Bulletin of Computer Science and Electrical Engineering
Vol. 3, No. 2, December 2022, pp. 55~65
ISSN: 2722-7324, DOI: 10.25008/bcsee.v3i2.1164

Monitoring and Automatic Cooling Systems in Realtime Photovoltaic Based on IoT

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Article Info

Article history:

Received Dec 03, 2022
Revised Dec 15, 2022
Accepted Dec 24, 2022

Keywords:

Solar Panel
Monitoring
Automatic Cooling System
Internet of Things

ABSTRACT

Monitoring the results of solar panel performance has an important role to evaluate the performance of solar panels in hot outdoor environmental conditions. This study aims to provide a new direct and real-time monitoring method for monitoring voltage, current, and temperature in solar panels and automatic cooling systems for solar panel surfaces. To meet these needs, a solar panel temperature monitoring and control system has been designed. This system is equipped with voltage sensors, current sensors, and temperature sensors, a data transfer system that is integrated in the smartphone application, automatic control of the cooling system on the panel, and cloud storage for Internet of Things (IoT)-based data. storage. The design of this system is based on the Arduino Uno microcontroller which is connected to Blynk IoT via the ESP8266 Wi-Fi module with serial communication so that the system can be controlled and monitored in real time. The results obtained from this monitoring system are measurement data for each sensor which can be directly stored and displayed on the Blynk application dashboard in real time. From the results of a comparison of testing the cooling system on the surface of the panel for application variation 2 with a setpoint of 35 °C, an average temperature drops of 8.79 °C or 21.1% is obtained and for variation 3 with a setpoint of 30 °C, the average temperature drop of 8.69 °C or 20.89% compared to without using a cooling system with an average temperature of 41.57 °C. So that the use of a cooling system with water flow is very useful for public knowledge in terms of lowering the temperature on the surface of the solar panel, so that it will increase the output of the solar panel.

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1. INTRODUCTION

The need for electrical energy in Indonesia is always increasing from year to year. Therefore, to meet the demand for electrical energy, the Indonesian government through the Ministry of Energy and Mineral Resources (KESDM) wants to increase the energy output desired by the community. Therefore, the use of PLTS is very appropriate and supports government plans. From PLTS itself, the most important thing is solar panels or photovoltaic because this tool is a tool that can absorb energy from solar radiation. One of the factors driving the growth of EBT generators is through solar and water [1][2].

It can be seen from the environmental temperature in Indonesia which is classified as hot, therefore there is a need for cooling for PLTS, especially in the photovoltaic section. The increase in the surface temperature of the solar cell affects the output power, so we can see that the increase in the surface temperature of the photovoltaic causes the work system of the solar cell to be disrupted [3][4][5][6].

With the development of technology that is now entering the 4.0 era, one of the systems prioritizes IoT. The Internet of Things is a technology that really helps the role of human life. The IoT-based solar panel performance monitoring and control system, the bottom line is that the energy produced by solar panels can be monitored using a monitoring system. In addition to using an IoT-based monitoring control system, it is very influential in disconnecting and activating the connection of electricity to the battery for energy supply [7][8] [9].

This research will be carried out research to create an automatic monitoring and cooling system on photovoltaic in real time based on IoT [10]. Where later the temperature on the surface of the solar panel is monitored automatically by input via a temperature sensor. If the temperature on the surface of the panel exceeds the normal temperature limit, the temperature is lowered by the flow of water controlled by the Arduino [11]. With the research and manufacture of this tool, it is hoped that the output power from photovoltaic production can be maximized and the efficiency value will increase [12][13][14] [15].

2. RESEARCH METHOD

This research was carried out in stages and systematically. At the design and manufacture stage the module is divided into two, namely software design for sensor readings and automatic cooling systems and hardware design including determining tool specifications and tool design. Testing on the module is carried out to prove that the module or tool design is ready for use in research.

The data needed in this study includes the panel surface temperature, output voltage, and panel output current. The data will be processed through microcontrol and Blynk to monitor the performance of solar panels as a monitor for the success of the cooling system and temperature control in this study.

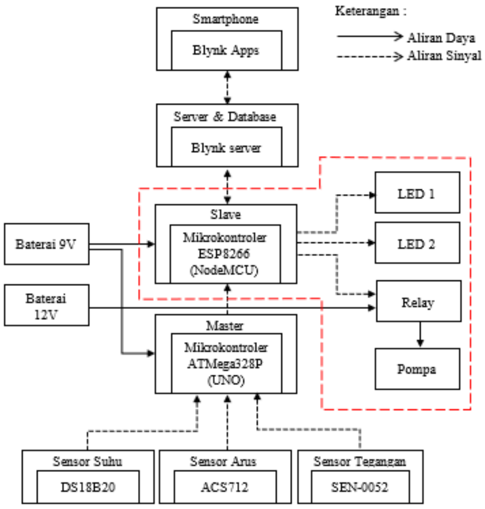

Figure 1. Overall System Block Diagram

2.1 Components Required in Research

a. Solar Panels

Solar panels are a renewable power generator made of several semiconductor materials. The working system is to convert sunlight energy into electrical energy. This process utilizes the photovoltaic effect. The material for making solar panels is composed of several semi-ductor materials such as germanium, titanium oxide, silicon, and so on. Basically, it consists of a p-n junction that has the same function as a diode, when the sun's energy hits the surface of the solar panel, the energy is absorbed by the electrons in the p-n junction to move from the diode part of the p-junction to the n-junction and then flows out through the wires connected to it. mounted on a solar panel. [16][17]

To increase the value of solar panel efficiency, one way is to reduce or maintain the maximum temperature of the solar panel when operating with a temperature of 25°C. A normal temperature increase in the solar panel will weaken the voltage, every 1°C increase (from 25°C) will reduce by about 0.4% of the total power produced or will decrease 2 times for every 10°C temperature increase in the solar panel.[18] To find the efficiency value of solar panels, we can use equation (1), which is a comparison of equation (2) with equation (3) [19][20][21].

$$\eta = \frac{P_{OUT}}{P_{IN}} \times 100\% \quad (1)$$
$$P_{OUT} = V \times I \quad (2)$$
$$P_{IN} = Ir \times A \quad (3)$$

b. Solar Charge Controller (SCC)

Solar Charge Controller is an electronic equipment that functions to charge direct current to the battery (charge) or discharge direct current from the battery to the load (discharge). In addition, the solar charge controller also protects the battery, which inputs energy from solar panels, which tends to be unstable when the battery capacity is full (overcharging) [22].

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Figure 2. Solar Charge Controller

c. Arduino UNO

Arduino Uno is an Arduino branded product that uses an Atmega 328 microcontroller. This tool can be used to create simple to complex electronic circuits [23].

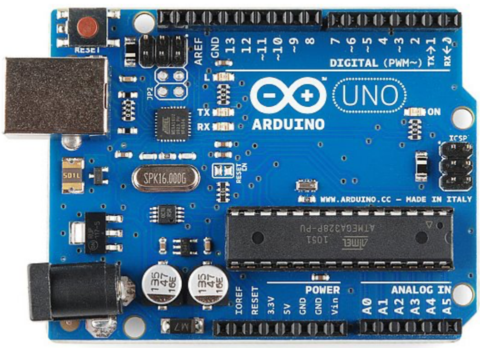

Figure 3. Arduino uno

d. NodeMCU

NodeMCU is a microcontroller similar to aruino. NodeMCU has advantages over Arduino because in NodemMCU there is a system on chip ES8266 which is embedded in NodeMCU.

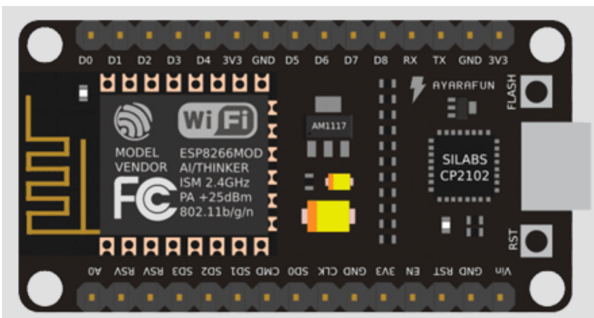

Figure 4. NodeMCU

NodeMCU is also an arduino development for IoT systems. NodeMCU has GPIO ports from D0-D10, PWM functionality, 12C and SPI interfaces, and 1 wire interface [24].

e. ACS721 (Sensor arus)

Current sensor is an electronic component that has a function to detect the amount of electric current flowing. One type of current sensor that is commonly used is ACS712 [25].

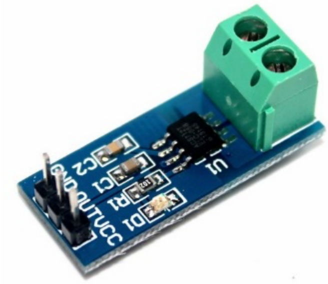

Figure 5. ACS721 current sensor

f. SEN-0052 (Voltage Sensor)

The SEN-0052 voltage sensor is a type of sensor which has the ability to measure electric voltage. This sensor is based on the resistance pressure principle and can reduce the input voltage of the terminal to 5 times that of the original voltage [23].

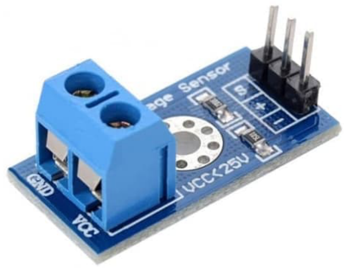

Figure 6. Voltage sensor SEN-0052

g. DS18B20 (Temperature Sensor)

The DS18B20 temperature sensor is a type of sensor which has a function to detect room temperature. The ability of this sensor can detect temperatures ranging from -55°C - 125°C with an accuracy level (+/- 0.5°C) with 9 – 12-bit resolution. So that this temperature sensor can be a temperature-based control [26].

Figure 7. DS18B20 temperature sensor

2.2. Hardware Design (Hardware)

In Figure 2 is the design of the research module that will be made. The solar panel is located above the module frame with 2x50 Wp specifications of the poly-crystaline type connected in parallel. The monitoring module is placed above the foot of the frame and the water pool is placed next to the foot of the frame. placement of water ponds and water pumps is placed not far from the solar panels because the pump used has a flow rate limit and the ability to push water vertically [5].

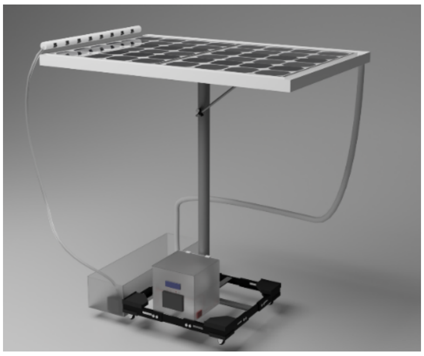

Figure 8. Module Design

The hardware used in this study are:
1. 100 Wp solar panel
2. 5 W & 7 W LED lights
3. Solar Charge Controller PWM KW1210
4. 12 V 5AH Battery
5. 12 V DC motor
6. ATmega328P microcontroller
7. ESP8266 Wi-Fi Module Microcontroller
8. 9 V battery
9. ACS712 sensor
10. DS18B20 Sensor
11. SEN-0052 sensor
12. Relay 1 channel
13. LCD display

These components are then assembled into a system as depicted in the diagram in Figure 8.

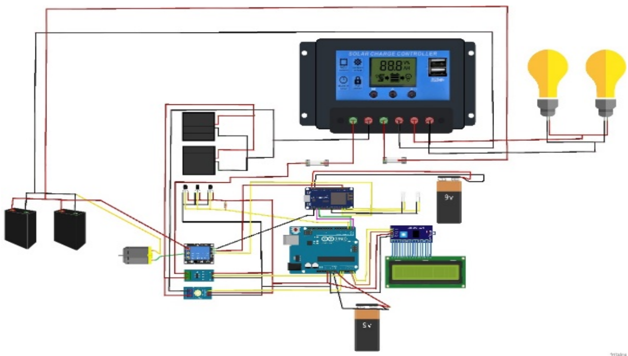

Figure 9. Overall system wiring diagram

In Figure 9, is an illustration of the monitoring module design. This module is equipped with a 24/48V PWM type SCC, 2x16 LCD to display temperature monitoring data, ATMega328P (Uno) microcontroller with ESP8266 WiFi module, DS18B20 sensor to read temperature values, SEN-0052 sensor to read voltage values, ACS712 sensor to read the value of the output current from the solar panel, and a DC 10V fuse as an installation safety.

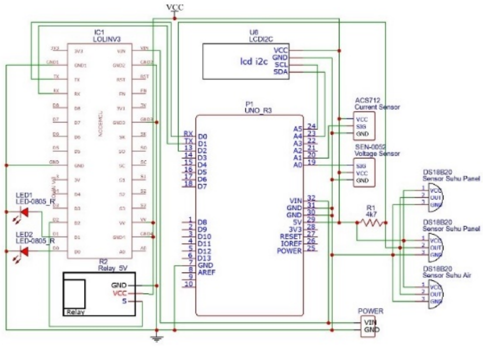

Figure 10. Schematic diagram of the monitoring module

All sensors are then connected via the pins on the Arduino Uno microcontroller which are connected to the ESP8266 as a WiFi module. The DS18B20 sensor is connected to a 4.7 KΩ resistor as a pullup from the data line to help the data transfer process run stably. In this circuit there is a relay to control the DC pump as a regulator of water flow on the surface of the panel which is connected to pin 2 of the ESP8266 WiFi module.

2.3 Software Design (Software)

The design of the software for the overall module system consists of 2 systems, namely a monitoring system and an automatic temperature control system. This system consists of ATMega328P and ESP8266 microcontrollers. The monitoring system on solar panels is a panel performance monitoring technique using sensors that are coupled with a microcontroller and integrated into the Blynk software [27].

3. RESULTS AND DISCUSSION

3.1 ACS-712 Sensor Testing

This test was conducted to prove that the ACS-712 sensor readings can work accurately to read the output current on the solar panel. The data taken is in the form of readings from the ACS-712 current sensor and then processed by finding the difference in error using equation (4), and the percentage of error using equation (5).

$$\underset{Error}{\Delta} = |baca\ Sensor\ ACS712 - baca\ Tangampere| \quad (4)$$

$$\%\,Error = \frac{\Delta\ Error}{Pembacaan\ Tang\ Ampere} \times 100\% \quad (5)$$

Table 1. ACS-712 Sensor test data

Time	Sensor ACS-712 (A)	Tang Ampere (A)	Δ Error	% Error
06.15	0,63	0,52	0,11	21,15
06.30	0,64	0,64	0	0,00
06.45	0,87	0,88	0,01	1,14
07.00	0,95	0,92	0,03	3,26
07.15	1,08	1,03	0,05	4,85
07.30	1,14	1,12	0,02	1,79
07.45	1,22	1,2	0,02	1,67
08.00	1,41	1,37	0,04	2,92
......				
17.15	0,09	0,13	0,01	30,77
17.30	0	0	0	0,00
17.45	0	0	0	0,00
18.00	0	0	0	0,00
	Average of *Error*		0,05	3,3 %

Based on the test results in table 1, the reading between the ACS-712 current sensor and the ampere meter has an average error value of 0.05 and the percentage error obtained in the current sensor reading is 3.3%. This value is so small that the ACS-712 sensor readings in this study are quite accurate.

3.4 Panel Surface Temperature Comparison

The temperature comparison test on the surface of the solar panels was carried out 3 times on different days with a duration of 12 hours from 06.00 WIB to 18.00 WIB and data collection intervals every 15 minutes. Variation 1 was conducted on Tuesday, 29 March 2022, then variation 2 was tested on Wednesday, 23 March 2022 and variation 3 was tested on Thursday, 24 March 2022 at the research location.

Table 2. DS18B20 sensor test data

Time	Solar Panel Temperature		
	Variation 1 (°C)	**Variation 2 (°C)**	**Variation 3 (°C)**
06.15	23,80	26,62	25,65
06.30	27,87	26,19	26,69
06.45	30,12	27,44	27
07.00	31,19	28,25	28,12
07.15	31,90	28,18	29,3
07.30	33,80	28,25	29,69
07.45	35,38	28,69	29,9
08.00	36,90	30,56	30,00
...	....	....	....
17.15	30,56	28,69	28,12
17.30	29,87	28	28,37
17.45	29,50	27,87	27,27
18.00	29,12	26,62	27,25
	41,57	**32,78**	**32,88**

Based on table 2, the results of the DS18B20 sensor test were obtained by taking 3 times with three different variations. In each variation there is the highest temperature value at different times. In variation 1 the highest temperature occurred at 12.45 at 55.4 °C, for variation 2 the highest temperature occurred at 12.00 with a value of 40.8 °C, while for variation 3 the highest temperature occurred at 14.30 at 38.42 °C. The difference in value and time is affected by the weather on different days and the cooling system that works. In variation 1 it has the highest heat temperature value; this is because the variation is applied without using a cooling system. Can be seen more clearly for the comparison of the average panel surface temperature that occurred for one day (06.15 - 18.00) in each variation. It can be seen from the three test variations, variation 1 has the highest average temperature among the others with an average value of 41.57 °C. Compared to variation 2 using a cooling system with a setpoint of 35 °C, an average temperature of 32.78 °C is obtained, so that the average temperature decrease is 8.79 °C or 21.1%. Whereas with variation 3 using a cooling system with a setpoint of 30 °C, an average temperature of 32.88 is obtained so that the average temperature decrease is 8.69 °C or 20.89%. So overall the application of variations on the surface of the solar panel using this water-cooling system has succeeded in reducing the surface temperature of the solar panel.

3.5 Communication Testing

3.5.1 Serial Communication

Serial communication is a communication line for sending and receiving per-bit data sequentially and alternately on the ATMega328P microcontroller.

A. Send Data

In the process of sending data from reading panel surface temperature sensors, pool water temperature sensors, voltage sensors, and current sensors sent to the ATMega328P microcontroller to carry out several commands starting from processing sensor data and sending data to ESP8266 via serial communication. Figure 10 is a display of data reception.

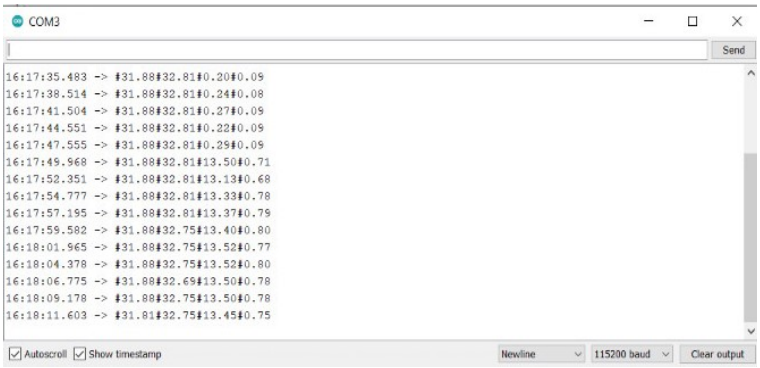

Figure 11. Serial monitor send data

B. Receive Data

After sending serial data by the ATMega328P microcontroller, the data is received and processed by the ESP8266 microcontroller, which will later be processed to be stored and displayed on the Blynk dashboard.

Figure 12. The Blynk dashboard receives data

3.6 Blynk Testing

3.6.1 Setup WiFi

The tests carried out before the temperature monitoring and control process were to make the ESP8266 microcontroller connected to the internet network which would later be useful for the communication network between the ESP8266 and the Blynk Server. Testing the Wi-Fi Set Up is done by uploading the program as shown in Figure 12.

```
char auth[] = "tmRJ7L90IUkdit4OdRsv1ORTdRwhHnXp";
char ssid[] = "ASHAR2";
char pass[] = "SELASELA7979";
void setup() {
  Serial.begin(115200);
  Blynk.begin(auth, ssid, pass);
}
void loop() {
  Blynk.run();
}
```

Figure 13. ESP8266 WiFi Setup Program

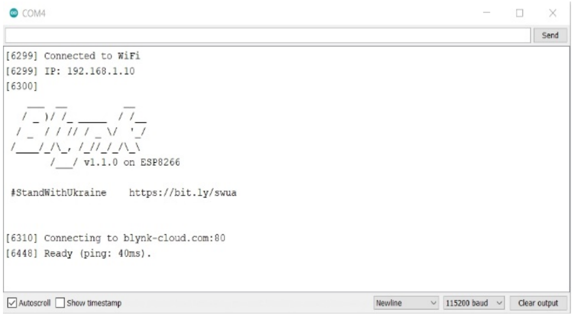

Figure 14. Serial monitor on the ESP8266 WiFi Setup

3.6.2 Auto Coolant control test

This test is carried out to prove that the automatic cooling mode can work according to plan. The data taken is the result of running the program and observing relays, LEDs and switch buttons in the application**.**

Table 3. Auto cooling mode test data

Mode	temperature	Relay	LED 1	LED 2	Switch Button
1	≥30°C	ON	ON	OFF	Mode1
	<30°C	OFF	ON	OFF	Mode1
2	≥35°C	ON	OFF	ON	Mode2
	<35°C	OFF	OFF	ON	Mode2

Based on the test results in table 3, when using the mode 1 cooling system with a setpoint temperature of 30°C, you only need to press the switch button on the application to 'mode 1', then the LED 1 indicator light will turn on and the relay will turn on when the temperature is ≥30°C and off when the temperature is <30°C. Likewise, if the switch button is shifted to 'mode 2', the mode 2 cooling system will run with the LED light indicator 2 on.

3.6 Data Record Testing

This test is carried out starting from receiving and processing sensor reading data via microcontrol then the data is displayed on the Blynk app dashboard as real-time monitoring to carry out automatic temperature control actions via Blynk. The data received will be stored via the Blynk Server, which will later be stored in the Blynk Cloud. To test the sending of data records that have been recorded and have been stored in Blynk, it can be accessed by
pressing the export to CSV command.

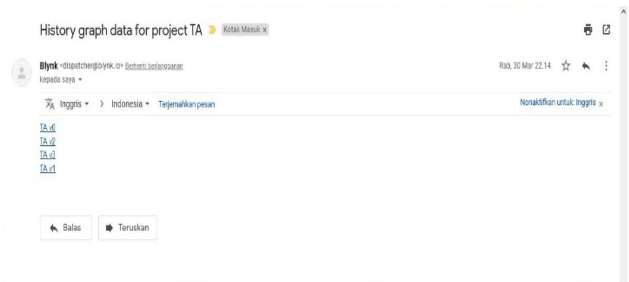

Figure 15. Display of receiving data files on google mail

Based on Figure 18, the data sent by Blynk was successfully sent to Google Mail. The data received is in the form of a CSV file which is divided into four files, namely panel temperature sensor files, pool temperature, voltage and current. According to the data format and the virtual pin variable order.

4. CONCLUSION

Based on the results of testing and analysis in this study, it can be concluded that the control of the monitoring system and automatic cooling system on solar panels is running well. Monitoring is carried out by monitoring the output value of the solar panel in the form of a temperature value on the surface of the panel with an average sensor error value of 3.1%, voltage with an average sensor error value of 1.7%, and current with an average sensor error value of 2.6% so that it can be said sensor readings are quite accurate. For an automatic cooling system with water pump control using 2 modes that are connected online and integrated with the Blynk application, it works well. The results obtained from the use of a cooling system on the surface of the panel with the application of variation 2 (setpoint 35°C) an average decrease in temperature of 8.79°C or 21.1% and variation 3 (setpoint 30°C) an average decrease in temperature of 8 .69°C or 20.89%. So that the use of this cooling system on solar panels is considered effective in reducing the surface temperature of the panel.

References

[1] K. ESDM, *RUPTL 2021- 2030, Pemerintah Tingkatkan Porsi Pembangkit Listrik Berbasis EBT*. 2021.

[2] A. K. Tripathi, M. Aruna, and C. S. N. Murthy, “Performance evaluation of PV panel under dusty condition,” *Int. J. Renew. Energy Dev.*, vol. 6, no. 3, pp. 225–233, 2017, doi: 10.14710/ijred.6.3.225-233.

[3] R. Pido, “Analysis of the Effect of Increasing Solar Cell Surface Temperature on Output Power,” *Gorontalo J. Infrastruct. Sci. Eng*, vol. 2, no. 2, 2019.

[4] M. A. Fares, L. Atik, G. Bachir, and M. Aillerie, “Photovoltaic panels characterization and experimental testing,” *Energy Procedia*, vol. 119, pp. 945–952, 2017.

[5] H. Terzioǧlu, F. A. Kazan, and M. Arslan, “A new approach to the installation of solar panels,” *Proc. - 2015 2nd Int. Conf. Inf. Sci. Control Eng. ICISCE 2015*, no. April, pp. 573–577, 2015, doi: 10.1109/ICISCE.2015.133.

[6] Y. Hishikawa *et al.*, “Voltage-dependent temperature coefficient of the I-V curves of crystalline silicon photovoltaic modules,” *IEEE J. Photovoltaics*, vol. 8, no. 1, pp. 48–53, 2018.

[7] D. R. Alwy, “Design and Development of Internet of Things (Iot) Based Solar Panel Performance Monitoring and Control Systems,” vol. 14, no. 3, 2019.

[8] S. Adhya, D. Saha, A. Das, J. Jana, and H. Saha, “An IoT based smart solar photovoltaic remote monitoring and control unit,” *2016 2nd Int. Conf. Control. Instrumentation, Energy Commun. CIEC 2016*, pp. 432–436, 2016.

[9] V. K. V and S. G, “Arduino Based Smart Solar Photovoltaic Remote Monitoring System,” *Malaysian J. Sci.*, vol. 41, no. 3, pp. 58–62, 2022, doi: 10.22452/mjs.vol41no3.8.

[10] A. S. Samosir, A. F. Rozie, S. Purwiyanti, H. Gusmedi, and M. Susanto, “Development of an IoT Based Monitoring System for Solar PV Power Plant Application,” *Proc. - ICCTEIE 2021 2021 Int. Conf. Converging Technol. Electr. Inf. Eng. Converging Technol. Sustain. Soc.*, pp. 82–86, 2021, doi: 10.1109/ICCTEIE54047.2021.9650634.

[11] G. Oviedo Hernandez, D. M. Godinho Ariolli, P. S. Enriquez Paez, and P. V. Chiantore, “Trends and innovations in photovoltaic operations and maintenance,” *Prog. Energy*, vol. 4, no. 4, 2022, doi: 10.1088/2516-1083/ac7c4f.

[12] H. Samaulah, Y. Basir, M. Helmi, F. Faturrizky, and A. Sugawara, “Efficiency Analysis of Tracking and Stationary Solar Panel Modes Against Solar Radiation,” *J. Eng. Sci.*, vol. 5, no. 1, 2018, doi: 10.21272/jes.2018.5(1).h4.

[13] M. Narayanan, “Techno-economic analysis of solar absorption cooling for commercial buildings in India,” *Int. J. Renew. Energy Dev.*, vol. 6, no. 3, pp. 253–262, 2017, doi: 10.14710/ijred.6.3.253-262.

[14] A. R. Jatoi, S. R. Samo, and A. Q. Jakhrani, “Influence of temperature on electrical characteristics of different photovoltaic module technologies,” *Int. J. Renew. Energy Dev.*, vol. 7, no. 2, pp. 85–91, 2018.

[15] D. Cho and J. Valenzuela, “Optimization of residential off-grid PV-battery systems,” *Sol. Energy*, vol. 208, pp. 766–777, 2020, doi: 10.1016/j.solener.2020.08.023.

[16] R. R. A. Siregar, “Sistem Monitoring Kinerja Panel Listrik Tenaga Surya Menggunakan Arduino Uno,” *Jetri J. Ilm. Tek. Elektro*, vol. 14, 2017.

[17] G. G. Kim *et al.*, “Prediction Model for PV Performance with Correlation Analysis of Environmental Variables,” *IEEE J. Photovoltaics*, vol. 9, no. 3, pp. 832–841, 2019.

[18] Y. Yuliananda, “Pengaruh Perubahan Intensitas Matahari Terhadap Daya Keluaran Panel Surya,” *LPPM Untag Surabaya*, vol. 01, no. 02, pp. 147–154, 2015.

[19] Y. Setyaningrum, ““Pengukuran Efisiensi Panel Surya Tipe Monokristalin Dan Karakterisasi Struktur Material Penyusunnya,” *Its*, vol. 8, no. 02, pp. 17–25, 2017.

[20] M. Libra, T. Petrik, V. Poulek, I. I. Tyukhov, and P. Kourim, "Changes in the Efficiency of Photovoltaic Energy Conversion in Temperature Range with Extreme Limits," *IEEE J. Photovoltaics*, vol. 11, no. 6, pp. 1479–1484, 2021, doi: 10.1109/JPHOTOV.2021.3108484.

[21] B. Li, D. Diallo, A. Migan-Dubois, and C. Delpha, "Performance evaluation of IEC 60891:2021 procedures for correcting I–V curves of photovoltaic modules under healthy and faulty conditions," *Prog. Photovoltaics Res. Appl.*, no. February, pp. 1–20, 2022, doi: 10.1002/pip.3652.

[22] R. Vijay, G. . Sathishkumar, and Ezhilarasan, "Design and Performance Analysis of Solar Hybrid Power Generation," *Int. J. Res. Appl. Sci. Eng. Technol.*, no. December, 2018, [Online]. Available: https://www.researchgate.net/publication/329453272_Design_and_Performance_Analysis_of_Solar_Hybrid_Power_Generator.

[23] P. Putu and T. Winata, "Design of an Output Monitoring System and Data Recording on an Arduino Microcontroller Based Solar Panel," *Molecules*, vol. 3, no. 1, pp. 1–6, 2016.

[24] N. H. L. Dewi, M. F. Rohmah, and S. Zahara, "Prototype Smart Home With Nodemcu Esp8266 Module Based on Internet of Things (Iot)," *J. Tek. Inf.*, p. 3, 2019.

[25] F. Integrated and and S. I. H. L. Current, "ACS712," pp. 1–15, 2020.

[26] R.T.M. Sitepu, "Solar Based Thermo Electric Cooler (TEC) Cooling System," *J. Pembang. Wil. Kota*, vol. 1, no. 3, pp. 82–91, 2020.

[27] M. Putriani, "Monitoring System for Characteristics Test Equipment," *J. Elektro*, vol. 3, no. 2, pp. 1–12, 2019.