

IoT-Based Electrical Power Consumption Monitoring System in Households Using ESP32 and PZEM-004T

Kemas Muhammad Wahyu Hidayat^{1*}, Muhammad Khozi Al-Faris²

^{1,2}Universitas Muhammadiyah Palembang, Sumatra Selatan, Indonesia

^{1*}kemaswahyuh@gmail.com, ²ghozialfaris28@gmail.com



*Corresponding Author

Article History:

Submitted: 05-07-2025

Accepted: 11-07-2025

Published: 01-12-2025

Keywords:

PZEM-004T; ESP32; IoT; Households.

Brilliance: Research of Artificial Intelligence is licensed under a Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0).

ABSTRACT

Electricity consumption in the household sector is often poorly controlled, leading to energy waste and increased electricity bills. To address this issue, this study presents the design and implementation of an electricity consumption monitoring system based on the Internet of Things (IoT) using the ESP32 microcontroller and PZEM-004T sensor. The system allows real-time monitoring of electrical parameters such as voltage, current, power, and energy, with data displayed on digital devices like smartphones or computers. Measurement data from the sensor is transmitted wirelessly to an IoT platform via Wi-Fi, enabling users to monitor electricity usage anytime and anywhere. A prototype method was used in this research, covering hardware and software design, sensor integration, and system testing. The testing results show that the system effectively provides accurate and responsive electricity usage data. With this system, users can identify usage patterns, detect high-power appliances, and make informed decisions to improve energy efficiency. The ability to access real-time data helps prevent energy waste and control monthly costs more effectively. Beyond individual benefits, this system also supports wider energy conservation initiatives by promoting conscious energy consumption behavior. The integration of IoT technology in household energy management demonstrates a practical solution for creating smarter and more sustainable living environments. This study confirms the potential of IoT-based systems to enhance energy awareness and support efforts in reducing overall electricity consumption.

INTRODUCTION

The development of an electricity consumption monitoring system based on the Internet of Things (IoT) aims to provide a solution for more efficient and sustainable household energy management. (Maulida, Indrianto, and Rochmawati, n.d.) This system allows users to monitor electricity usage in real-time, identify daily consumption patterns, and take concrete steps to improve energy efficiency. By using the ESP32 microcontroller and PZEM-004T sensor, the system accurately measures essential electrical parameters such as voltage, current, power, and energy. The collected data is then transmitted to an IoT platform via a Wi-Fi connection, enabling users to access the information from smartphones or computers anytime and anywhere with ease. One of the key features of this system is its ability to send notifications or alerts when electricity usage exceeds a predetermined threshold. This empowers users to take immediate actions, such as turning off high-power appliances or reducing load, to prevent unnecessary energy waste. (Handarly et al., 2022) As a result, the system not only contributes to lower monthly electricity bills but also plays a significant role in encouraging more responsible energy usage behavior. Beyond the direct benefits for individual users, this system also supports broader efforts in environmental sustainability and carbon emission reduction. In an era of increasing concern about climate change and global energy consumption, the adoption of such technology can make a meaningful difference. The system can also function as an educational tool, raising awareness and promoting energy-saving habits within households. (Firmansyah et al., 2022)

This research represents not only a technological innovation but also a practical contribution to promoting a culture of sustainability. With further development and integration into smart home ecosystems, this IoT-based monitoring system holds great potential to become an essential component in future smart home and smart city infrastructures, supporting a greener and more energy-conscious society. (Haafizhah, Anifah, and Zuhrie, n.d.)

LITERATURE REVIEW

The rapid growth of technology, particularly in the field of the Internet of Things (IoT), has led to the emergence of innovative solutions for household energy management. (Zaini and Bachrudin, n.d.) IoT technology enables devices to connect and communicate over the internet, allowing for real-time data monitoring, analysis, and control. This advancement has significantly impacted various sectors, including the energy sector, by enabling more efficient energy usage through intelligent monitoring systems. In the context of electricity consumption, many households still struggle



This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

with uncontrolled or inefficient use of electrical energy, often due to a lack of awareness or the absence of real-time information. (Sukadana, Prayoga, and Suriana, 2021) Conventional electricity meters typically only display total usage, without offering insight into daily or hourly consumption patterns. (Aryudha Yuntardi, Ismianto, Andayani No, n.d.) As a result, users are often unaware of how and when electricity is consumed the most, making it difficult to implement energy-saving practices effectively. To address these issues, the integration of microcontrollers such as the ESP32, along with sensors like the PZEM-004T, provides a practical and cost-effective solution. These components allow for accurate measurement of key electrical parameters, including voltage, current, power, and energy. (Dwi Alfian and Teknik Elektro, n.d.) When combined with wireless communication and user-friendly interfaces, such systems enable users to track their electricity usage anytime via mobile devices or computers. The ability to set consumption limits and receive alerts when usage exceeds the threshold adds a preventive function, helping users take immediate action to reduce energy waste. (George Asso and Dept, n.d.) Additionally, these systems promote behavioral change by increasing user awareness, which is essential for long-term energy conservation. Overall, the development of IoT-based electricity monitoring systems reflects a shift toward smarter, more sustainable living, aligning with the broader goals of energy efficiency and environmental preservation. (Riyadi Hartono, Haddin, Arief Marwanto, 2023)

METHOD

The method in this research refers to the systematic steps taken to design, develop, and test an Internet of Things (IoT) based electricity consumption monitoring system. (Isnianto and Puspitaningrum, n.d.) This method includes various aspects, starting from the selection of appropriate hardware components, such as the ESP32 microcontroller and PZEM-004T sensor for measuring current, voltage, power, and electrical energy, to the development of software for processing and sending data to the IoT platform in real-time (Lianda, Handarly, and Adam, 2021).

System development methods

This study refers to a prototype model with stages as shown in Figure 1. This research begins with a communication process to determine goals and quick planning to identify the needs and modelling designed (Yuniarto et al., 2023). The next stage is the construction of prototype which involves hardware assembly and programming. After the hardware and programs are completed, the next stage is to present for evaluation (deployment delivery and feedback) by potential users to get input regarding what is created and for further development. (Kajian and Elektro, 2022)

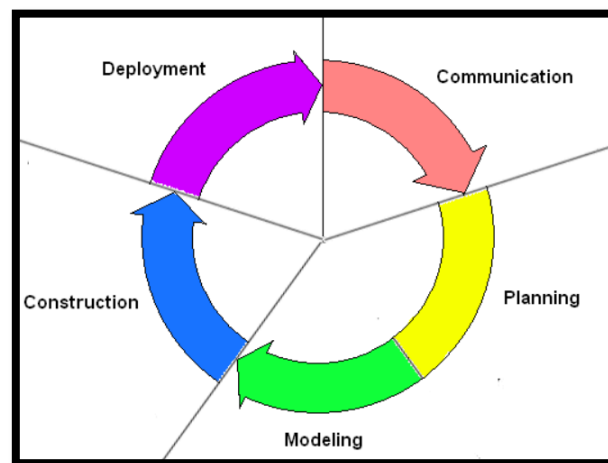


Figure 1. System development methods

Prototype method of IoT-based electricity consumption monitoring system:

1. Communication
Identifying user and stakeholder needs systematically to ensure the system meets its intended purpose.
2. Planning
Defining system requirements, selecting the PZEM-004T sensor and ESP32 microcontroller, and preparing technical specifications and budget for an efficient design.
3. Modeling
Designing the system using flowcharts and IoT architecture, ensuring accuracy and real-time notification features align with system goals.
4. Construction
Assembling hardware components (ESP32 and PZEM-004T) and programming them to read sensor data and transmit it to the Blynk IoT application.

5. Deployment

Installing the system at the designated location and conducting testing to evaluate sensor accuracy and performance under various electrical loads.

System Workflow Flowchart

The system work flowchart or flow diagram is used as an illustration of the process of how the system operates. The process is depicted through charts or symbols so that the information presented is easier to understand. (Supriyadi, Siti, Prodi, and Elektro, n.d.)

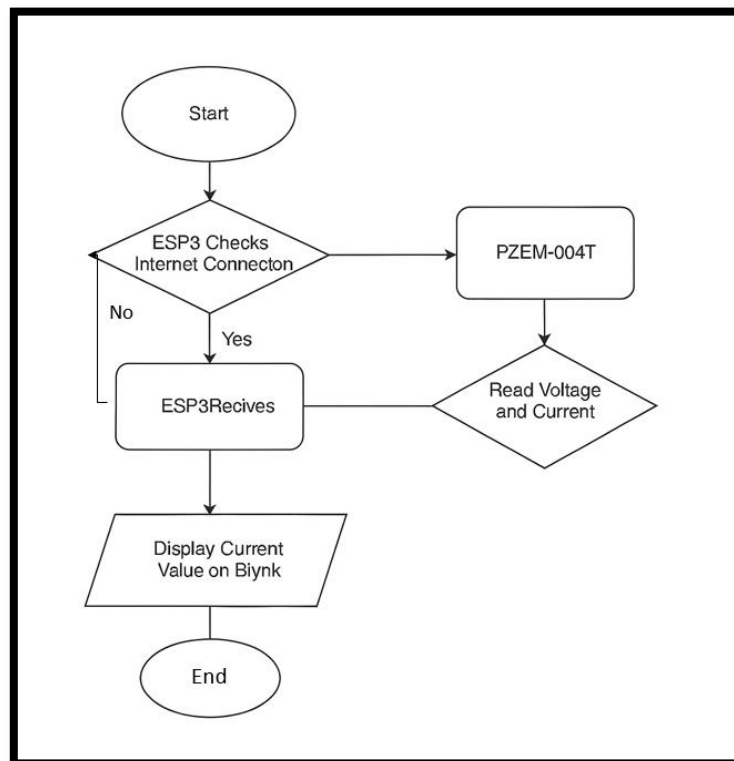


Figure 2 . System Workflow Flowchart

Steps of the IoT-Based Power Consumption Monitoring System

1. Electrical Parameter Measurement
The PZEM-004T sensor is used to measure parameters such as voltage, current, power, and energy consumption.
2. Data Transmission to Microcontroller
The measured data is sent to the ESP32 microcontroller for further processing.
3. Data Processing and Transmission
Once processed, the data is transmitted via Wi-Fi from the ESP32 to an IoT platform (such as Blynk or Thingspeak).
4. Data Visualization
The received data is displayed in a user interface that allows real-time monitoring through devices like smartphones.
5. Historical Data Monitoring and Analysis
The system supports historical data logging, enabling users to monitor and analyze electricity consumption patterns over a period of time.

RESULT

After all parts are assembled correctly and the program has been downloaded to the ESP32, the next step is to test the device that has been made, to see if it functions or not. Testing the circuit that has been completed and testing to send the sensor reading results to the LCD first, as shown in the picture below:



Figure 3 . Testing of kWh monitoring tools

House test 1

Table 1. Measurement results of house 1

Time	kWh House 1
2025-01-05 23:00 up to 2025-31-05 23:00	160.09

Based on the measurement results using the PZEM-004 sensor that has been connected to the monitoring system, it was recorded that the total electricity consumption over one month reached 160.09 kWh. This measurement was conducted on an electrical installation with a meter capacity of 1300 VA (1.3 kVA), which is generally used for household needs.

House test 2

Table 2. Measurement results of house 2

Time	kWh House 2
2025-01-05 23:00 up to 2025-31-05 23:00	201.84

House 2 uses an electricity power of 1300 VA, which falls into the category of non-subsidized household according to PLN regulations. During the monitoring period of a full month, the total electricity energy consumption in House 2 reached 201.84 kWh. This figure reflects the accumulation of usage from various household activities, including the use of electronic devices such as lighting, kitchen appliances, air conditioning, and other household devices.

DISCUSSION

The purpose of comparing house 1 and house 2 is to provide a clear picture of how much electricity each house consumes and how that consumption can be calculated in terms of rupiah. With this comparison, we can assess the efficiency of electricity usage in each house and understand the energy consumption patterns based on habits and the number of electronic devices used.

House 1 and House 2 each use an electrical power of 1300 VA, which falls under the R1 1300 VA non-subsidized tariff category according to PLN regulations. Based on the current electricity tariff of Rp 1,444.70 per kWh, an estimation of the monthly electricity costs is calculated based on the electricity consumption of each house.

1. House 1 recorded a total electricity consumption of 160.09 kWh in one month. With a rate of Rp 1,444.70/kWh, the estimate of its electricity cost is: $160,09 \text{ kWh} \times \text{Rp } 1,444,70 = \text{Rp } 231,274$
2. House 2 recorded an electricity consumption of 201.84 kWh during the same period. With the same tariff, the calculation is: $201.84 \text{ kWh} \times \text{Rp } 1,444.70 = \text{Rp } 291,615$

CONCLUSION

Based on the monitoring results of electricity consumption over one month, it can be concluded that both House 1 and House 2, which use an electrical capacity of 1300 VA and fall under the non-subsidized household category, show relatively high and balanced electricity usage. House 1 recorded a total consumption of 203.76 kWh with an estimated cost of IDR 294,365, while House 2 recorded 201.84 kWh with an estimated cost of IDR 291,615. This similarity indicates nearly identical usage patterns, serving as a reference for evaluating energy efficiency and optimizing future consumption. The variation in usage underscores the importance of household energy management awareness. Lower-consuming households likely implement energy-saving measures such as turning off unused electronics, using energy-efficient lighting, and limiting high-power appliances, whereas higher-consuming households may operate more devices



for longer periods or lack consistent energy-saving habits.

REFERENCES

- Aryudha Yuntardi, D., Ismianto, H., Studi, P. D., Listrik Bandara, T., and Penerbangan Surabaya Jl Jemur Andayani No, P. I. (n.d.). *PROTOTYPE KONTROL DAN MONITORING REFERIGRANT PADA OUTDOOR AC (AIR CONDITIONING) SPLIT BERBASIS ARDUINO VIA BLYNK*.
- Dwi Alfian, R., and Teknik Elektro, D. (n.d.). "Rancang bangun alat monitoring pemakaian tarif listrik dan kontrol daya listrik pada rumah kos berbasis internet of things" *RANCANG BANGUN ALAT MONITORING PEMAKAIAN TARIF LISTRIK DAN KONTROL DAYA LISTRIK PADA RUMAH KOS BERBASIS INTERNET OF THINGS*
- Firmansyah, V., Nadhira, V., Silvi, L., Apnita Dewi, T., Daeng Muhammad Ardiwinata km, J., and Teknik Fisika, P. (2022). IOT SISTEM MONITORING METER KWH DIGITAL MENGGUNAKAN SENSOR LDR DAN CODEIGNITER API SERVICE. In *Jurnal Material dan Energi Indonesia* (Vol. 09).
- George Asso, S., and Dept, C. (n.d.). *IoT Based Smart Energy Management System using Pzem-004t Sensor & Node MCU*. Retrieved from <https://www.amazon.in/Easy-Electronics-16x2->
- Haafizhah, F. N., Anifah, L., and Zuhrie, S. (n.d.). *Rancang Bangun Sistem Perhitungan Pemakaian Daya Pada Apartemen Secara Real-Time Berbasis Arduino 314 Rancang Bangun Sistem Perhitungan Pemakaian Daya Pada Apartemen Secara Real-Time Berbasis Arduino*.
- Handarly, D., Listrik, P., Elektro, J. T., Bathin, J., Sungain, A., Bengkalis, A., and Lianda, J. (2018). Sistem Monitoring Daya Listrik Berbasis IoT (Internet of Thing). In *Journal of Electrical Electronic Control and Automotive Engineering (JEECAE) 205 JEECAE* (Vol. 3).
- Isnianto, H. N., and Puspitaningrum, E. (n.d.). *MONITORING TEGANGAN, ARUS, DAN DAYA SECARA REAL TIME UNTUK PERBAIKAN FAKTOR DAYA SECARA OTOMATIS PADA JARINGAN LISTRIK SATU FASE BERBASIS ARDUINO*.
- Kajian, J., and Elektro, T. (2022). *RANCANG BANGUN PROTOTYPE SISTEM PENGENDALI DAN MONITORING GENSET BERBASIS INTERNET OF THINGS*. 7(1).
- Lianda, J., Handarly, D., and Adam, A. (2021). Sistem Monitoring Konsumsi Daya Listrik Jarak Jauh Berbasis Internet of Things. *JTERA (Jurnal Teknologi Rekayasa)*, 4(1), 79. <https://doi.org/10.31544/jtera.v4.i1.2021.79-84>
- Maulida, Z. A., Indrianto, R., and Rochmawati, L. (n.d.). *PROTOTYPE OF LORA-BASED ELECTRICITY THEFT DETECTION DEVICE USING SUM OF ABSOLUTE DIFFERENCE (SAD) METHOD*.
- Riyadi Hartono, D., Haddin, M., Arief Marwanto, dan, and Islam Sultan Agung Semarang Jl Raya Kaligawe, U. K. (2023). *CYCLOTRON: Jurnal Teknik Elektro Monitoring Daya Listrik Berbasis Internet of Things Menggunakan Metode Simple Exponential Smoothing untuk Prediksi Kebutuhan Energi*.
- Sukadana, I. W., Prayoga, D., and Suriana, I. W. (2021). Sistem Monitoring dan Audit Energi Listrik Berbasis Internet Of Things (IOT). *JTEV (Jurnal Teknik Elektro Dan Vokasional)*, 7(2), 139. <https://doi.org/10.24036/jtev.v7i2.112081>
- Supriyadi, E., Siti, D., Prodi, D., and Elektro, T. (n.d.). *Rancang Bangun System Monitoring dan Kendali Listrik Rumah Tangga Berbasis ESP8266 NodeMCU*.
- Yuniarto, W., Diponegoro, M., Program Studi Teknik Elektro, E., Negeri Pontianak, P., Barat, K., and Kunci, K. (2023). *Rancang Bangun Sistem Monitoring dan Kontrol Energi Listrik pada Beban 3 Fasa Menggunakan ESP32 Berbasis Internet of Things (IoT)* (Vol. 22).
- Zaini, M., and Bachrudin, M. (n.d.). *PERANCANGAN SISTEM MONITORING TEGANGAN, ARUS DAN FREKUENSI PADA PEMBANGKIT LISTRIK TENAGA MIKROHIDRO BERBASIS IOT*.