Website : jurnal.umj.ac.id/index.php/icecream

Design of Overheating Detection and Performance Monitoring of Solar Panel based on Internet of Things (IoT) using Smartphone

Haris Isyanto[1*], Wahyu Ibrahim[2]

[1,2] Department of Electrical Engineering, Universitas Muhammadiyah Jakarta
Jl Cempaka Putih Tengah 27, Jakarta Pusat, DKI Jakarta,
haris.isyanto@umj.ac.id

ABSTRACT

Solar panels are alternative energy from renewable energy. The primary problem with solar panels is heat. Ideally, the solar panel temperature is 25ºC. If the temperature of solar panels rises, the solar panel components will heat up. This results in a decrease in the performance of solar panels and causes the power output to be not optimal in the electricity production process. Therefore, we designed a device that could detect overheating early and monitor the power performance of solar panels based on the Internet of Things (IoT) using a smartphone. From the test results obtained by measuring the percentage comparison between measuring instruments and sensor applications, on the parameters of average voltage Vdc 1.32%, current 2.61%, temperature 2.14%, and power 3.89%. This research is expected to help monitor overheating early warnings and monitor solar panel parameters remotely via a smartphone without having to come to the location.
Keywords: Overheating Detection, Solar Panels, Internet of Things, Smartphone, Blynk Application

1. Introduction

Indonesia is an archipelagic country located on the equator where the daily average solar radiation level is relatively high, namely 4.5 kWh/m2/day. This can be used as the principal capital for generating electricity using solar cells. The main components of a solar cell system are solar cells that function to change sunlight energy into electrical energy [1], [2].
The main problem with solar panels is heat. The temperature level dramatically affects the performance of solar panels. Ideally, solar panels work at a standard temperature of 25^{O}C. When the temperature increases, it causes heat in the solar panel components. Then it will experience a decrease in performance which causes the power output produced is not optimal in the electricity production process from solar panels, Solar Panel Efficiency, and the life of solar panels will decrease [3]–[5].
From the above problems, a solar panel temperature monitoring design based on the Internet of Things was made using a smartphone to measure temperature, power output, and high-temperature warning notifications to applications generated by solar panels. So that from these results, we can find out the maximum performance of solar panels through the Internet of Things-based monitoring.

2. Material and Methods

Internet of Things (IoT) is the communication technology concept which uses internet connectivity that connects various objects such as interactions between equipment, between machines, and between other objects. IoT works with sensor applications to transmit or transmit data and can control objects over the internet. So that an integrated ecosystem can be created between objects. The IoT concept is shown in Figure 1 [2], [5]–[11].

Figure 1: IoT Concept

2.1. Solar Panels

The word photovoltaic comes from the Greek word where light is voltaic, which was discovered by Alessandro Volta. A solar cell changes sunlight energy into electrical energy. The solar cell is made of cilium polycrystal rock, which is crushed into silica powder and then compacted into a rod shape, and after that, it is cut into 0.3 mm thick sheets. Solar cells in a state without irradiation have a working principle like a diode. After the solar cell gets sunlight up to the N-S surface, this energy is commonly called a photon. Then, the energy will collide with negatively and positively charged silicon, as a result of this collision will cause heat energy in the solar cell. [1], [3], [4], [8], [10]–[14].

2.2. Power Sensor

The power sensor is a component that monitors current and power with an I2C interface system or a compatible interface. This sensor also monitors voltage and voltage drop (shunt voltage drop) and supply voltage (bus supply voltage) using multiplication conversion, which is implemented in programming and filtering. The calibration value of this sensor can be programmed in combination with an internal multiplication that allows the power sensor readings to measure current in amperes and voltage in volts. [2], [6], [8], [10], [11], [14]–[18].

2.3. Temperature Sensor

Dallas Semiconductor manufactures the DS18B20 temperature sensor. The DS18B20's output is digital, so the DS18B20 no longer needs an ADC circuit. Speed of measurement and temperature value accuracy on the DS18B20 sensor is better when compared to the LM35DZ sensor. For temperature readings, The DS18B20 sensor has a single cable on the communication protocol. The DS18B20 sensor uses the following three pins: Data Input/Output, Ground, and +5V. The DS18B20 can measure temperature in the -55°C to 125°C range and operates accurately with an error of ±0.5°C with a range from -10°C until 85°C. [7], [19]–[25].

2.4. Blynk Application

Blynk is the application based on the iOS and Android operating systems that function to control a NodeMCU ESP8266 microcontroller and raspberry pi. This application can be connected with hardware components, monitoring/displaying data from sensor components, storing data, etc.

In this study, the prototype for monitoring solar panels and overheating based on IoT uses the blynk application, which aims to monitor the voltage, current, and power of solar panels and temperature monitoring by providing smartphone popup notification information. The following blynk app is shown in Figure 2 [6], [8], [10], [11], [13], [15], [16].

Figure 2: Monitoring of Solar Panel Overheating Detection on the Blynk App

2.5 Block Diagram of Overheating Detection and Monitoring of Solar Panel Performance

This system flowchart functions as an overheating detection system and monitoring the performance of Solar Panels with a charging system (Off-Grid) to battery storage. With this system, it is capable of real-time monitoring of performance without using manual measuring tools. This system can be monitored via mobile phones via the Blynk application using the internet. The main components of the NodeMCU and the application must be connected to the internet to monitor all data using sensors to be monitored, namely: Current and voltage entering the solar panel, knowing the temperature of the solar panel in real-time. If there is a very drastic increase in temperature by the solar panel, it will send a notification in a popup to the smartphone. The communication used using the internet is functioning. Any data detected by the sensor will be sent data to the Blynk application. The flowchart of the system is shown in Figure 3.

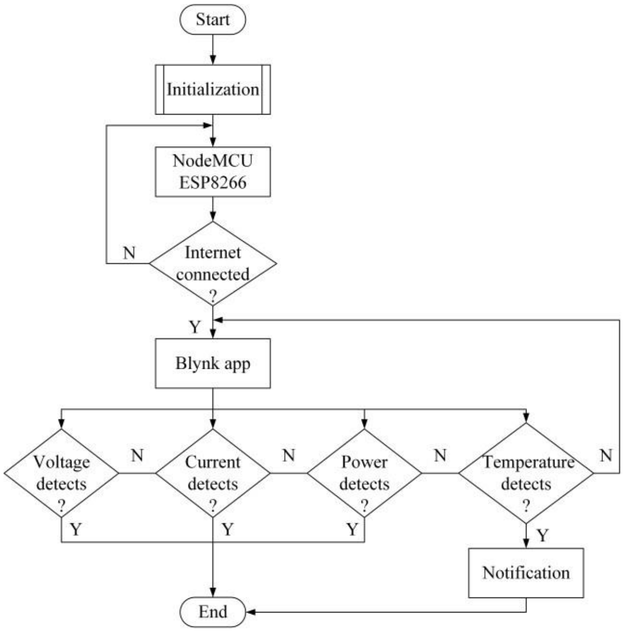

Figure 3: Flowchart of System

The purpose of this block diagram is to detect overheating and monitor the performance of solar panels on an off-grid system for charging batteries as remote monitoring through internet connection. Sensor system works when it detects the solar panel parameters from voltage, current, power and temperature to be monitored in real-time using the blynk application—overheating detection to notify when the temperature on the surface of the solar panel has increased. All major components such as applications and NodeMCU ESP8266 must be connected to the internet. The block diagram of monitoring of solar panel overheating detection could be shown in Figure 4.

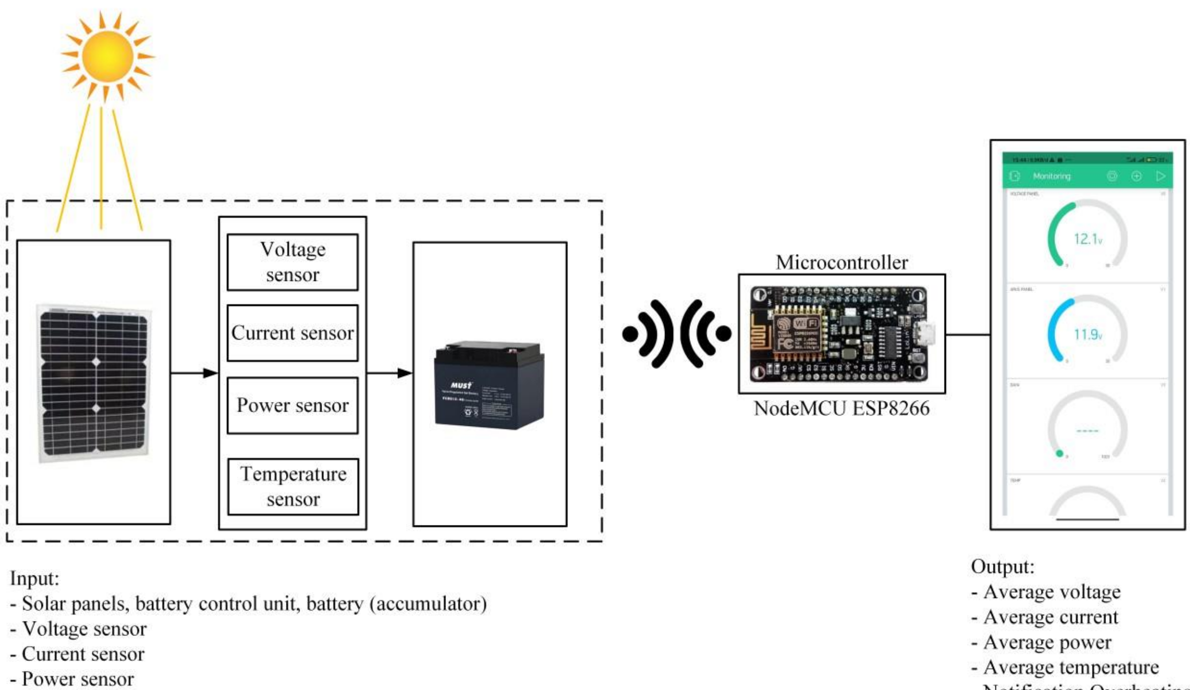

Figure 4: Block Diagram of Monitoring of Solar Panel Overheating Detection

2.6. System Entire Circuit

This whole circuit works to read the parameters of Solar Panel Voltage, Battery Voltage, solar panel temperature in real-time on the blynk application. This monitoring is carried out by controlling the system remotely though the internet connection to monitor charging on the solar panel. Then the system will display manual parameters that can be seen with a digital voltmeter and amper meter. The overall circuit of the system could be shown in Figure 5.

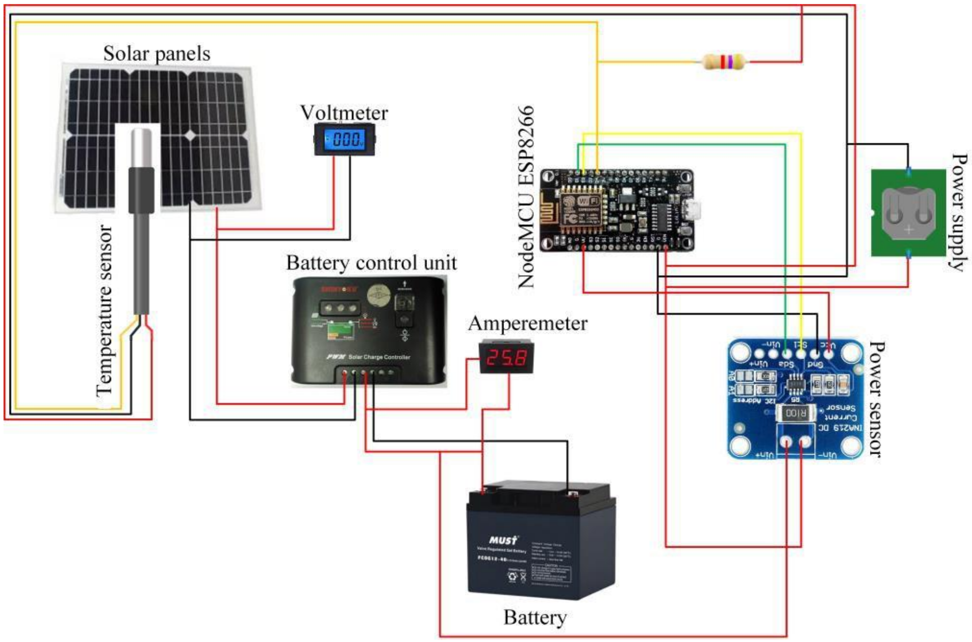

Figure 5: The Overall Circuit of the System

2.7. Design of Blynk App for Performance Monitoring of Solar Panel

On the blynk application dashboard, users can monitor the output parameters of solar panel on DC voltage, DC current, power, and solar panel temperature. Users can monitor these parameters in real-time using a smartphone. Dashboard design can view graphs of DC voltage, DC current, power, and temperature on the blynk application. And users can receive notifications when the solar panel overheating is detected in the form of a popup to the smartphone. Users can monitor remotely via a smartphone without having to come to the location. Therefore, in this research, we implement the Design of Overheating Detection and Performance Monitoring of Solar Panels based on the Internet of Things (IoT) using Smartphones.

3. Results and Discussions

At this stage, we will explain the testing of the overall device and the result of device performance. The device testing uses monocrystalline solar panels to perform monitoring tests via the Internet of Things. The tests measured are the parameters of the power, current, voltage, and temperature of the solar panel. From the test results obtained the percentage comparison between measuring instruments and sensor applications. And testing monitoring of solar panel overheating detection, as shown in Figure 6.

Figure 6: Testing Monitoring of Solar Panel Overheating Detection

3.1. Testing of Solar Panel Voltage

The purpose of this testing is to retrieve voltage data on the monitoring system device in the blynk application. This is to determine the ability and performance of the sensor voltage test. Testing of solar panel voltage is measured using a voltmeter. This test compares the percentage of error between the voltmeter manual measuring instrument and the voltage sensor application. Testing of solar panel voltage, as shown in Table 1.

Table 1: Testing of solar panel voltage

Time (minutes)	Voltmeter (volts)	Voltag e sensor	Difference	Error (%)
09.00	19,6	19,3	0,3	1,53
09.30	20,4	20,1	0,3	1,47
10.00	20,7	20,5	0,2	0,97
10.30	20,6	20,2	0,4	1,94
11.00	20,2	19,9	0,3	1,49
11.30	20,7	20,4	0,3	1,45
12.00	20,1	19,9	0,2	1,00
12.30	20,4	20,1	0,3	1,47
13.00	20,2	20	0,2	0,99
13.30	19,9	19,5	0,4	2,01
14.00	19,1	18,9	0,2	1,05
14.30	19,2	19	0,2	1,04
15.00	18,9	18,7	0,2	1,06
15.30	18,5	18,3	0,2	1,08
Average	**19,89**	**19,63**	**0,26429**	**1,32**

For calculating the percentage error of measurement between the voltmeter and the voltage sensor, it can be calculated using the following equation:

$$error\,(\%) = \frac{volt\ meter\ -\ voltage\ sensor}{volt\ meter}\ x\ 100\%$$

Based on the calculation of the comparison obtained, the results of the test are the percentage errors of measurement. Testing of the solar panel voltage can be shown in Figure 7.

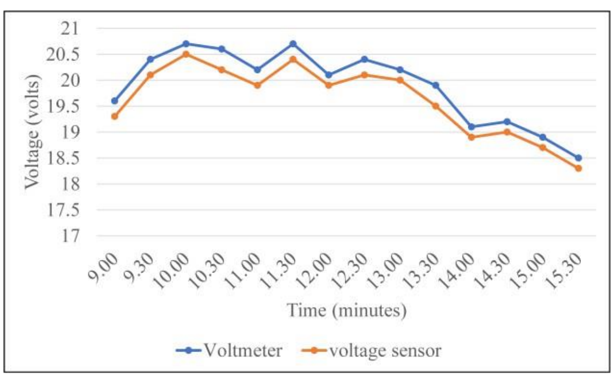

Figure 7: Testing of Solar Panel Voltage

3.2. Testing of Solar Panel Current

The purpose of this testing is to retrieve current data on the monitoring system device in the blynk application. This is to determine the ability and performance of the sensor current test. Testing of solar panel current is measured using an ampere meter. This test compares the percentage of error between the ampere meter manual measuring instrument and the current sensor application. Testing of solar panel current, as shown in Table 2.

Table 2: Testing of solar panel current

Tim e (minutes	Ampere meter (amperes	Current sensor (amperes	Difference	Error (%)
09.00	1.07	1.04	0.0	2.80
09.30	1.09	1.06	0.0	2.75
10.00	1.18	1.16	0.0	1.69
10.30	1.28	1.26	0.0	1.56
11.00	1.39	1.37	0.0	1.44
11.30	1.49	1.45	0.0	2.68
12.00	1.42	1.39	0.0	2.11
12.30	1.27	1.24	0.0	2.36
13.00	1.	1.07	0.0	2.73
13.30	0.92	0.88	0.0	4.35
14.00	0.81	0.78	0.0	3.70
14.30	0.78	0.76	0.0	2.56
15.00	0.71	0.69	0.0	2.82
15.30	0.69	0.67	0.0	2.90
Average	**1.09**	**1.06**	**0.0**	**2.61**

For calculating the percentage error of measurement between the ampere meter and the current sensor, it can be calculated using the following equation:

$$error\,(\%) = \frac{ampere\ meter\ -\ current\ sensor}{ampere\ meter}\ x\ 100\%$$

Based on the calculation of the comparison obtained, the results of the test are the percentage errors of measurement. Testing of the solar panel current can be shown in Figure 8.

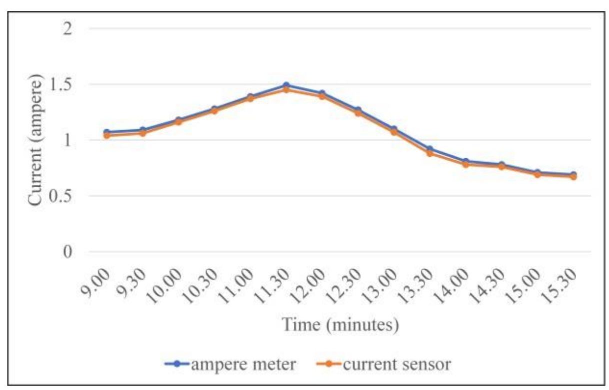

Figure 8: Testing of Solar Panel Current

3.3. Testing of Solar Panel Power

The purpose of this testing is to retrieve power data on the monitoring system device in the blynk application. This is to determine the ability and performance of the sensor power test. Testing of solar panel power is measured using a watt meter. This test compares the percentage of error between the watt meter manual measuring instrument and the power sensor application. Testing of solar panel power, as shown in Table 3.

Table 3: Testing of solar panel power

Time (minutes)	Watt meter (watt)	Power sensor (watt)	Difference	Error (%)
9.00	20.97	20.07	0.9	4.29
9.30	22.24	21.31	0.93	4.18
10.00	24.43	23.78	0.65	2.66
10.30	26.36	25.45	0.91	3.45
11.00	28.07	27.26	0.81	2.89
11.30	30.84	29.58	1.26	4.09
12.00	28.54	27.66	0.88	3.08
12.30	25.9	24.92	0.98	3.78
13.00	22.22	21.4	0.82	3.69
13.30	18.31	17.16	1.15	6.28
14.00	15.47	14.74	0.73	4.72
14.30	14.97	14.44	0.53	3.54
15.00	13.42	12.9	0.52	3.87
15.30	12.77	12.26	0.51	3.99
Average	**21.75**	**20.92**	**0.83**	**3.89**

For calculating the percentage error of measurement between the watt meter and the power sensor, it can be calculated using the following equation:

$$error\ (\%) = \frac{watt\ meter\ -\ power\ sensor}{watt\ meter}\ x\ 100\%$$

Based on the calculation of the comparison obtained, the results of the test are the percentage errors of measurement. Testing of the solar panel power can be shown in Figure 9.

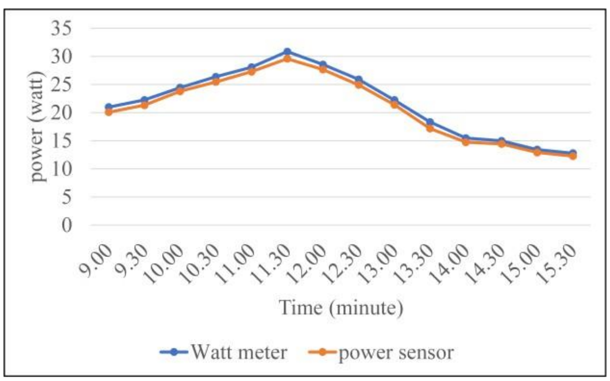

Figure 9: Testing of Solar Panel Power

3.4. Testing of Solar Panel Temperatur

The purpose of this testing is to retrieve temperature data on the monitoring system device in the blynk application. This is to determine the ability and performance of the sensor temperature test. Testing of solar panel temperature is measured using a thermometer. This test compares the percentage of error between the thermometer manual measuring instrument and the temperature sensor application. Testing of solar panel temperature, as shown in Table 4.

Table 4: Testing of solar panel temperature

Time (minutes)	Thermo meter (ºC)	Temperature sensor (ºC)	Difference	Error (%)
9.00	44.8	43.5	1.3	2.90
9.30	49.7	48.2	1.5	3.02
10.00	51.3	50.5	0.8	1.56
10.30	57.3	55.9	1.4	2.44
11.00	59.7	58.6	1.1	1.84
11.30	63.2	61.8	1.4	2.22
12.00	64.2	62.9	1.3	2.02
12.30	62.1	60.9	1.2	1.93
13.00	62.3	61.4	0.9	1.44
13.30	56.9	56	0.9	1.58
14.00	50.9	50.1	0.8	1.57
14.30	45.4	44.1	1.3	2.86
15.00	44.9	43.7	1.2	2.67
15.30	42.2	41.4	0.8	1.90
Average	**53.92**	**52.79**	**1.14**	**2.14**

For calculating the percentage error of measurement between the thermometer and the temperature sensor, it can be calculated using the following equation:

$$error\ (\%) = \frac{thermometer\ -\ temperature\ sensor}{thermometer}\ x\ 100\%$$

Based on the calculation of the comparison obtained, the results of the test are the percentage errors of measurement. Testing of the solar panel temperature can be shown in Figure 10.

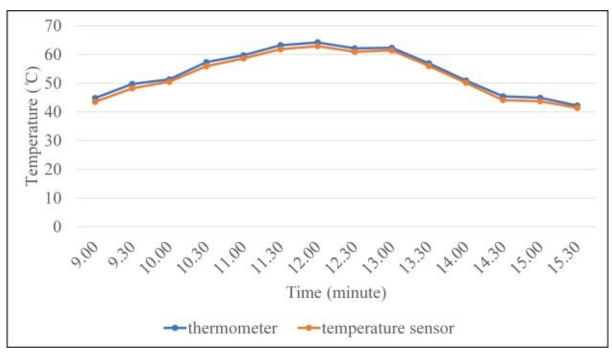

Figure 10: Testing of Solar Panel Temperature

3.5. Testing of Warning on Solar Panel Overheating Detection

This testing aims to send a notification popup warning to the smartphone that the temperature sensor detects, the solar panel overheating has exceeded 60° C. If this happens, the blynk application will display a notification popup on the smartphone "Solar Panel Overheating", as shown in Figure 11.

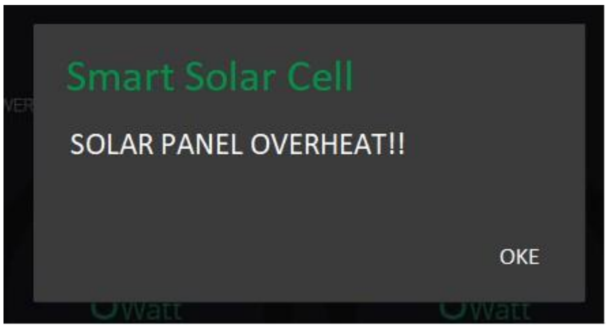

Figure 11: Solar Panel Overheating Notification

4. Conclusion

Based on the results of test, it is obtained that each sensor has a percentage comparison of measurement error between manual measuring instrument and sensor applications on the parameters of the average voltage 1.32%, current 2.61%, temperature 2.14%, and power 3.89%. From the results of sensor measurements on solar panel monitoring with the blynk application, the parameters obtained are an average voltage of 19.63 volts, current 1.06 amperes, power 20.92 watts, and temperature 52.79 °C. A strong Internet connection signal will significantly affect the performance of the device to be better for monitoring the performance of solar panels based Internet of Things (IoT). Our research is intended to help monitor overheating warnings and monitor solar panel parameters remotely via a smartphone without having to come to the location.

Acknowledgment

This research was supported by the Department of Electrical Engineering and the Faculty of Engineering, Universitas Muhammadiyah Jakarta.

References

[1] B. Budiyanto and H. Setiawan, "Analisa Perbandingan Kinerja Panel Surya Vertikal Dengan Panel Surya Fleksibel Pada Jenis Monocrystalline," *Resist. (Elektronika Kendali Telekomun. Tenaga List. Komputer)*, vol. 4, no. 1, p. 77, 2021, doi: 10.24853/resistor.4.1.77-86.

[2] M. Mungkin, H. Satria, J. Yanti, and G. B. A. Turnip, "Perancangan Sistem Pemantauan Panel Surya Polycrystalline Menggunakan Teknologi Web Firebase Berbasis Iot," *J. Inf. Technol. Comput. Sci.*, vol. 3, no. 2, pp. 319–327, 2020.

[3] D. Almanda and D. Bhaskara, "Studi Pemilihan Sistem Pendingin pada Panel Surya Menggunakan Water Cooler, Air Mineral dan Air Laut," *Resist. (elektRonika kEndali Telekomun. tenaga List. kOmputeR)*, vol. 1, no. 2, p. 43, 2018, doi: 10.24853/resistor.1.2.43-52.

[4] D. Almanda and B. P. Piliang, "Perbandingan Sistem Pendingin pada Konsentrasi Water Coolant, Air Mineral, dan Air Laut Menggunakan Panel Surya Fleksibel Monocrystaline 20 Wp," *Resist. (elektRonika kEndali Telekomun. tenaga List. kOmputeR)*, vol. 2, no. 2, p. 73, 2019, doi: 10.24853/resistor.2.2.73-82.

[5] N. M. Kumar, K. Atluri, and S. Palaparthi, "Internet of Things (IoT) in Photovoltaic Systems," *2018 Natl. Power Eng. Conf.*, pp. 1–4, 2018.

[6] R. L.R. Lokesh Babu, D. Rambabu, A. Rajesh Naidu, R. D. Prasad, and P. Gopi Krishna, "Solar Power Monitoring System using IOT," *J. Eng. Technol.*, vol. 7, no. 3.12, p. 526, 2018.

[7] H. Isyanto and A. Nandiwardhana, "Perancangan DC Cooler Berbasis Internet of Things," *Resist. (elektRonika kEndali Telekomun. tenaga List. kOmputeR)*, vol. 2, no. 2, p. 95, 2019, doi: 10.24853/resistor.2.2.95-104.

[8] M. S. Khan, H. Sharma, and A. Haque, "IoT Enabled Real-Time Energy Monitoring for Photovoltaic Systems," *Proc. Int. Conf. Mach. Learn. Big Data, Cloud Parallel Comput. Trends, Prespectives Prospect. Com. 2019*, pp. 323–327, 2019, doi: 10.1109/COMITCon.2019.8862246.

[9] D. D. Putra, B. Syihabuddin, M. A. M. raj Jabbar, A. Irsal, A. Purwadi, and A. Munir, "Energy Management System with IoT Connectivity for Portable Solar Power Plant," *IoTaIS 2020 - Proc. 2020 IEEE Int. Conf. Internet Things Intell. Syst.*, pp. 56–59, 2021, doi: 10.1109/IoTaIS50849.2021.9359705.

[10] M. S. Khan, H. Sharma, and A. Haque, "IoT Enabled Real-Time Energy Monitoring for Photovoltaic Systems," *2019 Int. Conf. Mach. Learn. Big Data, Cloud Parallel Comput.*, pp. 323–327, 2019.

[11] A. Kekre, "Solar Photovoltaic Remote Monitoring System Using IOT," pp. 27–29, 2017.

[12] A. Guwaeder, S. Member, R. Ramakumar, and L. Fellow, “Optimal Integration of PV Generation in Distribution Systems,” *2018 IEEE Conf. Technol. Sustain.*, pp. 1–5.

[13] H. Lee, W. Park, I. Lee, and A. S. Grid, “Energy Management Services based on Home Energy Grid Technology,” pp. 3–6.

[14] M. Bardwell, J. Wong, S. Zhang, and P. Musilek,

"Design Considerations for IoT-based PV Charge Controllers," no. 1, pp. 59–60, 2018, doi: 10.1109/SERVICES.2018.00043.

[15] M. R. Faleva, D. B. Santoso, and L. Nurpulaela, "Sistem Monitoring Energi Listrik Pada Kompor Penghasil Listrik Dengan Teknologi Internet of Things (Koliss-Iot)," *J. Elektro dan Telekomun. Terap.*, vol. 7, no. 2, p. 857, 2021, doi: 10.25124/jett.v7i2.3191.

[16] F. Triyuandika, I. K. Ningrum, W. Djatmiko, F. Teknik, and U. N. Jakarta, "Prototipe sistem energi terbarukan rumah tangga," *J. Autocracy*, pp. 114–127, 2018, doi: 10.21009/autocracy.05.2.7.

[17] M. H. Yaghmaee, "Design and Implementation of an Internet of Things Based Smart Energy Metering," *2018 IEEE Int. Conf. Smart Energy Grid Eng.*, pp. 191–194, 2018.

[18] O. Özel, "Thermal Modelling and Energy Management of a Smart Home with Renewable Energy Sources," pp. 97–102, 2020.

[19] Randis and Sarminto, "Aplikasi Internet of Things Monitoring Suhu Engine," *J. Tek. Mesin Univ. Muhammadiyah Metro*, vol. 7, no. 2, pp. 153–158, 2018.

[20] E. B. Raharjo, S. Marwanto, and A. Romadhona, "Rancangan Sistem Monitoring Suhu Dan Kelembapan Ruang Server," *Teknika*, vol. 6, no. 2, pp. 61–68, 2019.

[21] T. Informatika, F. Ilmu, K. Universitas, and S. Karawang, "SISTEM MONITORING SUHU DAN KELEMBABAN RUANG PRODUKSI BERBASIS WIRELESS SENSOR NETWORK PADA PT . XXX MANUFACTURING SERVICES INDONESIA," pp. 136–143.

[22] B. Ashish, "TEMPERATURE MONITORED IoT BASED SMART INCUBATOR," pp. 497–501, 2017.

[23] Y. A. Ahmad, T. S. Gunawan, H. Mansor, B. A. Hamida, A. F. Hishamudin, and F. Arifin, "On the Evaluation of DHT22 Temperature Sensor for IoT Application," pp. 131–134, 2021.

[24] F. Vinola and A. Rakhman, "Sistem Monitoring dan Controlling Suhu Ruangan Berbasis Internet of Things," *J. Tek. Elektro dan Komput.*, vol. 9, no. 2, pp. 117–126, 2020, [Online]. Available: https://ejournal.unsrat.ac.id/index.php/elekdankom/article/view/29698.

[25] I. Satria Wicaksana, F. Iman Ubaidillah, Y. Prasetio Hadi, S. Tyas Wahyu, and Istiadi, "Perancangan Sistem Monitoring Suhu Gudang Berbasis Internet of Things (Iot)," *Conf. Innov. Appl. Sci. Technol. (CIASTECH 2018)*, no. September, pp. 503–511, 2018.