Power Monitoring System of Home-scale Internet of Things (IoT)

by Eki 4

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Abstract— During the Covid-19 pandemic, there was an increase in the use of electrical energy on a household scale. This study developed a home-scale power monitoring system to monitor electrical power at a household scale. This research was conducted to facilitate access to home power monitoring via Android based on the Internet of Things using the Thinger.IO web browser and Telegram Messenger using the Bot feature. This power monitoring system develops using the ACS712 sensor as a current reader and the ZMPT101B as a voltage reader, using an ESP32 microcontroller with a WiFi module that can be connected online. The results of this study are that the accuracy of the ZMPT101B voltage sensor is excellent, with an accuracy value of 99.845%. The ACS712 current sensor has the highest difference value with a reference of 0.32 A and 0.04 A for the lowest difference value. The data logger system on Thinger.IO works well in recording data. The Bot Feature on the Telegram application can work well even though it has an average delay of up to 4.2 seconds, depending on the speed of the internet network.

Keywords—Current sensor, Voltage sensor, ESP32, Thinger.IO, Telegram, Internet of Things.

I. INTRODUCTION

Electricity is still an essential need for humans today. Most human equipment uses electricity as a source of energy. As humans grow, the need for electrical energy is increasing every year, while on the other hand, fossil fuels are starting to run out. Technology is proliferating, and the world of electronics plays an essential role in the growth and development of modern technology. Electronic devices are designed to make it easier for humans to work in various fields, for example, in industry or households. During the Covid-19 pandemic, people are more dominant at home, which has increased the use of electrical energy on a household scale, as evidenced by an increase in electricity bills.

The awareness of electricity consumers in saving and managing the use of electrical energy in the household needs to be improved. The way is by periodically monitoring the use of power at household loads, for example, through smartphones. We need a tool or system in the form of an electronic device that monitors household electricity consumption so that electricity management can be carried out better on a household scale.

Technology is not only used for communication between humans and humans; with technology, humans can communicate and connect with objects, and objects can also connect with other objects. That is commonly known as the Internet of Things (IoT). Internet of Things technology is starting to develop over time. Many studies integrate several systems using sensors, such as current and voltage sensors. They are paired to an electrical network to monitor electrical power consumption and connected to web browsers or applications on Android.

Related research was conducted by Yasirli Amri and Mukhammad Andri Setiawan [1]. This study developed a smart home system to monitor and control electrical energy in several electronic components such as lights, Air Conditioners, and others. This system is built using NodeMCU and RasberryPi devices for the Internet of Things. Controlling is done via a smartphone with the Bot application on Telegram.

The research was conducted by Ahmad Badrul Huda and Arif Nur Afandi [2]. In this study, an Automatic Transfer Switch (ATS) was designed using NodeMCU ESP8266 as a microcontroller and Internet of Things (IoT) device for communication from Android to the Automatic Transfer Switch (ATS) module. That research used PZEM 004-T sensor to read voltage and current values, a 5 Ampere AC Relay as input voltage sensor and main contact info, and a Direct Current Relay module as a generator on/off switch. To display the results through notifications on the Telegram application and the Blynk application as software to display monitoring results and as manual control via Android. The test results show that the Automatic Transfer Switch (ATS) takes 4 seconds to work when the PLN goes out.

Meanwhile, Win Hlaing et al., in their research, brought the concept of the Internet of Things (IoT) into an energy monitoring system that is cheap and easy to apply for our daily electrical power [3]. This system is made by implementing a low-cost wireless network and sensors for a web application that can read the unit automatically and send data automatically to the power user to see the current energy meter. This system consists of a digital electrical energy meter using the ESP8266 WiFi module and a web application for its management system. The ESP8266 WiFi module will be embedded into the meter, and the TCP/IP protocol will be implemented for communication between the meter and the web application.

Another research by Nur Ratnawati and Sunardi focused on developing tools for digitally monitoring electric current using the ACS712 sensor [4]. The microcontroller used is Arduino ATmega 328, assisted by a current measuring circuit equipped with a sensor mounted in series to the circuit to measure the current flowing. The test results show that the sensor can measure the current value at its peak with an error value of -0.066 and a standard deviation of 0.011419.

Based on the references above, the authors researched to develop Internet of Things technology in monitoring loading and electrical power at home through a data logger system, which can be accessed in real-time via the Telegram Messenger application by utilizing the Thinger.IO platform and the ESP32 module.

II. SYSTEM MODEL

A. Block Diagram

There are three stages of the system in this monitoring system, namely input, process, and output. The input in this study is the ACS712 current sensor and the ZMPT101B voltage sensor, which uses an ESP32 microcontroller. The output is a data logger from monitoring results in Thinger.IO and Telegram Bot chat notifications, as shown in Figure 1.
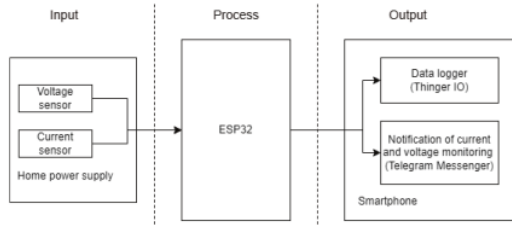

Fig. 1 Block diagram system.

The following is an explanation of the block diagram system Figure 1:

- The input section consists of the ACS712 current sensor and the ZMPT101B voltage sensor. The ACS712 current sensor functions as an AC current reader, and the ZMPT101B voltage sensor functions as an AC voltage reader.

- The ESP32 microcontroller carries out the process part. Input from the current sensor and voltage sensor via the Analog to Digital Converter (ADC) pin will be processed by the microcontroller and sent to the cloud online via a WIFI connection.

- The output part is the final result of processing. The output is a data logger system on the Thinger.IO platform and chats notifications for the Telegram Bot application.

B. Hardware Design

The design of the Power Monitoring System requires several supporting components, as shown in Table I. Requirements include all the supporting components of the tool. Before being used, each sensor is tested first to determine its accuracy value of the sensor.

TABLE I. COMPONENT.

No	Component Name	Total
1	ESP32 Microcontroller	1
2	Real-Time Clock	1
3	Current Sensor ACS712	1
4	Voltage Sensor ZMPT101B	1
5	Personal Computer/Laptop	1
6	Smartphone	1
7	Jumper	20

C. Software Design

The software design is done by configuring the configuration for the Telegram Messenger Bot, configuring the Thinger.IO, configuring the WIFI, and setting the time on the Real Time Clock on the Arduino IDE software.

D. System Design

The design of this monitoring system is shown in Figure 2. The pins on the ESP32 are connected to the sensors and RTC. Then, the ACS712 sensor is connected in series to the load to measure the current at the load. Furthermore, to measure the voltage at the load, the ZMPT101B sensor is connected in parallel to the load.
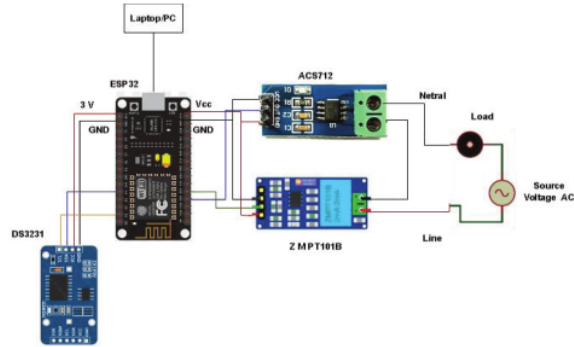

Fig. 2 System design.

E. System Test and Calibration

Tests on the system were carried out to determine whether following the plan. Calibration is a process of the ratio of the output of a measurement system to a standard with known accuracy. Test on the system carried out by the calibration test method. The calibration test was carried out by comparing the data on the ACS712 current sensor and the ZMPT101B voltage sensor with the measurement results from the ammeter and voltmeter measuring instruments. The test was carried out on households with an electric power of 450 VA.

1) ACS712 Current Sensor Testing and Calibration

In Table II, there are test results on the ACS712 current sensor against several household electrical loads and a comparison made on the test results with measurements using an ammeter. The results show a difference between the results of the ACS712 sensor test and the amperemeter measurement. The sensor works fairly well and is not too bad. The value with the highest difference is 0.32 A which occurs in the iron load, and the lowest difference in measurement results is 0.04 A which occurs at the 5 W LED lamp load.

TABLE II. CURRENT SENSOR TEST.

No	Load	Observed Results		Differences (A)
		Sensor AC (A)	Ampere meter (A)	
1	No Electrical Load	0.05	0	0.05
2	5 W LED Lamp	0.12	0.08	0.04
3	Fan	0.61	0.43	0.12
4	Electric Iron	1.45	1.13	0.32
5	Charger Smartphone	0.75	0.5	0.25

The results of the difference in readings occur in the ACS712 current sensor and the ammeter in the AC current reading. This is due to limitations in the sensitivity of the ACS712 sensor readings and ammeters. The difference in the sensitivity of the ACS712 sensor and the ammeter causes a difference in the current value reading.

2) ZMPT101B Sensor Testing and Calibration

Testing the ZMPT101B voltage sensor serves as a measurement value. The results on the voltmeter are used as a calculated value or a reference value. Data errors or errors are obtained using the following Formula 1.

$$\%Error= \left|\frac{Vmeasurement-Vcalculated}{Vmeasurement}\right|\times100\% \qquad (1)$$

The comparison between the measurement results and the calculation results in Table III has several differences that result in an error value. The error value in measuring this voltage is due to the difference in the accuracy value between the sensor and the analog voltmeter. The average error value on the ZMPT101B voltage sensor that occurs in this measurement is 0.155%. This means that the ZMPT101B voltage sensor has an accuracy value of 99.845%. This figure indicates that the measurement results from the ZMPT101B voltage sensor produce accurate and very good values.

TABLE III. VOLTAGE SENSOR TEST

No	Voltage Result		Error (%)
	Sensor AC (V)	Voltmeter (V)	
1	220.03	220	0.01
2	219.69	219	0.03
3	220.06	219	0.48
4	219.35	220	0.29
5	219.01	219	0.004
6	219.7	219	0.3
7	220.26	220	0.1
8	220.23	219	0.5
9	220.01	220	0.004
10	219.22	220	0.3
Average Error			0.155

III. RESULT AND ANALYSIS

In this study, testing was carried out on hardware, data logger systems, and notification systems via the user's Telegram Bot. In the results and analysis section, we will discuss the results of the system that has been created and the analysis of the system.

A. Hardware Prototype

The design and construction of the prototype of this monitoring system are shown in Figure 3. The system consists of the devices mentioned in Table 1: the ACS712 current sensor, ZMPT101B voltage sensor, RTC, and the ESP32 microcontroller.

The prototype of this system is implemented on an electrical load in the form of a 5 Watt LED lamp. The load is connected directly to the current sensor ACS712 in series and

directly to the voltage sensor ZMPT101B in parallel, according to the mains' rules for measuring current and voltage. Measurement of power is done by multiplying the current and voltage variables.
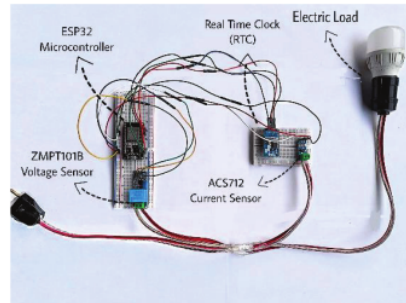

Fig. 3. Implementation system.

B. Data Logger System

The data logger system functions to record data online. The data received by the ESP32 from the sensors via WIFI will be sent to a cloud console from the Thinger.IO web browser. On the platform, data in the form of currents and voltages will be stored in real-time and will be stored in graphical form.

Monitoring results on the Thinger.IO platform are shown in Figure 4 below.

Fig. 4. Display data logger on Thinger.IO

The use of this electrical energy monitoring system was tested starting at 19.30 to 21.00. the results of these tests are shown in a graph of the value of the AC current, a graph of the value of the AC voltage, a graph of the value of electric power usage being used in VA, and displaying the value of current, voltage, and power per unit of time.

The value obtained from testing the ACS712 current sensor is getting more stable results at 0.5 amperes. Sometimes, there is a significant increase. The value of monitoring the AC voltage is fairly stable at 219-220 volts. On monitoring, power usage tends to be stable and ranges from 100 VA.

C. Telegram Bot Testing

Notifications by Telegram Bots will be carried out after a data request by the user to the system occurs. Data will be sent in real-time because there is an RTC that helps provide data in the form of time to the Telegram Bot. Requests for monitoring data via Telegram Bot can only be made with the keyword "Power Check". If the user requests monitoring data but does

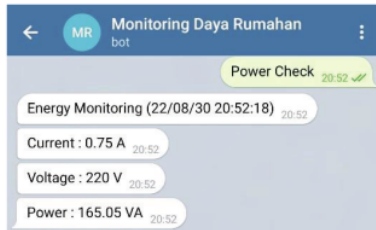not use the command, then the system will not respond and assume that it is not a command.

Fig. 5. Display on bot telegram.

There is a delay in giving notifications by the Telegram Bot. The researcher experimented with sampling delay up to 10 times and got the results of an average delay of up to 4.2 seconds. The researcher assumes that the delay in the Telegram Bot is influenced by the internet speed that can be done by ESP32. A good network on WIFI can not always be captured by ESP32 with good results. The delay experiment is shown in Table 4 below,

TABLE IV. DELAY ON TELEGRAM.

No	Number of Testing	*Delay* (s)
1.	1	5
2.	2	5
3.	3	3
4.	4	4
5.	5	3
6.	6	3
7.	7	4
8.	8	5
9.	9	5
10.	10	5
	Average Delay	4.2

D. Overall System Analysis

The home-scale current and voltage monitoring system is well designed and implemented according to the design. The results of the implementation and integration of the system consisting of the ACS712 current sensor and the ZMPT101B voltage sensor, Thinger.IO and Telegram produce measurements and data recording that can function correctly.

The ACS712 current sensor reads the electric current in the form of an analog signal, and the ZMPT101B voltage sensor reads the electric voltage value in the form of an analog

signal. The results of the readings of the two sensors will be sent to the ESP32 microcontroller via pins 34 and 35, which will be converted into digital form. The results will be processed and sent to the output online via a connected WiFi network. Thinger.IO will record data through the Telegram Bot application, and current and voltage data information will be notified. The Thinger.IO web browser is in charge of automatically recording data sent by ESP32 to the cloud. Data in the form of notifications will be sent in real-time after a data request by the user via the Telegram Bot application.

IV. CONCLUSION

The construction of a prototype of a home-scale current and voltage monitoring system based on the Internet of Things was completed by using the ACS712 sensor as the current reader and the ZMPT101B sensor as the voltage reader. Thinger.IO is used as an online data store through a cloud system available in the Thinger.IO web browser and uses the Telegram application to provide real-time notifications to users.

Testing the home-scale current and voltage monitoring system based on the Internet of Things is done by testing the ACS712 current sensor and ZMPT101B voltage sensor and then using the Avometer as a reference value for comparison. The result is that the ZMPT101B voltage sensor has fairly high accuracy, with an accuracy value of 99.845%. The current sensor has a different value, with the highest reference value of 0.32 A on the iron load and the lowest value of 0.04 A on the LED lamp load. Notifications via Telegram Bot occur with an average delay of up to 4.2 seconds.

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