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# Designing a Monitoring and Controlling System on IOT-Based Sockets

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***Abstract* – The government's program to promote energy conservation efforts is conducted by reducing the occurrence of vampire power in the surrounding environment, particularly in the household sector. For this reason, modifications are made to the socket so that it can be controlled and monitored remotely through an application on a smartphone. The hardware design uses the NodeMCU ESP8266 V3 as a microcontroller combined with the PZEM-004T sensor module to read current, voltage, and power values. Relay module is used to secure the circuit in case of higher loads. So that in the system, the three sockets can be monitored simultaneously. While the software design uses the MIT app inventor as the user interface, and the Thingspeak platform as a server. The data is saved in .csv format, which can be opened in Microsoft Excel. The data stored is in the form of the name of electronic equipment, the time of use, as well as the voltage, current, and power of the device. So that users can manage the use of electrical appliances at home and reduce the occurrence of energy vampires. The test results showed an average voltage error rate of 0.24% with a voltage range of 226 V–230 V, an average current error rate of 22.18%, and an error rate on power of 15.39%. This is caused by the measured load being too small, resulting in higher errors in current and power.**

***Keywords: App Inventor, NodeMCU ESP8266, PZEM-004T, Socket, Thingspeak***

## I. INTRODUCTION

The rapid development of technology encourages human to maximize its performance in everyday life, especially in IoT technology. Internet of Things (IoT) uses the internet to obtain information more quickly and easily, as well as to connect and control devices without the need for human intervention [1]. Electrical energy is the main source of all electronic equipment connected to the electrical system [2].

In connection with the increasing demand for electricity, according to National Electric Company (PLN) 2021 static data, PLN customers from the household sector amounted to 72,606,681, this is due to the large use of electronic equipment. But it is not known in detail which electronic equipment consumes higher electrical power, and PLN also has a limit on the electrical power capacity in each residential house [3]

Simple habits can give rise to vampire power, that is the habit of leaving electrical appliances in a standby state without being removed from the socket when leaving the house. So that electric current will flow from the electronic equipment cable that is still connected to the socket, which will cause heat hazards to the socket and energy waste [4].

These electric vampires are extremely dangerous because, according to data from www.standbylbl.gov or Lawrence Berkeley National Laboratory, electric vampires can consume 5% to 25% of total electricity used per month when in stand-by mode. For example, a laptop charger that is no longer connected to a laptop still consumes 1 watt of electricity, or 0.001 kWh.

For this reason, a tool that can monitor and control the use of electronic goods at home and can be combined with an IoT system is needed. Therefore, this research entitled "Designing a Monitoring and Controlling System on IoT-Based Sockets" has been proposed. With this tool, it is expected that users can reduce the occurrence of electrical vampires from electronic equipment, help managing the use of electronic equipment at home in real time, and save distance and time by using applications installed on the user's smartphone.

## II. METHODOLOGY

Research [5], uses the Arduino Nano CH340 as a data processor combined with the Wemos D1 mini for sending data online, and also a 2-channel relay. The result of this tool is that it can save electricity consumption worth Rp 53,320.99, or equivalently 36,908 kWh per month.

Research [6], uses the NodeMCU ESP8266, PZEM-004T, and 16x2 LCD to display data results to users, as well as the ubidots platform as an IoT platform, was displayed in the browser. The results of the study were obtained with voltage, current, and power error rate of 98.94%, 99.18%, 98.87%, respectively, a power factor of 98.44%, and an energy consumption rate of 97.89%.

Research [7], NodeMCU was used as the control center, a relay as a light switch, a PZEM-004T module as

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an electrical power monitoring sensor, and displaying data on Android applications. The research aims to control the lamp manually or automatically with a timer. The results of processing the data will be saved to the Firebase server.

Based on the literature studies, this research has the advantage of using previously created studies or systems. First, it can monitor three relays simultaneously. Second, it can display data using an application that is on the user's smartphone. Third, when data is processed using the Thingspeak platform, the results are saved in .csv format and can be converted to Microsoft Excel. This can make the users easier to manage the use of electronic equipment. This research also uses electronic equipment with different loads.

*A. System Design Method*

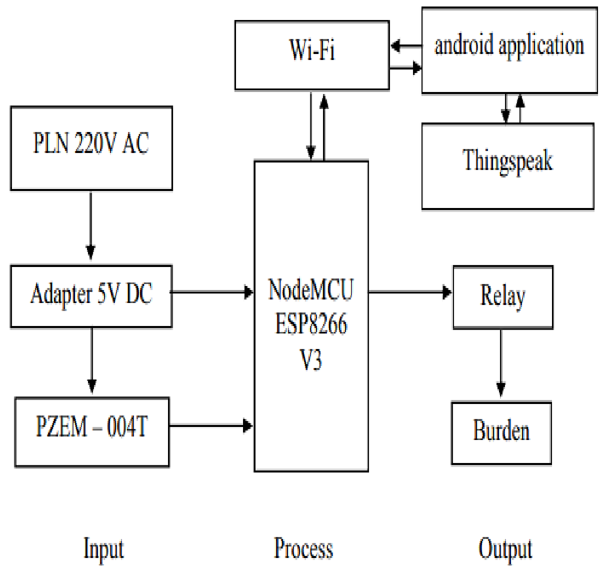


**Figure 1.** Block diagram of the system

Figure 1 shows the entire system, from inputs to processes and outputs. For input, in controlling the socket, a PLN (National Electric Company) power supply of 220V AC is given, which is converted by the adapter to obtain an output voltage of 5V DC which is the input voltage for NodeMCU. In the process of monitoring, the PZEM module that has been electrified and the internet connection will send a signal to the NodeMCU. So, NodeMCU will process that data to send to Thingspeak's servers and display that data on the user's smartphone. While controlling NodeMCU, it will send a digital signal to the relay module. For output, if a relay module has received a signal, the socket can be used by activating it through the application. The data that has been sent to the server will be displayed by the application installed on the user's smartphone.

The flowchart in Figure 2 depicts how this system operates: The tool can be run by connecting the plug to the 220 V AC contact box as well as the smartphone must be connected to the internet.

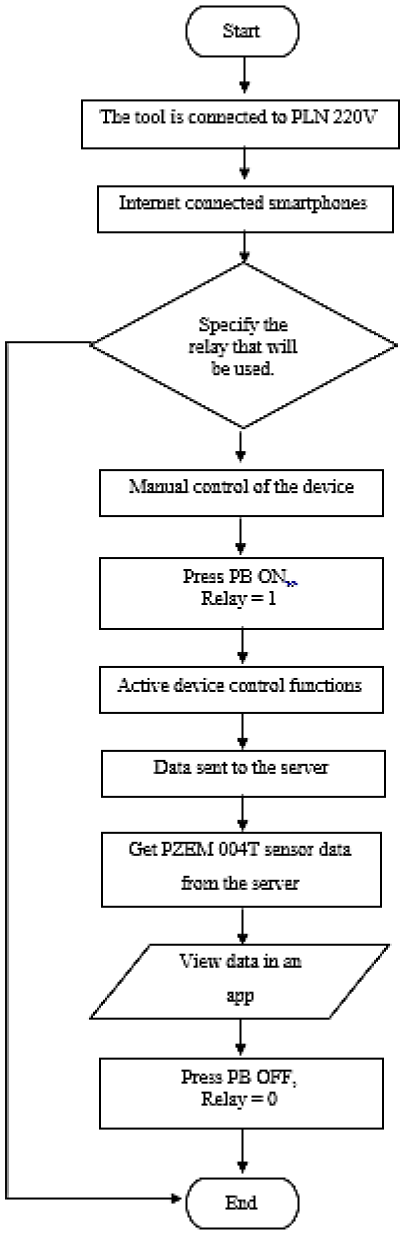


**Figure 2.** Flowchart of IOT-based socket control and monitoring system

After the smartphone is connected, the user will determine which relay to use (R1, R2, or R3). Before pressing the ON button, the user is required to fill in the name of the device to be connected. This aims to make it easier to store data for electronic device management. Furthermore, if the ON button is pressed, the relay will change its status to 1 (active), the electronic device will turn on, and the PZEM-004T sensor will get data and send it to the Thingspeak server. The data sent to the server is in the form of device name, relay name, voltage, power, current, and time. While the data that appears on the smartphone is the name of the device, power, voltage, and current. When the OFF button is pressed, the relay's status changes to 0 (off), and the electronic device turns off. The user will specify the relay or socket to be used via smartphone.

### *B. Hardware Design*

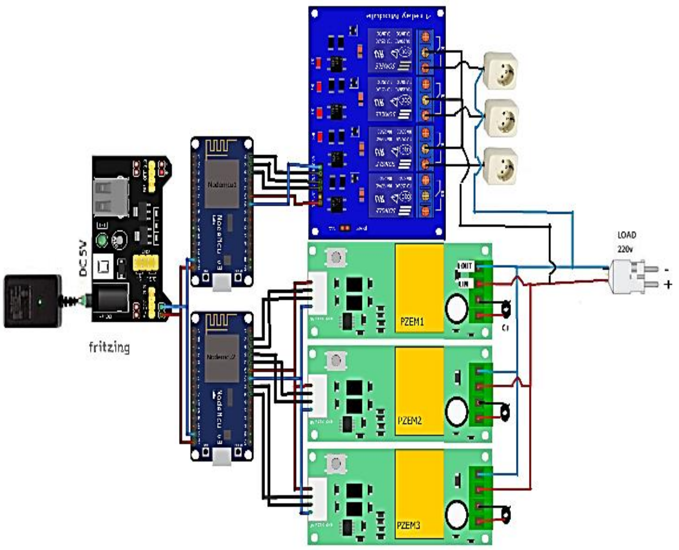


**Figure 3**. Wiring diagram

Figure 3 shows the overall hardware circuit image. In the network, there are two NodeMCUs: one on the controller is used as a client connected to the relay module, and another is used for wheel monitoring as a server connected to the PZEM module.

### *C. Software Design*

Software design begins with creating three programs, namely, programs for the Arduino system, for application systems, and Thingspeak server.

#### *1) Arduino Program*

This program is created by using Arduino IDE software version 1.8.19 by incorporating several libraries for components into the Arduino IDE. It aims to connect each component so that it runs according to its function. It further integrates the created program into the existing control system [8]. In the design, two program codes were made on Arduino, namely NodeMCU ESP8266 as relay control and NodeMCU ESP8266 as monitoring PZEM-004T.

#### *2) Android app program*

The Android program is made by connecting the inventor's blocks using the App Inventor software. App Inventor, from MIT (Massachusetts Institute of Technology), is a development tool used to create apps for phones and tablets. In designing the screen display, it can be done by connecting blocks, or using the "Click & Drag" [9].

#### *3) Thingspeak Server*

Three Thingspeak channels are created in the design, where each channel will be connected to a relay. It aims to store data on Thingspeak's cloud server. The data that has been displayed will also be stored in the Thingspeak cloud, it can be downloaded in .csv format, and can be converted into Microsoft Excel [10].


**Figure 4.** Appearance of one of the Thingspeak channels

Figure 4 shows the appearance of one of the three Thingspeak channels where the server will display the graphs of voltage, current, and power readings. The result is the data read by the PZEM 004T module. If the tool is off, then the graph will show the number 0. The circle image indicates if the socket is active. The "Lamp Indicator" shows the condition of the socket; if it is green, it means that the socket is active or can be used.

## III. Results and Discussion

### A. Result of Hardware Design

**Figure 5.** Control and monitoring tools for sockets

Figure 5 shows the results of the tool that has been designed. Visible a rectangular box with a size of 22 x 18 cm. The box is useful as a place for all components to be used as well as avoiding external interference, there are 3 stops at the top of the box.

### B. Functional Testing

This test aims to analyze the system for receiving and transmitting data on the NodeMCU ESP8266 with PZEM 004T, relay, and server thingspeak. The equipment used is a 5V MB102 power supply, which is used as a power supply for the NodeMCU ESP8266, PZEM 004T, and relays. The test procedure is carried out by stringing together the entire sub-system according to the block diagram of the tool design in Figure 3. The success parameters of the system are determined by whether the tool can connect and disconnect the flow of electricity.

### C. PZEM 004T Sensor Module Testing

This test aims to find out the level of accuracy of voltage and current readings by comparing the error rate for each socket measured by the design tool with a digital multimeter.

The test lasted for two days and required each socket monitor electronic equipment with varying loads:

1) First Day
   a) Socket-1 : Laptop Charger
   b) Socket-2 : Fan
   c) Socket-3 : Printer
2) Day two
   a) Socket-1 : TV
   b) Socket-2 : HP Charger
   c) Socket-3 : Electronic mosquito repellent

Each test was taken five times for an hour. Meanwhile, in the power test, the power value on the PZEM-004t sensor was compared to the power meter by conducting five experiments at each load.

#### 1) Voltage Testing

**Table 1.** Data from voltage monitoring

| No | Burdens | Multi meter | PZEM-004T | % Error |
|---|---|---|---|---|
| 1 | Laptop Charger | 228.9 | 229.1 | 0.09% |
| 2 | TV | 226.7 | 227.6 | 0.39% |
| 3 | Fan | 229.8 | 229.1 | 0.13% |
| 4 | Hp Charger | 226.7 | 227.7 | 0.47% |
| 5 | Printer | 230 | 230.1 | 0.06% |
| 6 | Electronic mosquito repellent | 226.6 | 227.1 | 0.24% |
| **Average** | | | | 0.23% |

Based on measurements and tests as shown in Table 1, the voltage difference between the measurement results and the multimeter is relatively low, with voltage readings with a range of 226 V–230 V which is still considered to be normal. The average voltage error is 0.24%. So it can be concluded that the voltage sensor readings have a high level of accuracy and precision.

#### 2) Current Testing

**Table 2.** Data from current monitoring

| No | Burdens | Multi meter | PZEM-004T | % Error |
|---|---|---|---|---|
| 1 | Laptop Charger | 0.27 | 0.31 | 15% |
| 2 | TV | 0.30 | 0.31 | 2.2% |
| 3 | Fan | 0.262 | 0.288 | 10.1% |
| 4 | Hp Charger | 0.068 | 0.06 | 11.3% |
| 5 | Printer | 0.019 | 0.025 | 27.6% |
| 6 | Electronic mosquito repellent | 0.020 | 0.029 | 46.7% |
| **Average** | | | | 18.8% |

Based on measurements and tests as shown in Table 2, the error in current readings is relatively high because the measured load is too small. The accuracy of the design tool in the current readings increases as the power of the electrical equipment increases. However, for tools with low power ratings, such as mobile phone chargers, printers, and electronic mosquito repellent, the percentage of error is high. A low-power device will cause a small current to enter the sensor module, resulting in a small analog output from the sensor. A small analog value that goes into the ESP8266 microcontroller's Analog Digital Converter (ADC) will produce an output close to 0 A. As for other electrical equipment, the current measured by the design tool is almost equal to the actual value, with the highest variance of 15%. One of the causes of this error is the inaccuracy of the voltage provided in the real world. The value of the supplied voltage may not be exactly 220V. Another factor is the possibility of a current leak in the system that the sensor fails to detect. The ambient temperature can also affect the accuracy of the sensor. If the temperature is higher, the resulting resistance will be even greater. The greater the resistance, the stronger the current flowing in the circuit will be.

### *3) Power Testing*

**Table 3.** Data from power monitoring

| No | Burdens | Power Meter | PZEM-004T | % Error |
|---|---|---|---|---|
| **1** | Laptop Charger | 35.9 | 36.94 | 4.25% |
| **2** | TV | 44.3 | 43.66 | 1.43% |
| **3** | Fan | 67.52 | 61.62 | 8.74% |
| **4** | Hp Charger | 6.34 | 7.4 | 17.50% |
| **5** | Printer | 2.3 | 1.98 | 38.96% |
| **6** | Electronic mosquito repellent | 5.92 | 6.28 | 6.08% |
| | **Average** | | | 15.39% |

Based on measurements and tests, as shown in Table 3 the error in power readings is relatively high because the measured load is too small. The accuracy of the design tool in the current readings increases as the power of the electrical equipment increases. However, for equipment with a low power rating, such as a printer, the percentage of error is the highest. In measuring the printer, the power obtained is small. This is because when retrieving printer data in a standby condition, the printer is on but inactive for printing process. This is comparable to the printer's data sheet; for standby mode, the power consumption is ± 2 W.

A low power tool will cause a small current to enter the sensor module, resulting in a small analog output from the sensor. A small analog value that goes into the ESP8266 microcontroller's Analog Digital Converter (ADC) will produce an output close to 0 A. For other electrical equipment with high power, such as a television, the power measured by the design tool is nearly identical to the actual value, with an average error of 1.43%.

### *D. Application Interface*


**Figure 6.** Application display when disconnected to the system

Figure 6 shows the condition of the application when it is disconnected to the Internet. In the electrical parameter column, there is an inscription "NAN," which means Not A Number. This is because the PZEM module not able to transmit data to the server.

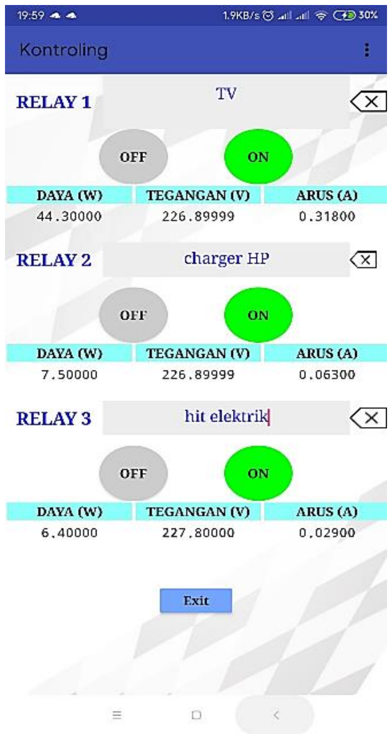


**Figure 7.** Display of the application when connected to the system

Figure 7 shows the state of the application when it is connected to the Internet and running. Where Relay 1, 2, and 3 are active. And in the parameter column, there is already a lift, which is the result of reading the PZEM module that has been sent to the server.

## IV. CONCLUSION

The average difference of voltage, current, and power readings between the designed tool and multimeter are 0.24%, 22.18%, and 15.39%, respectively. So it can be concluded that the current sensor readings have a lack of precision but can still be used for research purpose. The measured load is too small so that the error is relatively high. Its applications on smartphones can make it easier for users to control the use of electronic equipment at home. Where data processing on the socket monitoring and control system can be stored in the Thingspeak web and the data is downloaded in .csv format and can be converted into Microsoft Excel. Data is stored in the form of usage time, voltage, current, power, and the name of the connected electronic device. As a result, users can better manage their electronic use at home.

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