TTG Microcontroller-Based System with Internet of Things Technology for Monitoring Household Electricity Consumption

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Abstract

Electricity consumption needs to be monitored to minimize the cost of electricity usage. One source of wasteful use of electricity is the presence of household appliances that are forgotten to be turned off even though there is no one at home. The problem faced by many households is the lack of tools or systems to monitor electricity usage and controllers so that residents can turn off devices remotely if they forget to turn them off before leaving. The purpose of the community service is to apply microcontroller and IoT-based technology for controlling and monitoring household devices and their electricity consumption. The tool that has been made and implemented is equipped with a PZEM 004T sensor to read electricity consumption variables and electricity quality and the Blynk application on a smartphone so that residents can monitor whether there are devices still turned on and can turn them off remotely. In addition, residents can also monitor if the quality of electricity is not up to standard to prevent damage to household appliances. The community service results show that the implemented system has good performance. The implementation of the developed system has a positive impact on residents, namely being able to monitor their electricity consumption continuously, check whether there are household appliances that have been forgotten to be turned off, and turn them off remotely using the Blynk application.

Keywords: *Electrical energy consumption; Electrical power quality; Energy monitoring*

TTG Sistem Berbasis Mikrokontroler dengan Teknologi Internet of Things untuk Pemantauan Konsumsi Energi Listrik Rumah Tangga

Abstrak

Konsumsi energi listrik perlu dipantau untuk meminimalisir biaya penggunaan energi listrik. Salah satu sumber pemborosan penggunaan energi listrik adalah adanya peralatan rumah tangga yang lupa dimatikan padahal di rumah tidak ada orang. Permasalahan yang dihadapi oleh banyak rumah tangga adalah belum tersedianya alat atau sistem untuk memantau penggunaan energi listrik dan pengendali sehingga penghuni dapat mematikan perangkat secara jarak jauh apabila lupa tidak mematikannya sebelum pergi. Tujuan daripengabdian pada masyarakat ini adalah untuk menerapkan teknologi berbasis mikrokontroler dan IoT untuk pengendalian dan pemantauan perangkat rumah tangga dan konsumsi energi listriknya. Alat yang sudah dibuat dan diterapkan dilengkapi dengan sensor PZEM 004T untuk membaca variabel konsumsi daya listrik dan kualitas daya listrik dan aplikasi Blynk pada smartphone sehingga penghuni dapat memantau apakah ada alat yang menyala dan dapat mematikan secara jarak jauh. Hasil pengabdian pada masyarakat menunjukkan alat yang diterapkan mempunyai unjuk kerja yang baik. Dengan diterapkannya alat ini memberikan dampak positif bagi penghuni yaitu dapat memantau konsumsi energi listriknya secara kontinyu, mengecek apakah ada alat rumah tangga yang lupa belum dimatikan, dan mematikannya secara jarak jauh dengan menggunakan aplikasi Blynk.

Kata kunci: Konsumsi energi listrik, kualitas daya listrik, pemantauan energi listrik

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1. Introduction

The development of technology and the need to improve the quality of life in society has led to an increasing number of modern household appliances that use electricity such as rice cookers, refrigerators, air conditioners, televisions, fans, washing machines, lamps, and other devices. The more devices and the longer the duration of use, the higher electricity bill that must be paid. The amount of electricity bill is calculated based on the amount of electricity used in kilowatt hours (KWH) multiplied by the price per KWH which depends on the type of power subscribed to by the household, expressed in volt ampere units (VA). The long duration of use of these household appliances can be due to need so that the device is deliberately turned on because there are people who are still active in the house or forget to turn it off so that the device is still on even though there is no one in the house.

In addition to the quantity of electrical energy, the quality of electrical power also needs to be monitored because all household devices that use electrical energy require electrical power with a certain standard value. The two main electrical power quality variables are the voltage value of 220 V and the frequency of 50 Hz. The magnitude of this voltage and frequency can increase or decrease from its standard value due to various factors. Household devices usually have tolerance specifications if the voltage and frequency values increase or decrease. If the quality of electrical power is outside the tolerance value by the household device, it will be damaged [1]. Therefore, approaches to monitor the quality of this electrical power have been proposed, for example in [2], [3].

A common problem faced by lower-middle class households who subscribe to electricity with a power of 450 VA or 900 VA or 1300 VA is that the house is not equipped with a system to monitor or detect whether there are household appliances that are still on or not. The existence of a tool to monitor electricity consumption in this household will greatly help the community in knowing whether there are electrical appliances that are still on when the house is empty so that it can minimize the cost of using electricity and also early prevention efforts for other consequences such as the potential for fire and also for household characteristic analysis [4]. Due to the importance of monitoring electricity consumption, a tool to monitor electricity consumption has been proposed previously such as in [5], [6]. If there is no monitoring tool, the occupants of the house must return home to carry out checks which are very inefficient both in terms of time and finances so that it can be considered as inconvenient. This kind of equipment is not widely available on the market at this time.

The problems faced by the community above can be overcome by implementing microcontroller-based electronic technology and Internet of Things (IoT) technology. The purpose of this community service is to apply appropriate technology in the form of a microcontroller-based control and monitoring system and IoT technology to household electrical appliances and lighting systems so that they can be controlled and monitored directly from a distance by the owner. IoT technology has been used previously for household monitoring and control such as in [7], [8], [9]. The technology applied in the community service has control and monitoring features that are used in household devices.

2. Method

In general, the community services activity was carried out in several stages including: (i) assembly of monitoring tools, (ii) configuration of tools, (iii) application of tools in households, and (iv) monitoring and evaluation of the effectiveness of tool application. The

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methods and activities of the assembly and configuration stages of monitoring and control tools are described as follows.

2.1. General architecture

The general architecture of the applied monitoring and control system can be seen in the block diagram of Figure 1. The applied tool uses a PZEM 004T sensor which functions to detect and read voltage, current, frequency, power factor, electrical energy consumption on the electrical installation path leading to the monitored and controlled load. Using the PZEM 004T sensor can be said to be more efficient because one sensor can be used to detect several variables when compared to using sensors per variable as used in [10], [11]. The PZEM 004T sensor is a fairly popular sensor and is widely used, for example in [12], [13].

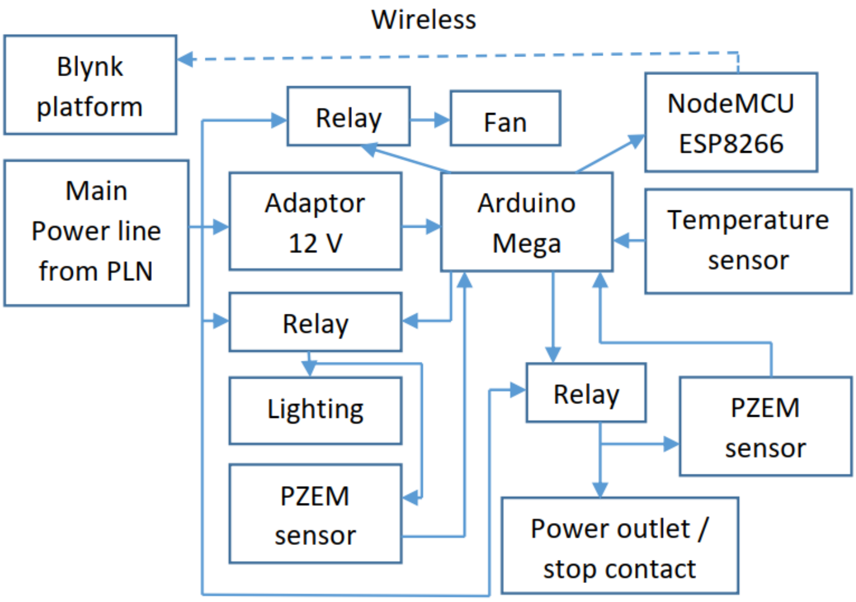

Figure 1. A block diagram representing the general architecture of the system being built

The load is divided into lighting systems and in the form of power outlets or sockets that can be used to turn on existing household appliances. The applied tool also has a temperature sensor used to read and regulate the rotation speed of the fan because in the lower middle class who subscribe to electricity of 1300VA and below, mostly they use fans as air conditioners. It is also equipped with a relay that functions as a socket that can be turned on/off remotely using a smartphone and a remote monitoring feature using the Blynk platform application on a smartphone. The use of the Blynk application on a smartphone is more efficient when compared to using a web that is specifically made as proposed in [14] or using SMS messages [15]. The Blynk platform is also quite popular and is also used in various applications, for example in [16]. In order for the tool to be connected to the Blynk platform, wireless internet access (wifi) is needed. The use of application technology on smartphones provides various advantages and conveniences so that it has also been used previously, including in [17]. The control and monitoring system used 2 microcontrollers, namely Arduino Mega used for processing all data from sensors and NodemCU ESP8266 microcontroller which is used for connecting the applied system to the internet/wifi. The NodemCU ESP8266 microcontroller is quite popular for various applications for example in [18], [19].

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2.2. Software configuration

The software program is created using the Arduino Integrated Development Environment (IDE). An example part of the program scripts display can be seen in Figure 2 which is a program for controlling fan speed. When the device is turned on, the temperature sensor, namely DHT 22, will detect the room temperature which will later be displayed in the Blynk application. To control the room temperature using a fan, it is necessary to determine the desired room temperature target which for this device is determined to be around 28 degrees Celsius so that when the temperature sensor (DHT 22) detects a room temperature between 28 ° C and 30 ° C, the device will automatically turn on the fan at speed mode - 1. Furthermore, when the temperature sensor (DHT 22) detects a room temperature of 30.1 ° C to 32 ° C, the device will automatically turn on the fan at speed mode - 2. Furthermore, when the room sensor exceeds 32 ° C, the device will automatically turn on the fan at mode - 3, but when the room sensor is less than or below 28 ° C, the fan will automatically turn off.

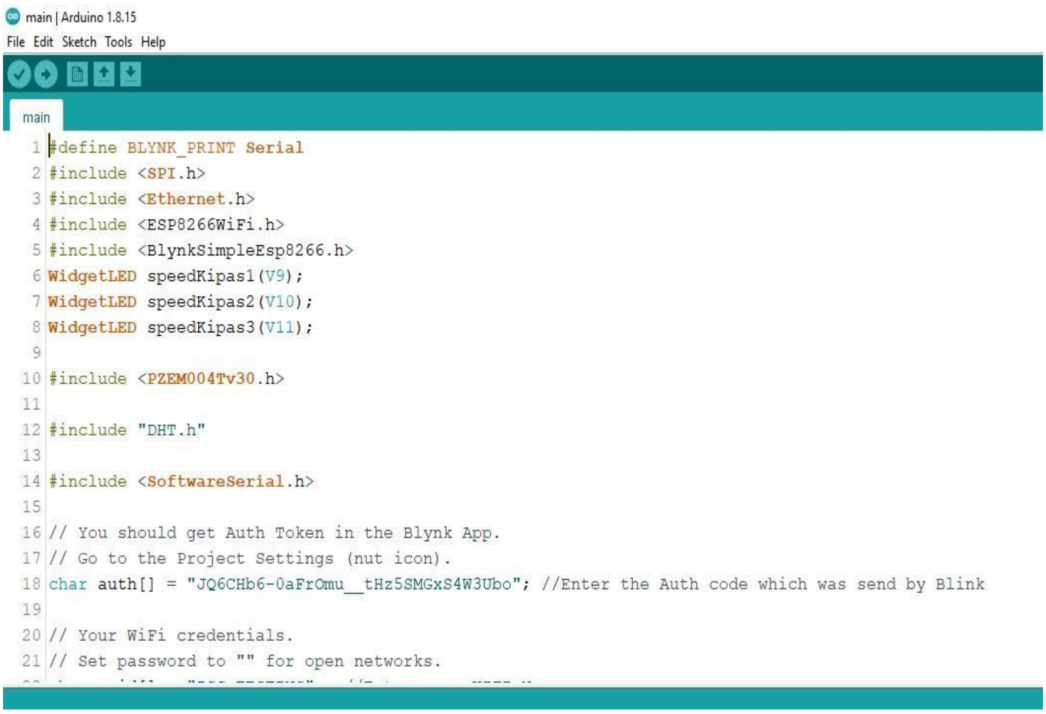

Figure 2. Sample of program script code

3. Results and Discussion

3.1. Implemented control and monitoring system

The implemented control and monitoring system can be seen in Figure 3(a). To protect against impact, splashes of water or other potential hazards, all hardware except the temperature sensor is placed in a standard protective panel contact used in electrical installations. The configuration of the applied system in the household can be seen in Figure 3(b).

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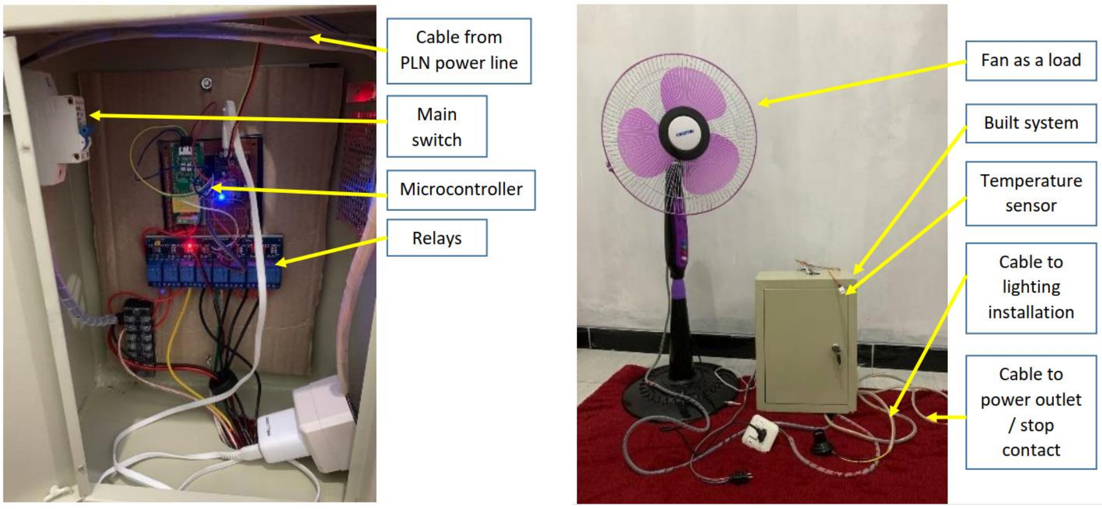

(a) (b)

Figure 3. Implemented control and monitoring system

3.2. Configuration and implementation of the control and monitoring system

The configuration and usage stages of the tool can be done with the following steps. Step 1: turn on the wifi that will be used for data communication by the applied system, after that the main switch/MCB located inside the panel box on the tool is turned on so that the controller and monitor system will be turned on as shown in Figure 3(a). Step 2: After the controller and monitor are turned on, the ESP8266 microcontroller will connect the applied system to the wifi that was turned on in step 1. In the ESP8266 microcontroller program, it has been set which wifi will be used for data communication identified based on the SSID name and password so that it will not be exchanged even though there is more than one wifi in that place.

Step 3: Open the blynk application that has been created on the smartphone then click the on button on the blynk application. The appearance of the Blynk application platform can be seen in Figure 4. To activate the application by pressing the triangle logo in the upper right corner, the Blynk application will turn on, after which the device will automatically get data from the temperature sensor. In the Blynk application there are 2 main menu features, namely the "Energy Monitoring" menu and the "Room Control" menu. By default, the Blynk application display will display the "Energy monitoring" menu feature. In this menu, users will be able to monitor room temperature, room humidity, display the indicator whether the fan is on or not and if it is on at what level, the value of the electric voltage, the amount of current, the electric power in Watts, the amount of electric energy consumption in KWH, the frequency of electric energy, and the power factor. The voltage value and the frequency of electricity are the 2 most important variables of electric power quality because if the value does not match the standard, it can damage electrical devices in the household. Although not the main variable, power factor is also important to monitor, which was also done previously in [20].

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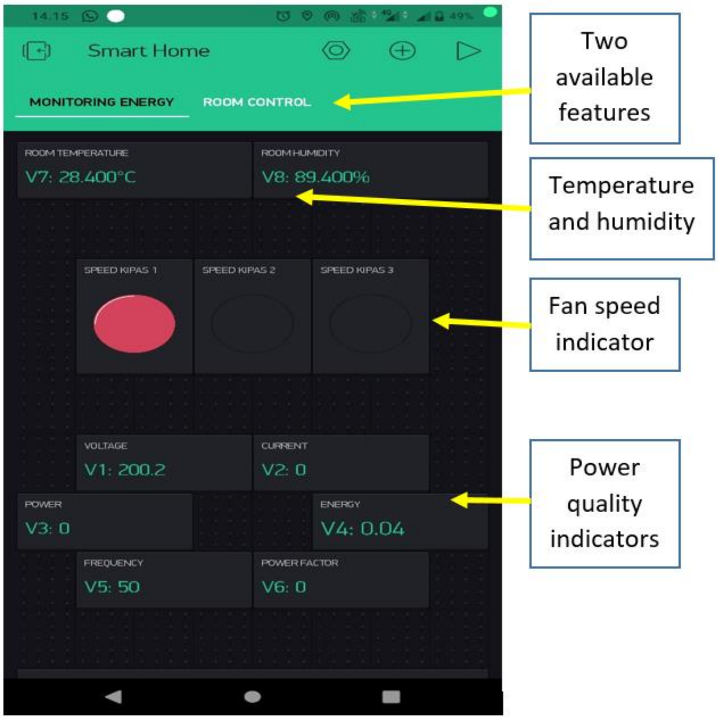

Figure 4. Blynk application display when turned on

If the user wants to control the room, the user can select the "Room Control" menu option, then the Blynk platform application display will change as shown in Figure 5. In this menu, there are two buttons, namely the button to control/turn on the lights and the button to turn on the power outlet/stop contact. The button is made a toggle system to turn it on and off.

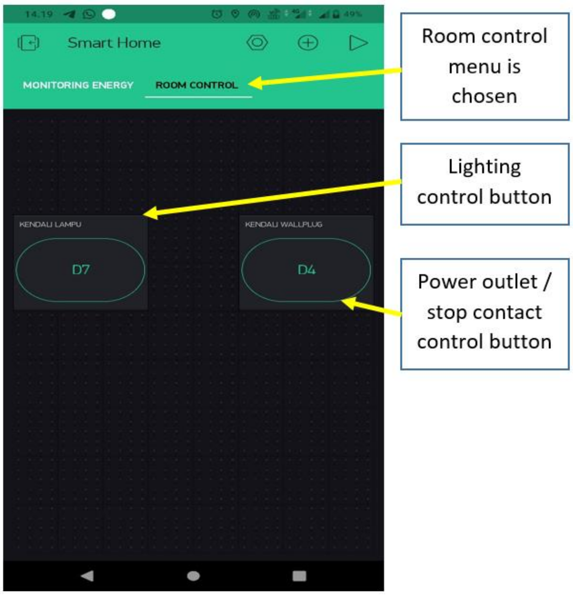

Figure 5. Blynk app view in Room Control mode

3.3. Evaluation of system performance effectivity

The first evaluation of the effectiveness of the tool's performance was carried out by operating the controller and monitor on the household equipment load, namely by using a soldering iron, lamp, and fan load. Table 1 shows the evaluation results, namely the values of voltage, current, power, frequency, and power factor displayed on the Blynk platform

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application on a smartphone for each load given. The monitoring was obtained from the reading of the PZEM sensor which was processed by the Arduino Mega microcontroller and then sent to the smartphone via the nodeMCU ESP8266 microcontroller. For the fan load, 3 speed variations were taken according to the 3 factory speed buttons. From the measurement results of the 3 loads used, the monitoring voltage showed an average value of 203.3V while the highest current was on the fan load with a speed of 3. As a consequence, the largest power was also on the fan load with a speed of 3. Of the three loads used for evaluation, it can be seen that the lowest current and power were on the soldering iron load, namely 0.07 A and 10W with a power factor of 0.66.

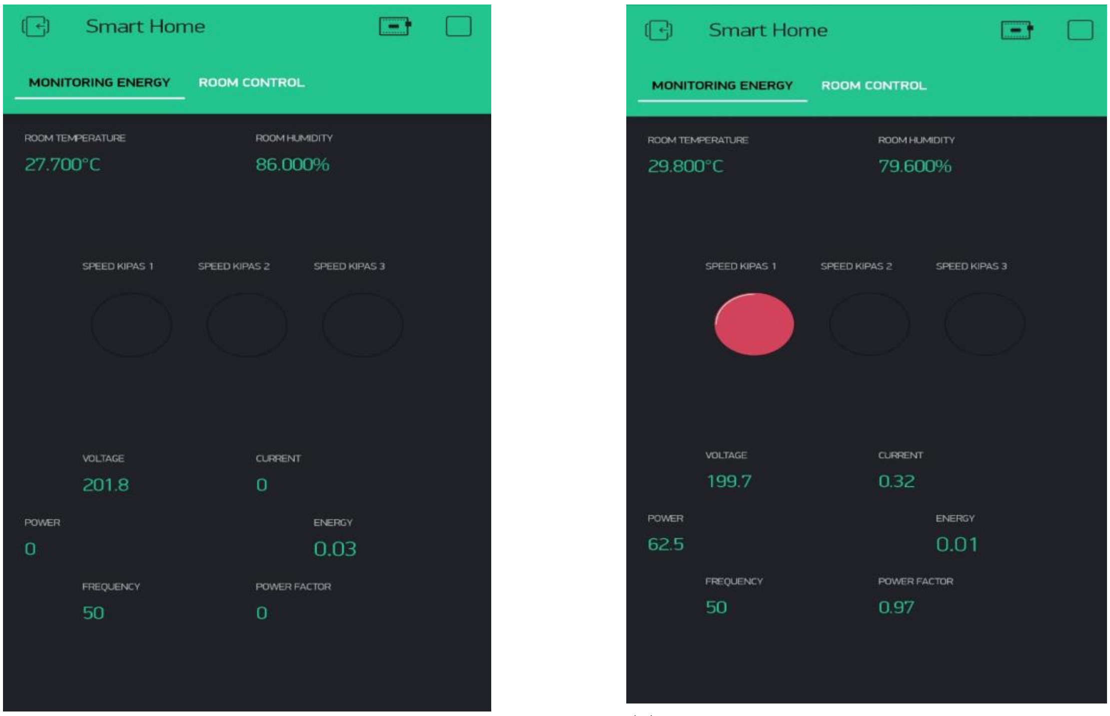
Table 1. Evaluation of tool performance for 3 household loads

Loads	Voltage (V)	Current (A)	Power (W)	Frequency (Hz)	Power Factor
Fan Speed 1	203.3	0.16	31	49.9	0.95
Fan Speed 2	203.2	0.17	34.7	49.9	0.98
Fan Speed 3	203.3	0.19	37.5	50	0.99
Light	202.9	0.13	26.2	50	1
Solder	203.4	0.07	10	50	0.66

The second performance effectiveness evaluation was carried out on the performance of the automatic fan controller for various room temperature ranges. Table 2 shows the evaluation result of automatic fan control according to the room temperature, when the room temperature is 25 - 27 ° C, the fan will not turn on, but when the room temperature starts to reach 28-29 ° C, the fan will turn on automatically at speed level 1. If the room temperature continues to rise to 30-31 ° C, the fan will increase to speed level 2, and if the room temperature rises to 32-34 ° C, the fan will automatically increase speed again to speed 3. The appearance of the Blynk platform application when the room temperature is less than 28 degrees Celsius and the fan is off can be seen in Figure 6(a), while the appearance when the fan is on at level 1 is shown in Figure 6(b) where the application displays a voltage value of 199.7 V, a current of 0.32A, a frequency of 50Hz, a power of 62.5W, and a power factor of 0.97. With these features, the applied system can be included in the smart energy meter category as summarized in [21].

Table 2. Testing of automatic fan control

Temperature	Fan Operation		
	Speed Level 1	Speed Level 2	Speed Level 3
25°C	-	-	-
26°C	-	-	-
27°C	-	-	-
28°C	ON	-	-
29°C	ON	-	-
30°C	-	ON	-
31°C	-	ON	-
32°C	-	-	ON
33°C	-	-	ON
34°C	-	-	ON



(a) (b)

Figure 6. (a) Display on Blynk app when temperature is below 28°C and no load, (b) display on Blynk app when full load and room temperature is above 28 °C

3.4. Condition Comparison Before and After Control and Monitoring System

The successful implementation of electrical energy consumption control and monitoring technology in households will have a positive impact as summarized in Table 3.

Table 3. Comparison of household conditions resulting from the application of control and monitoring technology

No.	Variable	Condition Before	Condition After
1	Detection and checking of household devices that are still on	Manual, occupants must enter the house/room	Residents can check from anywhere remotely using a smartphone application.
2	Turning off household appliances that you forgot to turn off	Manual. If the occupant is away, they must return home to turn off the devices that are still on.	From anywhere using the Blynk application on your smartphone, making it more convenient and saving time/energy.
3	Monitoring the quality of electrical power.	Cannot be done. If the quality of electrical power is not up to standard, the potential for damage to household appliances is very large.	Can be done anytime and anywhere by using the Blynk application on your smartphone.

4. Conclusion

The electrical energy consumption control and monitoring system has been successfully implemented on a household scale. The implemented system is equipped with a remote monitoring feature using the Blynk platform application on a smartphone. From the results of the stages of making the tool to the evaluation of the performance of the electrical energy control and monitoring tool that has been carried out, it can be concluded that the

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implemented control and monitoring system has good performance and is potentially able to increase the comfort of residents in operating their household devices.

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