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Control and Monitoring System for Electronic Equipment Power Usage in Homes Based on the Internet of Things (IOT)

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Abstract

The purpose of this research is (1) to achieve energy efficiency and cost savings (2) a control and monitoring system based on the Internet of Things (IoT) using the Node MCU ESP32 as the data processing center (3) enabling data processing from the PZEM-004T sensor and sending control commands to the solid-state relay (SSR) based on user input through a web application. The implementation of this system shows significant potential in reducing energy consumption and costs in households. With real-time feedback on energy consumption, users can make wiser decisions regarding the use of electronic appliances, thereby reducing energy waste. The ability to control remotely allows users to manage electronic appliances more effectively, enhancing security, and reducing unnecessary energy consumption. This study shows that manual electricity usage reaches 9.59%, while with the implementation of the IoT system it is only 5.49%, resulting in a 4.1% reduction in electricity consumption. This proves that the IoT system is more effective and efficient in managing the power consumption of electronic devices.
***Keywords**: Control and Monitoring, IoT, PZEM-004T, Node MCU ESP32*

1. Introduction

The current development of technology is progressing rapidly, in several fields of science, researchers continue to strive to develop technologies aimed at simplifying human tasks, one of which is in the field of IoT technology. (Internet of Things).(Pela & Pramudita, 2021) To manage electricity consumption at home, it is not limited to using a kWh meter, because the kWh meter only monitors and restricts overall electricity consumption.(Muhammad & Sardi, 2022) To save electricity usage, user awareness of turning off electronic devices is necessary, as forgetting to turn them off can lead to increased electricity bills.(Nyoman et al., 2019) Additionally, it also results in a decrease in the performance of electrical energy itself unless steps are taken to monitor power usage with the aim of raising awareness about energy conservation, thereby reducing daily electricity consumption.(Dedi Suarna et al., 2023)(Rizal & Karyana, 2019) Until now, monitoring electricity usage is still done manually, requiring direct inspection of the location where the measuring device is installed, which is considered impractical.(Hadi et al., 2022)(Tipantuna & Hesselbach,2021)

The electrical power calculation system uses a kilowatt hour (KwH) meter as a parameter to determine the amount of usage. (Shadiq & Mangani, 2021) The Kwh meter is a measuring instrument needed to measure power usage, as it serves as a benchmark for electricity consumption, from low voltage in residential areas to high voltage in industries.(Sembiring & Buchari, 2021) Until now, to monitor the current balance, it has been done manually by monitoring KwH and conducting manual measurements, causing issues to be detected late.(Khumaidi, n.d.; Pengendali et al., n.d.) The use of the tool does not provide information about the amount of electrical power used in real-time.(Lin et al., 2022) The kilowatt hour (Kwh) meter only shows the cumulative amount of power used.(Hendrawati et al., 2018) Therefore, a device is needed that can display real-time electricity usage to check, monitor, and control whether a device is functioning or not.(Pal et al., 2021a, 2021b)

2. Method

1. Research Stages

The research stages consist of four phases, starting with system analysis. The process begins with the System Analysis phase, which is the initial step in thoroughly understanding the system's needs. At this stage, a thorough analysis of user needs, system objectives, and existing constraints is conducted. The results of this analysis will serve as the foundation for designing a system that meets the identified needs. After the system analysis is complete, the process continues to the System Design stage. At this stage, the system design begins to be created based on the previous analysis results. The design includes the system architecture structure, interfaces, and technical specifications required for implementation. The main focus of this stage is to design an efficient technical solution that can meet business needs. The next stage is Program Design, where the design of the program or software to be used for implementing the system is carried out. At this step, the software components are further detailed, including algorithms, logic, and data structures that will be used to ensure that the design can be correctly implemented. After the program is designed, the next step is System Analysis Testing. This stage aims to test whether the system design and the program that have been created align with the specifications and needs identified in the initial stage. The testing process involves validation and verification to ensure that the system functions as intended without any errors. The final stage is the Research Result, where the results of the research and system development are analyzed and concluded. At this stage, the developed system is evaluated to ensure that the results align with the initial objectives and provide maximum benefits. The final results usually include reports, documentation, and the implementation of the system ready for use.

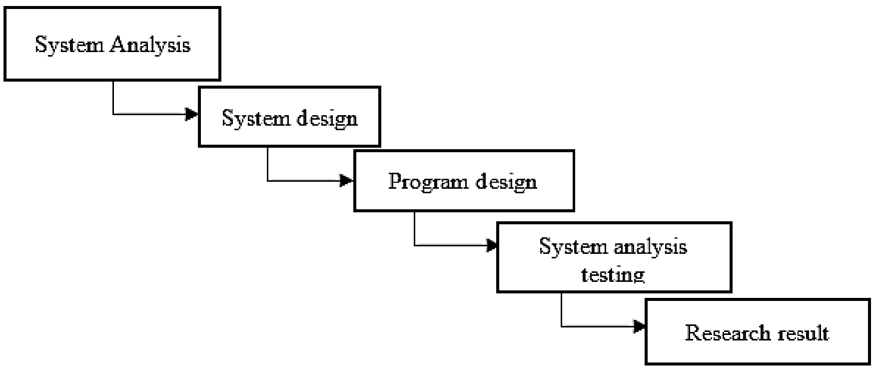

Figure 1. Research Stages

2. System Flowchart

Figure 2 of the system design flowchart shows, first, the start of the flowchart, which depicts an operational process involving the ESP32 MCU node, a microcontroller connected to the PZEM004T sensor, which is likely used to measure electrical parameters such as current, voltage, and power. The process begins with checking if the NodeMCU is active and ready. After that, the NodeMCU attempts to connect to WiFi, and if successful, it will connect to the web server. Next, the system reads data from the PZEM004T sensor and checks if the received data is accurate. If the data is accurate, the ESP32 NodeMCU will send the data to the web server. After the data is sent, the values of current, voltage, and power are displayed. This process also checks whether there is an active load. If there is, the process ends, and if not, the system will continue to display the values of current, voltage, and power, as part of a continuous monitoring loop. Overall, this flowchart illustrates the operational cycle from sensor data acquisition to data transmission and display, with condition checks at several points to ensure the operation runs correctly.

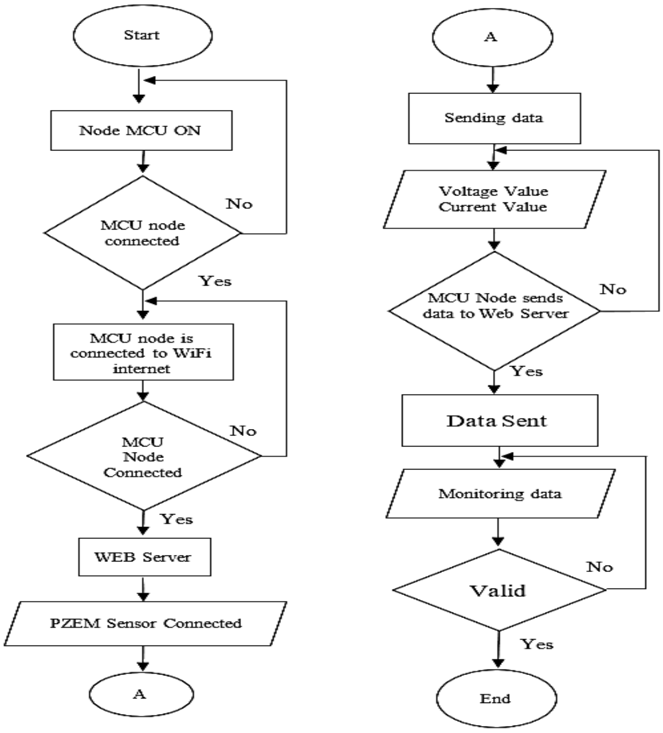

Figure 2. System Flowchart

3. System Architecture

Figure 3 shows overall, the design of this system depicts an intelligent smart home with a control and monitoring system that uses sensors to enhance security and energy efficiency. Through this system, users can control and monitor the state of the house remotely, as well as utilize the data obtained to make smarter decisions in electricity usage.

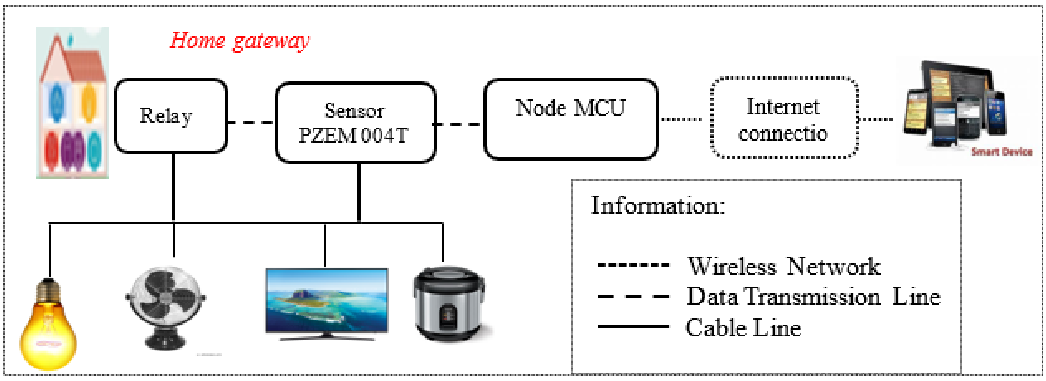

Figure 3. System architecture

4. System Circuit

At this stage, the author integrates the entire system circuit and designs the system layout into a printed circuit board. (PCB). This scheme shows the integration of each active device between two sources of remote communication support, namely Wifi and mobile devices, to control and monitor electronic equipment such as televisions, fans, rice cookers, and lights. The operation of controlling and monitoring uses a web server from the mobile device as a requirement for smart home users, where sensor data is processed into an analytical form to be displayed on the mobile device screen for control and monitoring performance.

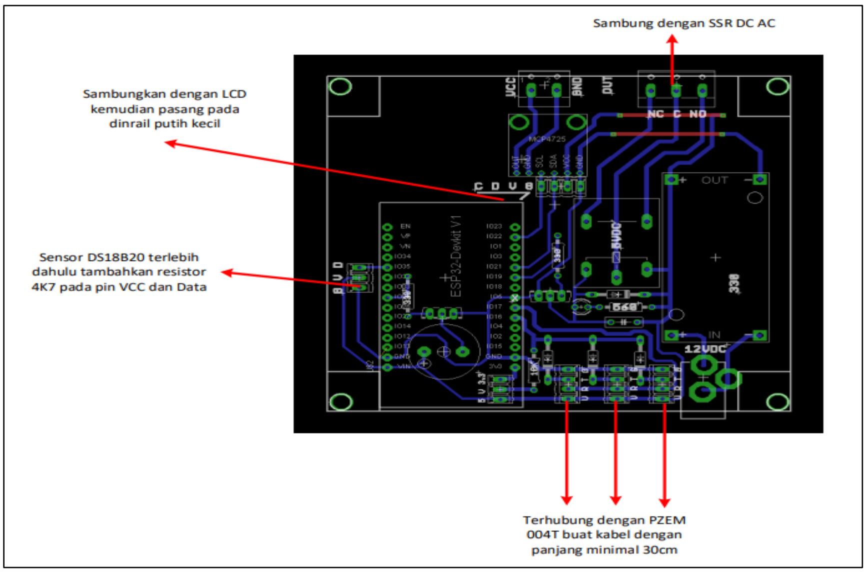

Figure 4. Printed Circuit Board (PCB)

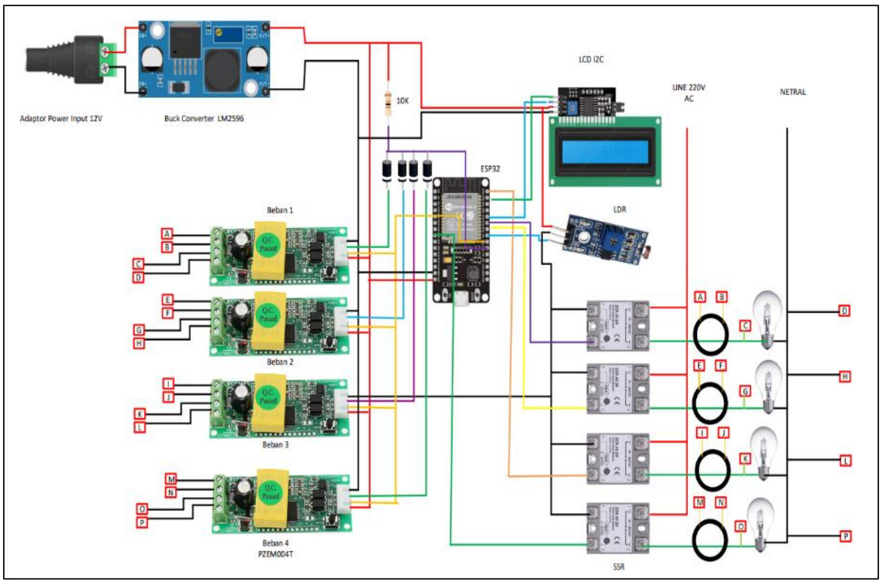

Figure 5. System Wiring Diagram

The system's working process shows the circuit diagram based on Figure 5 for the ESP32 microcontroller-based control system. The adapter converts the AC voltage from the wall into 12V DC, which is then reduced by the buck converter to a voltage suitable for the ESP32 MCU node and other components. The ESP32 microcontroller, which has Wi-Fi connectivity, acts as a programmable control center to manage various devices through relay modules.

The LCD screen provides an interface to display system information, while the LDR (Light Dependent Resistor) sensor is used to detect light levels. Solid state relay (SSR) allows the ESP32 MCU node microcontroller to control devices that require more power, such as lamps, fans, rice cookers, and televisions connected to an AC power source. This system can be operated manually or automatically, based on sensors or remote input via Wi-Fi.

Table 1. Electronic Components

No	Tool	information	Amount component
1.	Printed Circuit Board (PCB).	Media for Assembling Tool Components	1
2.	ESP32 MCU Node	Can be connected to the internet	1
3.	Solid state relay	As a switch to on/off the load	4
4.	PZEM 004T Sensor	Measuring as an electrical parameter	4
5.	Current transformer	Measuring the current flowing through a cable	4
6.	Electrical terminal	Connecting the load to the electric cur-rent	4
7.	Miniature circuit breaker 4C/900 VA	Provides protection in the installation in case of short circuit.	1
8.	12V power supply	To supply voltage to components	1
9.	Buck converter mod-ule LM2596	Monolithic IC that acts as the main com-ponent in a DC power supply step down circuit	1
10.	*Liquid crystal display*	Acts as a character display controller	1
11.	LDR sensor (Light de-pendent sessionor)	To conduct or inhibit electric current based on light intensity	1

In Table 1 are the components used to support the control and monitoring system for electricity usage based on the Internet of Things (IoT) in homes using a website platform.

2. Results and Discussion

1. Hardware

The implementation of hardware is the application of tools designed by assembling components to create remote control devices for IoT (Internet of Things)-based electronic devices. In Figure 6, there is hardware resulting from the system design implementation used to support the control and monitoring system for the power usage of IoT-based electronic devices using a website.

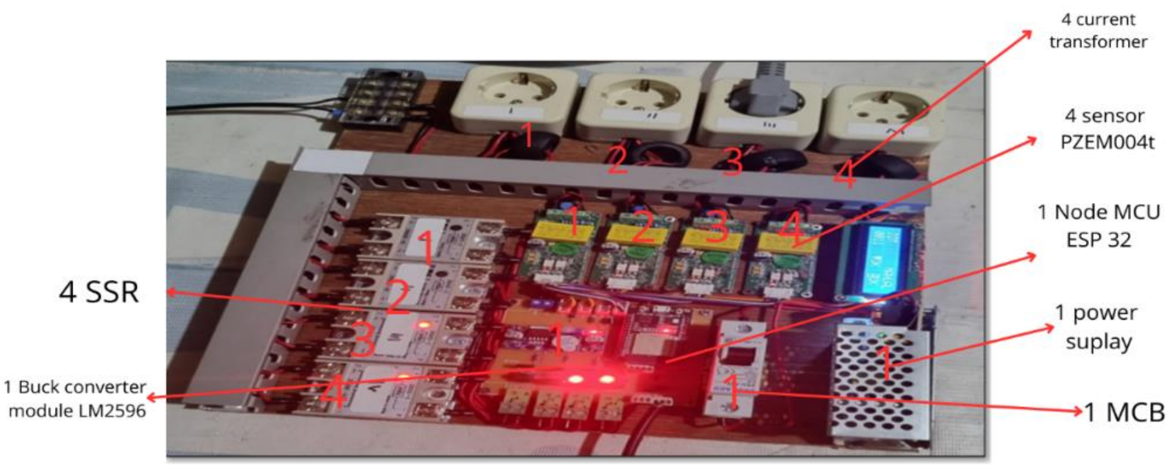

Figure 6. System Design

2. Software

In image 7, the initial display when the login is successful, where this page shows the conditions of loads 1 to 4 and can control electronic devices as well as set automatic and manual modes to turn the electronic loads on and off automatically using an LDR sensor. (Light Dependent Resistor).

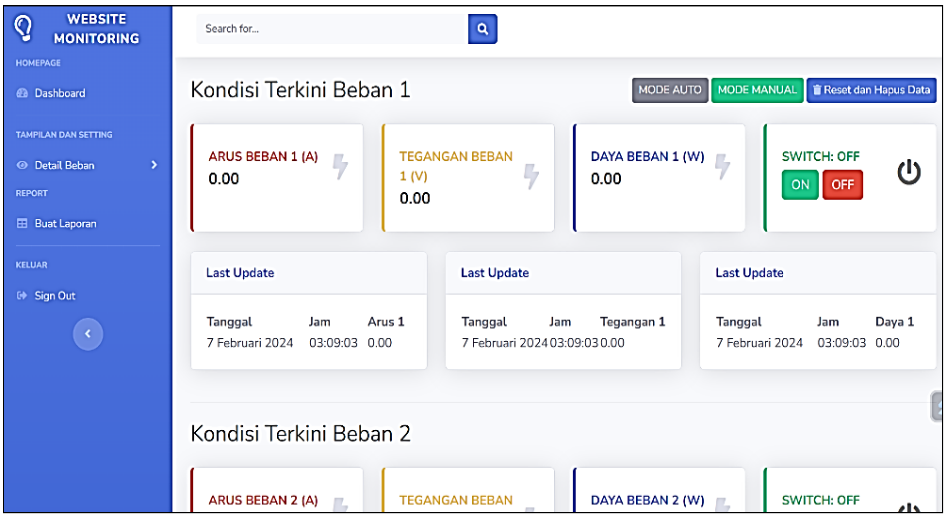

Figure 7. System dashboard

3. System Analysis Testing

System testing is a stage in the development of internet of things technology, especially in the context of control and monitoring systems for the usage load of electronic equipment in IoT-based homes. Here are the stages of system testing:

2.3.1. Current Analysis Testing (A) Electrical Load

In Figure 8, the results of the comparison between the PZEM004T sensor readings and the results of the clamp meter readings on the electrical load current (A) are shown.

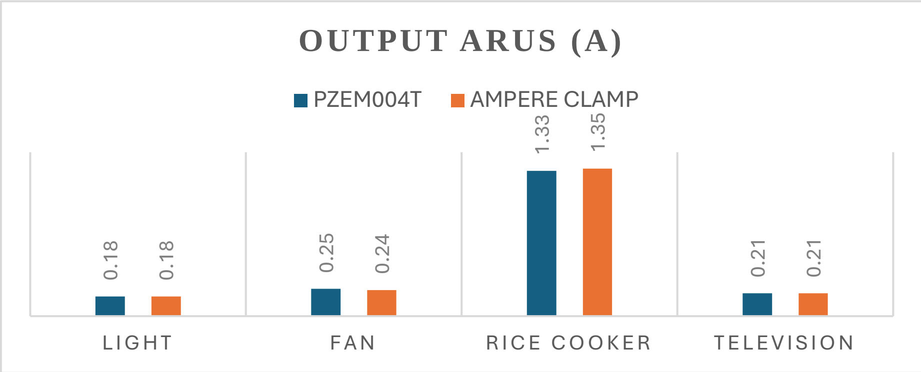

Figure 8. Comparison graph of current output (A)

Based on Table 2, it can be concluded that the average load current accuracy is 98% output from the readings of the sensor and clamp meter. The differing measurement values are caused by voltage instability during the reading process between the PZEM-004T sensor and the clamp meter. The measurement differences between the PZEM 004T sensor and the clamp meter occur due to differences in working principles, device characteristics, and conditions during the measurement. The PZEM 004T sensor works by directly reading the current through a connection to the electrical circuit, while the clamp meter measures the current inductively by clamping the conductor cable. The difference that occurs is quite small, so both devices can be considered to have good accuracy for measuring electric current.

Table 2. Analysis of current output comparison (A)

Burden	Current (A)		Difference (%)	Accuracy (%)
	Sensor PZEM 004T	Ampere Clamp		
Light	0.18	0,18	0%	100%
Fan	0.25	0,24	0,01%	99,67%
Rice cooker	1.33	1,35	0,02%	98,33%
Television	0.21	0,21	0%	100%

2.3.2. Voltage Analysis Testing (V) Electrical Load

In graph 9, it shows the results of the comparison test between the PZEM004T sensor readings and the test results from the ampere clamp reading at the voltage (V) of the electrical load.

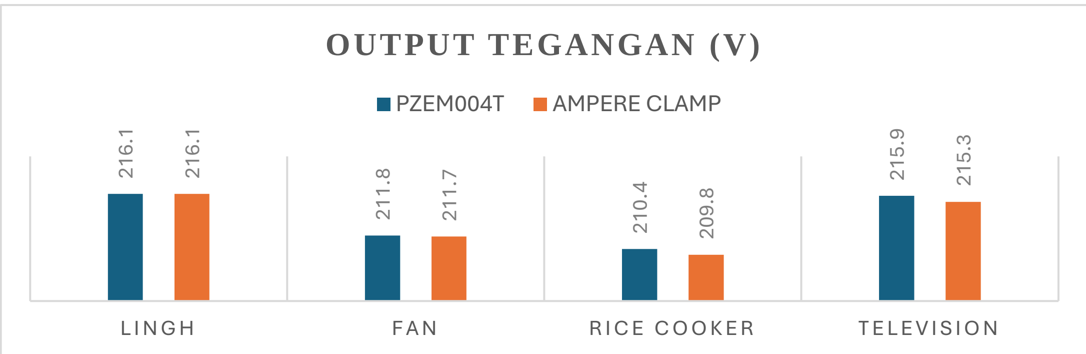

Figure 9. Voltage output comparison graph (V)

Based on Table 3, it can be concluded that the comparison of the sensor with the measuring instrument results in an average accuracy of 98%. The differing readings between the sensor and the clamp ammeter are usually caused by voltage instability during the reading process between the PZEM-004T sensor and the clamp ammeter.

Table 3. Comparative analysis of electrical load tension (A)

Burden	Voltage (V)		Difference (%)	Accuracy (%)
	Sensor PZEM 004T	Ampere Clamp		
Light	216.10	216.10	0%	100%
Fan	211.80	211.75	0,5%	99,5%
Rice cooker	210.40	209.80	1,04%	99,4%
Television	215.90	215.30	0,06%	99,4%

2.3.3. Power Analysis Testing (W)

In Figure 10, the results of the comparison between the PZEM004T sensor readings and the results of the ampere clamp reading on the power (W) of the electrical load are presented.

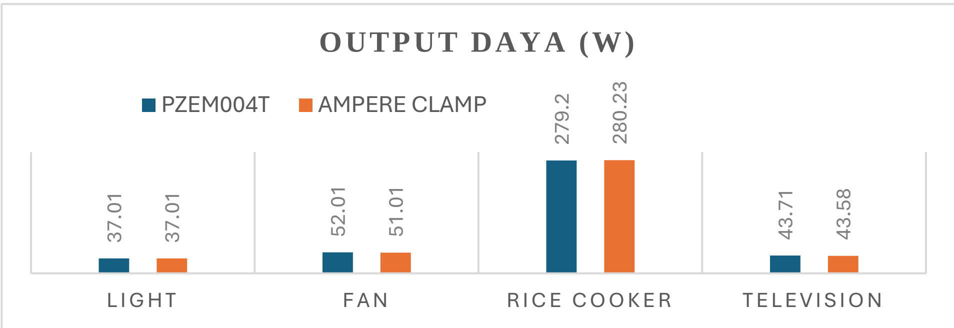

Figure 10. Power output comparison graph (W)

In Table 4, the analysis of power values generated from the reading of the ampere clamp meter is compared with the results obtained from the reading of the Pzem004T sensor.

Table 4. Analysis of electrical power comparison (W)

Burden	Load power (W)		Differ-ence (%)	Accuracy (%)
	Sensor PZEM 004T	Ampere Clamp		
Light	37.01	37.01	0%	100%
Fan	52.80	51.55	1.75%	98.25%
Rice cooker	279.20	280.23	1,3%	98,7%
Television	43,70	43,58	0.12%	99,88%

Based on the test results that have been conducted, there is an average accuracy value of 99%. The difference in power reading values is caused by the sensor readings occurring at different times or instability during the measurement, resulting in accuracy that does not match the calculations.

2.3.4. Electricity Usage

The system implementation was carried out in the onion warehouse of PT. Berkah Arfah Alaisyah, with each test using Internet of Things devices and manual calculations without Internet of Things (IoT) devices. In this case study, the researcher implemented and tested a prepaid meter with an electrical power of 1300 VA.

Table 5. Manual electricity consumption

Electrical Load	Watt	Hour (H)	Watt Hours (Wh)	KwH
Light	50 watt	24 h	1.200 wh	1,2 KwH
Television	100 watt	8 h	800 wh	0,8 Kwh
Fan 250 x2	500 watt	15 h	7,500 wh	7,5 Kwh
Rice cooker	300 watt	20 m	0,33	0,09 Kwh
Total = 950 watt		Total kWh= 9,59		

Table 6. Electricity consumption using the IoT system

Electrical Load	Watt	Hour (H)	Watt Hours (Wh)	KwH
Light	50 watt	12 h	600 wh	0,6 KwH
Television	100 watt	8 h	800 wh	0,8 Kwh
Fan 250 x2	500 watt	8 h	4.000 wh	4 Kwh
Rice cooker	300 watt	20 m	0,33h	0,09 Kwh
Total = 950 watt		Total= 5,49 KwH		

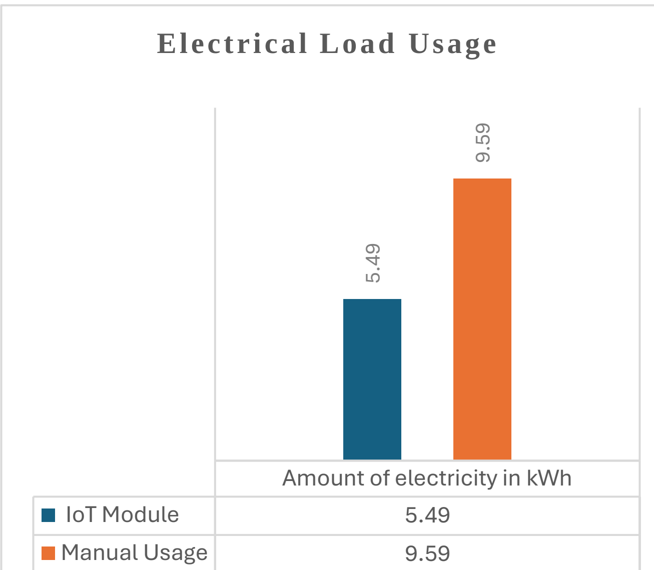

Figure 10. Power output comparison graph (W)

Based on the graph in Figure 10. The use of the Internet of Things (IoT) system shows significant efficiency compared to the manual method. The IoT system recorded a usage of 5.49%, while the manual method showed a usage value of 9.59%. In the implementation of the IoT system, it has more efficient performance, reducing usage by 4.1%. Measurement of current (A), voltage (V), and power (W) using an ammeter and PZEM004T sensor shows a high level of accuracy in the usage of electronic equipment displayed on the website. Comparative analysis can be made with direct measurements using an ammeter, yielding an average accuracy of 98% in the usage of electronic equipment loads.

3. Conclusion

The research results show that the system can improve electrical energy efficiency by 4.1%. The implementation of the Internet of Things system allows users to identify and manage equipment that uses excessive power. Additionally, the ability to control remotely provides comfort, security, and flexibility for users.

In the research on "Control and Monitoring System for Electronic Equipment Power Usage in Homes Based on the Internet of Things (IoT)," it can be concluded that the application of IoT in managing and monitoring the power consumption of electronic equipment in homes can provide many benefits in the security system of electrical equipment usage, thereby preventing damage to electronic devices. This system allows users to have better control over power usage, increases energy efficiency, and displays information on electricity consumption and the condition of household electronic equipment usage, proving a margin of error percentage of 0.08%.

This system can be widely adopted in households to reduce energy waste, optimize the use of electronic appliances, and provide more environmentally friendly solutions. Users can take advantage of remote monitoring and control features to adjust power usage according to needs, thereby supporting electricity cost efficiency.

For further research, it is to expand the scope of the study by testing the system on a larger scale and in more varied environments, for example, its application in office buildings or industrial facilities. Additionally, integrating with machine learning technology can be developed to provide automatic recommendations for more efficient power usage.

Reference

Dedi Suarna, Zahir Zainuddin, Hazriani, & Edy Sopyan. (2023). Rancang Bangun Pengontrolan Alat Elektronik Berbasis Internet of Things (IoT). *Journal of Informatics, Electrical and Electronics Engineering*, *2*(3), 75–82. https://doi.org/10.47065/jieee.v2i4.682

Hadi, S., Dewi, P., Labib, R. P. M. D., & Widayaka, P. D. (2022). Sistem Rumah Pintar Menggunakan Google Assistant dan Blynk Berbasis Internet of Things. *MATRIK : Jurnal Manajemen, Teknik Informatika Dan Rekayasa Komputer*, *21*(3), 667–676. https://doi.org/10.30812/matrik.v21i3.1646

Hendrawati, T. D., Wicaksono, Y. D., & Andika, E. (2018). Internet of Things: Sistem Kontrol-Monitoring Daya Perangkat Elektronika. *JTERA (Jurnal Teknologi Rekayasa)*, *3*(2), 177. https://doi.org/10.31544/jtera.v3.i2.2018.177-184

Khumaidi, A. (n.d.). *Sistem Monitoring dan Kontrol Berbasis Internet of Things untuk Penghematan Listrik pada Food and Beverage*.

Lin, Y. H., Tang, H. S., Shen, T. Y., & Hsia, C. H. (2022). A Smart Home Energy Management System Utilizing Neurocomputing-Based Time-Series Load Modeling and Forecasting Facilitated by Energy Decomposition for Smart Home Automation. *IEEE Access*, *10*, 116747–116765. https://doi.org/10.1109/ACCESS.2022.3219068

Muhammad, D., & Sardi, J. (2022). Rancang Bangun Sistem Monitoring Penggunaan Daya Listrik Rumah Tangga Berbasis Internet of Things (IOT). *JTEIN: Jurnal Teknik Elektro Indonesia*, *3*(2). https://doi.org/10.24036/jtein.v3i2.274

Nyoman, I., Hartawan, B., & Sudiarsa, W. (2019). ANALISIS KINERJA INTERNET OF THINGS BERBASIS FIREBASE REAL-TIME DATABASE. In | *Jurnal RESISTOR JURNAL RESISTOR* (Vol. 1, Issue 1). Online. http://jurnal.stiki-indonesia.ac.id/index.php/jurnalresistor

Pal, P., Parvathy, A. K., Devabalaji, K. R., Antony, S. J., Ocheme, S., Babu, T. S., Alhelou, H. H., & Yuvaraj, T. (2021a). IoT-Based Real Time Energy Management of Virtual Power Plant Using PLC for Transactive Energy Framework. *IEEE Access*, *9*, 97643–97660. https://doi.org/10.1109/ACCESS.2021.3093111

Pal, P., Parvathy, A. K., Devabalaji, K. R., Antony, S. J., Ocheme, S., Babu, T. S., Alhelou, H. H., & Yuvaraj, T. (2021b). IoT-Based Real Time Energy Management of Virtual Power Plant Using PLC for Transactive Energy Framework. *IEEE Access*, *9*, 97643–97660. https://doi.org/10.1109/ACCESS.2021.3093111

Pela, M. F., & Pramudita, R. (2021). SISTEM MONITORING PENGGUNAAN DAYA LISTRIK BERBASIS INTERNET OF THINGS PADA RUMAH DENGAN MENGGUNAKAN APLIKASI BLYNK. *Infotech: Journal of Technology Information*, *7*(1), 47–54. https://doi.org/10.37365/jti.v7i1.106

Pengendali, S., Listrik, P., Daya, D. P., Berbasis, L., & Nor, W. S. (n.d.). *Penerapan Internet Of Things (Iot)*. https://ojs.uniska-bjm.ac.id/index.php/eeict

Rizal, R., & Karyana, I. (2019). *Sistem Kendali dan Monitoring pada Smart Home Berbasis Internet of Things (IoT)*. *1*(2), 43–50.

Sembiring, S., & Buchari, M. A. (2021). Perancangan dan Implementasi Sistem Pengendalian dan Monitoring Penggunaan Peralatan Elektronik Berbasis Internet of Thing (IoT). *JURNAL MEDIA INFORMATIKA BUDIDARMA*, *5*(4), 1585. https://doi.org/10.30865/mib.v5i4.3353

Shadiq, J., & Mangani, S. A. (2021). Alat Monitoring Dan Kontrol Peralatan Listrik Pada Ruangan Berbasis Internet of Things. *INFORMATICS FOR EDUCATORS AND PROFESSIONALS*, *6*(1), 63–73.

Shodiq1, A., Baqaruzi, S., & Muhtar, A. (2021). Perancangan Sistem Monitoring dan Kontrol Daya Berbasis Internet Of Things. *Hal Jurnal ELECTRON*, *2*(1), 18–26.

Tipantuna, C., & Hesselbach, X. (2021). IoT-Enabled Proposal for Adaptive Self-Powered Renewable Energy Management in Home Systems. *IEEE Access*, *9*, 64808–64827. https://doi.org/10.1109/ACCESS.2021.3073638