Journal of Industrial Automation and Electrical Engineering
Vol. 01, No. 01, June, pp. 75~81

Monitoring and Controlling Electric Energy Usage Based on the Internet of Things

Luthfi Abdul Latif[1], Hambali[1], Ricky Maulana[1], Rahmat Hidayat[1]
[1]Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang, Padang, Indonesia

Article Info

Article history:

Received April 20, 2024
Revised May 10, 2024
Accepted May 30, 2024

Keywords:

Electrical energy usage
Control and monitoring
ESP32 microcontroller
Blynk

ABSTRACT

Electrical energy is one of the basic human needs whose use continues to increase along with the increase in daily activities. Uncontrolled electricity consumption can lead to energy waste and increased costs. Therefore, a system is needed that can monitor and control the use of electrical energy effectively. In this final project, we develop an Internet of Things (IoT)-based tool that is able to monitor and control the use of household electrical energy in real-time. This system uses ESP32 microcontroller, PZEM-004T current sensor, LCD to display the sensor output, and Relay as an automatic switch to regulate the on or off of electronic devices. Blynk platform is used as an intermediary between microcontroller and smartphone or PC to facilitate remote control. With this system, users can monitor daily energy consumption and control electricity usage efficiently, thus saving energy and costs. This research is expected to contribute to a smarter and more efficient management of household electrical energy.

Corresponding Author:

Luthfi Abdul Latif
Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang
Kampus UNP Pusat, Jl. Prof. Hamka, Air Tawar, Padang 25131, Indonesia
Email: luthfialtelka3@gmail.com

1. INTRODUCTION

One of the basic needs of humans today is electrical energy. Everyone needs electricity because almost every activity carried out by humans requires electricity. Household consumers also need electricity to carry out activities, which makes electricity consumption increasingly wasteful. Therefore, a system is needed that can monitor electricity usage so that electricity usage becomes more controlled [1]. Most electricity users still use electricity meters that have a monthly or postpaid payment system [2]. The use of prepaid electricity is also uncontrolled, such as electricity tokens that are filled with many kWh, but do not last long and cause users to usually not know how much electricity they use for 1 month [3]. Electronic devices will be damaged and costs will increase if there is often an electricity overload [4]. The increasing use of household electronics also causes an increase in electricity needs [5]. To facilitate saving electricity, information about the daily use of prepaid electricity is needed so that users understand the basics of electricity current needs [6]. This is necessary because uncontrolled household electricity use can lead to high or uncontrolled electricity bills. [7].

The concept of the Internet of Things aims to increase the benefits of a continuously connected internet network. The uses it has, such as data sharing and remote control, also apply to real-world objects [8]. The Internet of Things can be used and applied to control, monitor electrical energy usage and improve home electrical safety [9]. Management of electrical energy usage is a major concern, considering the increasing energy consumption that continues to increase along with the increasing number of electronic devices. Inefficient management can lead to energy waste and high costs. Therefore, a system is needed that is able to control electrical energy usage intelligently and efficiently [10].

This Internet of Things-based electrical energy monitoring and control system functions to control the use of home electrical energy remotely in real time in order to save electricity by turning off electronic

devices remotely. This system can also be called a smart home. A smart home is a home that has equipment that can be controlled remotely via a mobile device connected to the internet [11]-[12]. This system uses an ESP32 microcontroller. The power and electrical energy usage meter uses PZEM-004T. Furthermore, the LCD is used as a place to see the sensor output value, and the Relay as an automatic switch to regulate the on or off of electronic goods. The Blynk platform is used as an intermediary for microcontrollers and smartphones or PCs as a medium for controlling the use of electrical energy remotely.

2. METHOD

In making a tool, the first thing to do is design. Tool design is a planning process before making the tool. The purpose of this design is to make it easier to make the tool. Because in the design, the right circuit selection and calculation and component selection will be carried out [13]. In principle, systematic tool design will provide ease in making the tool. The block diagram of the designed system is shown in Figure 1.

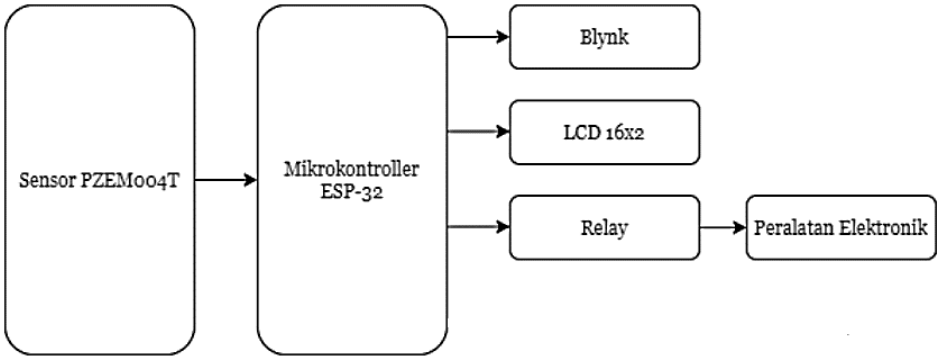

Figure 1. Diagram block of monitoring and control system electrical energy usage based on IoT

The system block diagram explains the input, process, and output of how the tool design works. The input used is the PZEM-004T sensor which functions to calculate the electrical load of electronic equipment that flows and sends data to the ESP32. The sensor on the PZEM-004T will output a value, namely Power (W) and Energy Used (kWh). The PZEM-004T sensor itself has a current transformer coil with a diameter of 3 mm which can be used to measure a maximum current of 100A [14]-[15]. After that, the ESP32 as a processor of input values from the PZEM-004T sensor uses serial communication and is used as a Relay control system via the Wifi network owned by the ESP32 so that it is connected to the internet. After that, the ESP32 sends the input value obtained from the PZEM-004T to Blynk [16]. The ESP32 is a microcontroller that has the ability to connect to the internet network independently via a WiFi hotspot signal [17].

The outputs used are Blynk, LCD, and Relay. Blynk as an Internet of Things platform uses smartphones so that homeowners can monitor home power anywhere. 16x2 LCD to display home energy and electricity being used. 16x2 LCD can display text according to program selection [18]. And relay as a control to turn on/off the electric current from Blynk, in this final project using 8 Relays as a circuit breaker on electronic equipment. Relay is a type of switch that is electrically controlled [19]. The explanation in the block diagram is Power (W) and Energy Used (kWh) which is drawn through the PZEM communication PIN to ESP32, the value will be processed on the microcontroller and sent to the Blynk application. Then, it will be displayed on the 16x2 LCD screen and the Blynk application on the smartphone. In addition, remote control on the Blynk application can be done to cut off the electric current using Relay.

Figure 2 shows the flowchart of the Blynk and ESP32 applications where the Blynk application is where the Electric Power (Watt) and Total Energy (kWh) data are displayed. The data displayed is data read by PZEM and then sent to the Blynk application. In the Blynk application, the user can press the button to disconnect / turn on the Relay. Software for monitoring and control systems using Blynk. The monitoring system uses a local Wifi internet network [20]. Making monitoring using the Blynk application can be done easily by simply utilizing the features in the Blynk application, everything related to the Internet of Things can be completed [21]. The Internet of Things is a multidisciplinary field and a dynamic universal network infrastructure [22]. To be able to use the Blynk application, users only need to download the application on the Playstore.

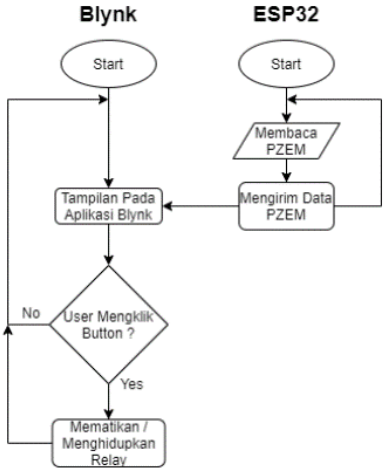

Figure 2. Flowchart of monitoring and control system electrical energy usage based on IoT

Figure 3 shows a hardware circuit that combines all the components used when assembled with each other. In the image you can see the PINs that connect the ESP32 to the Relay PIN, PZEM-400T Sensor, and I2C LCD PINs.

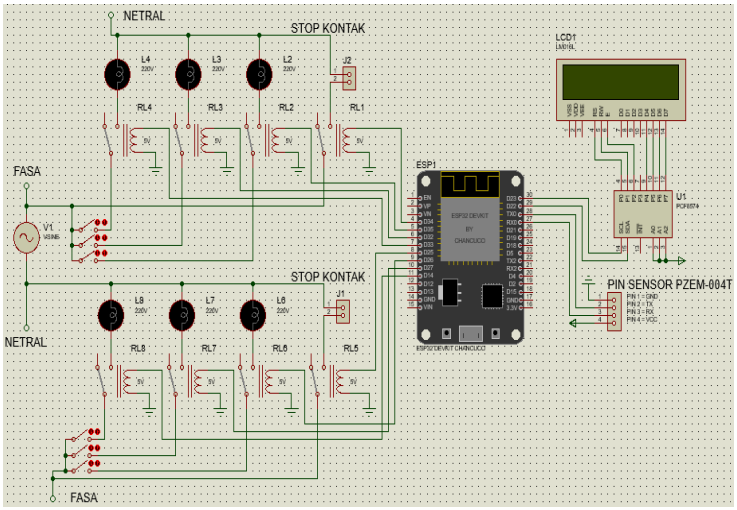

Figure 3. Circuit of monitoring and control system

This home electrical power monitoring tool is made in a rectangular shape with the components needed for monitoring on top. After designing the tool in a flat or two-dimensional (2D) shape, we will then design the shape of the tool. Figure 4 shows the shape of the tool that will be made.

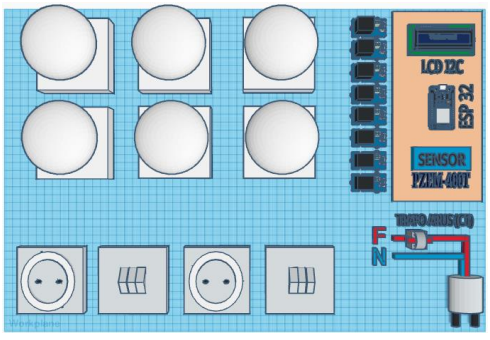

Figure 4. Hardware design of monitoring and control system electrical energy usage based on IoT

This tool uses ESP32 as a microcontroller. To be able to connect to the Blynk application, during registration there is a token that functions to connect the microcontroller and the Blynk application. Figure 5 is a layout configuration that is installed on the electricity monitoring view display. How to create this application project, users simply drag and drop components [23]-[25]. The explanation of the components in the image is that the button-shaped component functions as a switch that controls the Relay to turn on the lights and sockets remotely. Then the display of components such as a half circle or measuring instrument functions to display the measurement results from the sensor in the form of images and numbers.

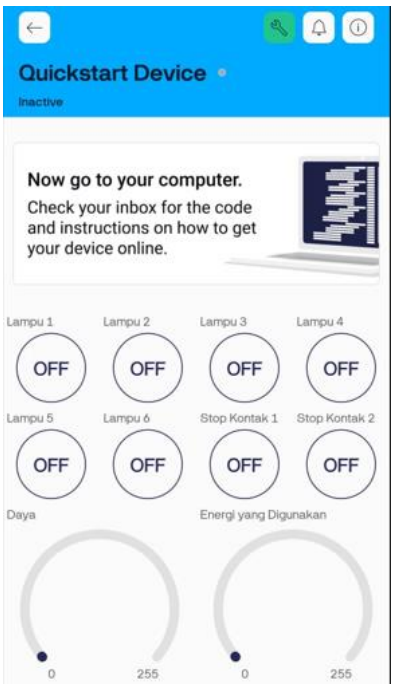

Figure 5. Software design of monitoring and control system electrical energy usage based on IoT

3. RESULTS AND DISCUSSION

The test was conducted to determine whether the system was functioning properly [25]. This test was conducted to run the overall function of the tool. Starting from ESP32, PZEM-004T sensor, Relay, LCD, and sending data from ESP32 to the blynk application on the smartphone. The mechanical form of the electrical energy monitoring and control tool can be seen in Figure 6. This design uses a 60 x 40 x 10 cm box and wiring using a 1.5 mm NYA cable on the AC circuit and using a 0.12 mm ribbon cable on the DC circuit. Below is the form of the tool box design.

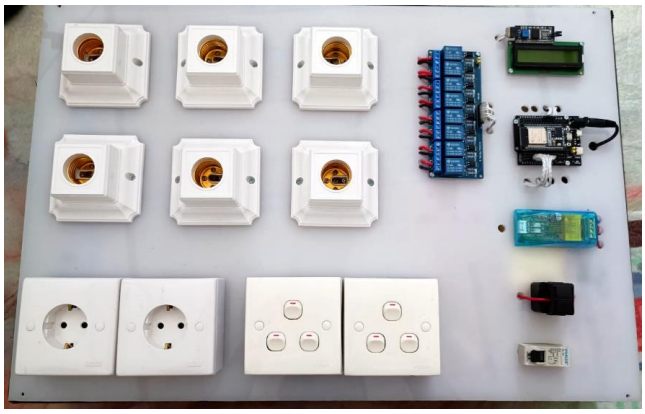

Figure 6. Results of making the tool

The program design is done using the Arduino IDE application. The program that has been created on the Arduino IDE will be uploaded to the ESP32 using a USB cable. Program testing is done to prove whether the program created is in accordance with what was planned. Testing is done on all components connected to the ESP32. The components are the PZEM-004T sensor, relay, and LCD. After the program is uploaded, the ESP32 can be directly connected to the Wifi that has been specified in the program created. With that, the ESP32 can be connected to the Blynk application on the smartphone. Program testing on the first component is done for the PZEM-004T sensor. Figure 7 shows the results of software testing on the LCD and blynk.

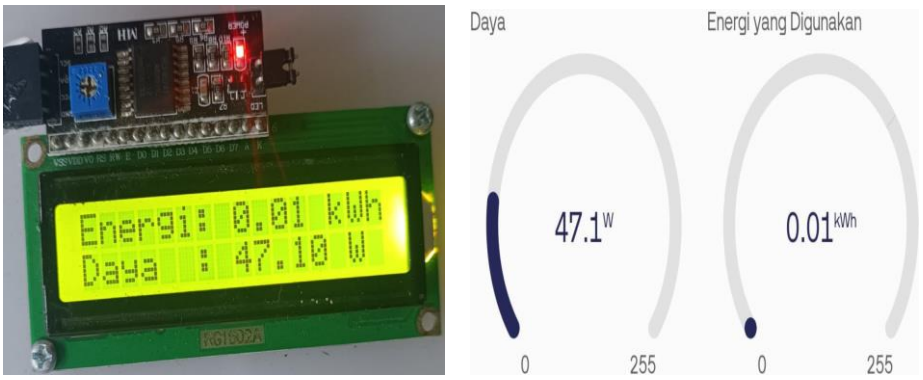

Figure 7. Software testing on the LCD and blynk

Next, the relay test is carried out. The test is carried out to adjust the relay pin on the ESP32 with the virtual pin used in the Blynk application. This test is carried out by connecting the relay to the ESP32 pin that has been specified in the program. The button used to turn the relay on and off is a virtual button created in the Blynk application. Table 1 is the result of relay testing by pressing the button on the Blynk application. In the table it can be seen that the test results are in accordance with the relay sequence with the blynk virtual button and the lights turn on according to the button pressed. So with that the relay can be turned off by the user remotely if they forget to turn it off when traveling.

Table 1. Test Results on Relay

No	Tombol Blynk	Relay								Load
		1	2	3	4	5	6	7	8	
1	Button 1	ON	-	-	-	-	-	-	-	ON
2	Button 2	-	ON	-	-	-	-	-	-	ON
3	Button 3	-	-	ON	-	-	-	-	-	ON
4	Button 4	-	-	-	ON	-	-	-	-	ON
5	Button 5	-	-	-	-	ON	-	-	-	ON
6	Button 6	-	-	-	-	-	ON	-	-	ON
7	Button 7	-	-	-	-	-	-	ON		ON
8	Button 8	-	-	-	-	-	-	-	ON	ON

Table 2. Monitoring test results

No	Time (minutes)	LCD		Blynk	
		Watt	kWh	Watt	kWh
1	1 Menit	88,30	0,00	88,30	0,001
2	5 Menit	84,80	0,01	84,80	0,007
3	10 Menit	73,90	0,01	73,90	0,014
4	15 Menit	75,9	0,02	75,9	0,02
5	20 Menit	76,40	0,03	76,40	0,026
6	25 Menit	75,5	0,03	75,5	0,033
7	30 Menit	76,00	0,04	76,00	0,04
8	35 Menit	57,50	0,04	57,50	0,045
9	40 Menit	55,20	0,05	55,20	0,05
10	45 Menit	55,00	0,05	55,00	0,055
11	50 Menit	53,40	0,06	53,40	0,059
12	55 Menit	54,30	0,06	54,30	0,064
13	60 Menit	53,90	0,07	53,90	0,069

Next, an IoT-based energy monitoring test was conducted. This test was conducted to monitor the results of energy and power measurements from the PZEM-004T sensor if used for a long time. Monitoring was carried out for 1 hour and data collection was carried out every 5 minutes. The load used in this test consisted of 6 25 Watt lamps, 1 HP charger, and 1 laptop charger. Table 2 is the test result of energy and electrical power monitoring using the PZEM-004T sensor and the energy and power measurement data is sent to the LCD and the Blynk application. In the table it can be seen that the measurement data displayed on the LCD and the Blynk application are the same. It's just that the LCD cannot display 3 digits behind the decimal point in the energy measurement results. The energy measurement data increases over time. And that means the PZEM-004T sensor can function properly.

4. CONCLUSION

The test results show that the entire device has worked well according to its purpose and works as expected, where the measurement data from the PZEM-004T sensor is processed first by the ESP32, then produces output to the LCD and the Blynk application. And the virtual button from the Blynk application can also be used to turn on and off the relay connected to the ESP32. The Internet of Things-based electrical energy monitoring and control system has the potential to help manage and optimize the use of electrical energy. With information and being able to control it in real time, users can make better decisions in energy use and reduce waste of electrical energy.

REFERENCES

[1] A. F. Ikhfa and M. Yuhendri, "Monitoring Pemakaian Energi Listrik Berbasis Internet of Things," *JTEIN J. Tek. Elektro Indones*., vol. 3, no. 1, pp. 257–266, 2022.

[2] A. Rasuli, and A. Anshory, "Pengatur Intensitas Cahaya secara Otomatis dengan Perintah Google Voice Assistant," *Jurnal Rekayasa Dan Teknologi Elektro*, vol. 17, no. 2, pp. 219– 226, 2023.

[3] A. Suryadi, and A. Nugroho, "Pemanfaatan Speed Bump sebagai Pembangkit Listrik Energi Alternatif," *Simetris J. Tek. Mesin, Elektro dan Ilmu Komput*, vol. 11, no. 1, pp. 307–312, 2020.

[4] R. Saputra, "Indonesia Energy Out Look 2019," *J. Chem. Inf. Modell*, vol. 53, nol. 9, pp. 1689–1699, 2016

[5] E. Kurt, K. Gulez, A. T. Ozdemir and A Kocatepe, "Design and Implementation of an IoT-based Energy Management System for Smart Buildings", *IEEE Access*, vol. 6, pp. 12650-12663, 2018.

[6] S. N. S. S. Siva and S. Ramakrishnan, "IoT-Based Intelligent Energy Management System for Sustainable Campus", *IEEE Internet of Things Journal*, vol. 5, no. 2, pp. 524-531, 2018.

[7] H. Kim and J. Yoon, "An IoT-Based Energy Management System for Smart Home", *Journal of Electrical Engineering and Technology*, vol. 13, no. 2, pp. 673-680, 2018.

[8] J. Kim, "IoT-Based Real-Time Energy Monitoring System for Sustainable Smart Homes", *IEEE Access*, vol. 7, pp. 38217-38227, 2019.

[9] F. Azizah and M. Yuhendri, "Solar Panel Monitoring and Control System Using Human Machine Interface," *Andalasian Int. J. Appl. Sci. Eng. Technol*., vol. 2, no. 03, pp. 149–158, 2022, doi: 10.25077/aijaset.v2i03.64.

[10] S. Wasoontarajaroen, K. Pawasan and V. Chamnanphrai, "Development of an IoT device for monitoring electrical energy consumption", *IEEE 8th Annual Information Technology Electronics and Mobile Communication Conference (IEMCON)*, pp. 725-730, 2017.

[11] B. S. Reddy and L. Umanand, "Energy Monitoring and control of distribution network using smart metering", *2018 Intl. Conf. on High Voltage Engg. and Applications*, Sept 2018.

[12] F. Ceglia, P. Esposito, A. Faraudello, E. Marrasso, P. Rossi and M. Sasso, "An energy environmental management and economic analysis of energy efficient system towards renewable energy community: The case study of multi-purpose energy community", *Journal of Cleaner Production*, vol. 369, pp. 133269, 2022.

[13] A. Chatterjee, S. Paul and B. Ganguly, "Multi-Objective Energy Management of a Smart Home in Real Time Environment", *IEEE Transactions on Industry Applications*, vol. 59, no. 1, pp. 138-147, Jan.-Feb. 2023.

[14] J. Kim, J. Byun, D. Jeong, B. Kang and S. Park, "An IoT-Based Home Energy Management System over Dynamic Home Area Networks", *International Journal of Distributed Sensor Networks*, 2015.

[15] P. Lissa, C. Deane, M. Schukat, F. Seri, M. Keane and E. Barrett, "Deep reinforcement learning for home energy management system control", *Energy and AI*, vol. 3, pp. 100043, 2021.

[16] L. Yu et al., "Deep Reinforcement Learning for Smart Home Energy Management", *IEEE Internet of Things Journal*, vol. 7, no. 4, pp. 2751-2762, April 2020.

[17] V. Marinakis and H. Doukas, "An Advanced IoT-based System for Intelligent Energy Management in Buildings", *Sensors*, vol. 18, no. 2, pp. p.610, 2018.

[18] A. Natarajan, V. Krishnasamy and M. Singh, "Occupancy detection and localization strategies for demand modulated appliance control in Internet of Things enabled home energy management system", *Renewable and Sustainable Energy Reviews*, vol. 167, pp. 112731, 2022.

[19] M. Rawte, S. Sharma and P. Lalwani, "Smart Prepaid Energy Meter based on Internet of Things", *International Journal of Computer Applications*, vol. 171, no. 2, pp. 23-26, 2017.

[20] M. Bisadi, A. Akrami, S. Teimourzadeh, F. Aminifar, M. Kargahi and M. Shahidehpour, "IoT-Enabled Humans in the Loop for Energy Management Systems: Promoting Building Occupants, Participation in Optimizing Energy Consumption", *IEEE Electrification Magazine*, vol. 6, no. 2, pp. 64-72, 2018.

[21] M.H Elkholy, T. Senjyu, M.E Lotfy, A. Elgarhy, N.S. Ali and T.S. Gaafar, "Design and implementation of a real-time smart home management system considering energy saving", *Sustainability*, vol. 14, no. 21, pp. 1-22, October 2022.

[22] Y. Liu, B. Qiu, X. Fan, H. Zhu and B. Han, "Review of smart home energy management systems", *Energy Procedia*, vol. 104, pp.

504-508, December 2016.
[23] A.R. AI-Ali, I.A. Zualkeman, M. Rashid, R. Gupta and M.A AliKarar, "A smart home energy management system using IoT and big data analytics approach", *IEEE Transactions on Consumer Electronics*, vol. 63, no. 4, pp. 426-434, November 2017.
[24] B. Zhou, W. Li, K.W Chan, Y. Cao, Y. Kuang, X. Liu, et al., "Smart home energy management systems: Concept configurations and scheduling strategies", *Renewable and Sustainable Energy Reviews*, vol. 61, pp. 30-40, August 2016.
[25] H. Kim, H. Choi, H. Kang, J. An, S. Yeom and T. Hong, "A systematic review of the smart energy conservation system: From smart homes to sustainable smart cities", *Renewable and sustainable energy reviews*, vol. 140, pp. 110755, April 2021.