

Internet of Things

## Design of IoT Based Electrical Parameter Monitoring System using NodemCu V3 and PZEM-004T V3 Sensor

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### ABSTRACT

This research aims to design an electrical parameter monitoring system based on the Internet of Things (IoT) using NodeMCU V3 and the PZEM-004T V3 sensor. The system is designed to monitor various electrical parameters in real-time, including voltage, current, power, power factor, frequency, and energy consumption with high accuracy. Data collected by the PZEM-004T sensor is transmitted to Blynk via a Wi-Fi connection facilitated by NodeMCU V3. Users can access this information through Blynk, enabling efficient energy consumption management. By integrating IoT technology, this system provides a practical solution for monitoring and controlling electricity usage in household environments. The implementation of this system is expected to help users optimize energy consumption and effectively reduce electricity costs.

## INTRODUCTION

Every household has a direct connection to the kWh meter for electricity usage. When electricity consumption exceeds the specified capacity, this can cause excess power that can potentially trigger a power outage. If this situation occurs repeatedly, electronic devices in the home, such as refrigerators, televisions, dispensers, lights, and air conditioners, can be damaged. High-power appliances such as air conditioners usually consume more electricity, but total electricity consumption is also affected by the duration of use. Even low-power devices used for a long time can consume more energy than high-power devices that are only used briefly. Therefore, it is important to understand the dynamics of power usage so that equipment continues to function properly and the risk of damage can be minimized.

PT PLN provides kWh meters as the main infrastructure for measuring daily electrical energy for residential, public facility, and industrial customers. Although it plays a crucial role in billing, conventional analog (postpaid) kWh meters have limitations in presenting real-time energy consumption data, making it difficult for users to monitor actual usage. Based on previous studies, an IoT-based system with PZEM-004T sensors and NodeMCU ESP8266 is able to measure electrical parameters (voltage, current, power, energy) with an accuracy of up to 99.87% for current and 99.52% for voltage [1,2,3].

Therefore, this study proposes the development of an IoT-based real-time monitoring system integrated with the Blynk platform to visualize energy consumption data and cost estimates according to PLN's basic tariff. This system is designed using the Prototyping method by utilizing the NodeMCU ESP8266 microcontroller as the data processing core and the PZEM-004T sensor module as an electrical parameter reader. The implementation of the Blynk application-based interface was chosen to facilitate remote monitoring access via smartphone, optimizing user flexibility in controlling energy usage.

Based on the problems that have been described, a monitoring system is needed that is able to monitor electrical parameters in real-time to improve the efficiency of energy use and reduce power waste. Therefore, this study is entitled "Design and Construction of an IoT-Based Electrical Parameter Monitoring System Using NodeMCU V3 and PZEM-004T V3 Sensor". This system is designed to provide convenience in monitoring voltage, current, power, and electrical energy consumption through the Blynk application in real-time. In addition, this system was developed to display estimated electricity usage costs based on power usage, so that users can control electricity consumption more optimally and manage electricity expenses more efficiently.

## METHOD

This study uses several stages in the research completion process that are carried out in general in this study, namely:

1. Identification of Problems and Research Objectives:
  - a. Identification of problems: At this stage, identification of the problems underlying this research is carried out. For example, the problem could be the difficulty in monitoring electricity consumption in real time, the lack of detailed information about electrical parameters, or the need to improve energy efficiency.
  - b. Research Objectives: Formulated based on the problems that have been identified. The goal could be to design and build an IoT-based electrical parameter monitoring system that is able to provide real-time information about voltage, current, power, energy, and power factor and test the performance of the system.
2. Literature Study and Concept Design:
  - a. Literature Study: Conduct an in-depth study of relevant literature, such as scientific journals, conference articles, textbooks, and other sources that discuss electrical parameter monitoring systems, IoT technology, NodeMCU V3, PZEM-004T V3 sensors, and the IoT platform to be used.
  - b. Concept Design: Formulate the basic concept of the system to be built, including system architecture, how it works, and features to be implemented. This concept must be in line with the research objectives and take into account the results of the literature study.
3. Hardware Design: Selecting hardware components that suit the system needs and designing an electronic circuit schematic that connects all of these hardware components.
4. Software Programming: Creating a program for NodeMCU V3 that functions to read data from the PZEM-004T V3 sensor, process the data, and send it to the Blynk platform.
5. Calibration and Testing
  - a. Calibrate the PZEM-004T V3 sensor to ensure that the data produced is accurate and precise. Calibration can be done by comparing data from the sensor with a standard measuring instrument that has been calibrated.
  - b. Test the entire monitoring system to ensure that all components are working properly and according to the expected specifications. Testing includes functionality testing, performance testing, and security testing.
6. Data Analysis and Report Preparation:
  - a. Analyze data obtained from system testing to evaluate system performance, identify potential problems, and provide recommendations for improvement.
  - b. Prepare a research report that documents the entire research process, from problem identification to data analysis and recommendations. This report must be written clearly, systematically, and easily understood.

This structured research flow is designed to provide an in-depth understanding of the process stages in developing an electric meter monitoring system. Each stage in this flow has its own role in realizing the research objective, which is to create a system that is not only capable of monitoring electric meters in real-time, but also provides convenience for users in managing and optimizing IoT-based energy consumption. In this way, it is hoped that this research will provide a significant contribution in helping individuals and organizations to monitor electricity use effectively, identify potential energy waste, and take the necessary steps to achieve better energy efficiency. iResearch flow of the electrical power monitoring system is shown in detail which can be seen in Fig. 1.

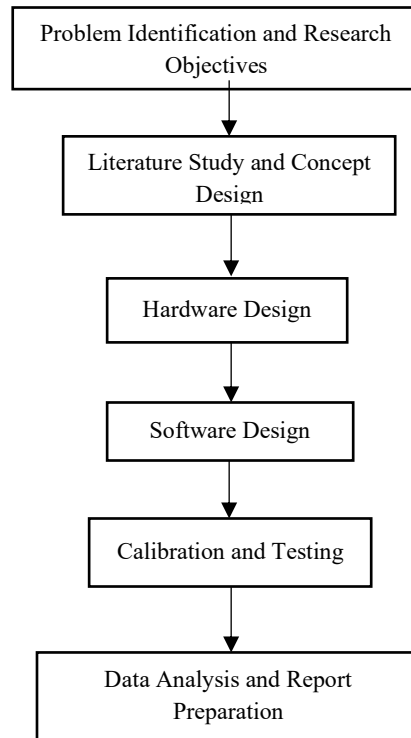


Figure 1. Research Flow

**Design of Devices**

In the design of an electrical power monitoring system based on the Internet of Things (IoT), Electronic goods are objects whose voltage will be measured, the power outlet is the connection for the electrical flow of electronic goods, the NodeMCU ESP8266 iV3 is used as a microcontroller to process and send data. The PZEM-004T V3 sensor functions to measure electrical parameters such as voltage, current, and power used. iRelay functions as an electronically controlled switch to disconnect or connect the power supply to a device connected to an electrical outlet. The measurement data is displayed locally using the i2c LCD, while the Blynk application allows users to monitor the data in real-time via a smartphone. The circuit of the electrical current monitoring system is as follows.

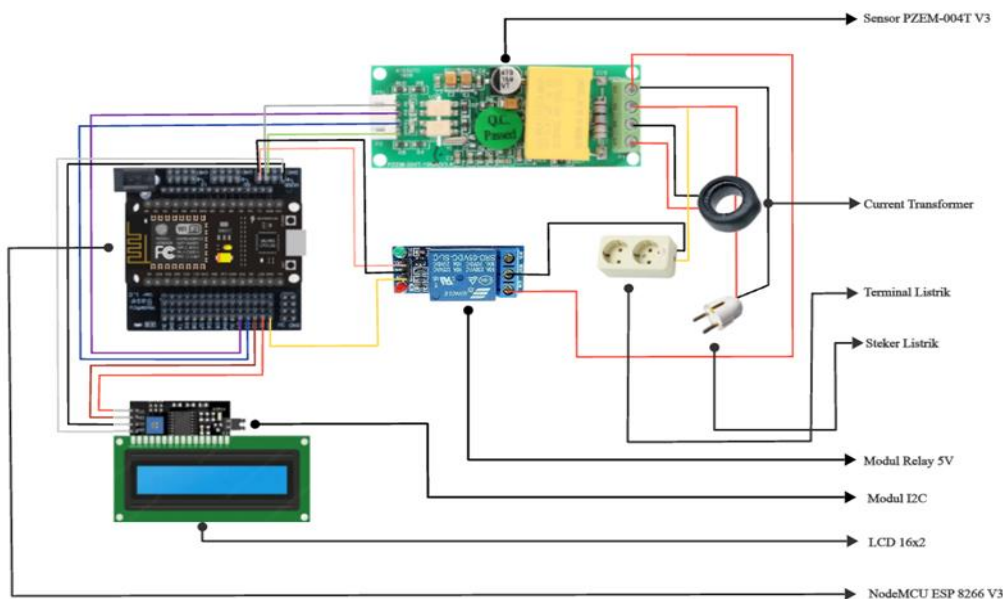


Figure 2. Tool Set

The electrical parameter monitoring system circuit shown in Figure 2. consists of several components connected to the NodeMCU microcontroller. Here is an explanation of the role of each component in the circuit:

1. NodeMCU iV3: It is an ESP8266 microcontroller that supports WiFi. Its function is to process data obtained from the electrical energy sensor, then process the information to be displayed on the LCD screen and also send it online to the server. In this way, users can monitor the use of electrical power online through the iBlynk application.
2. PZEM-004T iV3 Sensor: Is an electronic sensor which functions to measure various electrical quantities such as: Voltage (volt), Current (current), Power(power), Frequency, Energy Power Factor.
3. LCD i2C i16 ix2: This iLCD is used to display data that has been obtained from the iPZEM-004T sensor, such as voltage (Volt), current (Ampere), power (Watt), and also price according to power usage.
4. 5V channel relay: as an electronic switch that is controlled by the iNodeMCU to disconnect or connect the electrical current to the device that is connected to the iNodeMCU, thus making it possible to control the distance between the device.
5. Power outlet: Functions as an access point to connect various electronic devices that will be monitored, allowing these devices to operate properly.

## RESULTS AND DISCUSSION

The results and analysis of the IoT-based electrical parameter monitoring system will be discussed in depth. The discussion includes the performance of the designed system, starting from measuring electrical parameters by the PZEM-004T sensor, data processing using NodeMCU V3, to presenting data via LCD i2c and the Blynk application. In addition, evaluation of the system test results is carried out to assess the accuracy, reliability, and efficiency of the system in monitoring electrical parameters in real-time. With this discussion, it is hoped that readers can understand the performance and advantages of the designed system.

In the implementation of the tool testing, electrical parameters will be read from several electronic devices in the researcher's home which have a total power of 1300 watts. The data obtained from this measurement will be analyzed to calculate the cost of using the electronic devices within a 24-hour period. This test aims to provide accurate information about the amount of energy used by various electronic devices. The results of this test will be a reference for assessing whether the tool made has achieved the desired results or still requires further improvement.

### *Tool Design Results*

The hardware design results for the Internet of Things-based electrical meter monitoring system consist of several main components, namely NodeMCU ESP8266 V3, PZEM-004T V3 sensor, relay, and I2C LCD. These components work synergistically to monitor and manage the use of electrical power efficiently. The image below shows the physical configuration of the designed tool.

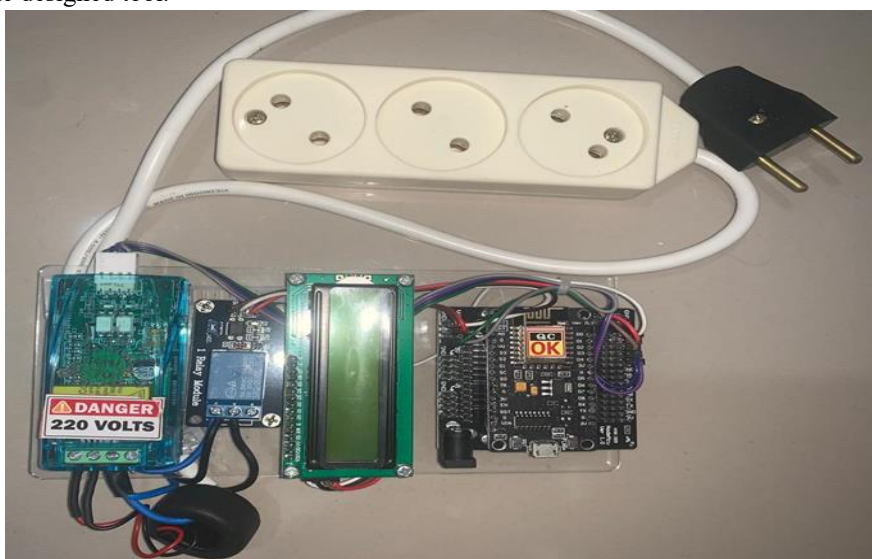


Figure 3. Tool Design Results

**Implementation and Testing of the System on Resistive Loads**

Resistive loads are a type of electrical load that only has electrical resistance (resistance) and does not have significant inductance or capacitance. This means that the current and voltage are in the same phase, without a phase angle shift.

The electronic item used in the test was an iron with a maximum power of 400 Watts. The test was carried out for 30 minutes, with monitoring every minute of the variation in the value of each parameter, as shown in Figure 4. In this test, the iron was operated under low power conditions to simulate minimal energy use but remained active.



Figure 4. Iron Testing

Table 1. Iron Measurement Data

Time (Minutes)	Voltage (V)	Current (A)	Measurement			
			Power On (W)	Energy (Kwh)	Frequency (Hz)	Estimated costs
0	221	1.66	367	0.000	50.1	0.00
5	220	1.68	369	0.031	50.0	44.79
10	223	1.67	372	0.062	50.2	89.57
15	219	1.70	373	0.093	49.9	134.36
20	218	1.69	368	0.124	50.0	179.14
25	222	1.67	371	0.155	50.1	223.93
30	220	1.68	370	0.186	49.8	268.71

Table 1 above shows the results of electrical meter measurements on an irresistible load for 30 minutes with a recording interval of every 5 minutes. The parameters observed include voltage, current, active power, energy, frequency, and estimated cost. The voltage is recorded as stable in the range of 218–223 V, with a current ranging between 1.66–1.70 A. The active power generated is in the range of 367–373 W, while the frequency remains within the PLN standard, which is 49.8–50.2 Hz.

The accumulated electrical energy increases gradually from 0.000 to 0.186 KWh, reflecting energy consumption proportionally to time. The estimated cost of electricity usage also increases linearly, from Rp0 to Rp268.71. These results indicate that the monitoring system used is able to record and display electrical data accurately, as well as provide real-time information that is useful for analyzing energy consumption and power efficiency.

### ***Implementation and System Testing on Capacitive Loads***

Capacitive loads are a type of electrical load that has a dominant capacitance element, causing the electric current to precede the voltage in the AC wave cycle. In other words, there is a phase angle shift between the current and voltage due to the capacitive characteristics. Capacitive loads are commonly found in electronic devices that use components such as capacitors.

In this test, the device used is an LED lamp with a maximum power of 12 Watts. The test was carried out for 30 minutes with data recording every 5 minutes to monitor variations in electrical parameters such as voltage, current, active power, energy, frequency, and cost estimates. During the process, the LED lamp was operated constantly to simulate light capacitive load conditions commonly found in household applications. Even at low power, this load remains active and shows stable energy consumption characteristics, as shown in Figure 5.



Figure 5. LED Light Testing

Figure 5 shows that the monitoring system tool has been used in testing with a capacitive load in the form of an LED lamp. This tool is able to read the electrical meter well during the test.

## **CONCLUSION**

Based on the results of the research that has been carried out by the author, there are several important points that can be concluded as explained below:

The IoT-based electrical parameter monitoring system was successfully designed and implemented using the NodeMCU ESP8266 V3 microcontroller and PZEM-004T V3 sensor. This system is capable of measuring electrical parameters such as voltage (V), current (A), active power (W), frequency (Hz), energy and energy (kWh) in real-time as well as calculating estimated electricity usage costs based on PT basic rates. PLN.

Data from measurement results from the PZEM-004T V3 sensor can be displayed in the LCD I2C and can also be monitored via the mobile application from the smartphone. This can enable users to monitor or control electrical energy consumption at any time via the WiFi connection. The Blynk application is also used to control relays, so that connected electronic devices can be activated or deactivated automatically.

Through the testing process and data collection on three different types of electrical loads, namely resistive loads using electricity, inductive loads using a fan, and passive loads using LED lights, the system that has been developed can measure various electrical parameters automatically. Accurate for each of these electronic devices. For irrisistive loads, the system records stable voltage between 218–223 V, active power 367–373 W, and accumulated energy of up to 0,186 kWh 30 minutes, with estimated costs reaching Rp268.71. For capacitive loads, the voltage is in the range of 221–224 V, the active power is around 11.2–11.5 W, with a total energy of i0.006 kWh and an estimated cost of iRp. 8.67. Meanwhile, on the inductive load, the voltage was recorded to be stable between i221–223 V, the active power was 59.64–69.46 W, with an energy of 0.038 kWh and the estimated cost reached Rp0.22. In general, the power system follows the power consumption dynamics of each type of load with a good level of precision. The gradual improvement in energy and cost

according to the duration of use shows that this system can be relied on to monitor electricity consumption, analyze energy efficiency, and assist users in managing power usage more wisely.

The monitoring system developed in this study not only functions as a technical monitoring tool for electricity consumption, but also provides added value through electricity cost estimation and load control features. These features allow users to more easily manage household electricity expenditure efficiently, increase awareness of daily energy consumption patterns, and prevent power waste. In addition, this system also plays an important role in maintaining the safety of electronic devices by preventing the risk of damage due to uncontrolled power surges. Thus, this system is not only useful from a technical perspective, but also makes a real contribution in supporting energy efficiency and saving electricity costs in the household environment.

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