SEMARAK ILMU PUBLISHING
202103268166(003316878-P)

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879

Optimization of Solar Power Plant with Variation of Solar Reflector Angles and Use of Passive Cooling Integrated Internet of Things

Abdullah[1], Maharani Putri[1], Muhammad Syahruddin[1], Nobert Sitorus[1], Abdul Kadir Jumaat[2], Abdul Rahim Ridzuan[3], Cholish[1], Priansus Rhein Rumahorbo[1], Zikri Noer[4,*], Masthura[5], Malik Abdul Karim[6]

1 Department of Electrical Engineering, Politeknik Negeri Medan, Medan City, North Sumatra 20155, Indonesia
2 Faculty of Computer and Mathematical Science, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
3 Faculty of Business and Management, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
4 Department of Physics, Faculty of Vocational, Universitas Sumatera Utara, Kota Medan, North Sumatra 20222, Indonesia
5 Department of Physics, Universitas Islam Negeri Sumatera Utara, North Sumatra 20371, Indonesia
6 Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Petronas, Bandar Seri Iskandar, 32610 Seri Iskandar, Perak, Malaysia

ARTICLE INFO

Article history:
Received 3 July 2024
Received in revised form 10 October 2024
Accepted 20 October 2024
Available online 20 November 2024

Keywords:
Solar panels; optimization; internet of things; reflector; cooling

ABSTRACT

With the growing global demand for energy, exploring alternative energy sources, particularly solar energy, in equatorial regions where abundant sunlight is essential. Solar panels, which convert sunlight into electricity, must be optimally positioned to capture the maximum amount of sunlight and operate within an ideal temperature range for efficiency. However, two key challenges must be addressed: ensuring solar panels are consistently aligned with the sun and managing heat buildup, which can reduce performance. This study proposes a specialized optimization system to enhance solar panel efficiency by addressing these issues. The system adjusts the angle of solar reflectors to maximize sunlight exposure. It incorporates passive cooling mechanisms, such as heatsinks and cooling blocks, which are attached to the back of the panels to regulate temperature. Real-time monitoring using Internet of Things (IoT) technology tracks critical parameters, including solar reflector angles, panel and ambient temperatures, light intensity, weather conditions and electrical output. A comparative analysis between standard solar panels and those equipped with this optimization system demonstrates that the latter significantly outperforms conventional setups. The system ensures maximum sunlight absorption, maintains optimal operating temperatures and boosts overall energy production. These findings underscore the potential of the proposed system to improve the reliability and efficiency of solar energy generation in equatorial regions, contributing to more sustainable energy solutions in high-sunlight environments.

1. Introduction

As technology advances, so does the use of alternative energy derived from solar energy. This is due to the inverse relationship between the annual increase in demand for electrical energy and the depletion or limited availability of fossil fuels, so this is a serious problem that needs to be addressed

* *Corresponding author.*
E-mail address: zikrinoer@usu.ac.id

https://doi.org/10.37934/arfmts.124.1.233248

immediately [1-3]. There are increasingly limited fossil energy sources, so developing and managing alternative energy sources is necessary [4-7]. One of these is solar energy sources, which are abundant and unlimited, especially in countries on the Kharif line. Especially in countries located on the equator, utilizing and maximizing the performance of solar panels is one method of using solar energy sources [8].

The solar photoelectric effect, whereby sunlight is converted into electronic energy, provides the fundamental basis for the operation of solar panels. Electricity is the basis of how solar panels work [9-11]. Two main factors- the amount of sunlight and the temperature of the solar panel- significantly impact how well solar panels optimize their electrical energy by analysing the voltage and current output [12,13]. A reduction in sunlight intensity affects the electrical energy generated by the solar panel. This manifests as a decrease in both the current and voltage produced by the device [14-16]. High temperatures on the surface of the solar panel caused by continuous sunlight cause the electrical power generated to decrease; starting from the causes the generated electrical power to decrease; starting from 25°C an increase of 1°C in the temperature by 1°C will cause a 0.5% decrease in the output power produced by the solar panel [17-19]. Optimization System of Solar Power Plant Optimization System with Solar Reflector Angle Variation and Passive Cooling via the Internet of Things was to address the shortcomings of the existing study [20-22]. This system maximizes the amount of sunlight intensity that the solar panels can absorb by adjusting the angle of the solar reflector or by focusing the reflected light toward the or by focusing the reflected light towards the centre of the solar panel surface [23,24]. This is done by integrating programming algorithms driving the reflector motor to get the maximum sunlight reflection value [25-27]. Furthermore, the implementation of passive cooling techniques at the base of the solar panel serves to maintain the panel's thermodynamic equilibrium with its operational temperature [28-31]. In addition, the system is monitored in real-time based on Internet of Things technology to ensure proper operation of the panels and to display the panel's characteristics through the use of cooling blocks that are installed or arranged on the back of the panel [32-35].

In this study, we have developed an optimization system designed to improve the efficiency of power plants that utilize solar energy. This system incorporates solar reflector angle variations and passive coolers integrated with the Internet of Things (IoT). Our system can adjust the reflector angle automatically, allowing for remote control and optimization of sunlight reflection onto specific surfaces, such as solar panels. The light sensors integrated into the solar panel drive the reflector motor, which directs sunlight to the panel's surface. The panel's cooling system employs passive cooling techniques, utilizing the aforementioned design concept. The thermal management system, comprising a heatsink and cooling block, the component in question is attached to the posterior aspect of the solar panel. This configuration avoids any unnecessary burden on the solar panel, ensuring optimal performance. This system does not consume and burden the solar panel's output because it does not require an activating power source. itself because it does not require a power source for activation. This system also has a real-time monitoring application feature that can be viewed through smartphones and laptops. Smartphone and laptop in real-time. The parameters monitored in this study are the degree of the solar reflector angle, solar panel temperature, environmental temperature, light intensity value, weather information, electric potential, electric flow and the power generated by each of the systems mentioned above. The study compares standard solar panels (devoid of system design) with solar panels that have undergone a system design. The Internet of Things-based technology enables the continuous monitoring of all system parameters, thereby ensuring optimal operation. This research aims to identify methods for improving the efficiency of electrical current storage for use among industrial and societal entities. It encompasses mandatory and optional components, contributing to advancements in the science and technology of efficient solar power modelling systems.

2. Methodology

Hardware and software design for system implementation optimization system for solar power plants with variations in solar reflector angle and passive cooling in conjunction via the Internet of Things [36]. This research employs a methodology incorporating passive cooling with the Internet of Things (IoT). The research process, illustrated in the fishbone diagram in Figure 1, serves as the foundation for this study.

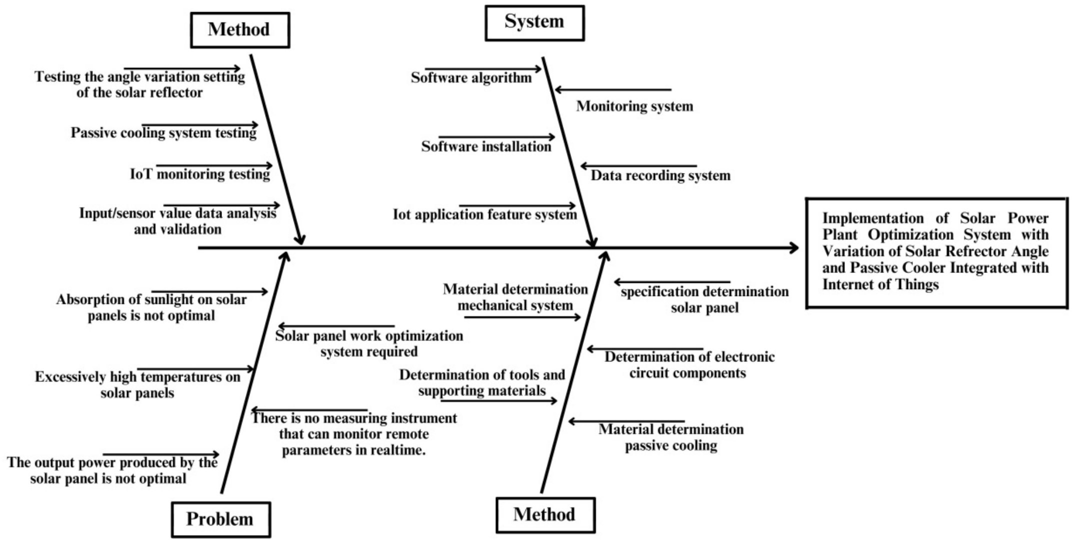


Fig. 1. Fishbone diagram of research roadmap

The research fishbone diagram above explains the flow of an implementation of deploying a solar power facility optimization system with variations in the angle of the solar reflector and passive cooling integrated with the Internet of Things, where the problems that arise because the absorption of sunlight on solar panels is not optimal, the temperature is too high on solar panels so that the power is not optimal. not optimal, the temperature is too high on the solar panel, so the output power is not optimal, so a system is needed. output is not optimal, so a system that has been adjusted is needed. The resulting system can work automatically in one system, such as methods, systems and material selection, such as passive pending materials. Setting the angle of the solar reflector to get the ideal angle that can be set from the detection of light sensors and remote control and the use of solar reflectors. can be set by light sensor detection and the solar panel's temperature can be controlled remotely and with passive cooling materials. The passive cooling materials are employed with a heating element and a mounting structure affixed to the solar panel's rear surface. This configuration enables the maintenance of the solar panel's optimal operating temperature. The working temperature of the solar panel. In this research, the following parameters are monitored: the degree of angle of the solar reflector and the temperature of the solar panel, ambient temperature, light intensity value, weather information, voltage, current and current. light intensity value, weather information, voltage, current and power compared to standard solar panels (solar panels without any design system). solar panels (solar panels without a system design) with the existence of a system design on solar panels that have been integrated with a system design. system on solar panels that have been integrated with remote monitoring features using real-time Internet of Things technology. using Internet of Things technology in real-time so that it can be implemented in the community and industry to improve the efficiency of electrical energy storage. Electrical energy storage efficiency. The flowchart of the research stages, as illustrated in Figure 2, outlines the systematic approach taken in this study as follows:

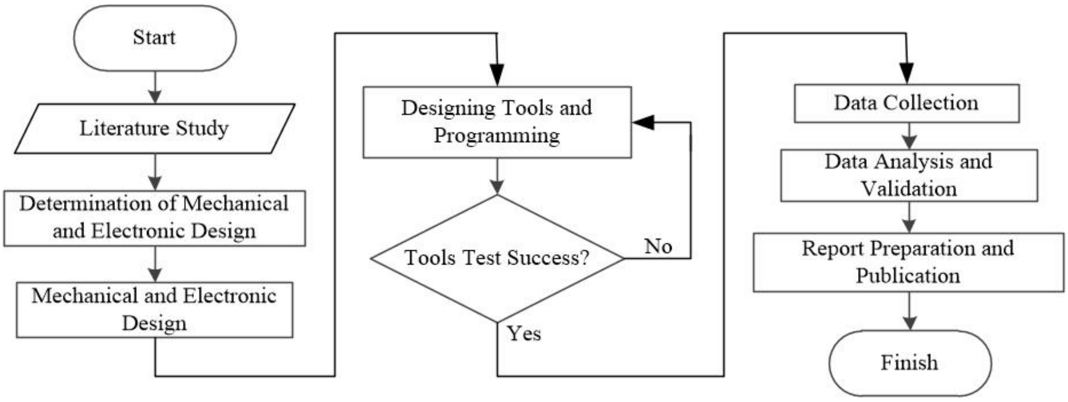


Fig. 2. Flowchart of research stages

The stages of research implementation are as follows, as shown in the flow chart above. The flowchart above shows that a literature study was conducted with references supporting the research and the use of components needed for system implementation. Once the requisite references have been obtained, the mechanics and circuit modules necessary for the system are identified and designed. This includes the mechanical design that must be created, the necessity for multiple circuit modules, such as controllers, sensors and other circuit modules, the types of DC motors and the specific type of DC motor and its driver, indicator display and Wi-Fi module used to integrate the system with the Internet of Things. Testing will be carried out on the things-based system to ensure that all mechanical designs are correct. and the circuit module can function properly after the circuit module and mechanical design are completed. Then, the entire circuit will be connected according to the system requirements. Next, create the program algorithm for the software. Once done, upload the program to the controller as the input and output control centre. The next step is to test the device to ensure the system is suitable. If not, adjust based on any issues that arise. However, based on the research, the stage of working on and creating the system design has been completed. Data collection, report preparation and publication.

This research will use the Arduino Mega data processing centre, which will receive inputs from the LDR light sensor, temperature sensor, GY-302 lux sensor and PZEM-017 module. The DC motor driver will control the DC motor and act as a system to adjust the angle variation of the solar reflector to maintain optimal sunlight reflection for the solar panel. In addition to an integrated Internet of Things application is used to monitor the system. system. The purpose of this monitoring application is to indicate important parameters of the system so that it can be observed and operated properly. The Figure 3 displays the entire system design diagram as follows:

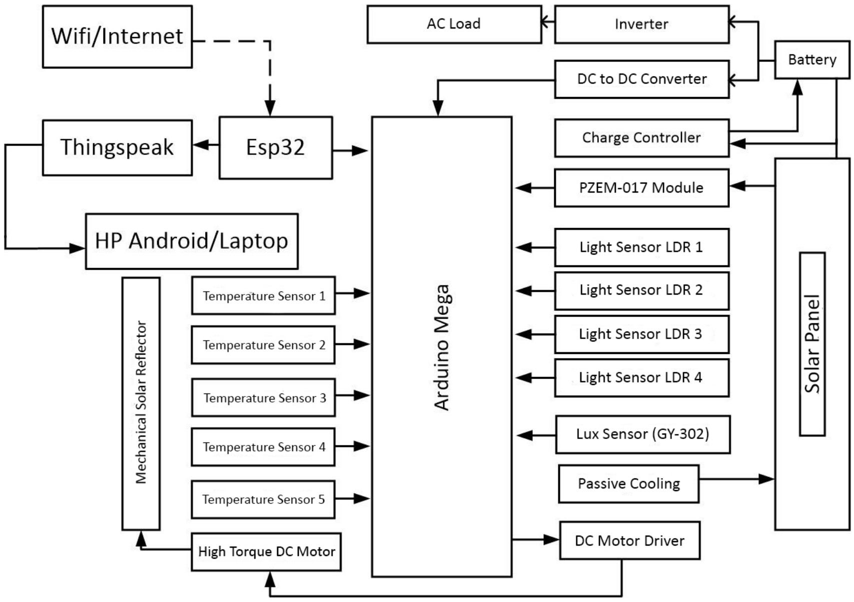


Fig. 3. Overall system design diagram

From the design diagram above, the needs of the system's main parts can be described: Arduino Mega, which serves as the centre for processing ESP32 Wi-Fi module readings and input/output. 120 WP solar panel, DC High Torque Motor, which moves the angle of the solar reflector based on instructions from the LDR light sensor, passive cooler, which regulates the temperature of the solar panel, DC Motor Driver, which controls the direction and rotational speed of the DC motor and LDR light sensor, which consists of five pieces and functions as a reflector light reflection detector by measuring changes in the resistance of the light that hits it, Lux Sensor GY-302 functions as a light intensity meter in Lux units with a resolution of 0 - 65535 lux. The PZEM-017 module measures current and voltage on solar panels with a monitor voltage range of 0 - 26 V and an operating voltage of 3 - 5 V. The ESP32 module is a Wi-Fi module in the Internet of Things design. Deep Cycle batteries are used to store power from solar panels. As a regulator of the voltage and current that the battery will get from the charge controller when converting the DC input voltage level into various DC output voltage levels, a DC-to-DC converter is used and an inverter is used to convert the DC voltage level into AC voltage to activate the AC load used.

3. Results

The results and discussion on the research of the solar power plant optimization system with variations in the angle of the solar reflector and the use of passive cooling integrated with the Internet of Things consist of five tests, namely testing the solar reflector angle variation setting system on solar panels, testing the output power of solar panels between solar panels without movement (static) and solar panels with solar reflector angle variation setting system, testing the passive cooling system of solar panels, testing the solar panel optimization system with solar reflector angle variation settings and passive cooling system and testing the monitoring system. The objective was to assess the efficacy of a solar reflector angle and passive cooling system, as well as to evaluate the monitoring and control mechanism reliant on the IoT is to be evaluated. The findings of the overall system design are presented in Figure 4(a) to Figure 4(c).

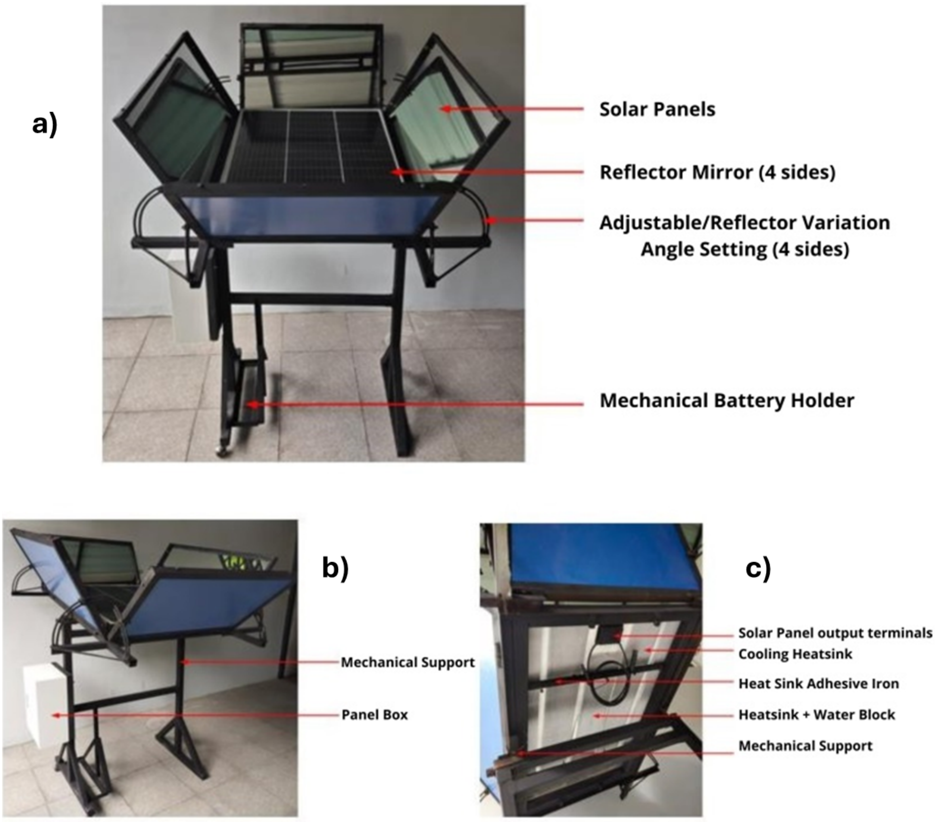


Fig. 4. Display of overall system design

3.1 Testing the Solar Reflector Angle Variation Setting System on Solar Panels

This experiment assessed the influence of solar reflected intensity variation on solar panel output power. The setup is designed to demonstrate how to alter the solar reflector angle on the solar panel output power. The outcomes of these trials are presented in Table 1 and Figure 3.

Table 1
Testing the solar panel reflector angle variation control system

No	Solar Angle Four Reflector Side $(^{o})$	Percentage Increase in Panel Output Power Solar Panel (%)
1	15	2
2	30	34
3	45	17
4	60	-4
5	75	-19

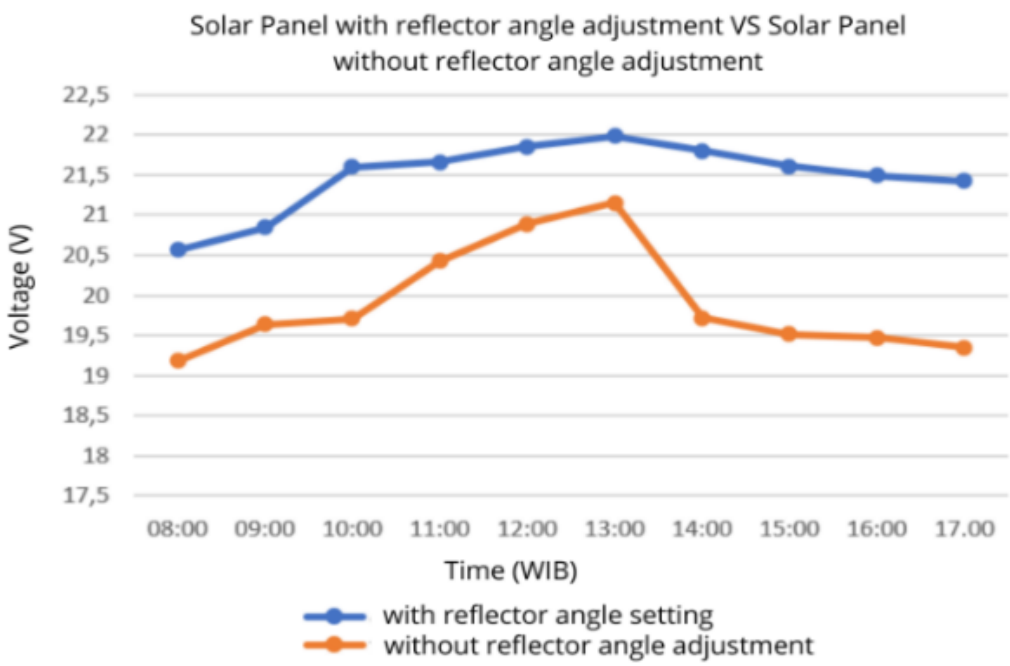
Table 1 shows that the best angle of the four-sided solar reflector arrangement is at 30^{o} with a percentage increase in solar panel output of 34%. In this condition, the reflector function has worked as a reflector of sunlight to the solar panel, while the worst angle of the solar reflector position is at an angle of 75^{o} with a percentage increase in solar panel output power of -19 % in this condition can be it can be said that the solar light reflector process is not working properly so that the performance of the solar panel decreases. what happens is a decrease in the performance of solar panels.

3.2 Static Solar Panel Testing with Angle Variation Setting System Solar Reflector

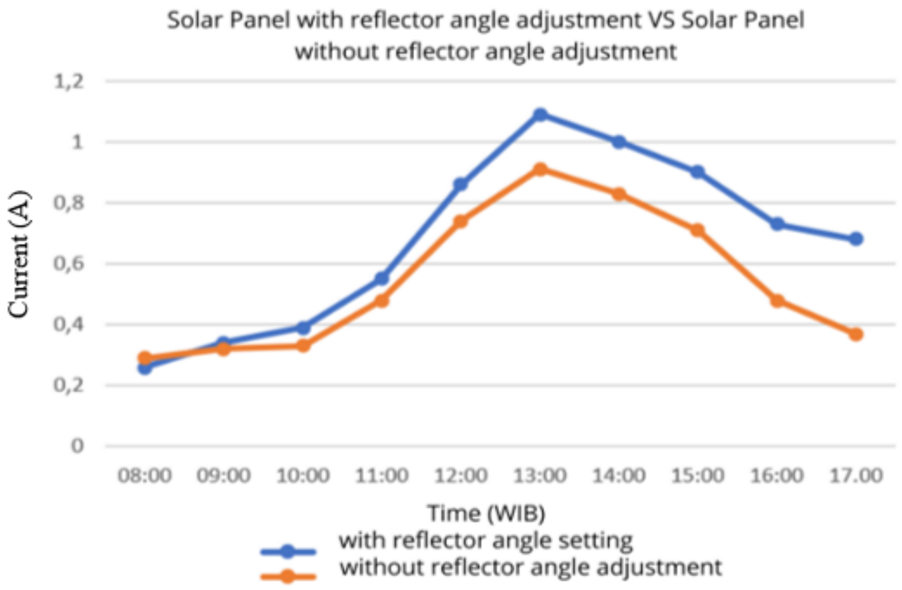
Testing the output power of solar panels between static solar panels (without any movement) and solar panels with a solar reflector angle variation adjustment system shows how the process of optimizing the performance of renewable energy sources such as solar panels can be enhanced by modifying the angle of the solar reflector in comparison to that of conventional, non-adjustable solar panels. This test positions the solar reflector at an angle of 30^{0}. The findings obtained from this study are detailed in Table 2 and Figure 5(a) to Figure 5(c).

Table 2
Testing the output power of solar panels with and without solar reflector angle variation regulation system

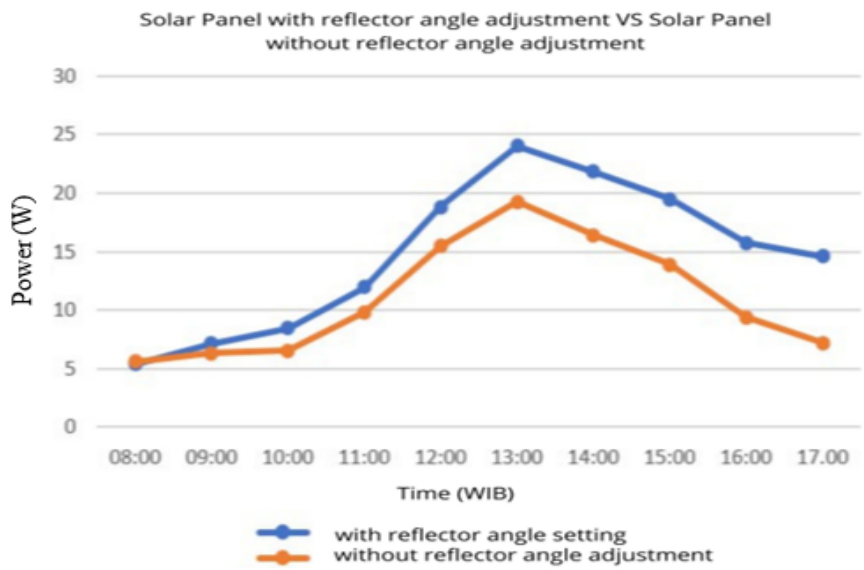
Hours (WIB)	Solar Panel with Settings variation of solar reflector angle			Solar Panels without Settings Reflector Angle			Conditions Weather
	Voltage (Volts)	Current (Ampere)	Power (Watt)	Voltage (Volts)	Current (Ampere)	Power (Watt)	
08:00	20,57	0,26	5,40	19,18	0,29	5,59	Sunny
09:00	20,85	0,34	7,14	19,64	0,32	6,31	Sunny
10:00	21,6	0,39	8,47	19,71	0,33	6,53	Sunny
11:00	21,66	0,55	11,96	20,43	0,48	9,84	Sunny
12:00	21,85	0,86	18,84	20,89	0,74	15,49	Sunny
13:00	21,98	1,09	24,01	21,15	0,91	19,28	Sunny
14:00	21,8	1,00	21,85	19,72	0,83	16,40	Sunny
15:00	21,61	0,90	19,50	19,52	0,71	13,89	Sunny
16:00	21,49	0,73	15,74	19,47	0,48	9,37	Cloudy
17.00	21,42	0,68	14,61	19,35	0,37	7,19	Cloudy



(a)



(b)



(c)

Fig. 5. (a) Voltage versus time (b) current versus time (c) output power of solar panels with and without solar reflector angle variation

Following the testing of two sets of solar panels, one with and one without a regulation system and the subsequent calculation of their respective output powers, it was found that the solar panels with the system exhibited a total output power of 147.52 W. In contrast, the output of the solar panels without the system was 109.89 W. This allows the difference in the output power of solar panels to be calculated as follows:

Difference Pout total = ∑P With the system - ∑P Without the system
= 147,52 Watt – 109,89 Watt
= 37,63 Watt
% Power Increase (P) = (Difference Pout total / ∑P Without system) x 100
= (37,63 / 109,89) x 100
= 34,24 %
The percentage increase in panel output power was 34.24%.

3.3 Testing the Performance of Passive Panel Cooling Systems

Testing the work of passive cooling systems on solar panels shows how the system works by utilizing thermal sink material and a cooling water block securely attached to the solar panel's rear surface. This configuration is designed with this research project's objective of examining methods of improving the power output of solar panels. The results can be found in Table 3.

Table 3
Testing passive cooling systems on solar panels

Time (WIB)	Solar Panel Temperature without Passive cooling (°C)	Solar Panel Temperature with Passive cooling (°C)	Selisih Suhu (°C)
08:00	28,7	28,5	0,2
13:00	48,9	44,4	4,5
14:00	46,4	42,5	3,9
16:00	42,6	39,2	3,4
17.00	39,3	34,6	4,7

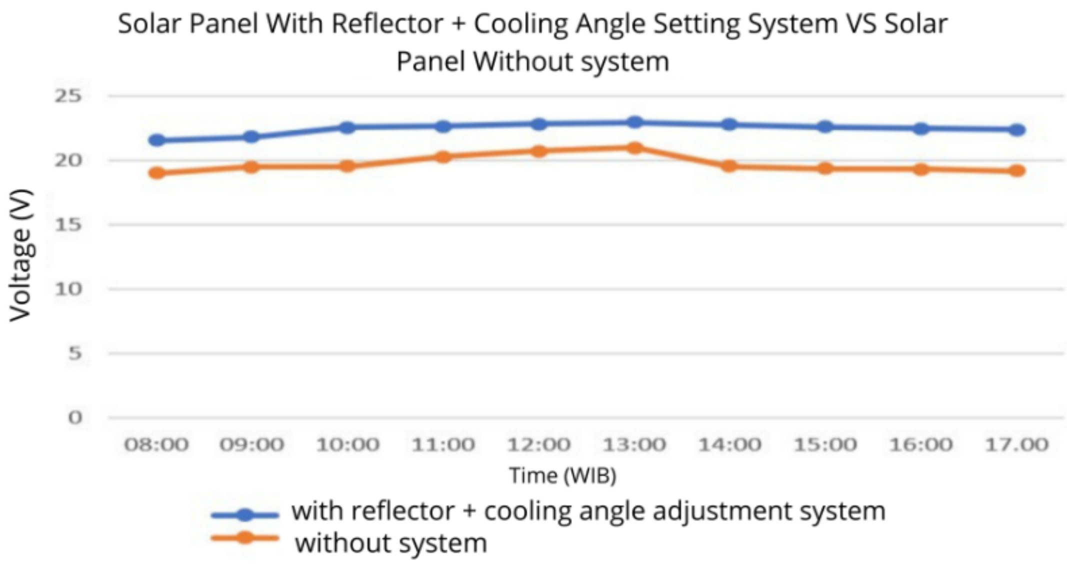
Based on Table 3. The above shows the work of the passive cooling system on solar panels. The cooling process has worked only with insignificant changes, as evidenced by the data presented in the table. The greatest temperature differential is observed at 17:00 WIB, with a magnitude of 4.7°C. This observation highlights the potential for further optimization of passive cooling design to enhance the efficacy of the cooling system.

3.4 Testing the Solar Panel Optimization System by Adjusting the Solar Reflector Angle and Passive Cooling System

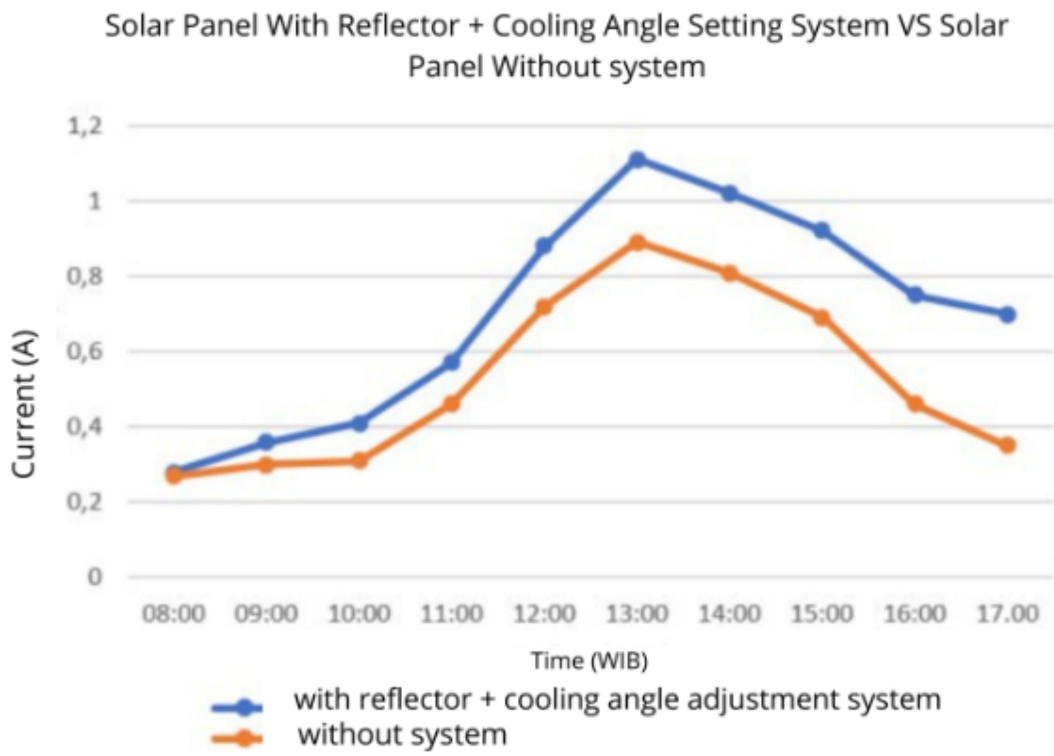
Testing the solar panel optimization system between solar panels with solar reflector angle variation settings and passive cooling systems and solar panels without solar reflector angle variation settings and passive cooling systems shows how the process of the efficacy of solar panels can be enhanced through the incorporation of reflector angle variation settings and passive cooling systems compared to solar panels without solar reflector angle variation settings and passive cooling systems. The efficacy of solar power can be optimized by modifying the angle at which the solar reflector is positioned and the passive cooling system is implemented in comparison to solar panels without such modifications. This experiment positions the solar reflector at an angle of 30°C. The results of this experiment can be found in Table 4 and the graph in Figure 6(a) to Figure 6(c).

Table 4
Testing the solar panel optimization system between solar panels with solar reflector angle variation settings and the system incorporates a passive cooling mechanism coupled with solar photovoltaics. However, it lacks a solar panel optimization system

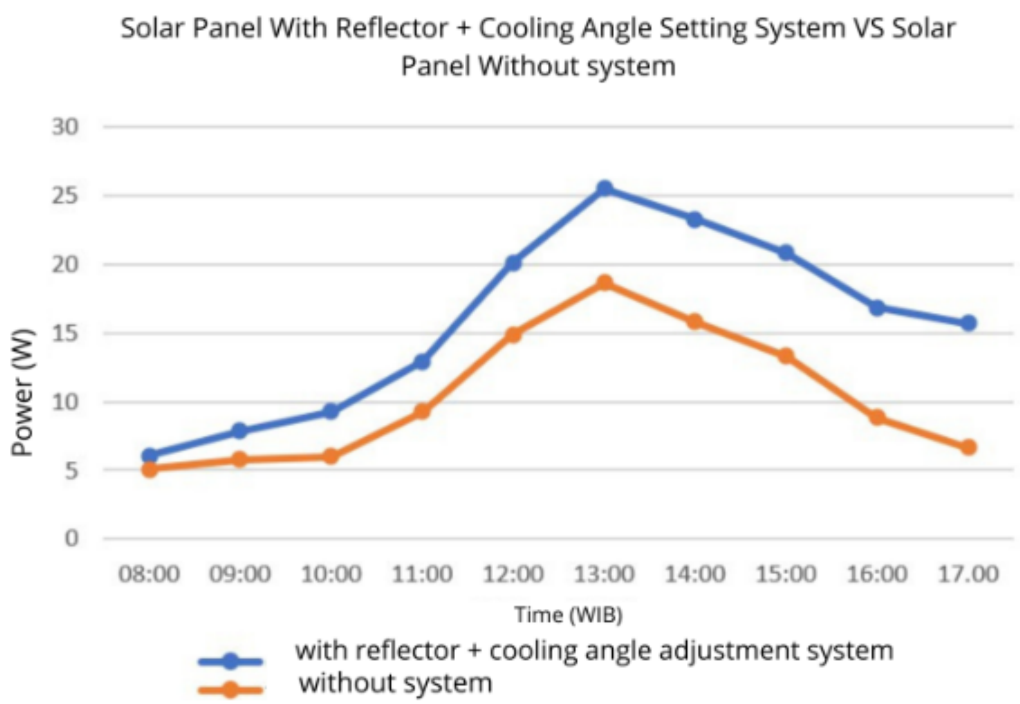
Time (WIB)	Solar Panel with System Reflector Angle Setting + Cooling			Solar Panel Without System			Conditions Weather
	Voltage (Volts)	Current (Ampere)	Power (Watt)	Voltage (Volts)	Current (Ampere)	Power (Watt)	
08:00	21,53	0,28	6,04	19,01	0,27	5,09	Sunny
09:00	21,81	0,36	7,87	19,47	0,30	5,80	Sunny
10:00	22,56	0,41	9,26	19,54	0,31	6,02	Sunny
11:00	22,62	0,57	12,91	20,26	0,46	9,28	Sunny
12:00	22,81	0,88	20,09	20,72	0,72	14,88	Sunny
13:00	22,94	1,11	25,48	20,98	0,89	18,63	Sunny
14:00	22,76	1,02	23,23	19,55	0,81	15,79	Sunny
15:00	22,57	0,92	20,78	19,35	0,69	13,31	Cloudy
16:00	22,45	0,75	16,85	19,30	0,46	8,84	Cloudy
17.00	22,38	0,70	15,68	19,18	0,35	6,67	Cloudy



(a)



(b)



(c)

Fig. 6. (a) Voltage versus time (b) Current versus time (c) Output power of solar panels with and without solar reflector angle variation

Based on testing the solar panel optimization system between solar panels with solar reflector angle variation settings and passive cooling systems with solar panels without system design, the total power of solar panels with solar reflector angle variation settings and passive cooling systems is 158.19 W. Solar panels without systems is 104.31 W so that the difference in power can be calculated:

Difference Pout total = ∑P With the system - ∑P Without the system
= 158,19 Watt – 104,31 Watt
= 53,88 Watt
% Power Increase (P) = (Difference Pout total / ∑P Without system) x 100
= (53.88 / 104,31) x 100
= 51,65 %
The percentage by which solar panel output power increased is 51.65%.

3.5 Testing the Internet of Things Integrated Monitoring and Control System Things

Testing this Internet of Things integrated monitoring and control system shows how the concept of remote monitoring and control utilizing IoT technology can be carried out on solar panel optimization systems optimization system by adjusting the angle of the solar reflector and passive cooling system using the Blynk application. Figure 7, Figure 8 and Figure 9 show some of these tests.

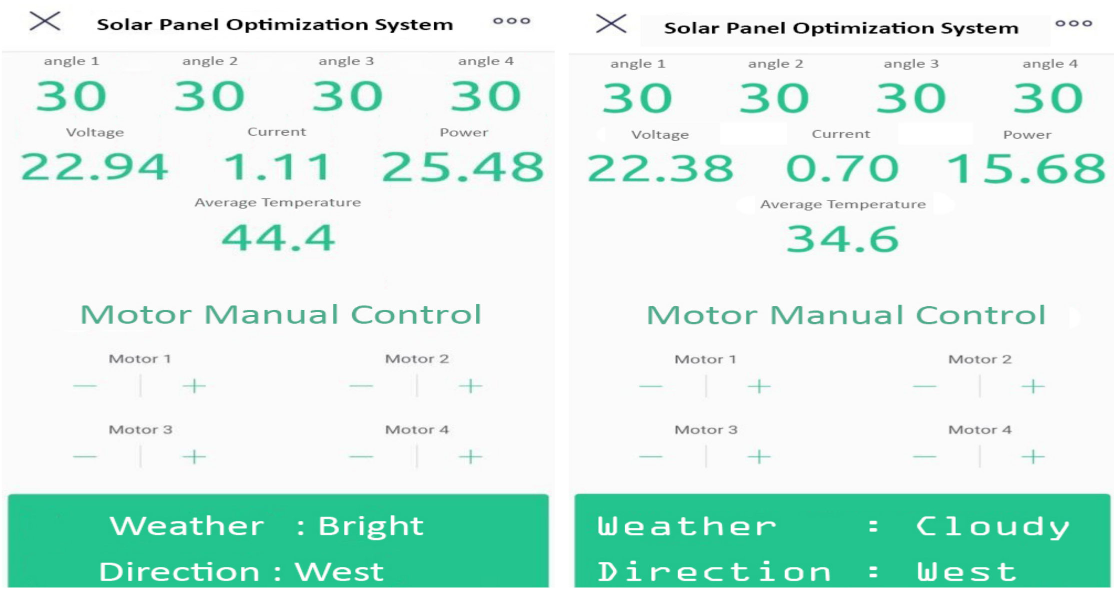


Fig. 7. Reading of monitoring results of the solar panel optimization system

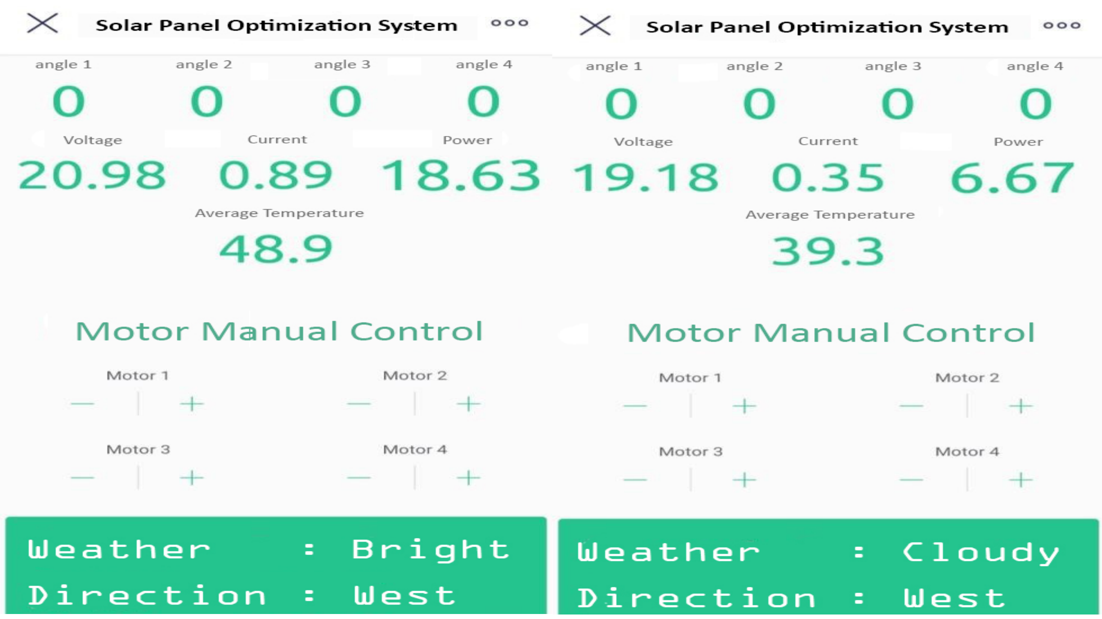


Fig. 8. Monitoring readings without solar panel optimization system

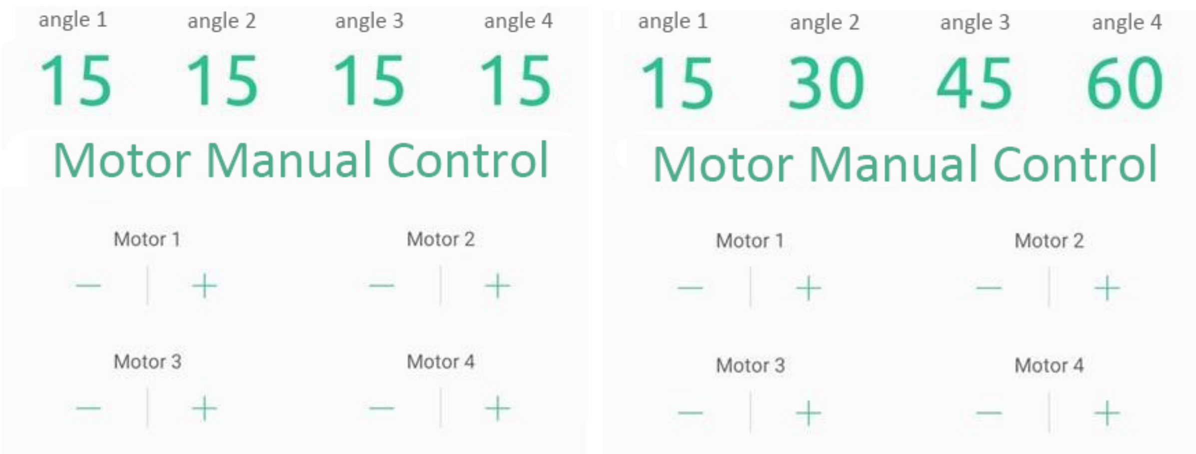


Fig. 9. Testing the Internet of Things integrated control system

From the tests carried out, all monitoring and control data, be it data of four solar reflector angle values, solar panel temperature, manual control of the motor, weather information, electric potential, electric current, Moreover, the solar reflector's output power could be effectively monitored and controlled. Through a single Blynk application, the output power delivered by the panel can be monitored and controlled with precision. This is made possible by integrating the application with the Internet of Things, which allows for seamless monitoring and control across a network of connected devices.

4. Conclusions

This research demonstrates the advantages of implementing an optimized system design for solar panels compared to standard, static setups. Solar panels with the system design allow automatic and manual control, providing flexibility and rapid fault correction. This feature is precious in ensuring continuous, efficient operation, as system malfunctions can be addressed immediately, minimizing downtime. The system also incorporates various functionalities, including adjustments for four solar reflector angle values, monitoring of solar panel temperature, manual control of the solar reflector drive motor, real-time weather data and voltage, current and power output measurements.

The testing confirms that the proposed system functions effectively as an Internet of Things (IoT)-integrated solar panel optimization solution. The variation in solar reflector angle, adjusted based on input from light and tilt sensors, has been proven to enhance solar panel performance significantly. The results show that the optimized system increases solar panel output power by 34.24% compared to static panels. Furthermore, when comparing the system to a setup with a solar reflector angle adjustment system and passive cooling, the optimized design achieved a remarkable 51.65% increase in output power. These improvements underscore the system’s capability to maximize sunlight absorption and maintain optimal operating conditions, resulting in greater energy production and system efficiency.

The research of IoT-based real-time remote monitoring further strengthens the system's reliability. It allows for continuous tracking of key parameters and enables proactive adjustments to maintain optimal performance. This feature is particularly advantageous in regions with variable weather conditions, where solar panel efficiency can fluctuate due to environmental factors.

Looking ahead, there are several promising avenues for future research and development. One potential direction is incorporating active cooling techniques, which could further enhance the thermal regulation of solar panels, particularly in high-temperature environments. Additionally, integrating advanced predictive algorithms that forecast weather patterns and adjust the solar reflector angles in anticipation of changes could lead to even more precise optimization. Such advancements would improve the overall efficiency of solar panel systems and ensure their adaptability to varying environmental conditions.

Acknowledgement
The authors would like to express their sincerest gratitude to the Director of POLMED and the Research and Public Services Centre (P3M) POLMED staff for their invaluable assistance and for providing the necessary resources and facilities to prepare this work. The authors would also like to extend their appreciation to the Directorate of Vocational Education, Ministry of Education, Culture, Research and Technology of the Republic of Indonesia, for their financial support of this project through DIPA POLMED 2023, contract number B/444/PL5/PT.01.05/2023.

References
[1] Adellea, Alitsha Jasmine. "Implementation of New Energy and Renewable Energy Policy in the Context of National Energy Security." *Indonesian State Law Review (ISLRev)* 4, no. 2 (2022): 43-51. https://doi.org/10.15294/islrev.v4i2.61093
[2] Nalule, Victoria and Theophilus Acheampong. "Energy Transition Indicators in African Countries: Managing the Possible Decline of Fossil Fuels and Tackling Energy Access Challenges." *Journal of Sustainable Development Law and Policy (The)* 12, no. 1 (2021): 1-48. https://doi.org/10.4314/jsdlp.v12i1.2
[3] Kulagin, Vyatcheslav A., Dmitry A. Grushevenko and Nikita O. Kapustin. "Fossil fuels markets in the “energy transition” era." *Russian Journal of Economics* 6, no. 4 (2020): 424-436. https://doi.org/10.32609/j.ruje.6.55177
[4] Karim, Malik Abdul, Mohamad Zaki Abdullah, Ahsan Waqar, Ahmed Farouk Deifalla, Adham E. Ragab and Muhammad Khan. "Analysis of the mechanical properties of the single layered braid reinforced thermoplastic pipe (BRTP) for oil & gas industries." *Results in Engineering* 20 (2023): 101483. https://doi.org/10.1016/j.rineng.2023.101483
[5] Karim, M., M. Abdullah and Tauseef Ahmed. "AN overview: the processing methods of fiber-reinforced polymers (FRPS)." *J. Mech. Eng. Technol* 12 (2021): 10-24. https://doi.org/10.34218/IJMET.12.2.2021.002
[6] Karim, Malik Abdul, Mohamad Zaki Abdullah, Ahmed Farouk Deifalla, Marc Azab and Ahsan Waqar. "An assessment of the processing parameters and application of fibre-reinforced polymers (FRPs) in the petroleum and natural gas industries: A review." *Results in Engineering* 18 (2023): 101091. https://doi.org/10.1016/j.rineng.2023.101091

[7] Karim, Malik Abdul. "Hoop, Stiffness And Axial Tensile Properties Of The Single Layered Braid-Reinforced Thermoplastic Pipe For Oil And Gas Applications." PhD diss., Universiti Teknologi PETRONAS, 2024. https://doi.org/10.1016/j.rineng.2023.101483
[8] Gong, Qipeng, Fangcheng Kou, Xiaoyu Sun, Yu Zou, Jinhan Mo and Xin Wang. "Towards zero energy buildings: A novel passive solar house integrated with flat gravity-assisted heat pipes." *Applied Energy* 306 (2022): 117981. https://doi.org/10.1016/j.apenergy.2021.117981
[9] Aftab, Sikandar, Muhammad Zahir Iqbal, Zeeshan Haider, Muhammad Waqas Iqbal, Ghazanfar Nazir and Muhammad Arslan Shehzad. "Bulk photovoltaic effect in 2D materials for solar-power harvesting." *Advanced Optical Materials* 10, no. 23 (2022): 2201288. https://doi.org/10.1002/adom.202201288
[10] Al-Ezzi, Athil S. and Mohamed Nainar M. Ansari. "Photovoltaic solar cells: a review." *Applied System Innovation* 5, no. 4 (2022): 67. https://doi.org/10.3390/asi5040067
[11] Lubis, Sudirman, Farel H. Napitupulu, Ilmi Abdullah, Tulus Burhanuddin Sitorus and Malik Abdul Karim. "Study of Comparison Heat Energy Disposal in Hollow Roof Cooling Water Tank using Natural Material." *Journal of Advanced Research in Applied Sciences and Engineering Technology* (2024): 14-42.
[12] Li, Zhe, Jian Yang and Pouya Asareh Nejad Dezfuli. "Study on the influence of light intensity on the performance of solar cell." *International Journal of Photoenergy* 2021, no. 1 (2021): 6648739. https://doi.org/10.1155/2021/6648739
[13] Sun, Chunlei, Yuan Zou, Caiyan Qin, Bin Zhang and Xiaohu Wu. "Temperature effect of photovoltaic cells: a review." *Advanced Composites and Hybrid Materials* 5, no. 4 (2022): 2675-2699. https://doi.org/10.1007/s42114-022-00533-z
[14] Soomar, Arsalan Muhammad, Abdul Hakeem, Mustapha Messaoudi, Piotr Musznicki, Amjad Iqbal and Stanislaw Czapp. "Solar photovoltaic energy optimization and challenges." *Frontiers in Energy Research* 10 (2022): 879985. https://doi.org/10.3389/fenrg.2022.879985
[15] Tobias, Rogelio Ruzcko, Matt Ervin Mital, Sandy Lauguico, Marielet Guillermo, John Rey Naidas, Marvin Lopena, Mark Ernest Dizon and Elmer Dadios. "Design and construction of a solar energy module for optimizing solar energy efficiency." In *2020 IEEE 12th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM)*, pp. 1-6. IEEE, 2020. https://doi.org/10.1109/HNICEM51456.2020.9400127
[16] Walker, Awnalisa and Soongeol Kwon. "Analysis on impact of shared energy storage in residential community: Individual versus shared energy storage." *Applied Energy* 282 (2021): 116172. https://doi.org/10.1016/j.apenergy.2020.116172
[17] Singh, Vineet and Vinod Singh Yadav. "Optimizing the performance of solar panel cooling apparatus by application of response surface methodology." *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science* 236, no. 22 (2022): 11094-11120. https://doi.org/10.1177/09544062221101828
[18] Rao, Sunil, Sameeksha Katoch, Vivek Narayanaswamy, Gowtham Muniraju, Cihan Tepedelenlioglu and Andreas Spanias. *Machine learning for solar array monitoring, optimization and control*. Springer Nature, 2022.
[19] Dhanalakshmi, Samiappan, Venkatesh Chakravartula, Rajamanickam Narayanamoorthi, Ramamoorthy Kumar, Gerard Dooly, Dinesh Babu Duraibabu and Ramalingam Senthil. "Thermal management of solar photovoltaic panels using a fibre Bragg grating sensor-based temperature monitoring." *Case Studies in Thermal Engineering* 31 (2022): 101834. https://doi.org/10.1016/j.csite.2022.101834
[20] Al-Shahri, Omar A., Firas B. Ismail, M. A. Hannan, MS Hossain Lipu, Ali Q. Al-Shetwi, R. A. Begum, Nizar FO Al-Muhsen and Ebrahim Soujeri. "Solar photovoltaic energy optimization methods, challenges and issues: A comprehensive review." *Journal of Cleaner Production* 284 (2021): 125465. https://doi.org/10.1016/j.jclepro.2020.125465
[21] Pavlík, Marek, L'ubomír Beňa, Dušan Medveď, Zsolt Čonka and Michal Kolcun. "Analysis and evaluation of photovoltaic cell defects and their impact on electricity generation." *Energies* 16, no. 6 (2023): 2576. https://doi.org/10.3390/en16062576
[22] Reddy, S. Uma Maheswara, N. Venkatesh, N. Siva Nagendra, P. Ram Prasad and M. Raja Nayak. "Study On New Design Techniques for Enhancement of Solar Panel Efficiency." In *2021 International Conference on Computing Sciences (ICCS)*, pp. 70-75. IEEE, 2021. https://doi.org/10.1109/ICCS54944.2021.00022
[23] Baccoli, Roberto, Amit Kumar andrea Frattolillo, Costantino Mastino, Emilio Ghiani and Gianluca Gatto. "Enhancing energy production in a PV collector–Reflector system supervised by an optimization model: Experimental analysis and validation." *Energy Conversion and Management* 229 (2021): 113774. https://doi.org/10.1016/j.enconman.2020.113774
[24] Beltagy, Hani. "A secondary reflector geometry optimization of a Fresnel type solar concentrator." *Energy Conversion and Management* 284 (2023): 116974. https://doi.org/10.1016/j.enconman.2023.116974

[25] Kim, Moon Keun, Khalid Osman Abdulkadir, Jiying Liu, Joon-Ho Choi and Huiqing Wen. "Optimal design strategy of a solar reflector combining photovoltaic panels to improve electricity output: A case study in Calgary, Canada." *Sustainability* 13, no. 11 (2021): 6115. https://doi.org/10.3390/su13116115

[26] Sirimanna, M. P. G., Jonathan D. Nixon and M. S. Innocente. "Performance of different optimization solvers for designing solar linear fresnel reflector power generation systems." In *International Conference on Energy and Sustainable Futures*, pp. 323-332. Cham: Springer Nature Switzerland, 2022. https://doi.org/10.1007/978-3-031-30960-1_30

[27] Srinu, Anagandula and K. Sreeram Reddy. "Significance of Melting Heat Transfer, Inclined Magnetic Field and Thermal Radiation on the Dynamics of Williamson Nanofluid Above a Stretching Sheet." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 111, no. 1 (2023): 41-57. https://doi.org/10.37934/arfmts.111.1.4157

[28] Abdulmouti, Hassan. "Passive Cooling Module to Improve the Solar Photovoltaic (PV) Performance." In *The 4th Int. Conf. on Environment, Chemical Engineering & Materials*. 2022.

[29] Mahdavi, Arash, Mousa Farhadi, Mofid Gorji-Bandpy and Amirhoushang Mahmoudi. "A review of passive cooling of photovoltaic devices." *Cleaner Engineering and Technology* 11 (2022): 100579. https://doi.org/10.1016/j.clet.2022.100579

[30] Nižetić, Sandro, Mišo Jurčević, Duje Čoko and Müslüm Arıcı. "A novel and effective passive cooling strategy for photovoltaic panel." *Renewable and Sustainable Energy Reviews* 145 (2021): 111164. https://doi.org/10.1016/j.rser.2021.111164

[31] Nemah, Mohammed Najeh and Bahaa Abdulhur Hatem Albarhami. "Controlling and Modelling a Grid Connected Photovoltaic System for Performance Investigation Purpose." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 111, no. 1 (2023): 28-40. https://doi.org/10.37934/arfmts.111.1.2840

[32] Raman, Ramakrishnan, Mehul Gor, R. Meenakshi, G. M. Jayaseelan, Abhay Chaturvedi, Syed Noeman Taqui, P. Ganeshan, Mohamed Ouladsmane and M. A. Kalam. "Solar energy measurement and monitoring model by using internet of things." *Electric Power Components and Systems* 52, no. 10 (2024): 1796-1807. https://doi.org/10.1080/15325008.2023.2246481

[33] Wu, XiuFeng, ChunYing Yang, WeiCHi Han and ZongRui Pan. "Integrated design of solar photovoltaic power generation technology and building construction based on the Internet of Things." *Alexandria Engineering Journal* 61, no. 4 (2022): 2775-2786. https://doi.org/10.1016/j.aej.2021.08.003

[34] Kaur, Parminder, Vikas Pandey and Balwinder Raj. "Comparative Study of Efficient Design, Control and Monitoring of Solar Power Using Internet of Things." *Sensor Letters* 18, no. 5 (2020): 419-426. https://doi.org/10.1166/sl.2020.4225

[35] Basha, Neelufer Z., F. Mebarek-Oudina, Rajashekhar Choudhari, Hanumesh Vaidya, Balachandra Hadimani, K. V. Prasad, Manjunatha Gudekote and Sangeeta Kalal. "Thermal Radiation Effect on Mixed Convective Casson Fluid Flow over a Porous Stretching Sheet with Variable Fluid Properties." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 111, no. 1 (2023): 1-27. https://doi.org/10.37934/arfmts.111.1.127

[36] Buede, Dennis M. and William D. Miller. *The engineering design of systems: models and methods*. John Wiley & Sons, 2024.