INDONESIAN JOURNAL OF INNOVATION AND APPLIED SCIENCES (IJIAS)
Journal Homepage: https://ojs.literacyinstitute.org/index.php/ijias
ISSN: 2775-4162 (Online)
Research Article

Volume 4	Issue 2	June (2024)	DOI: 10.47540/ijias.v4i2.1455	Page: 133 – 140

Comparative Study by Experiment of Design Cooling System Between Air Cooling and Water Spray Cooling Method for Optimization of Solar Photovoltaic

Galieh Ananda[1], Mohamad Dimas Nur Hakim[1], Rindi Wulandari[1]
[1]Department of Electrical Engineering, University of Swadaya Gunung Jati, Indonesia
Corresponding Author: Rindi Wulandari; Email: rindi.wulandari@ugj.ac.id

ARTICLE INFO

Keywords: Air Cooling, Comparative Study, Optimization of Solar Photovoltaic, Water Spray Cooling.

Received : 15 May 2024
Revised : 04 June 2024
Accepted : 28 June 2024

ABSTRACT

Solar photovoltaic is a renewable energy that has great potential and is quite cheap. However, solar cells are sensitive to temperature through the parameters of their semiconductor materials. The optimal solar photovoltaic temperature range is 25°C-40°C. Based on the study, the optimal temperature of the solar photovoltaic system is 41°C. The problem is that solar photovoltaics do not produce power optimally when the surface temperature reaches 41°C so the power produced decreases. The cooling system is one solution to overcome temperature problems in solar photovoltaics. The purpose is to design an automatic cooling system based on water and air spray using Arduino Uno which operates only at solar photovoltaic surface temperatures above 41°C and compare the working effectiveness of the cooling system using water spray and air when the surface of the solar photovoltaic reaches maximum heat and does not work optimally. Methods. Design and develop a water and air-spray-based cooling system using an experimental process. Results. The automatic cooling system has been designed using a water spray cooling method and a DC fan-based air cooling method. The water spray cooling method can reduce the temperature optimally with an average temperature of 38.67°C and the air cooling method can reduce the temperature optimally with an average temperature of 39.5°C. The water spray cooling method had an efficiency value of 36% and the DC fan-based water cooling method had an efficiency value of 16%.

INTRODUCTION

Solar photovoltaic is a renewable energy source that is included in the type of clean energy (Kusuma et al., 2023; Paquianadin et al., 2024; K. Latreche et al., 2024; Mosavi et al., 2019). Solar panel energy is a type of renewable energy that has great potential is quite cheap and can be applied on a large scale or household scale. Despite all its potential and significance(Khan et al., 2017), photovoltaic power still needs to be improved in several areas, especially in current large-scale applications, to compete with conventional energy sources (Azmi et al., 2023; Latiff et al., 2020).

Solar cells are sensitive to temperature through the parameters of their semiconductor materials (Widjanarko et al., 2021; Kamarudin et al., 2021; Niraj Kumar Kushwaha et al., 2023). When the surface temperature of the photovoltaic rises, the coefficient of performance of the panel drops (Conrado F. et al., 2019; Kalil Ahmed et al., n.d.). Solar cells work at an operating temperature of 25°C - 40°C (Virtuani et al., 2010; T. Laseinde & Ramere, 2019); Jaleel Mahdi et al., 2024). Above the maximum operating temperature (40°C), every 1ºC increase in temperature will cause a decrease in voltage of 0.331% and a decrease in power of 0.444% Supian et al., 2020); Rezki et al., 2023; Tabaei & Ameri, 2015). Figure 1 shows the results of our experiment in finding the maximum temperature value for solar panel operation. The graph shows that when the surface temperature reaches 41°C, the voltage value decreases due to the properties of semiconductor materials that work in a certain temperature range. From Figure 1, we determine the maximum working temperature value of solar panels, namely 41◦C.

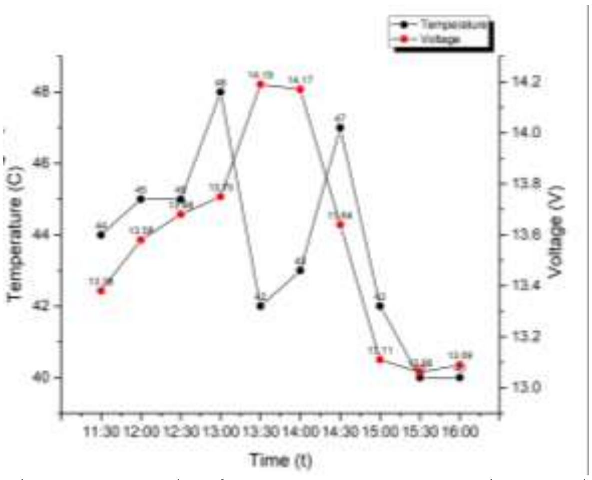


Figure 1. Graph of temperature versus solar panel output voltage value (Galieh Ananda et al., 2024)

Developing a cooling system is one way to overcome temperature problems in solar panels (Dhami Johar Damiri & Ditha Nevella Sembiring, 2023); Indra Bayu et al., 2023; Ahmed et al., 2022). The cooling system also functions to keep the photovoltaic module from experiencing irreparable damage, so that it can last a long time (Sultan et al., 2021; Mahmood Ibrahim et al., 2023; Milind et al., 2017). Many cooling methods are used to overcome temperature problems in solar panels(Dwivedi et al., 2020; Saleh et al., 2023). Among them are the water spray method and the cooling fan method. The cooling fan is turned on and off automatically by the temperature of the solar panel (Cho & Kim, 2019; Swatara Loegimin et al., 2020). The water spray is conducted to simulate the effects of solar irradiation on the efficiency of the PV (photovoltaic) panels (Ant. Ardtah Kristi et al., 2020; Mostakim et al., 2024).

(Ghorpade et al., n.d.) identified the best cooling technique for solar panels. It used several methods, namely water cooling, air cooling, and PCM (Phase Change Material) system, and found that water cooling is more efficient.(Syafiqah et al., 2017)discussed solar cooling with 6 different DC fan speeds. A DC fan speed of 3.07 m/s was selected as the optimal speed for the cooling system because it obtained the highest net output power savings, compared to the others.(Popovici et al., 2016) uses an air-cooled heatsink that increases the power of the solar panel from 6.97% to 7.55%. (Setyono et al., 2022)found an increase in almost all variations of solar panel tilt angles (15^o, 20^o, and 25^o), output power increased by an average of 22% and efficiency increased by an average of 2%. (Ceylan et al., 2014) The efficiency obtained using the water cooling method is 13% and without cooling is about 10%.

The goal of the paper is to design the most effective cooling system model to obtain the most optimal solar panel output power by comparing the work effectiveness between cooling systems using water spray and the water method when the solar photovoltaic surface reaches a temperature outside its working mode. The water method uses PDAM water with PH 7.8.

METHODS

Table 1. Solar panel specifications

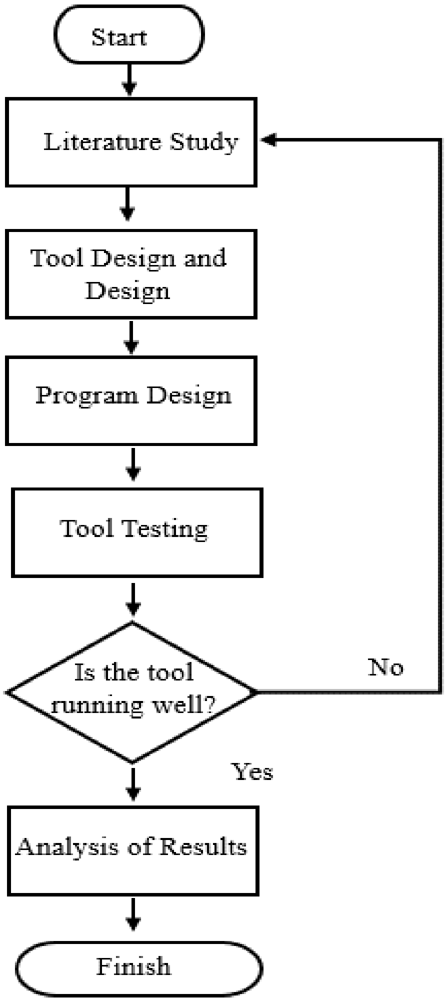
Specifications	Value
Materials	Monocrystalline
Maximum voltage value	18 Volt
Maximum current value	1,11 A
Maximum power output	20 Watt
Size	450 x 350 x 15 mm

2 (a)

2 (b)

Figure 2. Block diagram (a) cooling using the water cooling method (b) cooling using the water spray method

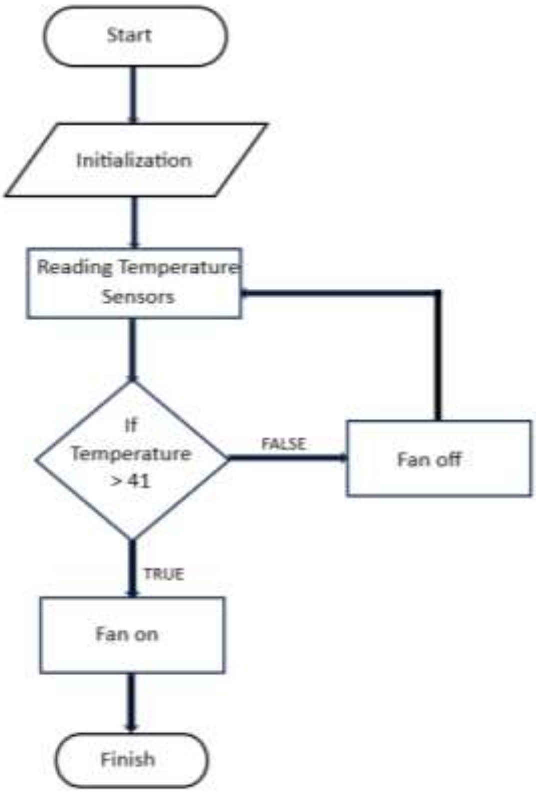
System descriptions. The solar panel made is 20 WP with a maximum power capacity of 20 watts further details can be seen in Table 1. In Figure 2(a) the system uses Arduino Uno as its microcontroller and DHT22 sensor as a temperature detector and a 12 V DC fan as a cooler from the solar panel. In Figure 2(b) the tools used are Arduino uno as the controlling brain, a DHT22 sensor to detect the temperature on the solar panel, and a DC 12 V pump to cool the solar panel. The block diagram of each cooling model can be seen in Figure 2(a) block diagram for the fan cooling model and 2(b) block diagram for the water spray cooling model.



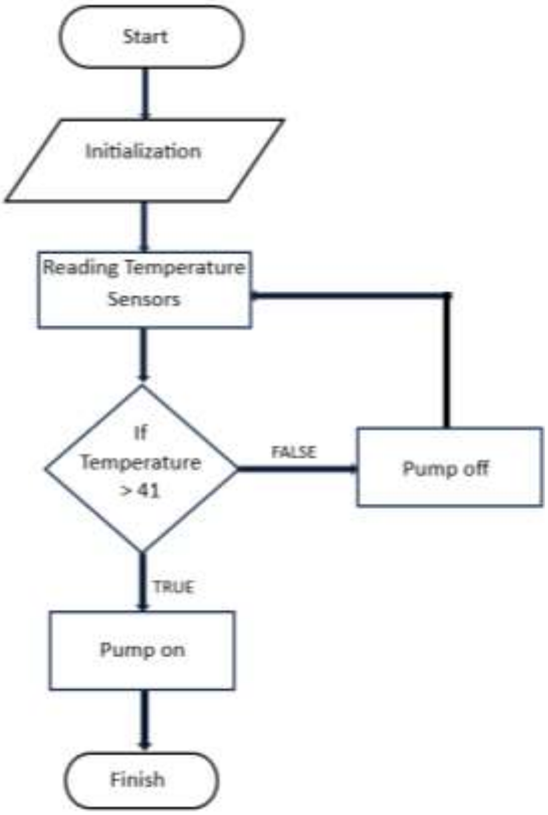
3 (a)

Figure 3. Flowchart (a) research stages

This research adopts the quantitative experimental method, where this approach is applied to system design and data analysis. The results will be compared with data generated by static solar panels without cooling, as well as data generated using a solar panel cooling system. This research involves the steps in Figure 3(a)



4 (a)



4 (b)

Figure 4. Flowchart (a) cooling using the water cooling method (b) cooling using the water spray method

The PV cooling system work program begins by turning on the LCD and giving several display commands. Next, the DHT22 sensor will read the temperature value on the solar panel and set a temperature limit with an upper limit above 41°C and a lower limit below 41°C. If the temperature is > 41 then the relay is active so it will turn on the pump or fan. Conversely, if the temperature is < 41 then the relay is off and stops the pump or fan. The flowchart of the designed PV cooling controller system is as in Figures 4.a and 4.b.

Basic calculation. The main calculation relation is the equation of efficiency system (O. T. Laseinde & Ramere, 2021).

$$\text{Efiensi}=\frac{(\text{Pwith-Pwithout})}{\text{Pwithout}}\times 100\% \quad (1)$$

When Pwith is Power from a solar panel with a cooling system, and Pwithout is a solar panel without a cooling system

Experimental setup. The experiment was carried out from 08:00 to 16:00 in clear, cloudless weather at the University of Swadaya Gunung Jati (7GCW+C9) Sunyaragi, Kota Cirebon, Jawa Barat, Indonesia. Data was taken around April 2024. Solar panels are in a static position at an angle of 30° and facing west. Temperature measurements are carried out with a thermos gun and DHT22 sensor embedded in each system. Figure 4 shows the model of the solar panel system that was created, Figure 4a shows an air-cooled solar panel with a fan, 4b shows a spray water-cooled solar panel.

5 (a)

5 (b)

Figure 5. Flowchart 5(a) Air-cooled solar panel with fan coupled with solar panel without a cooling system, 5(b) shows spray water

RESULTS AND DISCUSSION

The performance of the cooling system using water and air spray media has been carried out, the measurements carried out produce a comparison of the surface temperature values of the solar panels, the voltage and current produced by the system and are shown in Figures 5, 6, and 7 respectively.

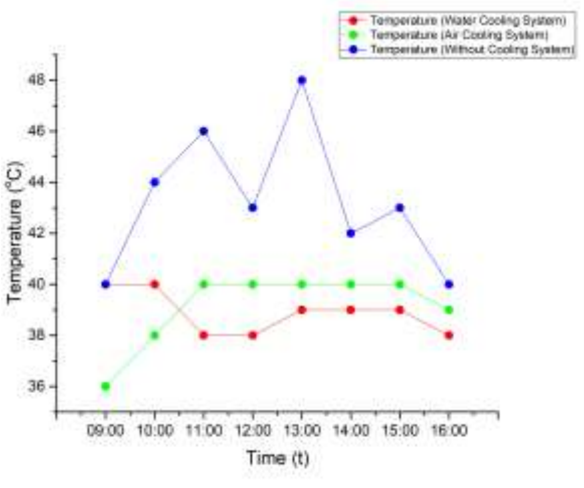


Figure 5. Temperature comparison graph for solar photovoltaic

The water spray cooling method can reduce the temperature optimally with an average temperature of 38.67°C and the air cooling method can reduce the temperature optimally with an average temperature of 39.5°C. From Figure 5, it can be seen that the water spray method takes the lead in reducing the system temperature (red line) and follows the water cooling method (green line), this shows the first recommendation that the water spray method is more significant than the water cooling method.

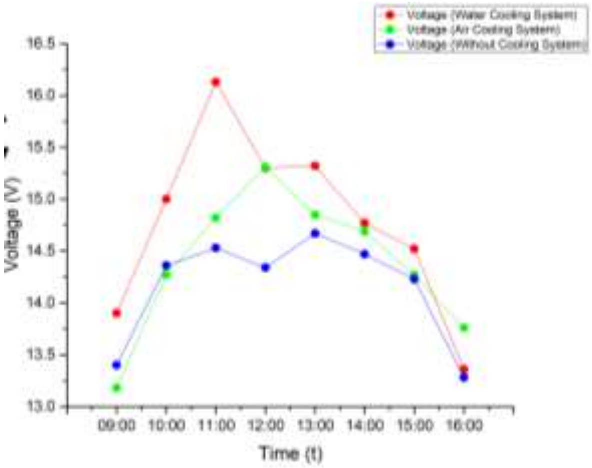


Figure 6. Voltage comparison graph for solar photovoltaic

The water spray cooling system method achieves the maximum voltage generated by the solar panel of 16.13 V and the air cooling method gets the maximum voltage by the solar panel is 15.31 V. From Figure 6, it can be seen that the water spray method reaches the maximum voltage of the system (red line) and is followed by the air cooling method (green line), this shows the first recommendation that the water spray method is more significant to get the optimal voltage compared to the air cooling method.

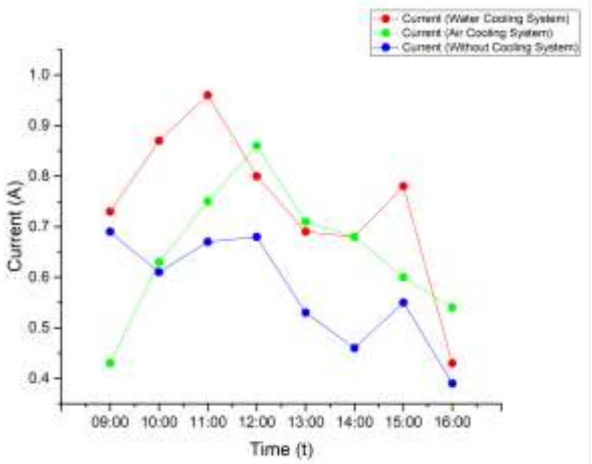


Figure 7. Comparison graph of current in solar photovoltaic

The water spray cooling system method reaches the highest current of 0.96 A at 11:00 a.m., while the maximum current generated by solar panels with the water cooling method is 0.86 A at 12 p.m. From Figure 7, the highest current occurs in the water spray cooling method (red line) and followed by the air cooling method (green line), it can be recommended that the water spray method is more optimal for obtaining current compared to the water cooling method.

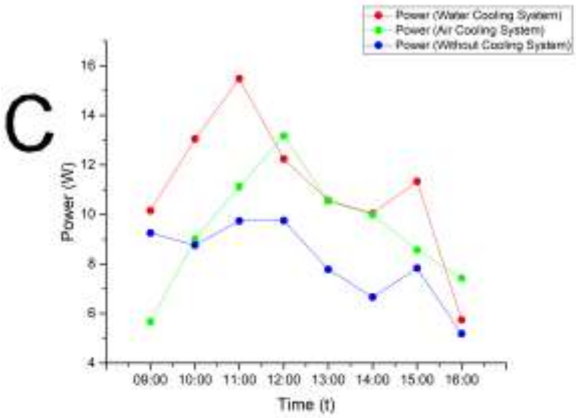


Figure 8. Power comparison graph for solar photovoltaic

The water spray cooling system method produces power at 09.00 a.m - 16.00 p.m which is 88.6 Watts and the highest power is obtained at 11.00 a.m of 15.48 Watts, while the air cooling method produces power at 09.00 a.m - 16.00 p.m of 75.47 Watts and the highest power is at 12.00 p.m of 13.17 Watts. From Figure 8, the highest power occurs in the water spray cooling method (red line) and followed by the air cooling method (green line), it can be recommended that the water spray method has the highest power compared to the air cooling method.

Table 2. Solar panel output power

No.	Time	Power Output (Watt)		
		Water Spray	Air Cooling	Without Cooling
1	9.00	10.15	5.67	9.25
2	10.00	13.05	8.99	8.76
3	11.00	15.48	11.12	9.74
4	12.00	12.24	13.17	9.75
5	13.00	10.57	10.54	7.78
6	14.00	10.04	9.99	6.66
7	15.00	11.33	8.56	7.83
8	16.00	5.74	7.43	5.18
Total		88.6	75.47	64.95

The results of the voltage and current measurement study can be seen in Figures 6 and 7, the performance of the solar photovoltaic cooling system using the water spray method is significant leading to a maximum current value of 0.95 A and a medium value of 16.3 Volts. This shows the second recommendation that the water spray method can significantly increase the voltage and current output of solar photovoltaics. Proven in Table 2, namely data on solar panel output power which is calculated based on the measured current and voltage.

Power efficiency calculations. Based on Table 2, power efficiency calculations are then carried out using Equation 1. Cooling system water spray method:

$$\text{Efiensi}=\frac{(\text{Pwith-Pwithout})}{\text{Pwithout}}\times 100\%$$

$$\text{Efiesensi}=\frac{(88.6-64.95)}{64.95}\times 100\%$$

$$\text{Efiesensi}=\frac{23.65}{64.95}\times 100\%$$

Efiensi=36.41%

Air cooling method with DC fan:

$$\text{Efiensi}=\frac{(\text{Pwith-Pwithout})}{\text{Pwithout}}\times 100\%$$

$$\text{Efiesensi}=\frac{(75.47-64.95)}{64.95}\times 100\%$$

$$\text{Efiesensi}=\frac{10.52}{64.95}\times 100\%$$

Efiensi=16.19%

The result is that the solar panel cooling system using the Water Spray method increases power absorption efficiency by 36.41% and for the water cooling method the power absorption efficiency increases by 16.19%. From all the recommendation results in this study, the most effective cooling system for increasing power output efficiency and optimizing temperature is using the water spray cooling system method.

Conclusion

The automatic cooling system designed uses a water spray cooling method and a DC fan-based air cooling method. The water spray cooling method can reduce the temperature optimally with an average temperature of 38.67°C and the air cooling method can reduce the temperature optimally with an average temperature of 39.5°C. By comparing the voltage and current and calculating the power output values produced by each system, it was found that the water spray cooling method had an efficiency value of 36.41% and the DC fan-based water cooling method had an efficiency value of 16.19%. Henceforth, the solar panel cooling system should use the water spray method because it has a higher efficiency value and lowers the temperature more quickly than a cooling system that uses the air method.

References

1. Ahmed, O. K., Algburi, S., Daoud, R. W., & Aziz, E. F. (2022). Photovoltaic storage solar collector: Experimental assessment. *Energy Reports*, *8*, 13698–13707.
2. Ant. Ardtah Kristi, Abdullah Alhaddad, Muhammad Abdurrahman Hafidhuddien, Noviadi Arief Rachman, Agus Risdiyanto, Bambang Susanto, & Agus Junaedi. (2020). Perancangan Sistem Pendingin Photovoltaic dengan Memanfaatkan Kontroler Water Spray. *ELKHA*, *12*(2), 47–53.
3. Azmi, M. S. F. M., Hussain, M. H., Rahim, S. R. A., Mid, E. C., Shaari, A. S., Hashim, N., Husny, N., & Ahmad, M. F. (2023). Hybrid Cooling System for Solar Photovoltaic Panel. *Journal of Physics: Conference Series*, *2550*(1).
4. Ceylan, I., Gürel, A. E., Demircan, H., & Aksu, B. (2014). Cooling of a photovoltaic module with temperature controlled solar collector. *Energy and Buildings*, *72*, 96–101.
5. Cho, I., & Kim, H. (2019). Study on PV Panel Cooling System using IoT with ESS for Preventing Reduced Efficiency of Solar Panel. *IOP Conference Series: Earth and Environmental Science*, *342*(1).
6. Conrado F., Ostia, J., Jesus Martinez, Kebet A. Abonal, Almira Marie M. Miranda, Christian Dave P. Urquia, & Jonathan Andrei S. Cruz. (2019). A Comparative Study of Different Self-Cooling Mechanisms for Photovoltaic Systems. *International Conference on Control*, 11–14.

7. Dhami Johar Damiri, & Ditha Nevella Sembiring. (2023). Perancangan Automatic Cooling System Solar Power (AuCS-SP) Berbasis Arduino Uno Untuk Mempertahankan Kinerja Solar Panel. *Prosiding Seminar Nasional Energi, Telekomunikasi Dan Otomasi*, 210–219.
8. Dwivedi, P., Sudhakar, K., Soni, A., Solomin, E., & Kirpichnikova, I. (2020). Advanced cooling techniques of P.V. modules: A state of art. *Case Studies in Thermal Engineering*, *21*.
9. Galieh Ananda, Mohamad Dimas Nur Hakim, & Rindi Wulandari. (2024). *Rancang Bangun Solar Panel 20WP untuk Menentukan Suhu Operasi Kerja*.
10. Ghorpade, S., Farakte, B., Kulaye, S., Pawar, S., & Wagh, D. (n.d.). *Efficiency Improvement Of Solar Panel Using Different Cooling Techniques-A Review*.
11. Indra Bayu, J., Budi Sulistiyawati, I., & Putu Agustini, N. (2023). Monitoring Pengaruh Suhu Pada Panel Surya Terhadap Performa Keluaran Pembangkit Listrik Tenaga Surya. *Jurnal Fortech*, *4*(1), 27–32.
12. Jaleel Mahdi, E., Algburi, S., Al-Abadi, N., Ahmed, O. K., & Ahmed, A. K. (2024). Photovoltaic panel cooling using ground source energy: CFD simulation. *Results in Engineering*, *22*.
13. K. Latreche, R. Taleb, A. Bentaallah, A.E. Toubal Maamar, M. Helaimi, & F. Chabni. (2024). Design and experimental implementation of voltage control scheme using the coefficient diagram method based PID controller for two-level boost converter with photovoltaic system. *Electrotechnical Complexes and Systems*, *1*(1), 1–9.
14. Kalil Ahmed, O., Hassan, A. A., Fadhel Abbas, E., & Waadullah Doud, R. (n.d.). *Ntu Journal for Renewable Energy Numerical and experimental assessment of PV/Solar Chimney*.
15. Kamarudin, M. N., Rozali, S. M., & Jamri, M. S. (2021). Active cooling photovoltaic with IOT facility. *International Journal of Power Electronics and Drive Systems*, *12*(3), 1494–1504.
16. Khan, M. A., Ko, B., Nyari, E. A., Park, S. E., & Kim, H. J. (2017). Performance evaluation of photovoltaic solar system with different cooling methods and a Bi-reflector PV system (BRPVS): An experimental study and comparative analysis. *Energies*, *10*(6).
17. Kusuma, V. A., Aprillia, H., Suprapto, S. S., Ramadhani, M. N., Firdaus, A. A., & Putra, D. F. U. (2023). Analysis of the effect of a microcontroller-based solar panel cooling system on temperature and power output. *International Journal of Applied Power Engineering*, *12*(2), 119–125.
18. Laseinde, O. T., & Ramere, M. D. (2021). Efficiency Improvement in polycrystalline solar panel using thermal control water spraying cooling. *Procedia Computer Science*, *180*, 239–248.
19. Laseinde, T., & Ramere, D. (2019). Low-cost automatic multi-axis solar tracking system for performance improvement in vertical support solar panels using Arduino board. *International Journal of Low-Carbon Technologies*, *14*(1), 76–82.
20. Latiff, M. R., Hassan, O. A., Ahmad, M. S., Norjali, R., & Zainal, M. S. (2020). Improve Efficiency of An Automated Photovoltaic Solar Tracker with Cooling System for Renewable Energy Application. *Progress in Engineering Application and Technology*, *1*(1), 257–266.
21. Mahmood Ibrahim, A., R. Ibraheem, R., & Bakr Weli, R. (2023). Energy Saving in Batteries Using the Photovoltaic System. *Al-Kitab Journal for Pure Sciences*, *4*(1), 78–94.
22. Milind, N., Antony, M., Francis, F., Francis, J., Varghese, J., & U K, S. (2017). Enhancing the Efficiency of Solar Panel Using Cooling Systems. *International Journal of Engineering Research and Applications*, *07*(03), 05–07.
23. Mosavi, A., Salimi, M., Ardabili, S. F., Rabczuk, T., Shamshirband, S., & Varkonyi-Koczy, A. R. (2019). State of the art of machine learning models in energy systems, a systematic review. In *Energies* (Vol. 12, Issue 7). MDPI AG.
24. Mostakim, K., Akbar, M. R., Islam, M. A., & Islam, M. K. (2024). Integrated photovoltaic-thermal system utilizing front surface water cooling technique: An experimental performance response. *Heliyon*, *10*(3).
25. Niraj Kumar Kushwaha, Prashant R.D, & Sagar K.C. (2023). *Design and Experimental Study of A Solar PV Cooling System*.

26. Paquianadin, V., Sam, K. N., & Koperundevi, G. (2024). Maximizing solar photovoltaic system efficiency by multivariate linear regression based maximum power point tracking using machine learning. *Electrical Engineering and Electromechanics*, *2024*(1), 77–82.
27. Popovici, C. G., HudiŞteanu, S. V., Mateescu, T. D., & CherecheŞ, N. C. (2016). Efficiency Improvement of Photovoltaic Panels by Using Air Cooled Heat Sinks. *Energy Procedia*, *85*, 425–432.
28. Rezki, M., Rusilawati, R., & Irfan, I. (2023). Optimalisasi Daya Panel Surya Menggunakan Sistem Pendingin Berbasis Air Otomatis. *Jurnal EEICT (Electric Electronic Instrumentation Control Telecommunication)*, *6*(2).
29. Saleh, M. J., Atallah, F. S., Algburi, S., & Ahmed, O. K. (2023). Enhancement methods of the performance of a solar chimney power plant: Review. In *Results in Engineering* (Vol. 19). Elsevier B.V.
30. Setyono, G., Kholili, N., & Rakhmadanu, Y. (2022). The Impact of Utilization The Solar-Panels With a Cooling-Water System as a Source of Micro-Power Generation. *Infotekmesin*, *13*(1), 87–92.
31. Sultan, T. N., Farhan, M. S., & Salim Alrikabi, H. T. H. (2021). Using Cooling System for Increasing the Efficiency of Solar Cell. *Journal of Physics: Conference Series*, *1973*(1).
32. Supian, B. A., Ekaputri, C., & Priharti, W. (2020). Increasing the output power of solar panel by using cooling system. *IOP Conference Series: Materials Science and Engineering*, *830*(3).
33. Swatara Loegimin, M., Sumantri, B., Ari Bagus Nugroho, M., Ayub Windarko, N., Elektronika Negeri Surabaya Jl Raya ITS, P., & Sukolilo, K. (2020). Sistem Pendinginan Air Untuk Panel Surya Dengan Metode Fuzzy Logic. In *Jurnal Integrasi* (Vol. 21, Issue 1).
34. Syafiqah, Z., Irwan, Y. M., Amin, N. A. M., Irwanto, M., Leow, W. Z., & Amelia, A. R. (2017). Thermal and electrical study for PV panel with cooling system. *Indonesian Journal of Electrical Engineering and Computer Science*, *7*(2), 492–499.
35. Tabaei, H., & Ameri, M. (2015). Improving the Effectiveness of A Photovoltaic Water Pumping System by Using Booster Reflector and Cooling Array Surface by A Film of Water. In *Transactions of Mechanical Engineering* (Vol. 39, Issue 1).
36. Virtuani, A., Pavanello, D., Friesen, G., Virtuani, A., Pavanello, D., & Friesen, G. (2010). *Overview of Temperature Coefficients of Different Thin Film Photovoltaic Technologies*.
37. Widjanarko, W., Alia, N., Dani, A., & Perdana, F. A. (2021). Experimental analysis of temperature, light intensity, and humidity on rooftop standalone solar power plant. *IOP Conference Series: Materials Science and Engineering*, *1073*(1), 012047.