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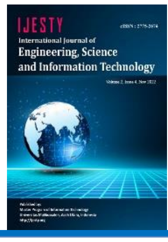

Electrical Energy Monitoring and Control System in Boarding Rooms Based on The Internet of Things

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Abstract

Electrical energy is an essential requirement in various activities today. Almost all electronic devices that are used require electrical energy to operate. Therefore, the public needs to know how much electrical energy is used to maintain the quality of electronic devices. Electrical energy monitoring is a process of monitoring and a source of information on electrical energy that can be viewed directly or remotely with real-time output results. Electrical energy monitoring is designed as a routine process of collecting or measuring information source data that determines the level of electricity consumption achievement in real-time. By using real-time information technology, the operating conditions of the hardware system and programs have clear timeframes. Based on this background, the authors want to conduct research designed to monitor and obtain sources of information on the results of the use of electrical energy in boarding rooms, of course this monitoring tool is based on microcontrollers and the Internet of Things (IoT), with the creation of this monitoring of electrical energy, with all parameters electricity such as voltage, current, electric power, electrical energy, and power factor used can be measured using the PZEM-004T sensor. Monitoring electrical energy using the NodeMCU platform as an input and output processor will then be displayed on the control panel display and internet of things (IoT) based Blynk server. From these problems, the authors are interested in conducting research that aims to monitor and obtain sources of information on the use of electrical energy in boarding rooms. This monitoring tool is based on a microcontroller. In addition, this monitoring tool is also based on IoT so that power consumption can be monitored directly and remotely with real-time output results. From the results of the measurement test using the PZEM-004T sensor, it was obtained that the difference in the value of the deviation that occurred was relatively small for voltage 0.538%, current 0.007%, electric power 0.383%, electrical energy 0.005% and power factor 0.039%, it was concluded that the PZEM-004T sensor could be used to further observations. At the same time, the real-time control panel output results to the Blynk server using the NodeMCU ESP8266 produce real-time work, as well as the use of relays as controllers of the tools that have been made, have been tested and obtained satisfactory results.

Keywords: *PZEM-004T Sensor, Relay, NodeMCU ESP8266, Blynk, Internet of Things.*

1. Introduction

Electrical energy is an essential requirement in various activities today. Almost all electronic devices that are used require electrical energy to operate. Therefore, the public needs to know how much electrical energy is used to maintain the quality of electronic devices. This quality needs to be known because it can affect electrical equipment's performance and service life. The aspect that can affect the value of electric power is the quality of electric power multiplied by the unit of time (hours) [1].

Based on the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia (ESDM-RI), Number: 14 of 2012, Regulations concerning Energy Management Related to Medium-Long Term Programs Including Increasing Equipment Efficiency. In this effort, the measurement stage is carried out to determine the consumption of electrical energy used [2]. Electrical energy monitoring is designed as a routine process of collecting or measuring information source data that determines the level of electricity consumption achievement in real-time. By using real-time information technology, the operating conditions of the hardware system and programs have clear timeframes.

Previously, research was carried out by Angher Dea Pangestu in 2019. This study discussed the accuracy of the tools made, which ranged from 96% to 98% on inductive and resistive loads used for research. From the results of the tests carried out, the authors were inspired to create a real-time monitoring system for electrical energy [3].

Subsequent research by Achmad Furqon and friends has made a monitoring system design using the PZEM-004T sensor to read voltage and electric current as input, the NodeMCU module to send data to the database, and the relay as control. The process of determining the measured electrical power is in the form of data sent to the Firebase real-time database and retrieved by Android from the internet, thus enabling this monitoring system to operate from any distance. Sensor readings show error accuracy. Sensor measurement results show an error accuracy of ± 1.8% compared to a digital multimeter. From the results of the research that has been done, the authors came up with a new idea in the measurement stage, namely monitoring electrical energy using the Blynk platform to make the measurement process more accessible and make it faster and more flexible [4].

Related research has been carried out using the Internet of Things (IoT), created by Kevin Ashton, executive director of the Auto-ID Center, MIT, in 1999. A device can transmit data over a network without using a computer or human device and can be accessed via long distance; with the IoT system, a user can monitor electricity consumption without going directly to the location [5].

From these problems, the authors are interested in conducting research that aims to monitor and obtain sources of information on the use of electrical energy in boarding rooms. This monitoring tool is based on a microcontroller. In addition, this monitoring tool is also based on IoT so that power consumption can be monitored directly and remotely with real-time output results. This design the author made with the title "Electrical Energy Monitoring and Control System in Boarding Rooms based on the Internet of Things (IoT)". The tool created by the author aims to help power users to provide information on the amount of electricity consumption consumed in boarding rooms and to help power users save on their consumption.

2. Literature Review

2.1. Electrical Voltage

The voltage can also be interpreted with current and resistance, the potential energy difference between two points measured in volts. Voltage is required to transfer a charge from one terminal to another. Electrical voltage can be measured using tools that are usually used, such as a voltmeter or multimeter [6]. The following equation can formulate electrical voltage.

$$V = I \,.\, R \quad (1)$$

2.2. Electrical Current

An electric current is generated due to the movement of electric charges, while the unit that expresses control is called the Coulomb. The definition of current is the rate of charge change per unit of time measured in units of amperes (A). Electric current flows from high to low potential, which can be measured using an electric current meter, usually an ammeter or multimeter [7]. The following equation can formulate electric current.

$$I = \frac{Q}{t} \quad (2)$$

2.3. Electrical Power

The rate at which electrical energy is absorbed is called power. In contrast, electric power is the amount of electrical energy that flows every second or joule per second measured in watts. In other words, electric power is the amount of work da voltage source does to produce an electric current per unit of time (joules) [8].

Active power (P) is the power needed at the current load. The unit of active power is the watt which can be measured using a wattmeter. The dynamic power equation is as follows:

$$P = V \,.\, I \,.\, \mathrm{Cos}\,\theta \quad (3)$$

2.4 Power Factor

Power factor (pf) is defined as the ratio between the reactive power (watts) and the real power (VA) used in AC circuits or the phase angle difference between the voltage and current expressed by the power factor. The power factor has a value between 0-1 which can be defined as a percentage (%). The ideal power factor value is close to 1 because a low power factor value can be detrimental and result in a high electric current [9]. The power factor can be formulated as follows.

$$\mathrm{Cos}\,\theta = \frac{P}{S} \quad (4)$$

2.5. Electrical Energy

Energy is the ability to do work, i.e., stored work. This understanding is not much different from physics; energy can be interpreted as the ability to do work. At the same time, electricity is a unit charge consisting of positive and negative controls [10].

The energy used in electrical equipment is the rate of energy use (power multiplied by the time the equipment is used). If power is measured in watt-hours, then watt hour (watt hour = Wh) is the energy released if 1 watt is used for 1 hour, by the formula [11].

$$W = P.t \quad (5)$$

2.6. Standard Deviation

The standard deviation is used when the data is extensive and has a dispersion of the average value so that the value of Sx will be significant. Still, if the data has a shallow distribution of the average value, the standard deviation value will be low [12].

$$\mathrm{Error} = n_t + n_u \quad (6)$$

$$\mathrm{Error}\% = \left(\frac{|n_t + n_u|}{n_t}\right) * 100\% \quad (7)$$

$$\bar{x} = \frac{x_1 + x_2 \dots + x_n}{n} \quad (8)$$

Standard deviation or standard deviation is a variability calculation technique with a very excellent race level compared to the range and interquartile range techniques. The standard deviation is one way to measure group variation in quantitative data; the value of Sx indicates the level of variance of a set of data [13].

$$SD = \sqrt{\frac{\sum x^2}{N}} \quad (9)$$

2.7. Monitoring System

The monitoring system is a routine process of collecting data from various sources to the activity's objectives. Monitoring efforts are used as information feedback to balance simple designs and targets. The data collected is real-time data [14].

The stages in the monitoring system are divided into three processes, namely:

1. Monitoring data collection process
2. Monitoring data analysis process
3. The process of displaying data

2.8. Internet of Things (IoT)

The Internet of Things (IoT) is a concept where an object can send data over a network without human-to-human or human-to-computer interference. IoT uses several technologies to expand internet network connectivity, including connecting equipment, machines, and other objects using network sensors and actuators to obtain data, regulate their performance, and produce automated work processes [15].

Fig 1. The concept of the Internet of Things

2.9. Blynk

Blynk is an application platform built for the Internet of Things (IoT). These applications can control hardware, view sensor data, store data, visualize, and much more. The Blynk application consists of 3 main parts, namely the application (app), server, and library, so the authors chose the Blynk application as the author's research platform. Widgets on Blynk include Button, Value Display, and History Graph [16]. The following is the display of the Blynk application shown in Figure 2.

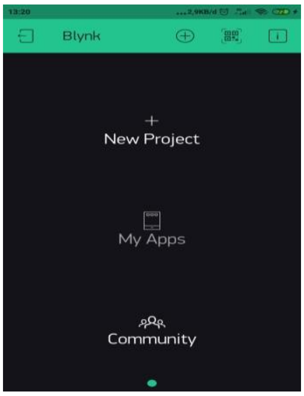

Fig 2. Initial display of the Blynk application

2.10. Arduino IDE

Arduino integrated development environment (IDE) is software that functions to create programs and upload them from a computer to the Arduino physical board. The program began using the Arduino IDE software to illustrate the design. The Arduino IDE makes it easy for users to write and upload code to the Arduino Uno and NodeMCU microcontroller boards [17].

The Arduino IDE program consists of a program editor, compiler, and uploader, namely:

1. Program editor: a window that functions to write and edit programs.
2. Compiler: functions to check whether there are errors or not in the program code that has been made.
3. Uploader: functions to upload (upload) the program results made to the Arduino board.

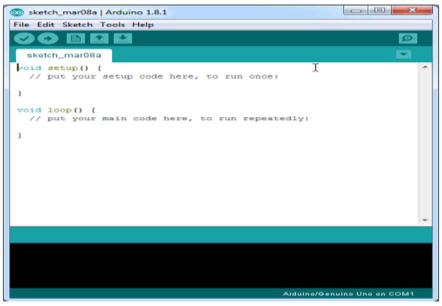

Fig 3. Display of the Arduino IDE software

2.11. NodeMCU

NodeMCU ESP8266 is a development derivative module of the ESP8266 ESP-12 IoT platform modules. Functionally, this module is almost similar to the Arduino module platform; only it is dedicated to connecting to the internet. There are multiple I/O pins so that they can be developed as a monitoring application for IoT projects. The NodeMCU module used is version 1.0 (unofficial) [18].

Fig 4. NodeMCU ESP8266

2.12. Relays

In general, the working principle of a relay is that it is classified as a type of switch in which the button functions as a closed or open circuit in an electric current that is controlled by a trigger or trigger signal from other electronic devices so that the electric current can be connected [19].

Fig 5. 2 Channel Relays

2.13. PZEM-004T sensor

The PZEM-004T sensor is hardware that functions to measure voltage, current, active power, frequency, power factor, and vibrant energy, a module without a display function, data is read through the TTL interface. The PZEM-004T board measures 3.1 × 7.4 cm. The PZEM-004T module is wound with a CT coil with a diameter of 3 mm, which is used as a current measurement with a maximum of 100A [20].

Fig 6. PZEM-004T Sensor

2.14. LCD (Liquid crystal display)

Liquid crystal display (LCD) is an organic mixture layer between a transparent glass layer with transparent indium oxide electrodes in the form of a seven-segment display and an electrode layer on the glass back. When the electrodes are activated by an electric field (voltage), organic molecules are generated. Long and cylindrical, according to segment electrodes [21].

Fig 7. LCD I2C size 16x2

3. Method

The research methodology is the stages, procedures, and specific techniques when presenting several activities carried out so that they can be well conceptualized and more structured. A flowchart makes it easier to analyze and implement an Electrical Energy Monitoring and Control System in Internet of Things (IoT) Based Boarding Rooms. Here are some blog research diagrams that can be seen below.

3.1. Electrical Energy Monitoring Tool Work System

Before entering the realization stage, an understanding of the tool's work system must be made so that the implementation of the design can be arranged as desired. The following is a flow chart of the electrical energy monitoring work system, as shown in Figure 9 below:

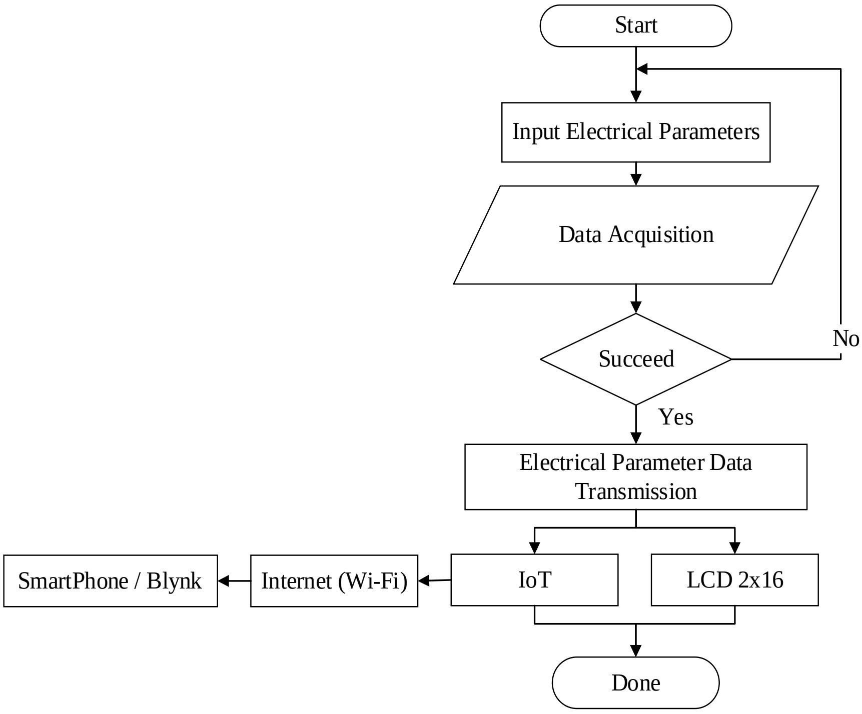

Fig 9. Tool work system flow chart

The tool work system flow chart can be described as follows:

a. Input electrical parameters measured using CT and input sources from sensors.
b. Data acquisition, namely the measured electrical parameter values, voltage, current, electric power, electrical energy, and power factor that work according to orders; if successful, the data can be processed. If not, then the sensor rereads the electrical input.
c. Transmission of electrical parameter data on LCD and IoT access using NodeMCU, which is sent to the server via WiFi.

4. Result and Discussion

An electrical energy monitoring tool can also be called a control box designed, built, and carried out in the testing phase. The testing phase is carried out by conducting a system functional test to determine the level of success and accuracy of the monitoring tool.

4.1. Test Results of Electrical Energy Monitoring Tool

The results of testing the electrical energy monitoring tool are divided into functional testing and testing of the overall system performance. The tests that have been carried out show the tool's level of function and performance, which will be explained in the description below.

a. PZEM-004T Sensor Test Results

   Results of the PZEM-004T sensor are carried out to see the level of accuracy of the sensor in measuring electrical parameters and whether it can work properly or not, which consists of the results of testing voltage, current, electric power, electrical energy, and power factor which are explained for each test below.

   1. Voltage Testing

      The voltage test is carried out three times by adjusting the AC source voltage on the autotransformer to 100V, 200V, and 220V. It is measured using a voltmeter measuring instrument and a connected control panel.

Table 1. The overall results of the voltage deviation on the PZEM-004T sensor

Testing	Voltage	Phase 1	Phase 2
		Standard Deviation	Standard Deviation
1	100	0.206	0.141
2	200	0.228	0.204
3	220	0.538	0.454

From the three results of the voltage test performed on the sensor for phases 1 and 2 above, the standard deviation (deviation) of the entire measurement is below 0.538%. The results of the variations that occur are relatively small, so it can be concluded that measurements using the PZEM-004T sensor for voltage can be used for further observations.

2. Flow Testing
   The test is carried out first by adjusting the AC source voltage on the autotransformer at 220V for each phase. Then set a fixed current value of 0.06A, 0.07A, and 0.1A, which is measured using a meter and control panel that is already connected.

Table 2. The overall results of the current deviation on the PZEM-004T sensor

Testing	Current (A)	Phase 1	Phase 2
		Standard Deviation	Standard Deviation
1	0.06	0.001	0.001
2	0.07	0.001	0.001
3	0.1	0.007	0.006

From the three results of the current test carried out on the sensor for phases 1 and 2 above, the standard deviation (deviation) of the entire measurement is below 0.007%. The results of the variations that occur are relatively small, so measurements using the PZEM-004T sensor against the current can be used for further observations.

3. Electrical Power Testing
   The test is carried out first by adjusting the AC source voltage on the autotransformer at 220V for each phase. Then tested using a 14-watt lamp, 18-watt lamp, and 23-watt lamp, measured using a meter and a connected control box.

Table 3. The overall results of the deviation of the electric power on the PZEM-004T sensor

Testing	Electrical power (W)	Phase 1	Phase 2
		Standard Deviation	Standard Deviation
1	14	0.146	0.383
2	18	0.179	0.150
3	23	0.039	0.085

From the three results of the electric power test carried out on the sensor for phases 1 and 2 above, the standard deviation (deviation) of the entire measurement is below 0.383%. The results of the variations that occur are relatively small, so it can be concluded that measurements using the PZEM-004T electric power sensor can be used for further observations.

4. Electrical Energy Testing
   Electrical energy testing is carried out by dividing the average value of active power by units of time per hour; this is done because the department of electrical energy is the kilowatt hour (kWh). After the test series has been completed, the test is carried out by recording the average active power value divided by the test time used. Each test is carried out with a duration of 60 seconds and uses a 220V AC voltage. This electrical energy test was tested using a 14-watt lamp, an 18-watt light, and a 23-watt light.

Table 4. The overall results of the deviation of electrical energy on the PZEM-004T sensor

Testing	Phase 1	Phase 2
	Standard Deviation	Standard Deviation
1	0.004	0.001
2	0.005	0.001
3	0.005	0.001

From the three results of testing the electrical energy carried out on the sensor for phases 1 and 2 above, the standard deviation (deviation) of the entire measurement is below 0.005%. The results of the variations that occur are relatively small, so it can be concluded that measurements using the PZEM-004T electrical energy sensor can be used for further observations.

5. Power Factor Testing
   Power factor testing is first carried out by uploading a unique program for power factor testing and creating a test circuit using an autotransformer, cosphimeter, control box, tested load, and sufficient connecting cables. The test is carried out first by adjusting the AC source voltage on the autotransformer at 220V. Then tested setting the bag used a 14-watt lamp, 18-watt lamp, and 125-watt electric motor to be measured using a connected cosphimeter and control box.

Table 5. Overall results of power factor deviation on the PZEM-004T sensor

Testing	Phase 1	Phase 2
	Standard Deviation	Standard Deviation
1	0.010	0.006
2	0.007	0.039
3	0.000	0.000

From the three results of the power factor test carried out on the sensor phase 1 and 2 above, the standard deviation (deviation) of the entire measurement is below 0.039%. The results of the variations are relatively small, so measurements using the PZEM-004T sensor on the power factor can be used for further observations.

6. Relay Performance Test Results
This relay test aims to determine the actions and conditions of the relay so that they are as expected. In the standard relay position installation, both relays 1 and 2 are connected to NC (Normally Closed). The following table shows the results of relay testing.

Table 6. Relay test results

Relays	Condition of coils	Relay Position	Information	Testing
Relays 1	LOW	NO	disconnected	Right
	HIGH	NC	Connect	Right
Relays 2	LOW	NO	disconnected	Right
	HIGH	NC	Connect	Right

The table above is the result of relay testing, which is intended to determine whether the condition of the relay is as expected and can interlock when source 1 comes from 220VAC or source 2 comes from a USB cable with an active 5VDC voltage.

4.2. Test Results of Electrical Energy Monitoring Tool

Realization of Electrical Energy Usage Monitoring System
Completing the monitoring system is the natural result of a tool successfully designed and tested for feasibility. Realization is carried out at a predetermined boarding location. The system realization process is then performed by installing the design results in the electrical box.

Table 7. Overall test results

Day Date	Dorm room	Power	Energy	Cost
Wednesday 07-12-2022	1	18.2	1.8	IDR 2,433.60
	2	79.9	2.1	IDR 2,839.20
Thursday 08-12-2022	1	18.1	1.81	IDR 2,447.12
	2	82.2	2.11	IDR 2,852.72
Friday 09-12-2022	1	18.2	1.83	IDR 2,474.16
	2	83.2	2.14	IDR 2,893.28
Saturday 10-12-2022	1	18.1	1.81	IDR 2,447.12
	2	84.3	2.16	IDR 2,920.32
Sunday 11-12-2022	1	18.2	1.81	IDR 2,447.12
	2	85.6	2.3	IDR 3,109.60

Electrical energy was monitored for five days to see the use of electrical power in boarding rooms. The use of electrical energy on Wednesday/07 December 2022, namely in boarding room 1, is 1.8 kWh with an electric power of 18.2 W and an electricity cost of Rp 2,433.60. Whereas in boarding room 2, the electricity consumption is 2.1 kWh with an electric power of 79.9 W, and electricity costs Rp 2,839.20; from monitoring data on the first day, it reaches 80 W. The comparison between boarding room 1 and room 2 is extensive because the use of electronic devices in room boarding house one is less than in room 2.

Conclusion

Based on the results and discussion of the electrical energy monitoring system that has been made, it can be concluded that:

1. The PZEM-004T sensor can measure a three-phase electrical box using three sensors for each phase. From the results of the measurement test using the PZEM-004T sensor, it was obtained that the difference in the value of the deviation that occurred was relatively small for voltage 0.538%, current 0.007%, electric power 0.383%, electrical energy 0.005% and power factor 0.039%, it can be concluded that the PEZEM-004T sensor can be used for further observation or monitoring.
2. The NodeMCU module can send control box output data to the Blynk server through an accessed program, namely by entering API keys uploaded to NodeMCU as a serial communication using Internet of Things (IoT) access and producing real-time output.
3. The created electrical energy monitoring tool can measure the use of electrical energy in two boarding houses per day, which is monitored directly on the control box display and via the Blynk server, which can be accessed remotely.

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