DESIGN OF COOLING SYSTEM AUTOMATION ON SOLAR CELL BASED ON PROPORTIONAL INTEGRAL DERIVATIVE (PID)

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ABSTRACT
The electrical energy produced by solar cell technology in the form of electrical energy depends on the intensity of sunlight and depends on the performance of solar panels. The design or research design that will be carried out is to design an automatic system as a cooler on the surface of solar panels using several components needed, including solar panels, NodeMCU ESP8266, INA219 sensor, LCD, battery, DHT11 sensor, DC water pump, and MIT APP inventor. This tool is to optimize the performance of solar panels and get optimal voltage output and solar panel cleaners, using the PID method which functions to regulate the rotation speed of the motor / DC pump that will be operated on this tool which can be monitored through an application on a mobile phone.

Keywords: *Solar Panel, Temperature, Proportional Integral Derivative (PID), Microcontroller.*

1. INTRODUCTION

Solar energy is also called one of the main natural resources as a process that occurs on earth. Energy from the sun itself helps many physical things and conditions on earth. As for the fulfillment of basic human basic needs, especially in terms of electrical energy. Along with the increasing population in Indonesia, the need for electrical energy has also increased. Currently, the supply of electrical energy still depends on coal, natural gas and petroleum as the main sources. So that the capacity of this energy is increasingly limited and the price is increasingly expensive. The location of Indonesia itself is at the equatorial crossing point which has ample opportunities for solar energy throughout the year compared to other countries. This is an advantage that needs to be developed and optimized. Solar energy is the main source of energy at this time the availability of abundant natural resources that will not run out and are environmentally friendly. Solar energy is considered one of the best alternative energy sources today and will continue to be the most important energy source in the future. Utilization of solar energy can be through the use of solar panels or solar cells, can convert solar energy directly into electrical energy, so that it can be utilized in the form of street lighting scale, home lighting, and so on. So that it requires a cooling system to prevent hot temperatures from the sun so as not to damage the components of solar panels and batteries. Damage caused by overcharging is caused by poor performance of the regulator system so that it can result in excessive voltage. To optimize the performance of solar panels, a system is needed as a cooler on solar panels to ensure that the output voltage can work optimally, so a system is needed as a good cooler. The electrical energy obtained by solar cell technology in the form of electrical energy depends on the intensity of sunlight and depends on the performance of solar panels. To achieve optimal performance in areas with high temperatures. Solar cell performance will continue to work stably and best and get optimal temperature results when working at temperatures between 25°C and 35°C.

2. METHOD

2.1 Research design

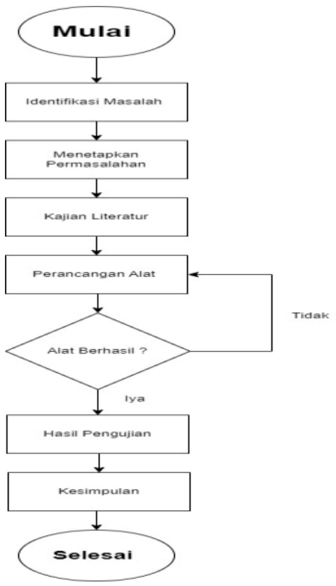

Figure 1 Research design

The research method in this implementation is generally divided into 7 stages which include:

a. Stage 1: Problem Identification
At this stage, research is carried out on problems that often occur in the peak duration of solar panels in order to get maximum charging. When the temperature of the sun is excessive.

b. Stage 2: Defining The Problem
Then after knowing the existing problems, the next step is to determine the problems that occur on the peak solar panel.

c. Stage 3: Literature Review
After obtaining the problems that occur in peak solar panels, then further conduct a literature review by conducting research on the design of the tool on the components that will be used.

d. Stage 4:Tool Design
After conducting a literature review, at this stage is designing the tool, designing the components of the tool, software, and hardware needed as a solution to the problems that have been identified.

e. Stage 5: Tool Testing
After the assembly of the tool is complete, the next stage is to conduct testing to ensure that the tool operates as expected or not.

f. Stage 6: Testing Results
At this stage, it will be seen from the results of testing the tools that have been made by researchers.

g. Stage 7: Conclusing
At this stage, researchers determine the conclusions of the component equipment that has been made by researchers, whether it can solve the problems that have been identified.

2.2 Tool Design

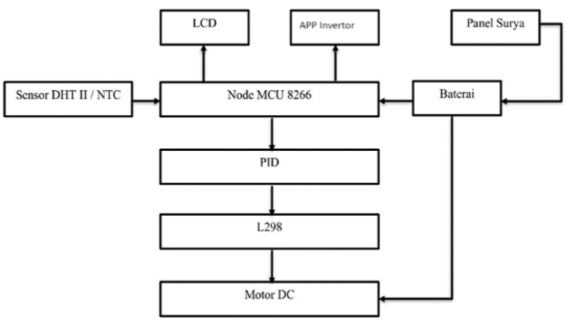

Figure 2 Tool Design

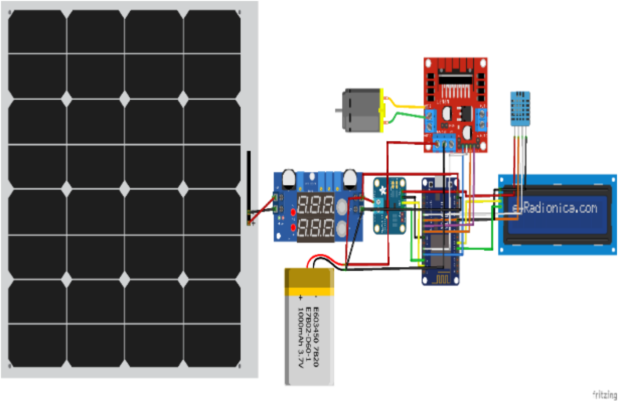

Figure 3 Wiring Diagram

With the block diagram above, it can be explained that the flow diagram is as follows:

1. Battery or 12 VDC power is the source for which will be used as a power supply in the study.
2. The 12 VDC voltage from this battery will be used to power the Arduino and motor driver.
3. The 5 VDC voltage that has been stepped down will activate the MCU 8266 Node.
4. The DHT / NTC Temperature Sensor is used as a temperature detection device that will be installed in the solar panel layer.
5. The MCU 8266 node functions as a control to determine the temperature value that has been read by the Temperature sensor and functions to give commands to the L298 Driver.
6. The L298 driver functions to regulate the speed of the DC motor pump.
7. PID Control is used to regulate the Coolling System watering time on solar panels.

2.3 How It Works

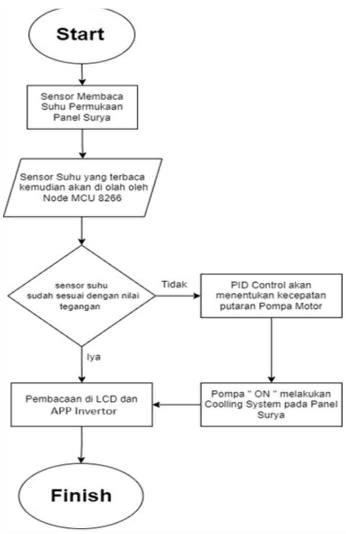

Figure 4 How The Tool Works

This tool works with solar panels that have been equipped with DHT11 or NTC temperature sensors. Then it is read by the NodeMCU ESP8266 which functions as a controller in this research, then the results of the temperature sensor reading will be adjusted to the voltage value that has been measured using the previous AVO meter. After that we get a temperature value where the voltage decreases, and the results of this value will be used as a measurement benchmark that will be set on the NodeMCU ESP8266. In this research the author uses the PID method to regulate the rotation speed of the DC motor/pump that will be operated on this tool. In this research, the author uses a battery for the power supply of the device which includes: Motor pump, NodeMCU ESP8266.

2.4 Tool Components

A. Hardware

1. NodeMCU ESP8266
   The NodeMCU ESP8266 electronic board consists of an ESP8266 chip and can perform microcontroller-like operations and access the internet via a Wi-Fi network.
2. DC Pump
   DC water pump is a device that uses DC (Direct Current) electric power as a power source for its operation.
3. LCD
   Liquid crystal display (LCD) is a media display that utilizes liquid crystal as the main element. LCDs can display images or text. LCD can produce a display consisting of many pixel light points, where each pixel is one liquid crystal.
4. DHT 11/NTC Sensor
   The DHT11 sensor is a calibrated module sensor that can detect humidity and air temperature. This sensor is known for its high level of stability and highly accurate calibration features.
5. Battery
   A battery is a device that functions through an electrical chemical process, where the energy is converted into chemistry when charging and the chemical energy is converted back into electrical energy when discharging.
6. MPPT
   Maximum Power Point Tracking (MPPT) is an important electronic system in PV (Photovoltaic) systems to ensure that the system can produce maximum power.
7. INA219 Sensor
8. INA219 sensor is a sensor that functions to measure two parameters, namely air temperature and humidity in the form of voltage (volt) and current (ampere).

B. Software

1. Arduino IDE
   Arduino Integrated Developmnet Environment (IDE) is software used to develop programs on the Arduino Mega 2560 Pro. Programs which are written using the Arduino IDE software are known as sketches.
2. MIT APP Inventor
   App Inventor is a software that allows users to develop Android devices through Apps. The software is designed to produce simple applications without requiring in-depth knowledge of programming languages. Users can also design Android apps as they wish using the various components and layouts available.
3. PID Controller
   Proportional-Integral-Derivative (PID) control is one of the control methods in automatic control systems, where the control parameters can be determined in order to get the desired system response with a small overshoot error rate. This control integrates three main elements, namely proportional, integral, and derivative elements, to achieve optimal control performance.

2.5 Data Analysis Technique

This research will design a device to overcome the problems that have been identified previously. The data analysis techniques used include several methods.

1. Literature study method, which is a way of examining, exploring, and studying theories that support the solution of the problem under study.
2. The literature method, namely from various reference books and information from lecturers and relatives as well as from several sites on the internet which are very helpful in obtaining a theoretical basis as a source in this writing and references to the problems raised by the author.
3. Observation method, namely making observations by going to the field in order to find supporting data and information, which if not obtained through literature and laboratories. So that it can be accounted for its existence.
4. The calculation analysis method, namely by analyzing the construction calculations of the designed components.
5. Experimental method, namely by testing the tool to get data on the experimental results of the program made by simulation so that it helps in solving existing problems.
6. Discuss, namely consulting and guidance with lecturers and other parties who can help the implementation of this design. competent parties in supporting the implementation of this tool design.

3. RESULTS AND DISCUSSION

This test was conducted by researchers to obtain performance, namely by knowing the measurement results of the temperature and voltage sensors, in hot solar conditions based on the voltage capacity produced and displayed on the LCD and Application. And testing the accuracy of the sensor by comparing the measurement results of the sensor using the DHT11 sensor and Digital

Thermometer as a comparison of the measurement results. Therefore, this test also aims to understand the condition of the system so that this application can operate normally and optimally.

3.1 Hardware Testing Results

a. Solar Panel Testing

In this research series, the author uses a 20 WP Solar Panel. The component is the main object that will be the generator to charge the battery voltage and receive the work process from the cooling system. Solar panels will be kept at a certain temperature using the existing circuit so that the output voltage is maximized.

Table 1 Solar Panel Testing

Pengujian Panel Surya					
jam	T	I	Pembacaan AVO	Pembacaan LCD	Pembacaan Android
07.00-09.00	13,3	1,76	13,3	13,2	13,2
11.00-13.00	17,4	1,80	17,4	17,3	17,3
15.00-17.00	12,7	1,69	12,7	12,6	12,6

The first test on the 20WP solar panel, after testing it can be concluded that the panel can function to supply the load and to find out the results of the voltage generated by the panel whether it can be used for battery charging or not, in this test the solar panel can function to charge a 12Volt battery. And can be used as a power source to turn on the DC Pump.

b. INA219 Voltage And Current Testing

In this tool design using the INA219 sensor to measure the value of current and voltage output by the Solar Panel. Measured data will be sent to the minkrokontoller and displayed on the Android application. INA219 sensor testing is carried out to determine the level and accuracy of the results of measuring the DC voltage and current of the solar panel output. The test is carried out by comparing the voltage value on the LCD with the measurement results using a measuring instrument.The following table shows the test results of the INA219 sensor:

Table 2 INA219 Sensor Test Result Data

No.	Pengukuran Alat Ukur (V)	Tampilan LCD (V)	Selisih (V)	*Error (%)*
1.	13,3	13,2	0,1	0,75%
2.	17,2	17,1	0,1	0,58%
3.	17,4	17,3	0,1	0,57%
4.	16,9	16,8	0,1	0,59%
5.	17,4	17,3	0,1	0,57%
6.	18,9	18,8	0,1	0,52%
7.	12,7	12,6	0,1	0,78%
8.	13,1	13,0	0,1	0,76%
9.	13,2	13,1	0,1	0,75%

From the test results of the INA219 sensor, it can be concluded that the INA219 sensor can be used as a voltage sensor reading in the Cooling System 10 design circuit as evidenced by the test results using an AVO meter and reading on the LCD.

c. DHT11 Temperature Sensor Testing

DHT11 sensor testing is done by placing the temperature sensor behind the solar panel, to get the temperature value on the solar panel in the DH11 sensor which produces an accurate value, then by comparing the temperature value on the Digital Thermometer. Therefore, a study is needed to get a temperature sensor that has the most accurate reading accuracy. The use to determine the sensor can be determined through the calculation of the comparison between the DHT11 sensor and the Digital Thermometer by looking at the error value, and if the error value has been obtained then the sensor is declared feasible and accurate, so it can be calculated for the error comparison using the following formula:

$$e = |Xo - Xs\ |\ Xo\ x100\%$$

Description:

e = Error (%)

XO = Actual data

XS = Sensor data

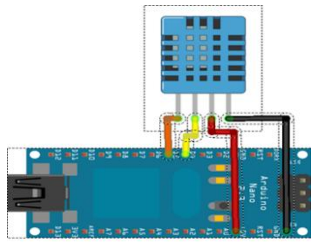

Figure 5 DHT11 Sensor Circuit

From the test results of the DHT11 sensor, it can be concluded that the error comparison between the DHT11 temperature sensor and the Digital Thermometer, where the DHT11 sensor has an error below 0.5%, with the error results obtained by the DHT11 sensor having a different error difference, and can send the reading data to the Arduino which is displayed on the LCD and Android Application.

d. Cooling system Testing

In this test, the author uses a method using a comparison between the watering time and temperature set point so that it can match the adjusted temperature and the following temperature is a list of tables used:

Table 3 Cooling System Test Results Data

Pengujian *Cooling System*						
Jam	Suhu	Suhu *Set Point*	Waktu	PWM	Tegangan Awal	Tegangan Akhir
07.00-09.00	37^0	$34{,}5^0$	39s	250	18,1	12,8
	36^0	$34{,}5^0$	34s	250	18,1	12,8
	35^0	$34{,}5^0$	33s	250	18,1	12,8
	34^0	$34{,}5^0$	32s	115	18,1	12,9
	$34{,}4^0$	$34{,}5^0$	10s	0	18,1	18,5
11.00-13.00	40^0	$36{,}9^0$	40s	250	17,8	12,8
	39^0	$36{,}9^0$	42s	250	17,8	12,7
	38^0	$36{,}9^0$	45s	250	17,8	12,7
	37^0	$36{,}9^0$	37s	250	17,8	12,7
	36^0	$36{,}9^0$	32s	95	17,8	14,5
	$36{,}8^0$	$36{,}9^0$	20s	0	17,8	18,6
15.00-17.00	35^0	$32{,}1^0$	35s	250	13,2	12,7
	34^0	$32{,}1^0$	33s	250	13,2	12,6
	33^0	$32{,}1^0$	28s	125	13,2	12,9
	32^0	$32{,}1^0$	20s	0	13,2	13,2
	$32{,}0^0$	$32{,}1^0$	10s	0	13,2	13,6

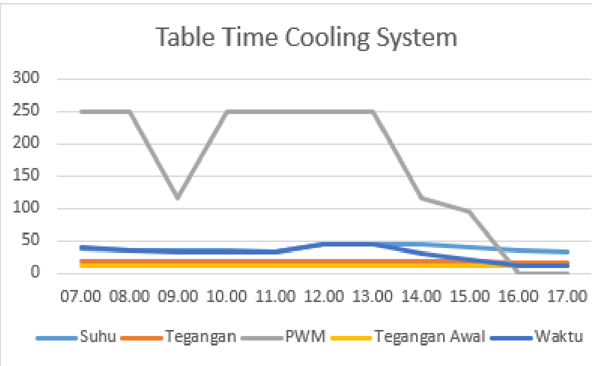

Figure 6 Cooling System Graph

From the test results of the Cooling System above, the author gets data which at 07.00-09.00 with a temperature of 370 which has a voltage of 18.1 V, cooling is carried out with a set point temperature of 34.50 for 2m 28s, after cooling, the voltage result is 18.5 V with a temperature of 330 with PWM 250 which is controlled by PID.

e. Battery Testing

Batteries are tested to find out whether the battery is still functioning properly or not as a power source when solar panels cannot charge. In this study, the battery functions to turn on the load, namely the 12Volt DC Pump which is used for the Colling System on the surface of the solar panel and control.

Figure 7 Battery Testing

From the battery test results, this time the battery that has been tested shows 12.3 Volts can be useful properly, and the solar panel is able to charge the battery to supply the DC pump and control.

f. LCD Testing

In this tool research circuit, the author uses an LCD (Liquid Crystal Display) which aims to show the readings of Voltage, Current, Temperature and PWM. Voltage, Current, Temperature and PWM readings by sensors and processed by NodeMCU8266. And displayed through the LCD.

Figure 8 LCD Display

From the results obtained through LCD testing, the LCD can display temperature, voltage, PWM and current sensor readings, so the LCD performs well as expected.

g. DC Water Pump Testing

The author tests the DC pump to cool the surface of the solar panel, according to the temperature sensor set point we have applied (Set Point). Testing the DC Pump this time is whether the pump can run properly or not and is proven by the results, that the pump can function as it should.

Figure 9 DC Pump Testing

The DC pump will be used as a contribution to watering or as a Solar cell cooler, which is a tool or machine component used to transfer a liquid from one place to another by adding energy to the liquid continuously through a piping system. The water pump used for the cooling system is DC 12V which operates a DC motor and uses 12volt direct voltage as its energy source. The results of the analysis show that the pump can operate properly without problems as it should and can reduce the temperature on the surface of the solar panel, and the pump performance is in accordance with the expected parameters.

h. NodeMCU ESP8266 Testing

Testing on this microcontroller aims to find out whether this NodeMCU ESP 8266 microcontroller can function and work properly or not. The following is a test table of the NodeMCU ESP 8266 Microcontroller:

Table 4 NodeMCU ESP8266 Testing

Pengujian	Kondisi
Port NodeMCU ESP8266 terdeteksi oleh PC	Normal
Compiling coding NodeMCU ESP8266	Normal
Upload coding NodeMCU ESP8266	Normal
Program dan sistem NodeMCU ESP8266 sesuai	Normal
Serial monitor terbaca sesuai *baudrate*	Normal
Tegangan pin 5V	Normal
Tegangan pin 3,3V	Normal
Pembacaan nilai ADC analog *input*	Normal
Pembacaan nilai digital *input*	Normal
Tombol *reset*	Normal

Based on tests conducted when the NodeMCU ESP8266 is given a voltage source, that the NodeMCU ESP8266 is able to respond to the output data from the temperature sensor readings. So that the NodeMCU ESP8266 can function.

3.2 Software Testing Results

a. Arduino IDE

Arduino IDE which is used as software to develop and program Arduino microcontroller boards.

The Arduino IDE testing steps are as follows.

a. Run the Arduino IDE software on a laptop or computer.
b. Open the system program that has been coded according to the needs.
c. Verify the program that has been opened to ensure whether there are steps that are still incorrect in coding.
d. Connect the microcontroller to a laptop or computer using a data cable.
e. Upload the Arduino IDE coding program to the microcontroller.
f. Observe the process of uploading the program until the words done compiling appear.
g. Test (running) tools that have been given a coding program and pay attention to the suitability of the work process of each component.

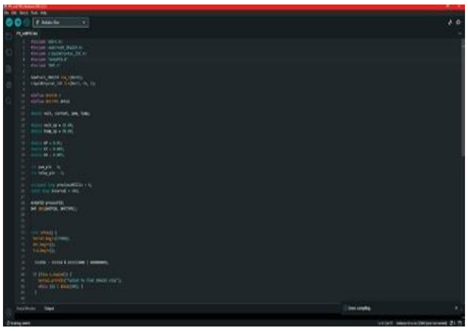

Figure 10 Arduino IDE Testing

From testing the programming results, it can be concluded that the Arduino IDE coding program for the NodeMCU ESP 8266 microcontroller can run and as desired. This is known by the absence of error messages in the verify and compiling sketch process. After the compile process, a done compling command appears which means the process is successful.

b. MITT APP Inventor

MIT App Inventor is an Android application for sending IOT data that has been connected to the NodeMCU ESP8266 used to monitor Voltage, Current, and PWM and can set set setpoints. Applications and NodeMCU ESP8266 can be connected via an internet connection. So that it can be controlled and monitored remotely as long as it is connected to an internet connection through an application installed on a mobile phone.

Figure 11 Application Creation On MIT APP Inventor

In this experiment, the program that has been made has run as desired and the results obtained that the reading is in accordance with what is displayed on the LCD, and has run as it should and can function to monitor remotely using the Internet (IoT) and can be installed on a mobile phone.

c. PID

PID Control works by continuously calculating the error value by comparing the actual value outputted with the desired value (setpoint).

Error value = actual value - setpoint value

After knowing the error value, the controller then tries to reduce the error value every time by changing the control variables that allow it to be changed to kp, ki, and kd values. The PWM, or Pulse Width Modulation, value is a control variable that can be changed by the PID controller.

And another coefficient set is that the temperature setpoint is 45 degrees. The last is the data update interval of 300ms. ArduPID declares a class called the PID process, in the future the PID process will be used to calculate the calculation results for PID control. The PID process has a sequence of variables that need to be entered based on the functionality stored in the ArduPID library, namely (actual value), (control variable), (desired value), kP, kI, kD. In the variable name code used, namely &temp, &pwm, &temp_sp, kP, kI, kD. & in this context is intended for variables whose values will change constantly. The PID system used is a reverse PID system where the output value will be the opposite value of the input. used to determine the output limit of the integral value, the integral value will not pass -10 and 10. The lower the temperature input from the setpoint, the PWM output will decrease. And vice versa, if the higher the temperature input from the setpoint, the pwm speed will increase.

Table 5 Proportional Integral Derivative Testing

Waktu	Timer	Suhu	*Set Point*	*Error*	P	I	D	PID	Servo (-)
1	39s	37^0	$34,5^0$	2,5	2,5	2,5	2,5	7,5	250
2	34s	36^0	$34,5^0$	1,5	1,5	6,5	-1	7	250
3	33s	35^0	$34,5^0$	0,5	0,5	6	-1	5,5	250
4	32s	34^0	$34,5^0$	-0,5	-0,5	4,5	-1	3	115
5	10s	34.4^0	$34,5^0$	-0,1	-0,1	3,4	0,4	3,7	0
1	40s	40^0	$36,9^0$	3,1	3,1	3,1	3,1	9,3	250
2	42s	39^0	$36,9^0$	2,1	2,1	8,3	-1	9,4	250
3	45s	38^0	$36,9^0$	1,1	1,1	8,4	-1	8,5	250
4	37s	37^0	$36,9^0$	0,1	0,1	7,5	-1	6,6	250
5	32s	36^0	$36,9^0$	-0,9	-0,9	5,6	-1	3,7	95
6	20s	$36,8^0$	$36,9^0$	-0,1	-0,1	4,5	0,8	5,2	0
1	35s	35^0	$32,1^0$	2,9	2,9	2,9	2,9	8,7	250
2	33s	34^0	$32,1^0$	1,9	1,9	7,7	-1	8,6	250
3	28s	33^0	$32,1^0$	0,9	0,9	7,6	-1	7,5	125
4	20s	32^0	$32,1^0$	-0,1	-0,1	6,5	-1	5,4	0
5	10s	$32,0^0$	$32,1^0$	-0,1	-0,1	5,4	0	5,3	0

Furthermore, after finding the results of the cooling system test to determine the error in the PID using the following formula.

Error = Temperature - Set Point
P = Kp x Error
I = Ki x (Total Error + Past Error)
D = Kd x (Error - Past Error)
PID = P + I + D
Overshoot = Stable Timer/Set Point temperature x 100%

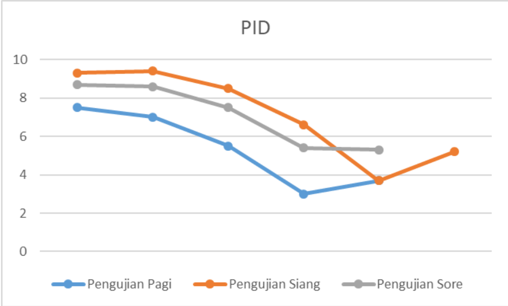

Figure 12 PID Graph Testing

From the table and graph above:

Morning Testing Overshoot = 39s/60 = 0.65/34.5 x 100% = 0.018%

Daytime Testing Overshoot = 45s/60 = 0.75/36.9 x 100% = 0.020%

Afternoon Testing Overshoot = 35s/60 = 0.60/32.1 x 100% = 0.019%

In the above tests from the table and graph results to determine the PID system control error, the authors get the results in the morning time test temperature of 370 with a setpoint of 34.50 which has an overshoot of 0.018%, in the afternoon time test temperature of 400 with a setpoint of 36.90 which has an overshoot of 0.020%, and in the afternoon time test temperature of 350 with a setpoint of 32.10 which has an overshoot of 0.019%.

3.3 Discussion Of Research Results

Research entitled Cooling System Automation Design on Solar Cells Based on Proportional Integral Derivative (PID), can determine some of the weaknesses and advantages of the tools that have been made, including the following.

a. Weaknesses

1. There is an error or difference between the measurement results of the measuring instrument and the sensor data displayed on the LCD and application.
2. Requires a stable internet connection on mobile phone.
3. The tool design is still on a small scale.

b. Pros

1. The design of the device has been equipped with a voltage, current, and temperature monitoring system using a NodeMCU ESP8266 microcontroller whose data is displayed on the LCD and android application.
2. The design of the tool has a sprayer and water pump that can clean and reduce the temperature on the solar panel.

3. The cooling system on the tool is automatic when cooling the solar panel.

CONCLUSIONS AND RECOMMENDATIONS

a. Conclusion

Based on the test results and discussion of the Cooling System Automation Design on Solar Cell Based on Proportional Integral Derivative (PID), conclusions can be drawn, among others, as follows.

1. Solar intensity greatly affects the amount of power generated, if the solar intensity is lower, it decreases the amount of power generated, while higher solar intensity increases the amount of power generated.
2. Making Cooling System Automation Design on Solar Cells Based on Proportional Integral Derivative (PID), using several components in this system design including batteries, INA219 sensors, LCDs, DHT11 sensors, DC water pumps, NodeMCU ESP8266 microcontrollers integrated with IOT using android smartphone-based applications. Broadly speaking, the system can work well.
3. Based on the results of the research conducted cooling affects the output on the surface of the solar panel, both before and after watering. The results obtained after cooling in the morning were 18.5 V, in the afternoon 18.6 V, and in the afternoon 13.6 V.
4. The use of the PID method in this system can produce a more stable DC pump. This is because the control system regulates the PWM of the DC pump well, the results of the stabilization test in the morning time have an overshoot of 0.018%, in the afternoon time test which has an overshoot of 0.020%, and in the afternoon time test which has an overshoot of 0.019%.

b. Advice

Based on the discussion and conclusions of the Cooling System Automation Design on Solar Cells Based on Proportional Integral Derivative (PID), suggestions that can be given include the following.

1. In further research, this tool is expected for the water used in the cooling system process on solar panels to add a water filter, so that the water used remains clean.
2. In future research this tool can add some more accurate temperature sensors on the surface of solar panels.
3. In further research using a stable internet connection network to make it easier to monitor remotely via cellphone.
4. In future research to get optimal watering results, you can use sprayers and DC pumps that have greater pressure.

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