Radio Frequency Identification (RFID) was also used to detect items quickly and acted as a tag to communicate for the smart building [17]. Besides, it is making full use of the inherent benefits of sensing networks collecting environmental

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information on energy consumption. The research presents a deployment of the Internet of Things (IoT) in systems that have made smart homes energy efficient, secure, and remotely accessible. The goal of this research is to design a system that provides smart switching, monitoring, and control of loads to reduce the units consumed and hence the electricity bills [18]. Besides, there was a method for building the Cyber-physical system, which is IoT, for monitoring and controlling the energy of electrical devices. Many were using Raspberry Pi as the microcontroller for the project research. It also featured the database system that utilizes MySQL since it is dependable and open source [19, 20].

2. Reviews

The Malaysian government is constantly reassessing its energy policy to guarantee the long-term security and reliability of the energy supply since it acknowledges the significance of energy as a crucial component in economic and social development. Dedicated efforts are being made to ensure that renewable and depletable energy resources are sustainable. [21]. Many prototype systems based on home security, automation, remote systems monitoring [22], and control in real-time energy have been implemented. Blynk application is popularly available on both Android and iOS devices to control real-time data on their system [23] other than is ThingSpeak platform[24]. The author can get the status of their sensors by assigning the virtual pin on the widget data corresponding to the code function at the Blynk platform[25,26,33]. The sensors that were used for the prototype are DHT11 for temperature and humidity [28], passive infrared (PIR) was used to detect motions [29], and ultrasonic. Another study based on the author in this paper discusses the usage and implementation of Wireless Network Sensors (WSN) as the surrounding environment data gathering for long-term usage [30]. The research used Linux as the Operating system (OS) on its Open smartphone [31]. A gateway was used in the research's design to communicate with the sensor that was put into position within the experiment field. The gateway's responsibility is to keep the transfer rate constant and, in the case of an interruption, to resume data transmission. Additionally, it has GPRS signal usage for long-distance operation, a MySQL database system, and Java as the primary programming tool for coding. This paper encountered IoT energy monitoring as energy monitoring is crucial. Since the students liked working on their laptops, they frequently left them on while in class and somehow forgot to switch them off—wasteful use of energy results from this. Electricity is crucial because it is a scarce resource within itself. Smart electricity consumption not only reduces bills but also helps in reducing non-renewable sources [32]. The future smart grid would help to benefit both the users and the electricity-providing companies with smart pricing techniques. In addition, wise costing can be utilized to further societal goals, shifting the wholesale market toward the demand side. It might be difficult for energy firms to gather a lot of data concerning a user's electricity consumption pattern.

This research aims to design and develop a system that monitors daily energy usage using the Blynk app. The recorded energy will then be analyzed and evaluated to save energy usage. This study's scope includes an energy analysis of students' appliances using laptops and computers and tracking energy use with the Blynk app, which alerts users via Android concerning energy usage status. Thus, it is helpful to learn how much energy current students use daily from this study. Certain students work on their assignments on laptops or computers.

Additionally, some students enjoy watching movies, listening to music, and playing video games. Consistently keeping track of their daily energy consumption and conducting analyses based on it is important. They are students with limited resources. To help people save money on their electricity bills, this study suggests ways to reduce their energy consumption.

After a specific amount of time, this system model also serves the purpose of alerting the user about daily electricity usage. Additionally, the system is an instance of an energy consumption display that can be seen on Android applications. It will also keep track of energy use until the user stops working. Users will start using electricity more effectively and indirectly reduce their electricity costs by doing this. The system can also be accessed online or via Wi-Fi for the purpose of analyzing energy usage. Finally, smartphone users work efficiently when they are online because the Android application allows users to monitor their energy consumption.

3. Materials and Method

This section explains the system architecture design, hardware, and software design.

3.1. System Architecture Design

There are several stages to developing the energy monitor using IoT, such as hardware design to collect the energy and development of software by using Blynk to record the energy. Moreover, the hardware setup required the hardware to be wired together, and the sensor was calibrated to ensure the reading was accurate to be collected. The Arduino IDE and Blynk application platforms are used to store the data on the Blynk cloud to be accessed. Lastly, there was a data analysis to determine the student's energy usage trend. Fig. 1 shows the system design for the research. This system consists of sensors, hardware, software, and a notification system to achieve the objectives of this research. Arduino will be mainly used for the sensor's attachment. Meanwhile, NodeMCU uploads the data receive from Arduino to the Blynk cloud server. The smartphone's energy usage notification can be viewed in the Blynk app, and it is also being used for exporting the data to be analysed with Microsoft Excel.

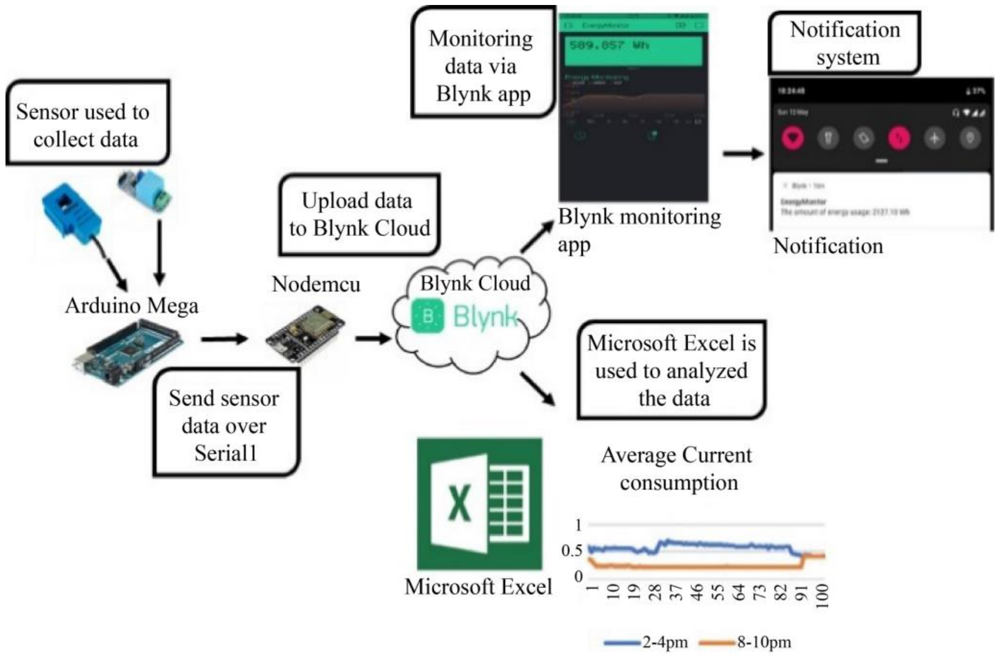

Fig. 1 System architecture design

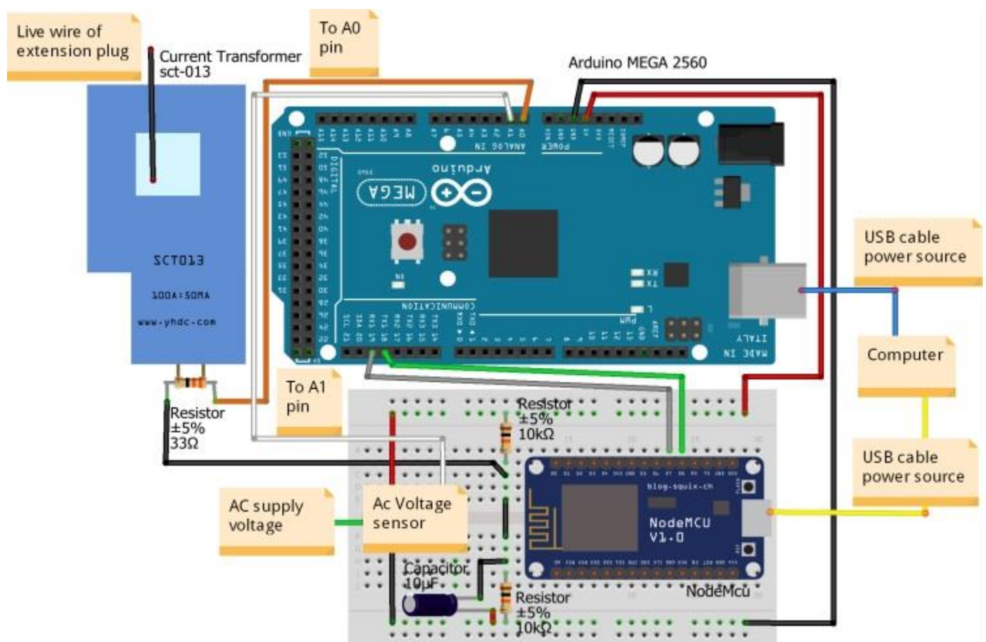

Fig. 2 Hardware design

3.2. Hardware Design

Figure 2 shows the hardware wiring diagram between NodeMCU, Arduino Mega, resistor, capacitor, voltage sensor, and current sensor wired on the breadboard. Arduino is a microcontroller used as a brain for this research. Moreover, it can supply the voltage from its 5V pin to the breadboard. The current sensor has been connected to a 5V voltage source on the breadboard, and its analog output is connected to the A0 pin on the Arduino. As for the voltage, the sensor is powered by using an AC supply on the extension plug, and its analog output is connected to the A1 pin. The way Arduino communicates with the NodeMCU is through the serial connection. The D8 and D7 pin on the NodeMCU is connected to RX18 and TX19 pin on the Arduino. This enables data transmission from Arduino to NodeMCU. Table 1 shows the list of the components used in this research.

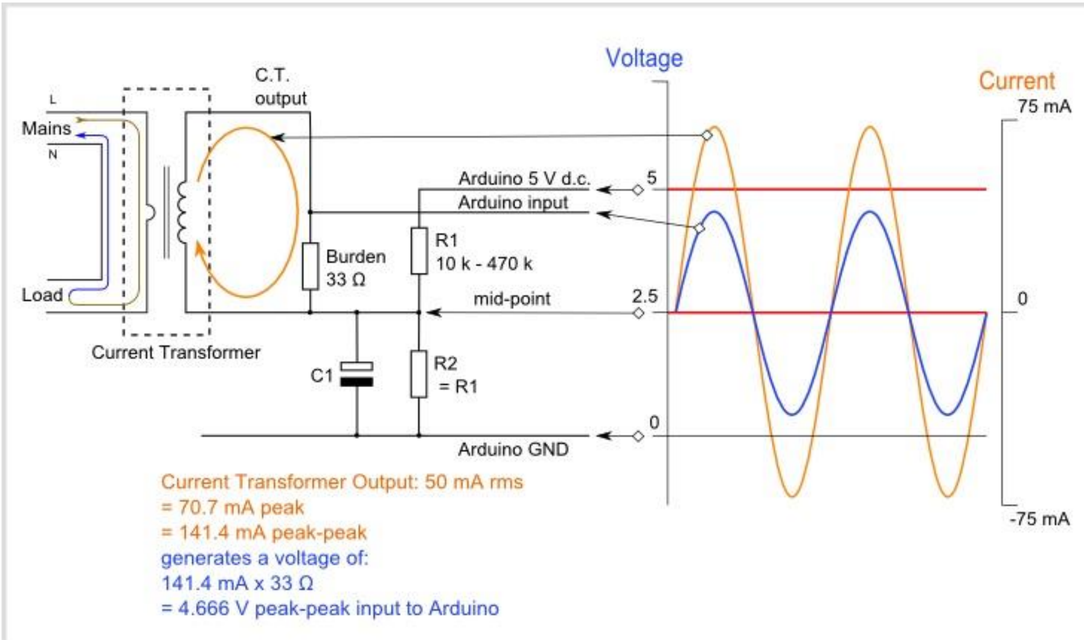

Fig. 3 Interfacing of a sensor with the Arduino

Table 1. Lists of components used

No of the item used	List of components used
1	Arduino Mega 2560
1	NodeMcu v1.0
1	Breadboard
1	Capacitor
1	AC Voltage Sensor
1	AC Current Transformer
2	Resistor 10k Ohms
1	Resistor 30 Ohms

3.2.1. Current Sensor Calibration

This current sensor comes without a burden resistor. Since this sensor is the current output type, it needs a burden resistor to convert the current signal to a voltage signal. Since Arduino can supply voltage up to 5V at max, the value of voltage, number of CT turns, and max RMS current of the CT clamps is substituted into the formula to get the output for the burden resistor. The output resistor value shown is 35 Ohms, which is not a common resistor. Moreover, a value of fewer than 35 Ohms which is 30 Ohms, is required since 30 Ohms is common. The reading values from the sensors are being sampled, and the average reading is taken in this research. Once the sensor has been set up to be interfaced with Arduino Mega, the analog output of the sensor will be wired to the A0 pin of the Arduino Mega. Figure 3 shows the interfacing of the sensor and the Arduino Mega board.

3.2.2. Voltage Sensor Calibration

Figure 4 illustrates the potentiometer beside the transformer of the voltage sensor. To enable us to take the correct AC voltage reading, the sensor calibration is required by setting the potentiometer until its reading is near to AC supply voltage for the house.

Fig. 4 Potentiometer with adjusted screw

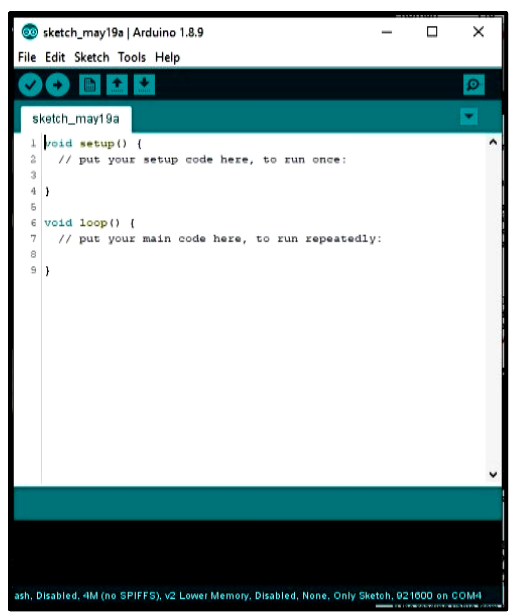

Fig. 5 Arduino IDE software

3.3. Software Design

Figure 5 shows all the written code written in the Arduino IDE platform. The coding in this platform allows us to verify first before the code can be uploaded. Once it has been verified, the code will be uploaded to the Arduino Mega and NodeMCU through the port cable connected to the computer.

Figure 6 shows the flowchart of the monitoring system for this research. To develop the monitoring system, the Blynk app is used. Firstly, the reading from NodeMCU is extracted into a different variable defined in the coding. Besides the reading is then uploaded to the Blynk cloud at an interval of 5 seconds.

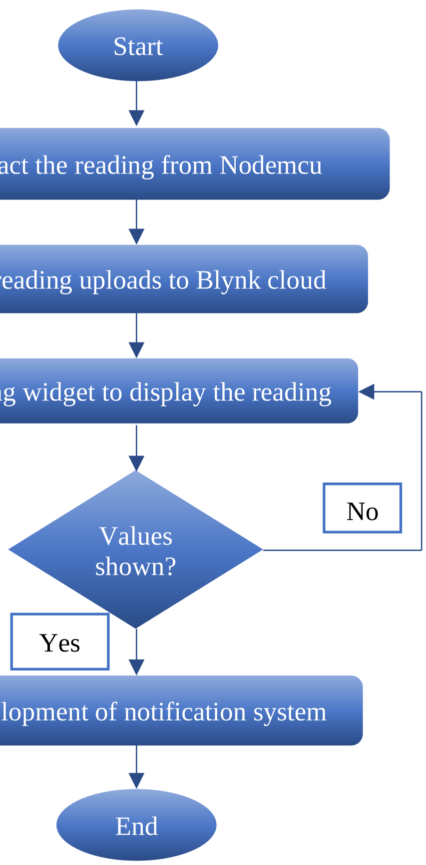

Fig. 6 Flowchart of a monitoring system

The widget is then dragged on the Blynk app layout, and its parameter for each reading is then defined. If there are no values shown on the widget after the monitoring process starts, this needs to debug the widget setting again. Finally, the notification system is then developed once the values on the widget are shown properly and tally with the output on the Serial monitor of the Arduino IDE.

3.3.1. Coding for Sensor Calibration

The coding for current and voltage sensors is calculated, and initially, the sensors need to be defined. The Emonlib library was used for this research provided by the OpenEnergyMonitor.org website. This library focuses on using the current transformer clamp for measurement. Besides, the pin to use needs to be defined. Without defining it first, the Arduino cannot show the reading from the sensors. *Coding for Blynk*: The code to Blynk indicates the reading has been uploaded to the Blynk Cloud. Besides that, it also can notify the user of the energy in the interval of 1 hour per notification for Watthour usage. Blynk needs to be authenticated first with the authentication code given by the Blynk app. Then it needs the Wi-Fi connection to establish the connection from the hardware to the internet. All the data uploaded to the Blynk cloud is then displayed in the widget.

4. Result and Discussion

4.1. Prototype Designed

A prototype is set up to record the current usage and notify the daily usage through the mobile app. The wiring of this research is simple and does not involve complex wiring on high voltage supply. The real current can be read by clamping the current sensor to the live or neutral wire. When the prototype is being on, the led on the NodeMCU will be blinking to indicate that the coding for receiving data is functioning well. It will blink every 5 seconds and at an hour interval, respectively.

4.2. Energy Monitoring System

Figure 7 shows the successful monitoring system. At the top of the system, it shows the start and stops button for the monitoring process. Below the start and stop buttons, the LCD widget displayed the total amount of the ongoing power consumption at an interval of one hour. The graph widget presents the reading values of voltage, current, and power. The graph has a time interval function that the user can keep track of the reading from either live, 30 minutes or 6 hours ago on its x-axis and reading values on the y-axis. Besides, it also features the exporting graph data to email to be analysed later.

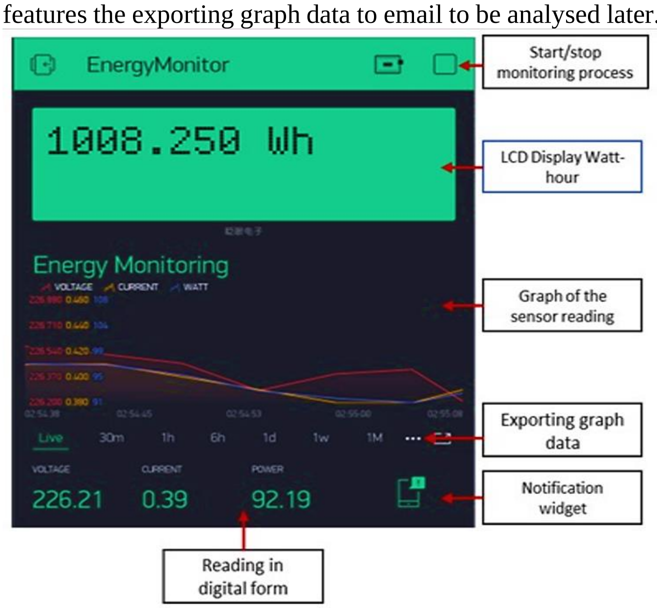

Fig. 7 Blynk interface of the prototype mobile apps

Furthermore, this research has a notification widget that displays the notification on the smartphone. The notification is a pop-up to the user, as in Figure 8. By pressing the three-dot icon on the graph widget, the user can export the data to the email. The user will receive an email as in Figure 9. Figure 10 shows the file that was exported and opened by 7zip software. Lastly, at the bottom of the interface is the widget that displays the current reading in digital form that will be updated at the interval of 5 seconds.

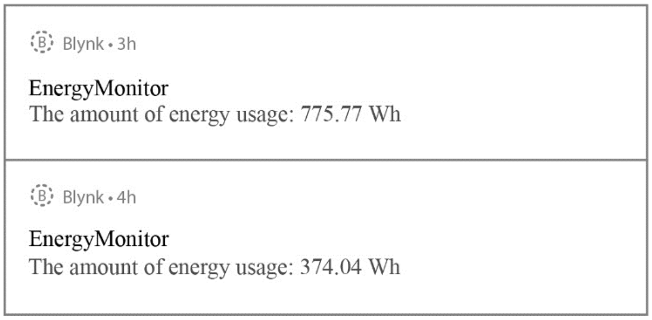

Fig. 8 Notification of monitoring energy system

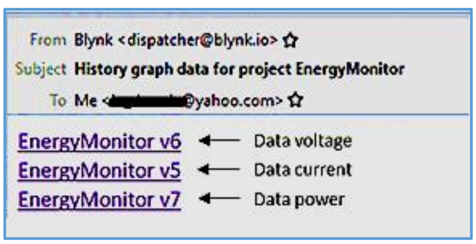

Fig. 9 Email contains the widget data

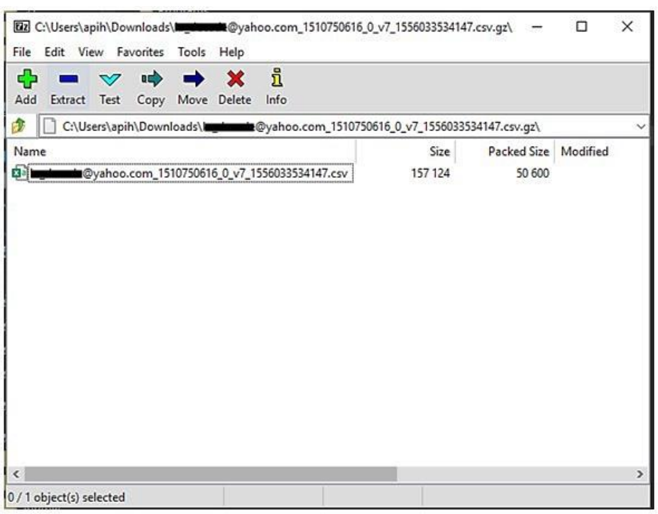

Fig. 10 zip software to open GZ compressed file

Table 2. shows the raw data that has been opened in Excel. It is quite unreadable at first, and it needs to do some calculations involving a formula specifically to convert the Epoch Unix Time into a readable format. Equation 1 is the equation to convert the Epoch Unix Time (E) to date and time with GMT+8 offset. Moreover, the value after conversion is shown in Table III.

Table 2. Raw Data

Current (A)	Epoch time unit
0.571891892	1.56E+12
0.666486484	1.56E+12
0.552413793	1.56E+12
0.663243243	1.56E+12
0.601891892	1.56E+12
0.654054054	1.56E+12
0.739117647	1.56E+12
0.573666667	1.56E+12
0.537941176	1.56E+12

Table 3. Conversion for time and date

Current (A)	Epoch time unit	Date and Time
0.571891892	1.56E+12	4/13/19 8:55 PM
0.666486484	1.56E+12	4/13/19 8:56 PM
0.552413793	1.56E+12	4/13/19 8:57 PM
0.663243243	1.56E+12	4/13/19 8:58 PM
0.601891892	1.56E+12	4/13/19 8:59 PM
0.654054054	1.56E+12	4/13/19 9:00 PM
0.739117647	1.56E+12	4/13/19 9:01 PM
0.573666667	1.56E+12	4/13/19 9:02 PM
0.537941176	1.56E+12	4/13/19 9:03 PM

Table IV illustrates the number of samples taken from three CSV files into one spreadsheet. Besides that, the reading data is close to theoretical values. This has been shown after the use of Eq. (2), where P = power, I = current, and V= voltage. It can be concluded that reading from the software is close enough to the theoretical values. This indicates that this research is viable and ready to implement.

$$E=(LEFT(D2,10)/60/60)/24+DATE\ (1970,1,1)+(8/24) \quad (1)$$

$$P = I * V\ (Watt,W) \quad (2)$$

4.3. Data Analysis

The students' energy usage analysis was recorded through the extension plug. The main appliances attached to the extension plug are Personal Computer (PC) and a laptop. Figure 11 shows the average energy usage for two weeks. There were over 421 samples recorded on both day and night. Besides, the time was set for each of the analyses to be precisely 6 hours each day and night.

Data shows the energy usage when both appliances are turned on from 8 PM to 1 PM. During this time, both appliances were on high load. This indicates that students were using more laptops and PC. It shows the highest peak of energy usage, which is nearly 170W. During this time, normally, the students use both appliances to do the assignment, surfing the internet, but instead, the students were playing games that time. The values of energy in the daytime, which can be seen from 10 AM to 3 PM, present a declining trend in the first 3 hours. The students were not at home during this time because they attended classes.

Table 4. Samples of verified power with theory data

No	Voltages (V)	Current (A)	Power (W)	Epoch unix time	Date and Time	Power from theory (W)
1	184.5816622	0.455	84.24657	1.55551E+12	4/17/2019 22:30	83.98465663
2	240.2634225	0.451764706	108.4774	1.55551E+12	4/17/2019 22:31	108.5425344
3	240.5911368	0.470571429	112.9934	1.55551E+12	4/17/2019 22:32	113.215315
4	239.7751373	0.465714286	111.4217	1.55551E+12	4/17/2019 22:33	111.6667068
5	239.8823489	0.476571429	114.4249	1.55551E+12	4/17/2019 22:34	114.3210737
6	239.9251382	0.472571429	113.252	1.55551E+12	4/17/2019 22:35	113.3817653
7	239.7211386	0.464	111.2926	1.55551E+12	4/17/2019 22:36	111.2306083
8	239.9919942	0.474666667	114.2436	1.55551E+12	4/17/2019 22:37	113.9161999
9	135.006294	0.715555541	73.65037	1.55551E+12	4/17/2019 22:38	96.6045017
10	239.0022801	0.402571429	96.03971	1.55551E+12	4/17/2019 22:39	96.21548934
11	238.8729935	0.392666667	93.608	1.55551E+12	4/17/2019 22:40	93.79746212
12	237.9035677	2.317499943	549.2728	1.55551E+12	4/17/2019 23:30	551.3415046
13	232.9137451	1.151499978	279.1467	1.55552E+12	4/17/2019 23:31	268.2001724
14	238.9109943	1.166923051	294.7037	1.55552E+12	4/17/2019 23:32	278.7907464
15	228.2861504	0.48125	109.8262	1.55552E+12	4/17/2019 23:33	109.8627099
16	228.9067455	0.41975	96.29282	1.55552E+12	4/17/2019 23:34	96.08360642
17	229.2542442	0.426410256	97.37575	1.55552E+12	4/17/2019 23:35	97.75636105
18	229.52812	0.459999994	105.6747	1.55552E+12	4/17/2019 23:36	105.5829338

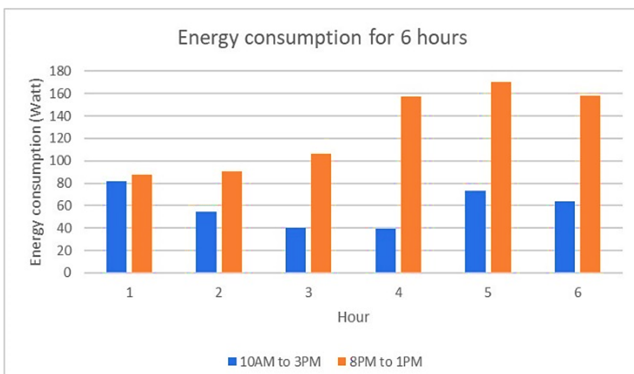

Fig. 11 Energy consumption for 6 hours of usage

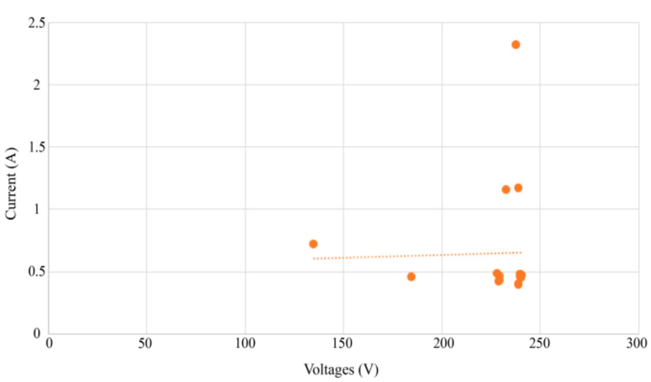

Fig. 12 Current (A) appears highly determined by Voltages (V)

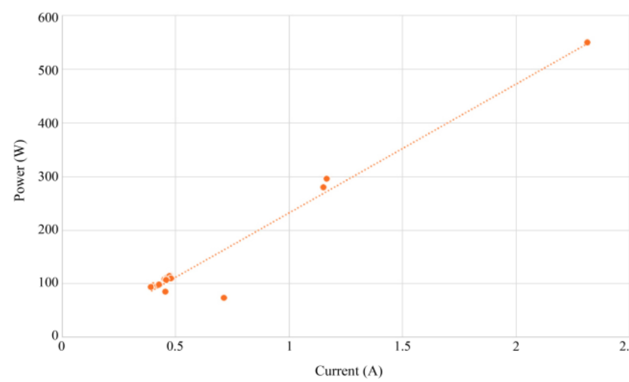

Fig. 13 Current (A) and Power (W) appear highly correlated

Thus, leaving only the PC has been turned on while the laptop has been turned off. The load produced from PC ranges from 40W to 50W. The total wattage usage is 353.1430W in the daytime while 770.3496W in the nighttime, analysed from the 421 samples taken. The energy usage for nighttime is 68% higher than in the daytime. This is because all students are at home and use laptops and PCs for surfing, doing assignments, and even playing games. Based on data collected in 2 days, the total usage is 1.123kW for 12 hours. Therefore, in a day, the student will use about 2kW for laptops and PC that are connected to the extension plug. To reduce energy usage, the maximum usage should not exceed 2kW a day for that extension.

Using this monitoring system, students can know the total amount of energy usage lively and notify the students about their energy usage through their smartphones. Finally, the students can reduce their energy usage, thus lowering the electricity bill for the next month.

Correlation refers to the degree to which two variables are related to each other in some way. Figure 12 presents an analysis of a positive correlation increase, and the other variable also increases for Current (A), which is highly determined by Voltages (V) with a reading of 0.0247. Figure 13 shows that Current (A) and Power (W) appear highly correlated to each other with a reading of 0.9791.

5. Conclusion

In conclusion, we can conclude that the objectives of this research were successful. The notification system developed by using the Blynk platform was successful. Notifications from the app allow users to know how much energy has been used in their daily lives. Besides that, users are aware of their energy usage, thus helping them to monitor their usage in their everyday life. Using the Blynk app, users can export the data from its widget to do energy analysis. The analysis shows that users were even more informed about real-life energy usage. This helps them to determine which appliances that cause a greater amount of power draw and avoid the prolonged usage of the appliances. The future recommendation has suggested using an online database system instead of manual analysis by Excel. Thus, it can minimize the workforce by the human, and all the analysis will be done by the software automatically, thus saving time on the analysis. Moreover, improving the hardware by using more expensive equipment, especially on the current sensor, is also recommended to minimize the error reading greatly. Furthermore, it is recommended to use a microcontroller with an analog sensor with the addition of Wi-Fi capability to reduce the need to troubleshoot the hardware and its software sides.

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