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Electricity Power Monitoring Based on Internet of Things

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ABSTRACT

Every year, electricity consumption in Indonesia has increased in line with population growth and the national economy. One of the factors causing an increase in electricity consumption in Indonesia, one of which is caused by the lifestyle of modern society which is wasteful in using electricity. Modern society is increasingly using electricity inefficiently. One potential solution to this problem is the use of the Internet of Things (IoT) concept. The Internet of Things, or IoT for short, is a system of connected computing devices whose sole purpose is to maximize the benefits of an internet connection. The system built using the PZEM-004T sensor which is processed by the Arduino Uno microcontroller will be sent to Wemos D1 Mini via serial communication (TX-RX) so that it can be displayed on the BLYNK New IoT application on a smartphone. As for the parameters that will be displayed in the BLYNK application, namely voltage, current, and power usage of electrical devices. By using this application, users will be able to more easily and effectively monitor and how much electrical energy is used by equipment remotely. This equipment has been tested from September to October, on 5 electronic devices such as lights, TVs, refrigerators, rice cookers, fans with satisfactory results, namely being able to monitor the use of electrical devices using smartphones through the BLYNK application.

1. Introduction

Perusahaan Listrik Negara (PLN) is a company under the Ministry of Badan Usaha Milik Negara (BUMN) which has the task of meeting all electricity needs in Indonesia [1]. Modern society is increasingly using electricity. Most human activities depend on electrical energy. The use of electrical energy must be as effective as possible because inefficient use of electrical energy results in an increase in overall electrical energy consumption. Consumption of electrical energy is very useful for various human activities [2]. When you leave electrical devices such as lights on standby when not in use, the use of electrical energy is not efficient. Therefore, we need a technique that allows us to control how electricity is used and ensure that it is not misused.

One potential solution to this problem is the use of the Internet of Things (IoT) concept. It is a system of connected computing devices whose primary purpose is to simplify the process of managing and monitoring physical goods, potentially for use in most daily activities [3].

The notion of the Internet of Things is essential in power usage monitoring, enabling more efficient optimization of consumption in response to specific requirements or situations. The program will display data based on the results of the lamp's assessment of electricity usage [4]. Among the measurements displayed are voltage, current, and power. The cornerstone of this program is BLYNK, which will transmit data obtained from electricity measurements to the internet [5]. By using this application, users will be able to more easily and effectively monitor and control how much electrical energy is used by lamps remotely [6].

Research conducted by Jefri Lianda, Dolly Handarly, Adam. To monitor the amount of electricity consumed on the Ubidots interface in real time. This system can display data in the form of graphs and tables and has an average accuracy rate of 97.56% [7].

Furthermore, research conducted by Ivan Safril Hudan, Tri Rijianto, to make it easier to monitor electricity consumption in boarding rooms based on IoT. The quantitative approach is one that is used when collecting data. During this research, voltage sensors, current sensors, small Wemos D1, 5V relays, and Arduino Uno R3 were used. This application will track the electricity generated by the Internet of Things. The results showed that the average error for testing the voltage sensor was 0.02%, the average error for testing the current sensor was 0.01, and the average error for testing the power value was 0.22% [8].

Research conducted by Tanto, Darmuji is to combine Arduino, ESP, and Android to track how much electricity is used in households. To ensure that the costs associated with paying for electricity each month do not increase, this consumption can be monitored using a smartphone. The author takes 37.36 watts per hour as the average amount of electricity used by lamps and solder as data, which we will then convert to rupiah [9].

In this study aims to track the use of electrical energy in relation to the cost of maintaining electronic equipment. Users are expected to be encouraged to limit their use of electrical energy to avoid wastage which can lead to increased costs after knowing these costs.

2. Method

Monitoring is an activity aimed at providing information obtained from the system. Monitoring will provide data on current (I), power (W), voltage (V), power factor (pf), cost (Rp), and energy (kWh). The purpose of this system is to monitor the accuracy of the quantity of current (I), power (W), voltage (V) that arises due to the use of electric power loads and provide data about the values that have been read.

Microprocessors used for control and instrumentation are a kind of digital electrical devices that have inputs and outputs, can read and write data, and can execute certain programs that have been written and erased. An on-chip microprocessor called a microcontroller can be used to operate electrical devices in an effort to increase energy and financial efficiency [10]. With the help of this microcontroller it is possible to minimize the amount of support required, finally centralize it, and operate legacy electronic systems, which previously required a lot of assistance from components such as IC, TTL, and CMOS [11].

Using the PZEM-004T sensor which is used to measure voltage (V), current (I), power (W), frequency (Hz), energy (kWh), and energy factor. With the integrity of this function, the PZEM-004T module is ideal for use as an experiment with pressure gauges in electrical networks such as homes [12]. So that the author creates a tool system that can monitor the power of home electrical devices using Internet of Things technology. (IoT) works by collecting information from sensor readings related to actual objects and sending that information to servers. The tool created consists of several supporting circuits such as the Arduino uno microcontroller [13], the PZEM-004T sensor, and Wemos D1 Mini. The results of the PZEM-004T sensor readings processed by the Arduino Uno microcontroller will be sent to Wemos D1 Mini via serial communication (TX-RX) so that they can be displayed on the BLYNK New IoT application on smartphones. As for the parameters that will be displayed in the BLYNK application, namely voltage, current, and power usage of electrical devices [14]

2.1. Device Design

Schematic design of the overall tool system circuit consisting of all circuits used in the tool system. The schematic details of the tool system are shown in Fig. 1.

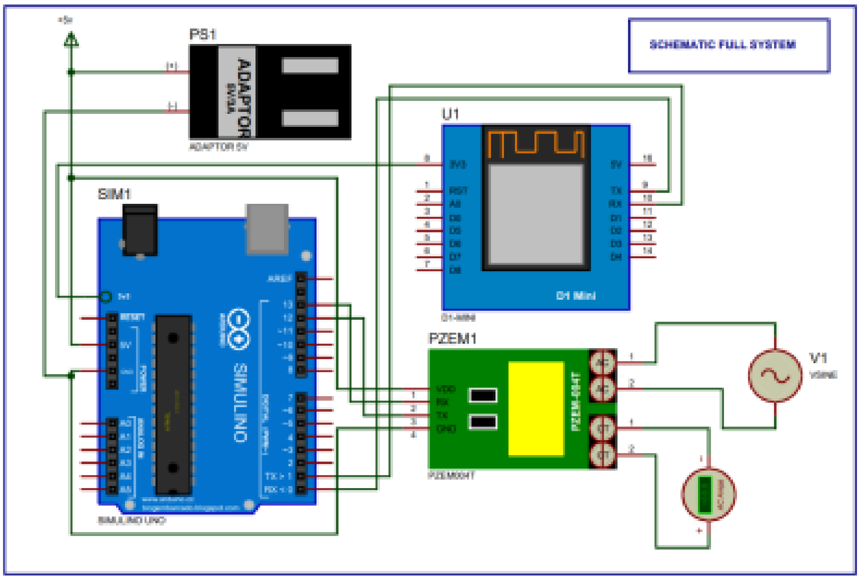

Fig. 1. Schematic of the tool system

Fig. 1 is a schematic of the tool system used in the final project tool. This schematic is a combination of all the circuits used. The 5 Volt adapter provides power supply voltage [15] to the Arduino 5V power pin or can also be via the USB connector on the Arduino Uno. The voltage obtained from the 5V adapter is then distributed throughout the input and output circuits. The PZEM-004T sensor reads the voltage and current values on the tested electrical device by connecting the AC IN pin to the PLN power grid and connecting the CT IN to a load-bearing socket cable. Arduino Uno processes the voltage and current data from the PZEM-004T sensor readings and sends them to Wemos D1 Mini.

The design of the software in this study contains the process of making flowcharts of how the tool works and designing the BLYNK interface. The flow diagram of how the tool works will later be used as a reference for building the tool program algorithm. While the design of the BLYNK interface contains the appearance of the BLYNK design that has been designed on the web dashboard and mobile dashboard. The views of the two dashboards are shown in Fig. 2 and Fig. 3.

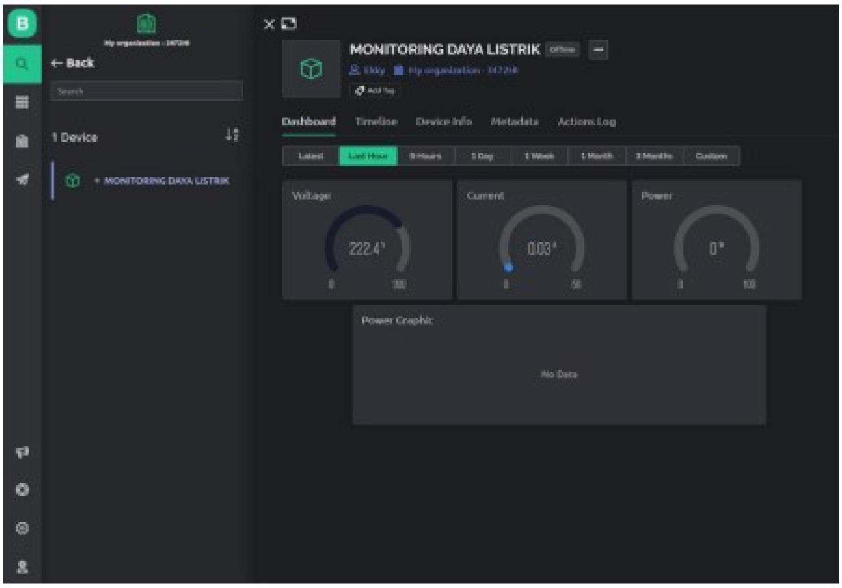

Fig. 2. Blynk web dashboard design

Fig. 2 is the design of the BLYNK Web Dashboard used in the tool system. The widgets used on the BLYNK web dashboard are outlined. Gauge 1 displays the voltage value, Gauge 2 displays the current value, Gauge 3 displays the power value, and Power Graphic displays the historical graph of power. While the display on the mobile dashboard is shown in Fig. 3.

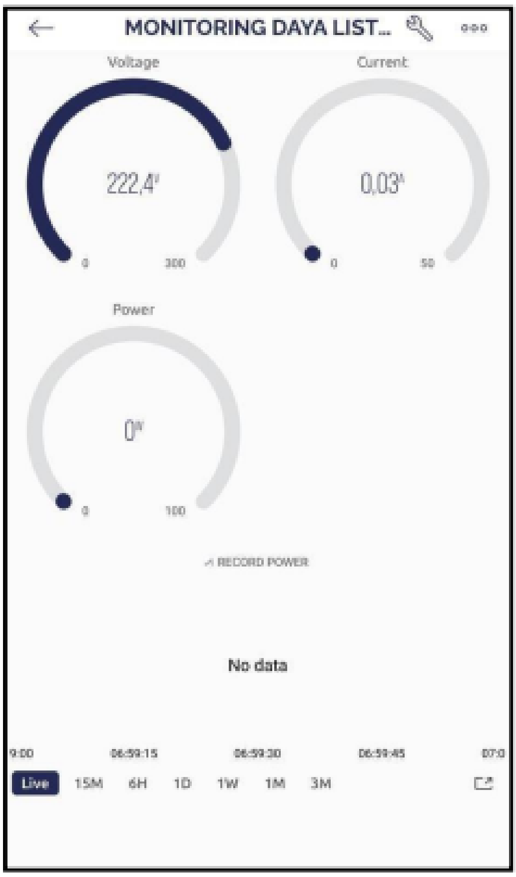

Fig. 3. Blynk mobile dashboard design

Fig. 3 is the design of the BLYNK Mobile Dashboard used in the tool system. The widget used on the BLYNK mobile dashboard is the same as the widget on the web dashboard described. Gauge 1 displays the voltage value, Gauge 2 displays the current value, Gauge 3 displays the power value. As well as Power Graphic as a graph history viewer from power.

2.2. Equation

Electrical voltage is the voltage that functions in a terminal element or component, a pole at a terminal, another pole that can increase the electric charge. Mathematically, the work done to move coulombs. Can be defined as the change in energy supported by the change in the cost of electricity in units of volts. The formula for finding the voltage can be obtained from Ohm's Law [16]. Follow equation (1) formula to find the tension.

$$V = I \times R \tag{1}$$

The amount of electric current that flows from one place to another during a circuit per unit time determines the flow of electricity that is generated. In electronic devices, you will get the current formula [17]. Equation (2) is used to get an electric current.

$$I = P/V \tag{2}$$

The active power of an electric load refers to the amount of energy it uses. The load connected to it will be responsible for absorbing electrical power, which will be generated by energy sources such as mains voltage. The voltage at each house is different, including 450 VA, 900 VA, 1300 VA, and so on [18]. Usually the voltage used in boarding rooms is 900 VA or 1300 VA. The following is equation (3) the formula for finding electric power.

$$P = V \times I \times \cos\varphi \tag{3}$$

The unit of reactive power is referred to as VAR (volt-ampere-reactive). This power is a type of power that causes power losses or reduces the value of the power factor (Cos phi). The following form represents equation (4) reactive power [19].

$$Q = V \times I \times \sin\varphi \tag{4}$$

Before an electrical load is added to the system, power is generated using electrical calculations, and it is this power that is proven. The creation of apparent power, denoted by the symbol VA, is a consequence of applying the power equation, which says that power equals voltage (V) times current (A) [17]. Apparent power can be calculated using equation (5).

$$S = V \times I \tag{5}$$

2.3. System Design

The system block diagram is an overview of the overall system which is depicted in the form of an arrangement of blocks that are configured to each other. The system block diagram consists of input, process, and output as shown in Fig. 4.

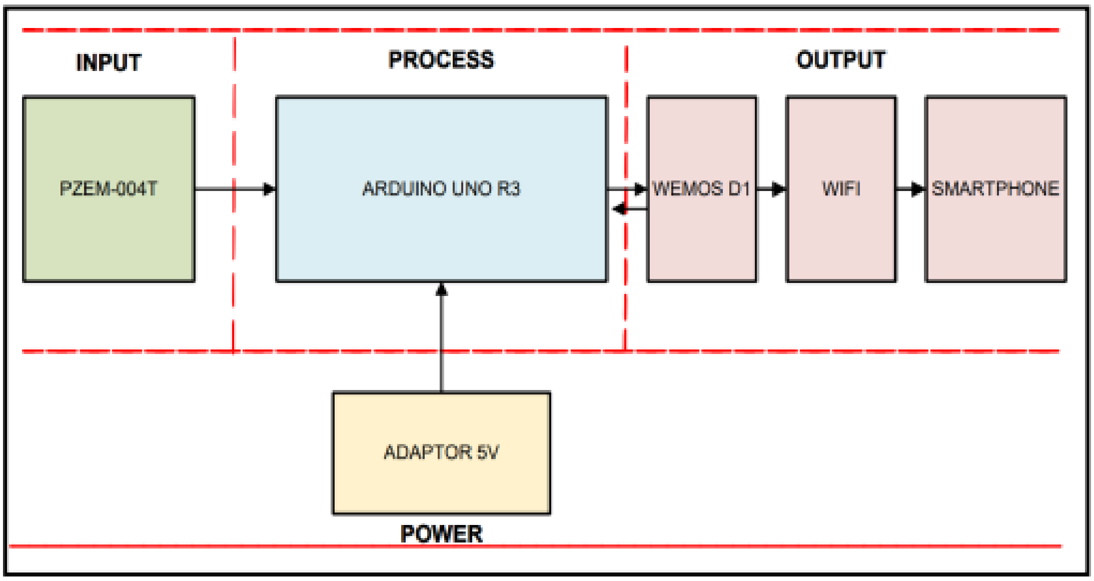

Fig. 4. Tool system block diagram

Fig. 4 is a block diagram of the tool system that describes the condition of the system as a whole. Based on the system block diagram shown in Figure 4, information is obtained if there are four parts of the system consisting of power, input, process, and output parts. The power section consists of a 5-volt adapter circuit that functions as the main power supply for the system. The input section consists of the PZEM-004T sensor which is used to read the AC current and voltage on the electrical device to be tested. The process part consists of the Arduino Uno microcontroller which controls the performance of the tool system. The output section consists of a series of Wemos D1 Mini, Wi-Fi and smartphones. Wemos D1 Mini acts as an intermediary between Arduino Uno and smartphones via a Wi-Fi network. The communication used between Arduino Uno and Wemos D1 Mini is using serial communication that takes advantage of the functions of the Rx (Receiver) and Tx (Transmitter) pins in each circuit.

2.4. Algorithm

The overall tool work system flow chart is shown in the flow chart in Fig. 5.

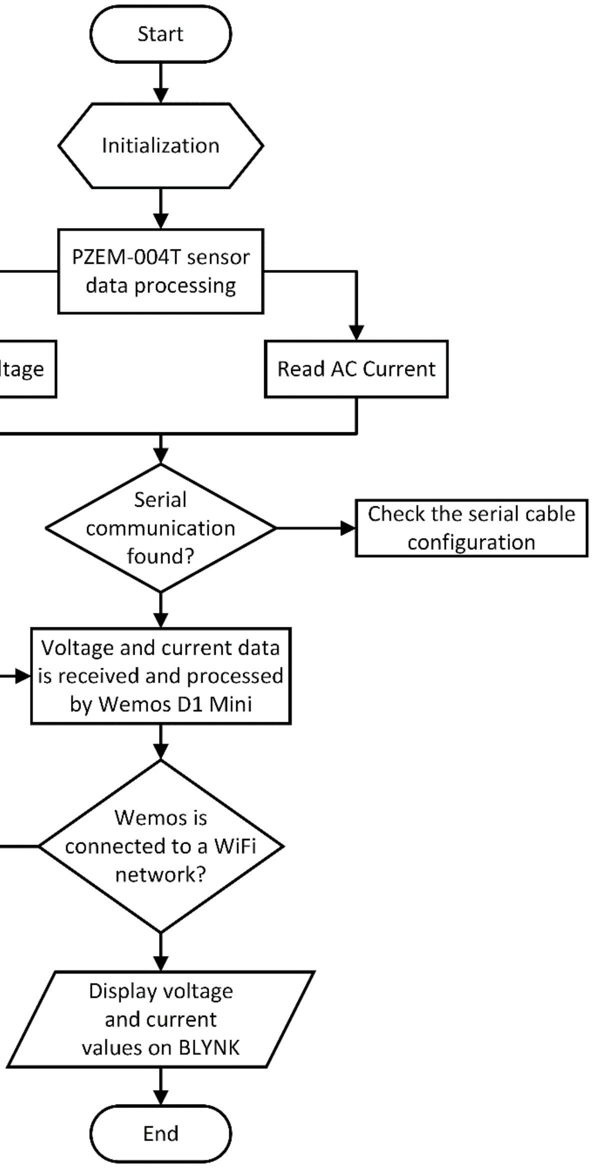

Fig. 5. Tool work flow diagram

The first stage is the initialization of the input/output connected to the microcontroller. The second stage is data processing on the PZEM-004T sensor. The PZEM-004T sensor reads two variables, namely AC voltage and current. The voltage and current values read by the PZEM-004T sensor are sent to Wemos D1 Mini via serial communication between Wemos and Arduino Uno. If serial communication between the two circuits is available, Wemos receives data on the value of the AC voltage and current [20] which is read by the sensor. PZEM-004T. However, if serial communication is not available/found, then the RX and TX serial cable configuration is checked [21]. The next condition is that if Wemos D1 Mini is connected to a Wi-Fi network, AC voltage and current data will be sent and displayed on the smartphone via the BLYNK application. However, if you are not connected to a Wi-Fi network, the data cannot be displayed on the smartphone.

3. Results and Discussion

The workings of the program being tested are when the Wemos D1 mini is in the process of connecting to a Wi-Fi network, the character "." will appear. Continuously. When Wemos D1 mini is connected to a Wi-Fi network, the serial monitor display will say "Connected to SSID: Wi-Fi" device shown in the Fig. 6.

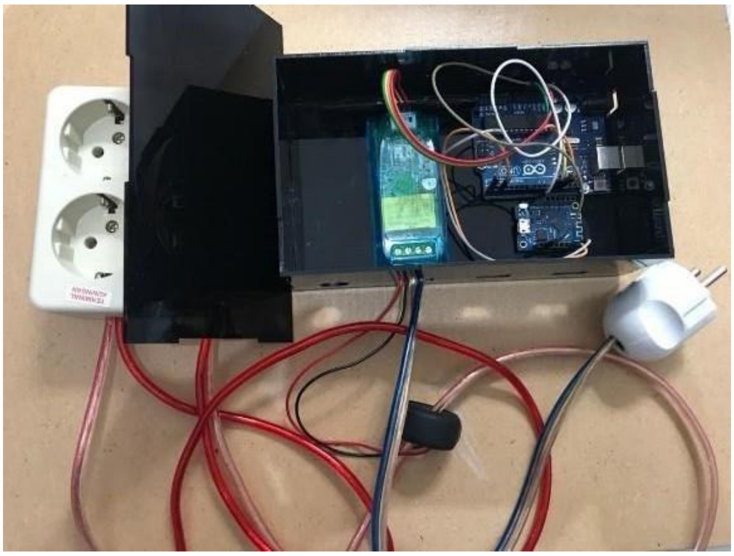

Fig. 6. Hardware assembling results

3.1. Wemos D1 Mini Testing

After calculating using the error percentage formula, the average error value is obtained which is presented in Table 1.

Table 1. The average percentage of the error in the Wemos D1 mini test

No	Test Subjects	Test Results (volts)	3V3 Arduino Uno Specifications	Difference	Error
1	Wemos D1 Mini Circuit Testing	3.26	3.3	0.04	1.212%
2		3.28	3.3	0.02	0.606%
3		3.24	3.3	0.06	0.818%
Average error percentage (%)					1.212%

Based on the results of the calculation of the average error percentage value shown by Table 1, the error value in the WEMOS D1 Mini-series test was obtained at 1.212%.

3.2. Program Testing On Wemos D1 Mini

So that the results of testing the program on Wemos D1 Mini with a summary of the test results using black box testing are shown in Table 2.

Table 2. Summary of the results of testing the program on Wemos D1 Mini

Testing activities	Expected realization	Test Results	Conclusion
Conducting program testing on the Wemos D1 Mini range	Wemos D1 is small capable of establishing a connection to a Wi-Fi network.	Wemos D1 mini successfully connects to the Wi-Fi network shown on the serial screen display of the monitor	[√] Accordingly [ ] Not as appropriate

3.3. PZEM-004 Sensor Program Testing

From the PZEM-004T sensor experiment, it was concluded that the PZEM-004T sensor reads voltage, current, and power which are then displayed on the serial monitor display. Based on the results obtained, a summary of the program results is obtained which is shown in Table 3.

Table 3. Summary of program test results on the pzem-004 sensor

Testing activities	Expected realization	Test Results	Conclusion
Conducting program testing on the PZEM-004T Sensor circuit	The PZEM-004T sensor is capable of displaying voltage, current and power values.	The PZEM004T sensor successfully reads the voltage, current, and power values at the LED TV load with rated voltage = 223 volts, current = 0.14 amperes, and power = 18.20watts.	[√] Accordingly [ ] Not as appropriate

Based on the calculation results from the electrical power monitoring test at 5 different electrical loads, a summary of the results is shown in Table 4.

Table 4. Estimation of the cost of using electrical devices

	Lamp	TELEVISION	Fan (Speed=1)	Fan (Speed=2)	Rice Cooker	Refrigerator
Electricity use/day (wH)	18	217.2	298.8	429.6	907.2	175.2
Electricity use/day (kWH)	0.018	0.2172	0.2988	0.4296	0.9072	0.1752
Electricity use/month (kWH)	0.54	6.516	8.964	12.888	27.216	5.256
Cost/daily	IDR 24.34	IDR 293.65	USD 403.98	USD 580.82	IDR 1,226.53	USD 236.87
Cost/month	IDR 730.08	IDR 8.809.63	IDR 12,119.33	IDR 17,424.58	IDR 36,796.03	IDR 7,106.11

The cost calculation results use the estimated duration of the device on which is set for 12 hours for all devices. Referring to the data from the testing results of monitoring the cost of the electricity load used in households, the most expensive cost is obtained, namely the rice cooker with a cost per/month of Rp. 36,796.03 and the cheapest cost is the lamp with a monthly fee of Rp. 730.08

4. Conclusion

Based on the results of the design and testing of how the monitoring system can be designed on electronic devices, namely by using an electrical socket that is used to calculate the voltage value on the electrical device connected to the socket. Current sensors, devices that detect the amount of current flowing through the sockets of various electrical devices, are also part of the cable. By using this application, users will be able to more easily and effectively monitor and how much electrical energy is used by equipment remotely. This equipment has been tested from September to October, on 5 electronic devices such as lights, TVs, refrigerators, rice cookers, fans with satisfactory results, namely being able to monitor the use of electrical devices using smartphones through the BLYNK application.

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