Home electrical power control and monitoring system based on the Internet of Things (IoT)

Handre Adiya[1], Dwiprima Elvanny Myori[1]
[1]Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang, Padang, Indonesia

Article Info

Article history:

Received July 14, 2025
Revised August 15, 2025
Accepted October 22, 2025

Keywords:

Use of electrical energy
Control and monitoring
Internet of Things
Blynk

ABSTRACT

The increasing demand for electrical energy in Indonesia is often not balanced with efficiency of use, especially in the household sector. Energy waste due to lack of real-time monitoring and control of electricity consumption is a serious problem. To address this problem, an Internet of Things (IoT)-based home electrical power control and monitoring system has been designed and built. This research aims to develop a prototype system that is able to monitor and control the use of electrical power remotely through applications on smartphones. The system uses an ESP32 microcontroller as the main processing unit, a PZEM-004T sensor to measure electrical parameters such as voltage (Volts), current (Ampere), power (Watts), and energy (kWh), and a relay module to control the flow of electricity to electronic devices. The measurement data is displayed in real-time on the TFT touchscreen LCD screen and the Blynk app on the smartphone, which also serves as a control interface. With the implementation of this system, it is hoped that it can increase public awareness of the more efficient use of electrical energy and provide solutions in saving electrical energy.

Corresponding Author:

Dwiprima Elvanny Myori
Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang
Kampus UNP Pusat, Jl. Prof. Hamka, Air Tawar, Padang 25131, Indonesia
Email: elvannymyori@gmail.com

1. INTRODUCTION

Electrical energy is one of the main human needs that plays a vital role in supporting various sectors of life. As the population increases, the need for electrical energy also increases significantly. However, the inefficient use of electrical energy is still a serious problem. In the household sector, energy-wasting behaviors such as leaving electronic equipment on when not in use and lack of awareness of the impact of waste are still common. One solution to save power is to monitor electricity consumption every day so that consumers can set limits and estimate electricity consumption [1]-[3].

Manual measurement of electrical power parameters using simple instruments such as a multimeter is considered inefficient because data cannot be obtained at all times and takes a long time. The development of Internet of Things (IoT) technology offers real-time power consumption monitoring and control solutions. Several previous studies have developed similar systems, such as IoT-based and Android-based monitoring and power consumption control systems [4]-[6]. Other studies have also utilized the Blynk platform and PZEM-004T sensors for electrical power monitoring [7], as well as using Firebase as a database [8]-[10]. Nonetheless, there is still room to improve accuracy, ease of use, and integration with local interfaces.

Therefore, this study aims to design an IoT-based electrical power control and monitoring system that can be accessed in real-time through applications on smartphones. The system uses an ESP32 microcontroller and a PZEM-004T sensor to monitor voltage, current, and power. The data is displayed via the Blynk app for remote monitoring and an LCD touchscreen for manual control. With this system, users can monitor energy consumption and control electronic devices remotely, thus hopefully improving the efficiency of electricity use in households [11]-[15].

2. METHOD

Explaining A block diagrams are used to illustrate the relationships between parts in a system. Block diagrams allow users to understand how the entire system works. Its main function is as a guide in arranging and connecting components in an electronic circuit.

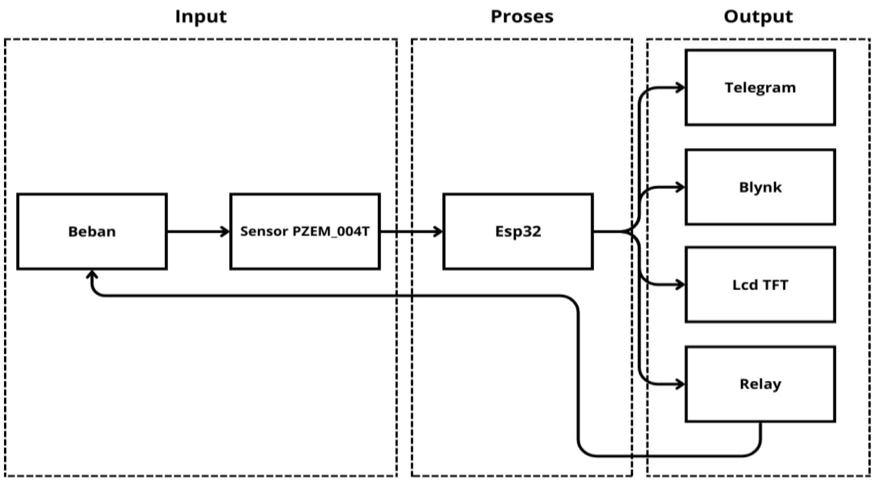

Figure 1. Block Diagram

A block diagram consists of three main parts: 1) Input Block – The PZEM-004T sensor functions as the main input that calculates the electrical load of electronic equipment and sends data in the form of Voltage (V), Power (W), Current (I), and Energy (kWh) to the ESP32. 2) Processing Block – The ESP32 microcontroller acts as the central processing unit, processing data from sensors and sending it to the output platform. The ESP32 also controls the relay module based on user commands over a Wi-Fi network. 3) Blok Output – The processed data is displayed on the Blynk app for remote monitoring, a TFT LCD for local monitoring, and Telegram for data log storage. The relay module serves as a control output to disconnect or connect the power supply to the load.

A circuit schema is a graphical representation that describes the relationships between components in a system. The circuit scheme ensures that each component is connected to each other so that the system can work according to its respective functions. In the depiction of a series scheme, each component can be depicted according to its own shape or represented by symbols. Figure 2 shows the Circuit schema of proposed system.

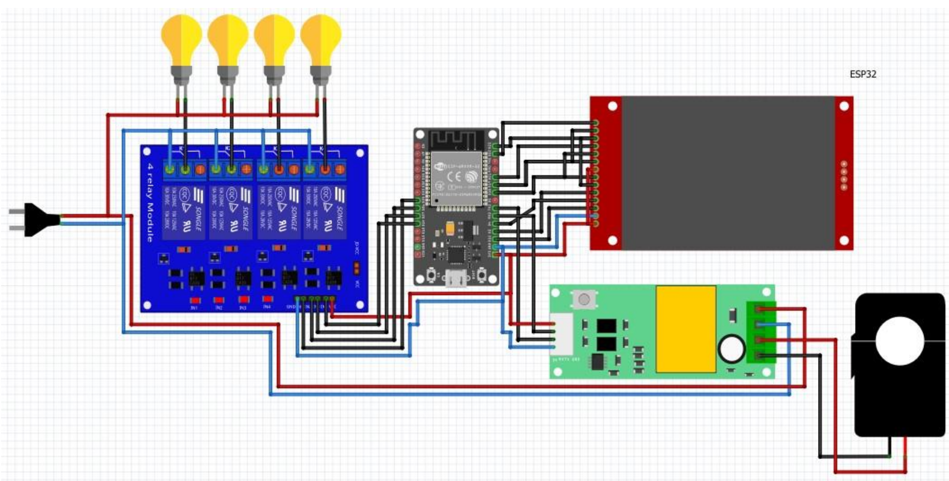

Figure 2. Circuit Schema

Flowcharts illustrate the logic and sequence of the system's work. The process begins with the initialization of the program on the ESP32. The PZEM-004T sensor continuously reads voltage data and other electrical parameters. The successfully read data is then processed by the ESP32 and transmitted in parallel to the TFT LCD display and *the Blynk* app. The user can provide commands via *Blynk* or touch screen to enable or disable the *load-connected* relay. Figure 3 shows the flowchart of sistem.

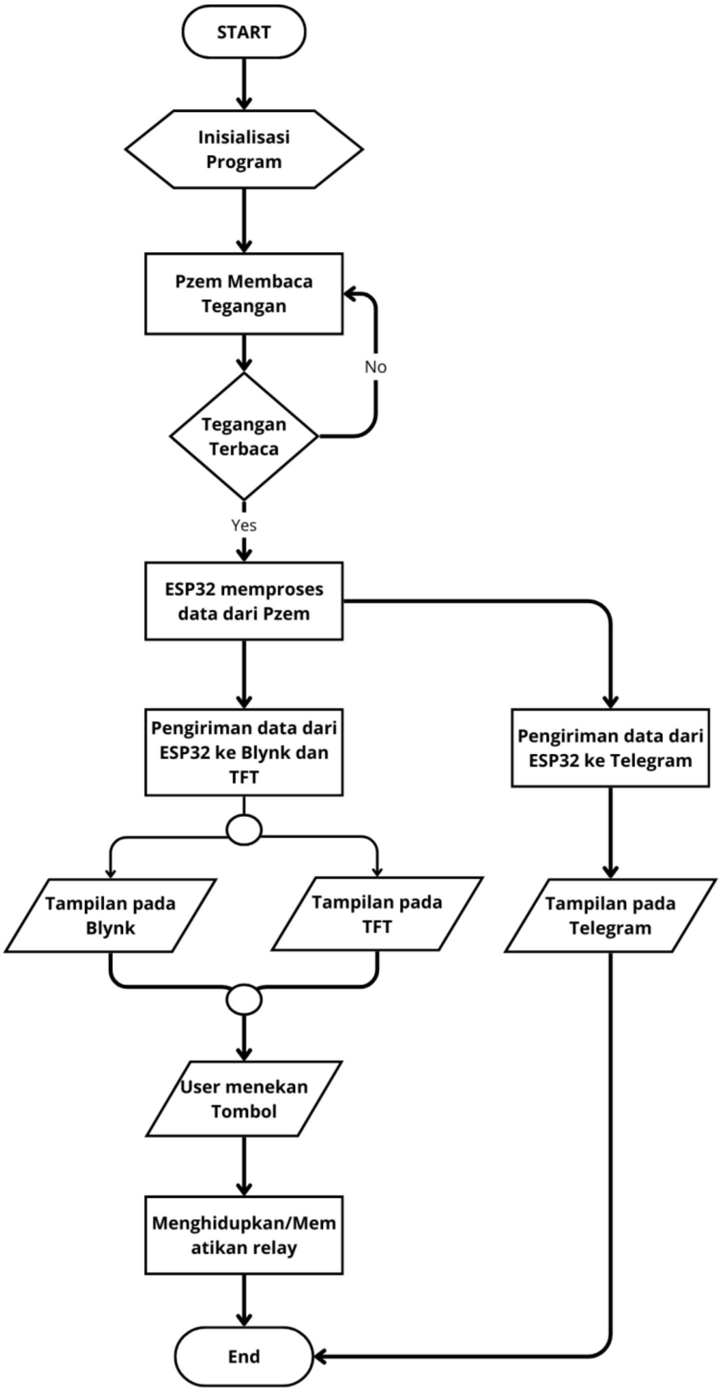

Figure 3. Flowchart

Hardware design is the process of designing, planning and developing the physical form of a system, including architectural design, component selection and technical specifications of the device to be made. The performance of the ESP32 as the main controller is vital in IoT applications for power monitoring [7]. The prototype tool for the electric power control and monitoring system in Figure 4 was designed using the SketchUp application with a scale of 1:10.

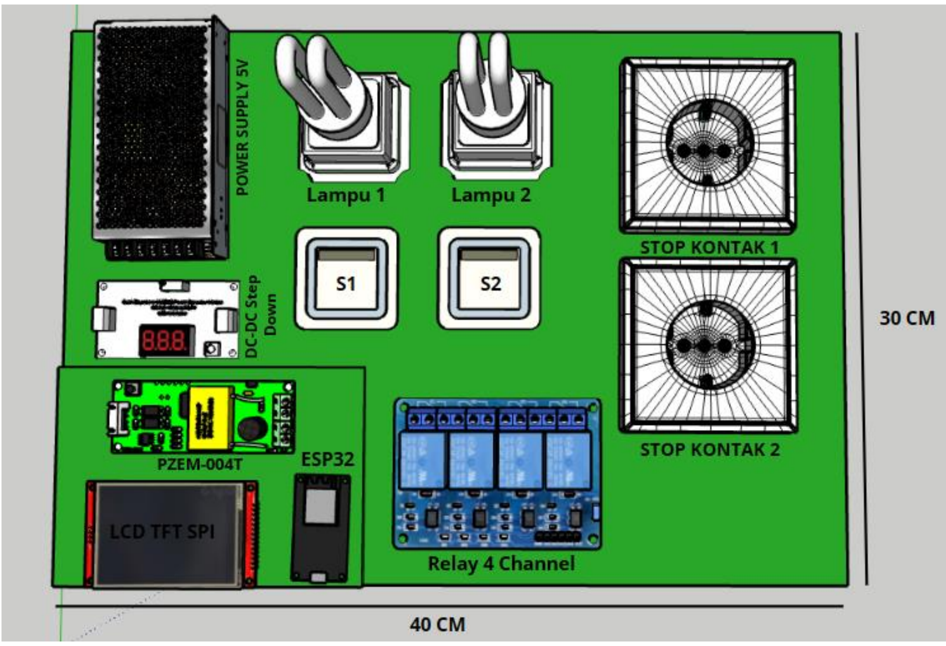

Figure 4. Hardware Design

Software design is a process that involves planning a software system that creates a framework to meet the needs of users. The design of the Internet of *Things-based home electrical power control and monitoring device* uses ESP32 as the controller, with Arduino IDE as the programming platform. The working principle of this tool is as follows: 1) Measurement of electrical parameters using the PZEM-004T sensor. The measurement data from these sensors will be processed by ESP32 to obtain the values of voltage, current, power, energy, frequency, and power factors. 2) After processing and obtaining the electrical parameter value, the ESP32 will send the data via a Wi-Fi connection or IoT network to be displayed on the TFT or *blynk* platform. 3) The electrical parameter data transmitted by the ESP32 will be displayed on the TFT and blynk platform with a Wi-Fi connection. The data to be displayed is voltage, current, power, energy, frequency, and power factor. The data display makes it easier to monitor electrical power in *real-time*. 4) There are 4 buttons that can control the on/off load on 4 relays. Users can control the Relay on the TFT as a remote control and *the blynk* app as a remote control

(a) (b)

Figure 5. Software Design (a) Data display on blynk (b) Program view on arduino

3. RESULTS AND DISCUSSION

In Testing is done to find out if the system can run properly. The tests carried out were ESP32, PZEM-004T, Relay, TFT LCD, and data transmission from ESP32 to the Blynk application. The mechanical form of the electrical energy monitoring and control tool can be seen in Figure 6. This design uses a 40 x 30 cm board 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. Result of making tool

The program was designed in the Arduino IDE and then uploaded to the ESP32 via USB. Functionality testing was performed on all installed components the PZEM-004T sensor, relay, and LCD. After the program was uploaded, the ESP32 immediately connected to a pre-configured WiFi network to connect it to the Blynk app. Figure 7 shows how the PZEM-004T sensor readings are displayed on the LCD and in the Blynk app as part of the software testing.

Figure 7. Software testing on LCD and blynk

The next step is testing the relay. This testing is done by matching the relay's communication pins to the virtual pins in the blynk application. The relay's communication pins are then connected to the ESP32's communication pins based on the program created. Tabel 1 is the result relay testing by pressing button on blynk application.

Tabel 1. Test Result on Relay

No	Blynk button	1	2	3	4	Load
1	Button 1	ON				ON
2	Buttonl 2		ON			ON
3	Button 3			ON		ON
4	Button 4				ON	ON

The next step is testing the accuracy of the PZEM-004T sensor. This test aims to determine how accurately the monitoring system can monitor electricity. The test is conducted by calculating the system's error rate during measurements. The sensor was tested with 10 different load types and the results were compared to the Zoyi ZT102A Multimeter. The results showed an average voltage measurement error of 1% and current of 5%. This *error rate* is considered acceptable for household-scale monitoring applications, which confirms that the PZEM-004T sensor is quite reliable. Tabel 2 is the result sensor testing.

Tabel 2. Result Sensor Measurement

NO	Load	Voltage			Current			Watt
		Multi meter	PZEM-004T	Error %	Multi meter	PZEM-004T	Error %	PZEM-004T
1	Tanpa beban	223,1	221,1	0,9	0	0	0	0,4
2	Kipas Angin	224,1	221,4	1,2	0,18	0,19	5	30,9
3	Lampu	224	222.2	0,8	0,02	0,03	5	2,5
4	Laptop	223	220,3	1,2	0,36	0,37	5	43,6
5	Setrika	224,3	222,5	0,8	1,56	1,57	5	345,8
6	Solder	223	220,2	1,2	0,11	0,12	5	27,9
7	Rice cooker	223,4	220,5	1,3	1,19	1,2	5	197,4
8	Smartphone	224,5	222,3	1	0,08	0,09	5	10,8
9	Speaker	223,1	221,5	0,7	0,14	0,15	5	0,14
10	Pompa Air	224	222,1	0,8	1,19	1,2	5	197,4

Tabel 3. Monitoring test results

No	Time(Minutet)	LCD TFT		Blynk	
		Watt	kWh	Watt	kWh
1	1 Minute	56,7	0	56,7	0,001
2	5 Minute	59,5	0,01	59,5	0,007
3	10 Minute	56,9	0,01	56,9	0,014
4	15 Minute	57,2	0,02	57,2	0,02
5	20 Minute	57,1	0,03	57,1	0,026
6	25 Minute	56,4	0,03	56,4	0,033
7	30 Minute	58,3	0,04	58,3	0,041
8	35 Minute	58,2	0,05	58,2	0,046
9	40 Minute	57,5	0,05	57,5	0,052
10	45 Minute	60,2	0,06	60,2	0,058
11	50 Minute	58,7	0,06	58,7	0,063
12	55 Minute	58,2	0,07	58,2	0,07
13	60 Minute	57,6	0,07	57,6	0,074

Next is tested the IoT monitoring system. This test was conducted to monitor the energy and power measurements read by the PZEM-004T sensor. Thorough system testing was performed for 1 hour with combined loads (30W soldering and 35W fan) to validate data stability and consistency. Tabel 3 is the result of energy and electrical power monitoring using PZEM-004T sensor, and the energy and power measurement data send to blynk application and LCD. During the test, the system ran steadily and the power (Watt) data displayed on the TFT LCD was consistently the same as that displayed in the *Blynk* app. This guarantees data integrity for users. After 60 minutes, the energy reading on *the Blynk* was 0.074 kWh, while on the LCD it was 0.07 kWh. These results are close to theoretical calculations (0.065 kWh), which prove the reliability of the system for real-world use. The difference in precision between *Blynk* and LCD is not an *error*, but rather a reflection of the function of each interface

4. CONCLUSION

Based on design and testing, this research has succeeded in realizing a prototype of a functional and reliable "Internet of Things Based on Home Electrical Power Control and Monitoring System". The system effectively integrates the ESP32 microcontroller, PZEM-004T sensor, relay module, and TFT Touchscreen LCD. The system's performance is proven to be accurate, with an average error of 1% for voltage measurements and 5% for current when compared to standard measuring instruments. The monitoring and remote control functionality through the Blynk platform runs well, allowing users to monitor electrical parameters in real-time and control the load from anywhere. The main value of this system is its ability to convert measurement data into actionable information, such as electricity cost estimates, so that it can empower users to identify waste and encourage energy-saving behaviors.For further development, it is recommended to create a custom Android-based application, use alternative platforms such as Thingspeak or Firebase, and add a Sim800L module to expand the network coverage.

REFERENCES

[1] J. P. Juaneza, “The development of a disruption responsive smart room technology with attendance management system,” *Int. Res. J. Sci. Technol. Educ. Manag.*, vol. 3, no. 1, May 2023, doi: 10.5281/zenodo.7777235.
[2] A. Q. Burhan and S. Islami, “Implementation of the Internet of Things using Blynk platform for smart home,” *Journal of*

Industrial Automation and Electrical Engineering., vol. 01, no. 02, pp. 114–119, 2024.
[3] I. A. Zualkernan, A. R. Al-ali, M. A. Jabbar, I. Zabalawi and A. Wasfy, "InfoPods: Zigbee-based remote information monitoring devices for smart-homes," in *IEEE Transactions on Consumer Electronics*, vol. 55, no. 3, pp. 1221-1226, August 2009, doi: 10.1109/TCE.2009.5277979.
[4] L. A. Latif, R. Maulana, and R. Hidayat, "Monitoring and Controlling Electric Energy Usage Based on the Internet of Things," *Journal of Industrial Automation and Electrical Engineering.*, vol. 01, no. 01, pp. 75–81, 2024.
[5] L. M. Silalahi, M. Rafi Indrawan, S. Budiyanto, D. Hanafi, A. Hamid and D. Ronaldo, "Smart Home Control System Design using Internet of Things Based Energy Harvesting Technology," *2024 IEEE 6th Symposium on Computers & Informatics (ISCI)*, Kuala Lumpur, Malaysia, 2024, pp. 43-48, doi: 10.1109/ISCI62787.2024.10667797.
[6] 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.
[7] P. Khanpara, K. Lavingia, R. Trivedi, S. Tanwar, A. Verma, and R. Sharma, "A context-aware internet of things-driven security scheme for smart homes," *Secur. Priv.*, vol. 6, no. 1, p. e269, 2023, doi: https://doi.org/10.1002/spy2.269.
[8] C. K. Rao, S. K. Sahoo, and F. F. Yanine, "A literature review on an IoT-based intelligent smart energy management systems for PV power generation," *Hybrid Adv.*, vol. 5, p. 100136, 2024, doi: https://doi.org/10.1016/j.hybadv.2023.100136..
[9] D. I. Cendana, N. V. Bustillo, T. D. Palaoag, M. A. Marcial and A. E. Perreras, "Harnessing Energy Consumption in a Smarthome IoT Framework," *2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData)*, Halifax, NS, Canada, 2018, pp. 88-96, doi: 10.1109/Cybermatics_2018.2018.00048.
[10] B. Andika and O. Candra, "Smart Room Control and Monitoring System Based on Internet of Things," *Journal of Industrial Automation and Electrical Engineering.*, vol. 01, no. 01, pp. 60–67, 2024.
[11] S. Fatima, N. A. Aslam, I. Tariq, and N. Ali, "Home Security and Automation Based on Internet of Things: A Comprehensive Review," {IOP} Conf. Ser. Mater. Sci. Eng., vol. 899, no. 1, p. 12011, Jul. 2020, doi: 10.1088/1757-899x/899/1/012011.
[12] A. Yang, C. Zhang, Y. Chen, Y. Zhuansun, and H. Liu, "Security and Privacy of Smart Home Systems Based on the Internet of Things and Stereo Matching Algorithms," *IEEE Internet Things J.*, vol. 7, no. 4, pp. 2521–2530, Apr. 2020, doi: 10.1109/JIOT.2019.2946214.
[13] A. Yudidharma, N. Nathaniel, T. N. Gimli, S. Achmad, and A. Kurniawan, "A systematic literature review: Messaging protocols and electronic platforms used in the internet of things for the purpose of building smart homes," Procedia Comput. Sci., vol. 216, pp. 194–203, 2023, doi: https://doi.org/10.1016/j.procs.2022.12.127.
[14] M. Albany, E. Alsahafi, I. Alruwili, and S. Elkhediri, "A review: Secure Internet of thing System for Smart Houses," Procedia Comput. Sci., vol. 201, pp. 437–444, 2022, doi: https://doi.org/10.1016/j.procs.2022.03.057.
[15] S. Budiyanto et al, "Design of control and monitoring tools for electricity use loads, and home security systems with internet of things system based on Arduino Mega 2560," {IOP} Conf. Ser. Mater. Sci. Eng., vol. 909, no. 1, p. 12020, Dec. 2020, doi: 10.1088/1757-899x/909/1/012020.