Electric Energy Consumption Monitoring System and Restricting Temperature Settings Air Conditioning Equipment

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ABSTRACT
In operating air conditioning equipment, often the user selects the temperature setting at the lowest temperature setting, for example at a temperature setting of 16^{o}C to 18^{o}C. This can result in a waste of electrical energy, where the lower the temperature setting chosen, the longer the compressor works to reach room temperature according to the temperature setting chosen. Another thing that can cause the waste of electrical energy from the operation of air conditioning equipment is in the case of the user's ignorance of the amount of consumption of electrical energy consumed by the air conditioning equipment.

This study aims to create a system that can operate in 2 operating modes, namely energy saving operation mode by limiting the temperature regulation of air conditioning equipment to a range of 24^{o}C to 27^{o}C and normal operating modes, and can monitor electrical energy consumption and the price paid in rupiah from the operation of the equipment.

From the results of the tests carried out, it was found that the system that was made could limit the temperature regulation of the air conditioning equipment in operation settings 24^{o}C to 27^{o}C in energy saving operation mode, so as to minimize the occurrence of waste of electrical energy from the air conditioning equipment.

Keywords
Monitoring, Electrical Energy, Energy Saving, Air Conditioning.

1. INTRODUCTION
One of the causes of electrical energy waste from the use of air conditioning equipment is in terms of temperature regulation. The lower the temperature setting selected, the greater the consumption of electrical energy supplied by the air conditioning equipment, because the operating time of the compressor takes longer to reach room temperature in accordance with the selected temperature setting. In addition, the thing that can influence the occurrence of electrical energy waste from the operation of air conditioning equipment is in terms of electrical energy intake from the equipment, where the user does not know how much electrical energy consumption of the air conditioning equipment when operating, so the user can adjust the temperature air conditioning equipment operation at a higher setting to avoid electricity waste [1][2][3][4].

One of the efforts of the Indonesian government in terms of saving electricity for the operation of air conditioning equipment, is the issuance of Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia No. 13 of 2012 concerning saving electricity consumption as stated in Article 4 Paragraph 2a number 6 which states that when using air conditioning equipment, it is done by regulating temperature and relative humidity in accordance with Indonesian National Standards, namely for workspace temperatures ranging from 24^{o}C to 27^{o}C with humidity air between 55% to 65%, and for lobbies and corridors temperatures range from 27oC to 30oC with air humidity between 50% to 70% [5].

For this reason, this research aims to create a system that can limit the temperature regulation of air conditioning equipment in the range of 24^{o}C to 27^{o}C for energy saving and normal operation settings, and can monitor electricity consumption and the price paid in rupiah from the operation of air conditioning equipment.

In producing a system of limiting temperature regulation and monitoring the electrical energy consumption of air conditioning equipment, it is necessary to support modules that are integrated with each other, where the modules include: Arduino Uno microcontroller based on the ATMega 328 microcontroller, which functions as a controller of the entire system work, in terms of temperature regulation and detection and information on the consumption of electrical energy from air conditioning equipment [6]; current sensor ACS 712 which functions as a sensor to detect the amount of electric current consumption from air conditioning equipment [7] [8], where the detection data will later be processed by the controller, then informed as electrical energy consumption data in watt hours (Wh) and payment data for electricity consumption in rupiah (Rp); infrared sensor (IR sensor), which functions as a medium for sending data to the temperature regulation of the air conditioning equipment; Liquid Cristal Display (LCD), which is used as an information media, to inform the process of regulating the temperature of air conditioning equipment, including information on the amount of electrical energy consumption and the price to be paid for the electrical energy consumption of the air conditioning equipment [9].

To run a system of limiting temperature regulation and monitoring the electrical energy consumption of air conditioning equipment, a program is needed that is implanted into the Arduino Uno microcontroller, where the software used for making the program is the Arduino IDE, with reference to the flowchart created [10] [11].

As for studies related to this paper, as has been done by:

1. Chiou,et al (2008), published in the journal Energy and Buildings entitled "The study of energy-saving strategy for direct expansion air conditioning system", in which research is related to energy-saving procedures in DX Air Conditioning system, with periodic downtime method, by setting the system's operating period and the system shutdown period of two ACs [12].
2. Zhou, et al (2007), published in the journal Energy and Buildings entitled "Energy simulation in the variable refrigerant flow air-conditioning system under cooling conditions", this research compare the energy consumption from air conditioning system with 3 different methods, namelyVariableRefrigerantFlow (VRF) system, Variable Air Volume (VAV) system and fan-coil plus fresh air (FPFA) system. The study was conducted with a simulation using the Energy Plus software. Simulation results show that the energy-saving potential of the VRF system reaches 22.2% and 11.7%, compared to VAV and FPFA systems [13].
3. Widell, et al. (2009) published in the International Journal of Refrigeration under the title "Reducing power consumption in multi-compressor refrigeration system", using linear programming model to minimize the compressor's electric energy consumption, the compressor's operation will be optimized according to the required load [14].
4. Ali Ramschie, at al. (2016), published in the International Journal of Computer Applications entitled Algorithms Air Conditioning Air Filter Detection System for Electric Energy Savings, the research conducted is related to making a control system algorithm that can detect when air filters from AC equipment have been dirty. When the AC air filter is dirty, the system will deactivate the air conditioner and inform it through the sound of the alarm and through the LCD display that the AC needs to be treated in connection with the air filter is dirty, so that waste of electrical energy can be avoided [15].

2. METHODOLOGI

The method used in the process of producing a system of limiting temperature regulation and monitoring of electrical energy consumption of air conditioning equipment is the prototyping method, where the stages include: the design stages which consist of designing system block diagrams and designing software for system operation purposes in the form of flow diagram. The next stage is the manufacturing process which consists of making the system with reference to the block diagram that has been made which is simulated through a Proteus simulation program and making software that refers to the flow diagram that has been produced. Next is the system testing phase which is carried out through a Proteus simulation program.

2.1 System Design

The control application developed in this paper is a system of limiting temperature and monitoring the consumption of electrical energy from air conditioning equipment, where the working principle of the system is as follows: When the system is first activated, the system will run normal operating mode, where in this normal operating mode the user can adjust the temperature of the air conditioning equipment from 16^{o}C to 28^{o}C. The temperature setting selection is made by pressing the temperature rise button for the temperature setting up and the temperature button down for the temperature setting. To switch from normal operating mode to energy saving operation mode, what needs to be done is to press the energy saving button. When the energy saving button is pressed, the temperature setting is automatically limited from 24^{o}C to 27^{o}C. When the temperature setting is at 24^{o}C, the temperature down button cannot be used, so the temperature setting cannot drop below the 24^{o}C limit. The temperature down button will function, if the temperature setting selected above 24oC. When the system is in energy saving mode, users can switch to normal mode by pressing the normal mode button. The LCD display functions to inform the operation of the air conditioner equipment whether it is in normal operating mode or in energy saving operation mode. Besides that, the information displayed is in the form of the amount of electricity consumption and the price paid for the air conditioning equipment as a process of monitoring the consumption of electricity. as well as information about the selected temperature setting. The system block diagram is shown in Figure 1.

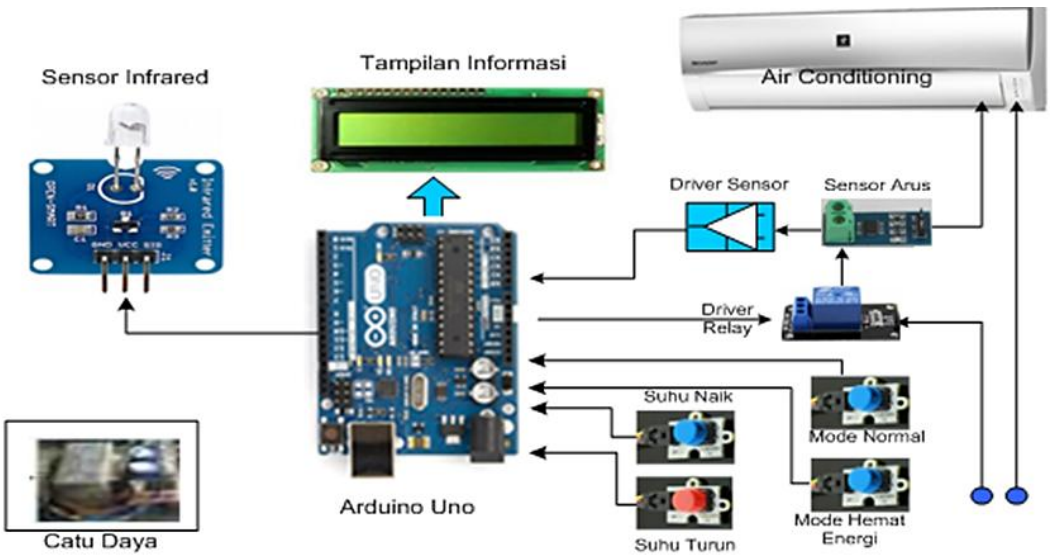

Fig 1: Block diagram system

The description of the Block diagram in Figure 1, is described as follows:

1. Arduino Uno, a microcontroller device that functions as a central working controller of the whole system.
2. Information display, in the form of an LCD that functions to inform about the temperature regulation, the amount of electricity consumption and the price paid for operating the air conditioning equipment.
3. Infrared sensor, functions as a medium for temperature regulation of air conditioning equipment, the operation of which is regulated through Arduino Uno.
4. ACS712 Current Sensor, serves as a detector for the current consumption of air conditioning equipment.
5. Driver Relay, functions as a magnetic switch that is operated through Arduino Uno, to activate and deactivate the work of the air conditioning equipment.
6. On button, functions as input to Arduino Uno, to activate the work of the whole system.
7. The Off button, functions as an input to Arduino Uno, to deactivate the work of the whole system.
8. Normal Mode Button, functions to select the air conditioner equipment settings for normal operation, without limited temperature settings.
9. Energy saving mode button, functions to select energy saving mode where the temperature setting is limited from 24oC to 27oC.
10. The power supply functions as a voltage supplier to all parts of the system that are integrated with each other.

2.2 Flow chart System (Algorithm)

In the software design process, the initial step taken is to make a flow chart that represents the working sequence of the system for operating the control system of temperature limitation and monitoring the electrical energy of air conditioning equipment. The flowchart of the temperature limiting control system and the electrical energy monitoring of air conditioning equipment is shown in Figure 2.

Description algorithm of the system as follows:

1. When the system is first activated, the system will read the energy saving button. If the energy saving button is not pressed, the system will operate in normal mode, where the temperature regulation of the air conditioning equipment can be used as in normal conditions, ie from the 16^{o}C setting to 28^{o}C settings. This situation will continue until the system detects a power saving mode button press. If the system detects a power saving button press, the system will enter the program section for setting the power saving mode.
2. When the system enters electricity saving mode, the air conditioning temperature setting is automatically set at 24^{o}C. in addition, the temperature down button for setting the temperature down on the air conditioner is deactivated. Then the system will read the button presses the temperature rises. If the temperature rise button is not pressed, the system will go to the current sensor data reading process, process the data into kWh data and pay price (Rp.), Then output it as information through the LCD display. If it is detected that the temperature button presses up, the temperature will be set at 25^{o}C, then the system will activate the temperature down button, so that the temperature selection below 25^{o}C can be made (24^{o}C). The temperature rise button will be deactivated when the temperature setting has been set at 27^{o}C. When the system is in the power saving mode, the system will continue to read whether the normal mode button is pressed or not. If the normal mode button is pressed, the system will enter the normal mode section.

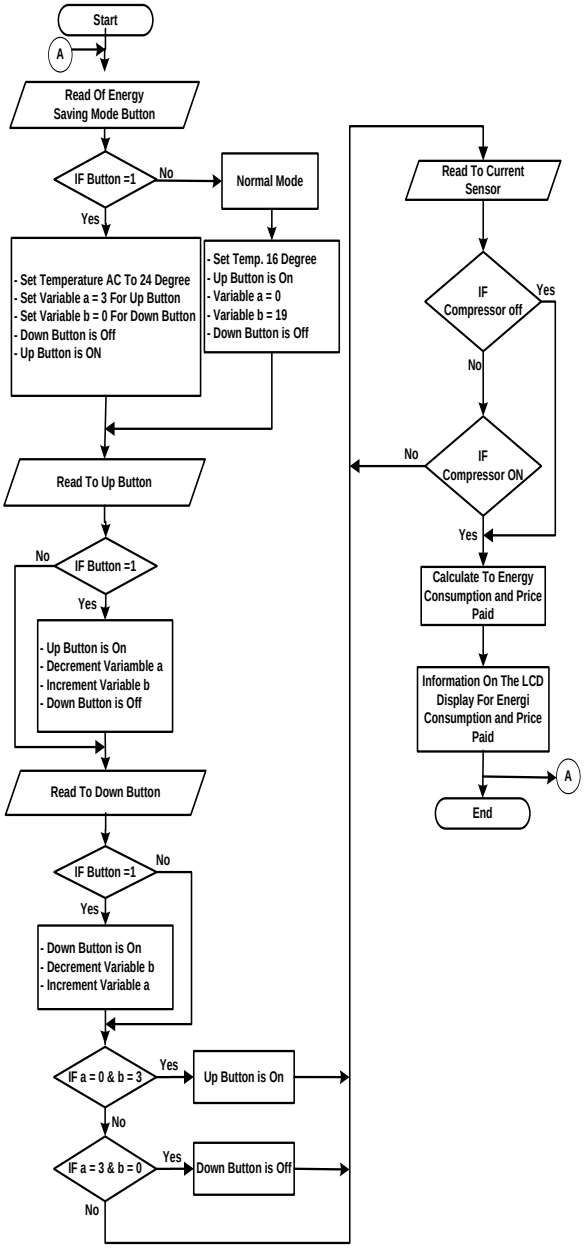

Fig 2:Flowchart system

2.3 Sistem Simulation Making

Making a system simulation is done by using the Proteus simulation program, where in this simulation program, an integrated series of systems is made which refers to the design results in the form of block diagrams that have been made. The system simulation is shown in Figure 3.

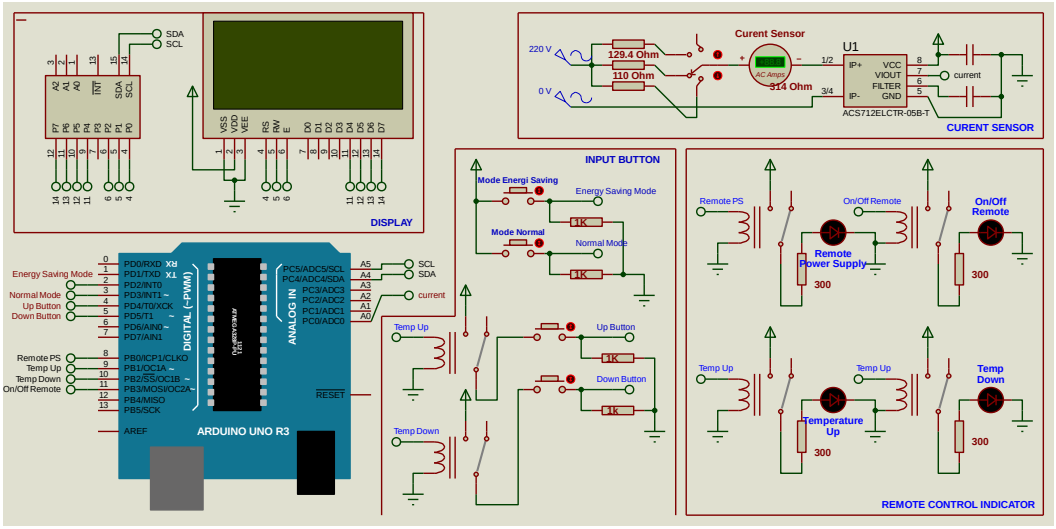

Fig 3: Simulation Sistems

3. RESULT AND DISCUSSION

The system simulation testing process aims to obtain data in connection with the work system that is made, whether the system has been made to function in accordance with the results of the design. System simulation testing is done through the Proteus simulation program, based on the simulation design that has been produced in the process of making hardware simulations. To run a simulation of the temperature limiting system for electrical equipment to save electricity, software is needed that is implanted into the Arduino Uno controller, where the embedded program is a program that has been generated through the stages of making software. The testing process includes:

3.1 System Testing When First Activation

The first time the system is activated, the system will enter the program section for normal mode settings, where in normal mode, the work of the air conditioning equipment will function normally, where the temperature regulation process can be carried out from the 16°C setting up to the highest limit of the equipment temperature setting air conditioning. Tests when the system is first activated in the normal operating mode state are shown in Figure 4.

From the test results as shown in Figure 4, it appears that when the system is first activated, the system will enter the normal mode of operation. In normal mode operation, the temperature setting of the air conditioning equipment is automatically set at 16°C. For setting the temperature selection when the system is first activated, the system automatically activates only the function of the temperature rise button through the active relay which functions as an input voltage provider to the temperature rise button, while the temperature drop button cannot be used, because it does not get an input voltage, because The relay is inactive. Besides that, the system will inform the user that the current operating mode is the normal mode, with the initial temperature setting at 16°C. The process of regulating the temperature selection can be carried out at settings of 16°C to 28°C.

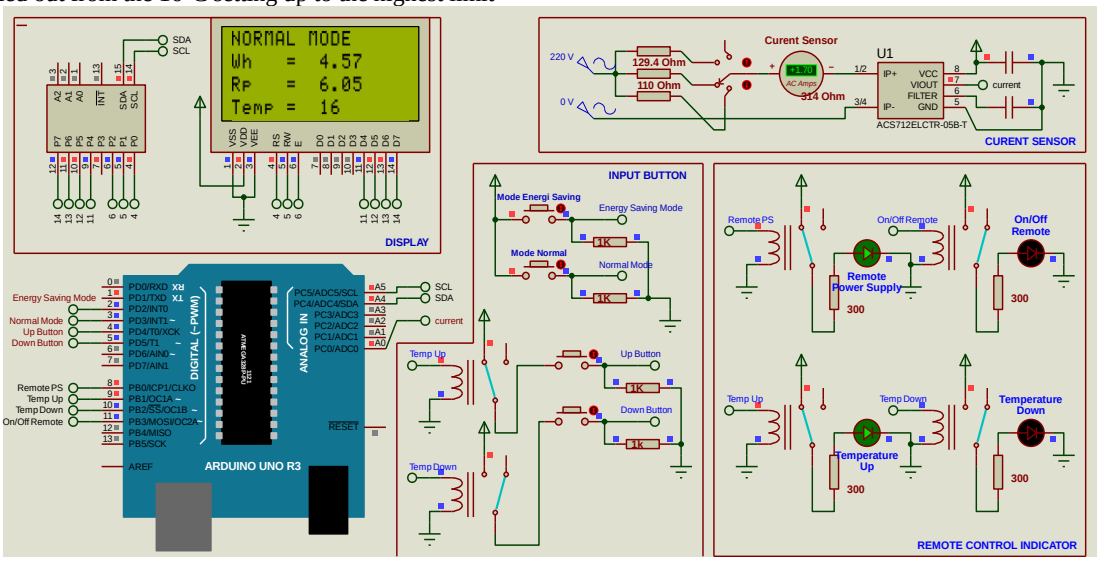

Fig 4: Tests when the system is first activated

When choosing a temperature above 16°C, for example the temperature 17oC, the system will automatically activate the temperature button up and the temperature button down, so that the temperature selection can be made to select a temperature below 17°C or above 17°C. The choice of temperature of 17°C is shown in Figure 5.

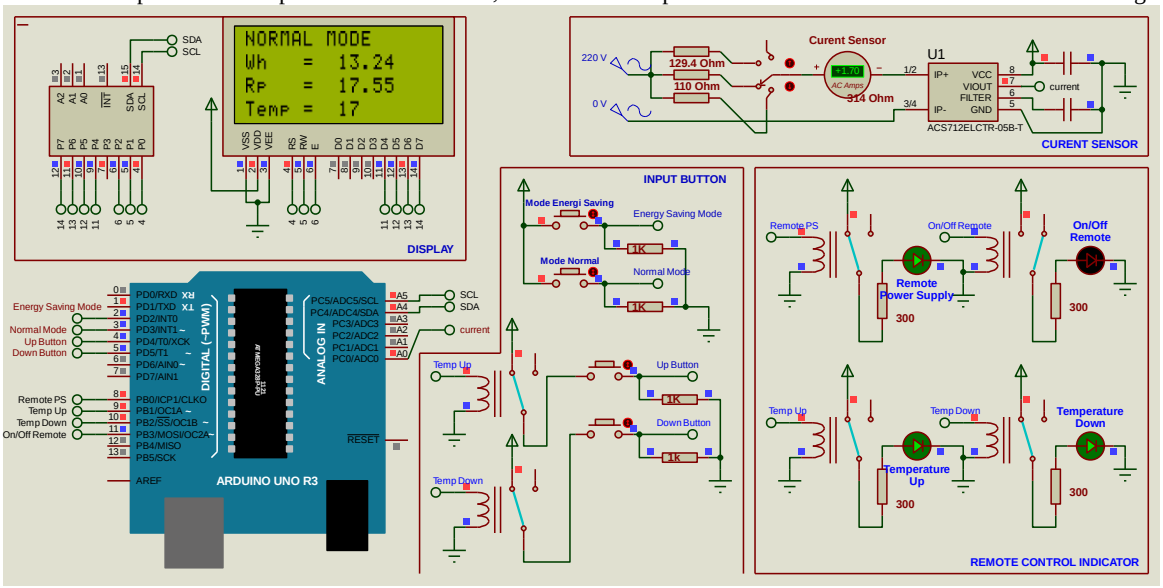

Fig 5: When choosing a temperature above 16°C

3.2 System Testing When First Activation

To switch from normal mode to energy saving mode, to do is press the energy saving mode button. When the system enters energy saving mode, the system automatically adjusts the temperature setting to 24°C. In the energy saving mode section, the temperature settings that can be performed on air conditioning equipment are limited to the range of 24°C to 27°C through the activation of the power supply on the temperature rise button and deactivation of the electricity supply at the temperature down button. The energy saving mode system test is shown in Figure 6.

From the results of system simulation testing for energy saving mode, as shown in Figure 6, it appears that only the temperature button up is active, while the down temperature button is inactive. It is intended that temperature settings below 24°C cannot be selected, in order to avoid the lowest temperature selection from operating air conditioning equipment, so as to avoid the waste of electrical energy.

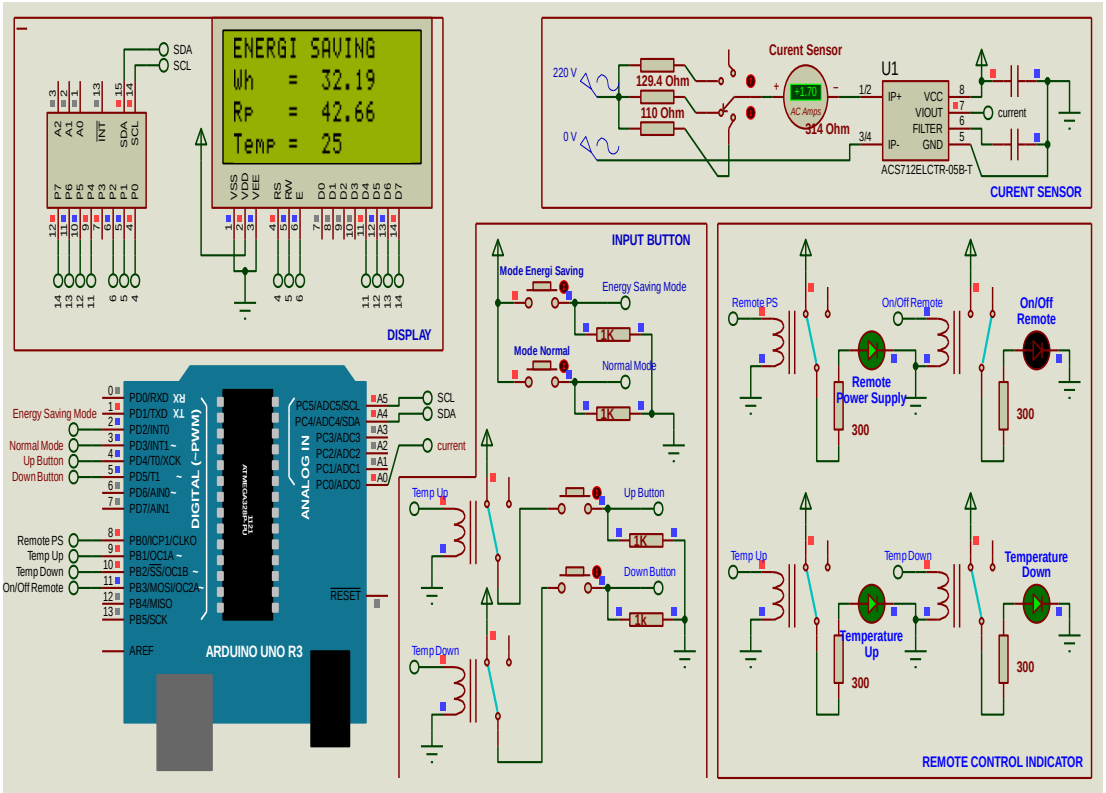

Fig 6: The energy saving mode system test

The temperature drop button will be activated, if the system detects that the temperature setting of the air conditioning equipment is above 24°C, as shown in Figure 7. The air conditioning temperature selection process in this energy saving mode can only be carried out in the range of 24°C to 27°C.

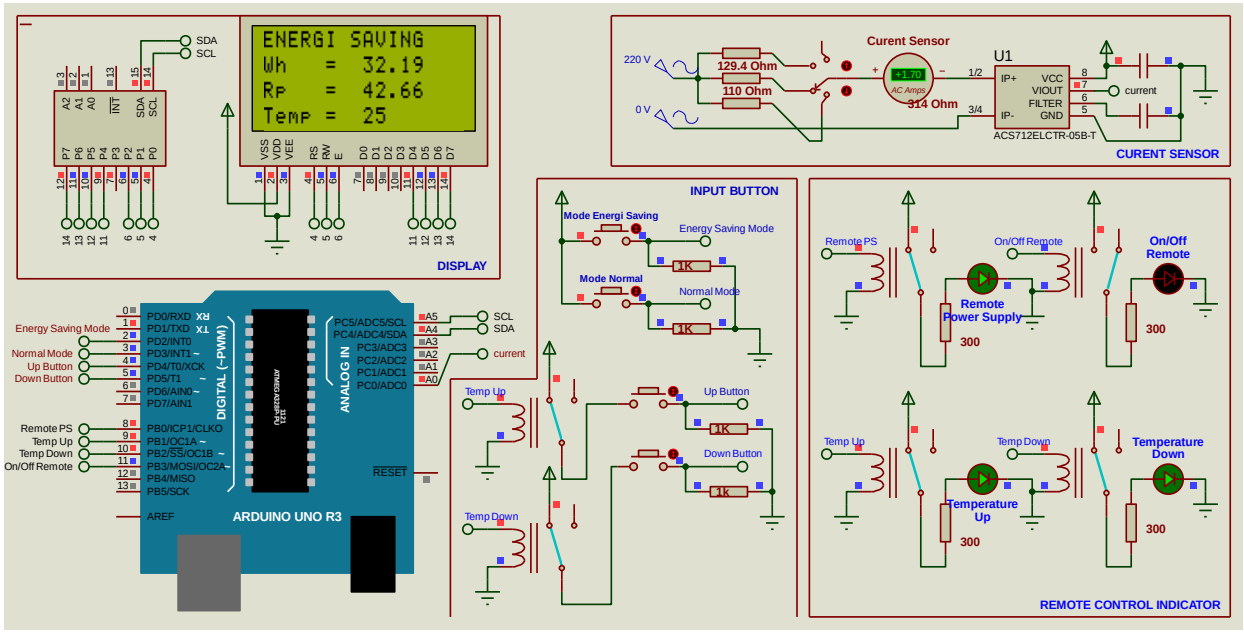

Fig 7: The temperature drop button will be activated

When the selection of the operating temperature of the air conditioning equipment has reached the maximum limit, in this case the setting has reached 27°C, the system will automatically deactivate the temperature selection process above 27°C, by deactivating the temperature rise button work, through deactivating the relay work which functions as a power supplier for the increase button temperature. Temperature options above 27°C are shown in Figure 8.

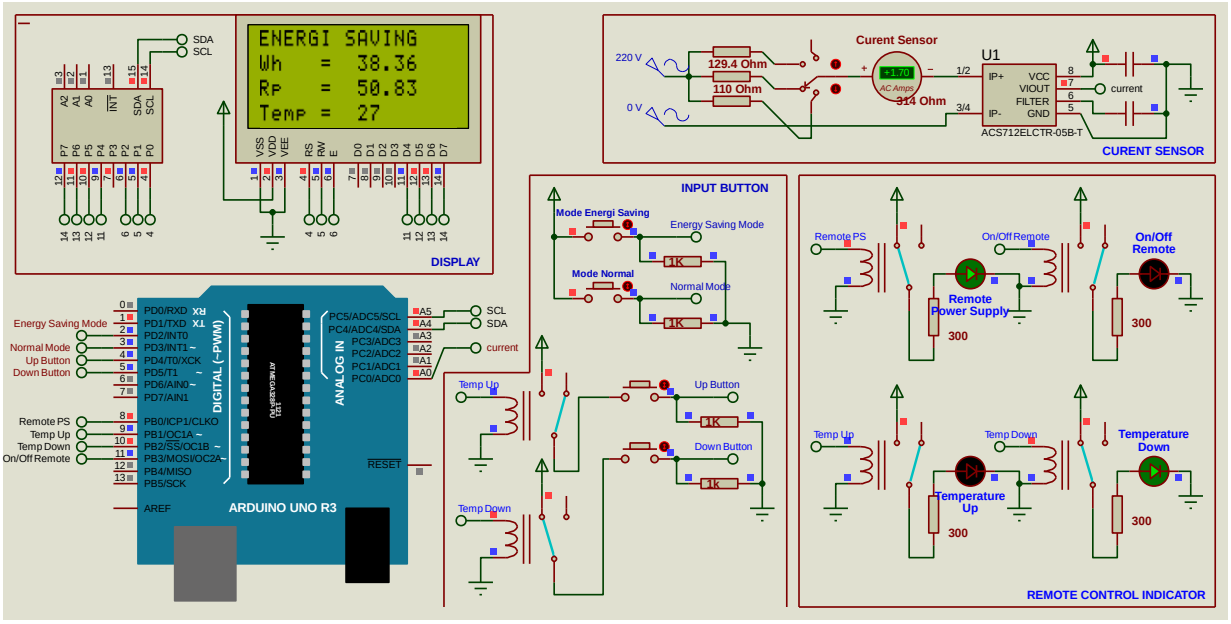

Fig 8: Temperature options above 27°C

3.3 System Testing For Monitoring The Process Of Electric Energy Consumption In Air Conditionng Equipment

To find out the amount of electricity consumption (Wh) and the amount to be paid (Rp) from the operation of air conditioning equipment, the system is tested in terms of the process of monitoring electricity consumption and the price to be paid in Rupiah (Rp). System testing for the monitoring process is shown in Figure 9.

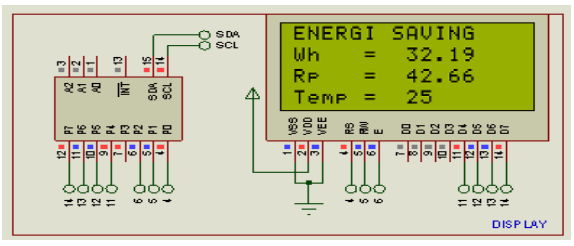

Fig 9: System testing for the monitoring process

From the results of tests conducted as shown in Figure 9, it appears that the system can carry out a process of monitoring the consumption of electrical energy and the amount of the price paid in Rupiah from the operation of air conditioning equipment and can inform it through the LCD display.

Part of the program carried out for the process of monitoring electricity consumption and the total paid price in Rupiah from the operation of air conditioning equipment is as follows:

The initial stage of the system is to read the value of the electric current consumed by the air conditioning equipment that is entered through the ADC, then the data read by the ADC will be processed to obtain the current value. The program part for the process of reading the value of electric current is as follows:

```
void read_adc()
{
dataADC = analogRead(current_sensor);
voltage_input = ((dataADC * 5.0)/1024);
current = ((voltege_input - 2.5)/0.186);
delay(300);
calculate_wh_Rp();
}
```

After the ADC data reading process is complete, the system will enter the program to calculate the amount of electricity consumption in watt hours (Wh) and the amount to be paid for electricity consumption in Rupiah (Rp) from the operation of the air conditioning equipment, as for the part the program is as follows:

```
void calculate_wh_Rp()
{
 p = (220 * current); // Electric Power Calculation
 i = i + p;  // Calculate For Total Current
 Wh = ((1.0/3600) * i);  // Calculate For Watt Hours
 Rp = ((Wh/1000) * 1325); // Calculate For Paid Price
```

Next, the process of calculating the amount of electrical energy consumption in watt hours (Wh) and the amount that must be paid for electricity consumption in Rupiah (Rp) from the operation of air conditioning equipment, then the system will inform via the LCD screen, where part of the program being run is as follows:

```
lcd.setCursor(0, 2);
lcd.print("Rp  = ");
lcd.setCursor(8, 2);
String paid price = String (Rp);
lcd.print(paid price);
lcd.setCursor(0, 1);
lcd.print("Wh  = ");
lcd.setCursor(8, 1);
 String watt hours = String (Wh);
lcd.print(watt hours);
delay(300);
}
```

From the results of monitoring carried out for 1 hour of operation, the system created can save electricity consumption of electricity to the operation of air conditioning equipment, by limiting the temperature regulation, which will only operate in the range of 24^{o}C to 27^{o}C. From the results of tests carried out, for normal mode operation at a temperature setting of 16^{o}C, the electrical energy consumption is 379.1 Wh, and for energy-saving operating modes at a temperature setting range of 24^{o}C to 27oC, it is measured for setting the temperature of 24^{o}C electricity consumption of 323.35 Wh, for setting the temperature of 25^{o}C electricity consumption of 308.48 Wh, for setting the temperature of 26^{o}C the consumption of electrical energy is 289.90 Wh and for setting the temperature of 27^{o}C electricity consumption is 275.03 Wh.

4. CONCLUSIONS

From the results of the tests carried out it can be concluded several things, namely:

1. The system that is made can limit the temperature regulation of the air conditioning equipment in operation settings 24oC to 27oC in energy saving operation mode, so as to minimize the occurrence of electrical energy waste from the operation of the air conditioning equipment. From the results of tests carried out, for normal mode operation at a temperature setting of 16oC, the electrical energy consumption is 379.1 Wh, and for energy-saving operating modes at a temperature setting range of 24oC to 27oC, it is measured for setting the temperature of 24oC electricity consumption of 323.35 Wh, for setting the temperature of 25oC electricity consumption of 308.48 Wh, for setting the temperature of 26oC the consumption of electrical energy is 289.90 Wh and for setting the temperature of 27oC electricity consumption is 275.03 Wh.
2. The system created can monitor and inform the amount of electrical energy consumption in Wh and the price paid in Rupiah from the air conditioning equipment through the information displayed on the LCD display, so that savings on the operation of the air conditioning equipment can be achieved.

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