Journal of Energy Systems

2024, 8(2)

2602-2052

DOI: 10.30521/jes.1352390

Research Article

Optimizing solar panel efficiency utilizing reflectors and water treatment techniques

Mathilda Laurensia
Parahyangan Catholic University, Electrical Engineering Department, Jalan Ciumbuleuit No. 94, Bandung, Indonesia, mathildal70@gmail.com
Levin Halim*
Parahyangan Catholic University, Electrical Engineering Department, Jalan Ciumbuleuit No. 94, Bandung, Indonesia, halimlevin@unpar.ac.id

Submitted: 30.08.2023
Accepted: 24.04.2024
Published: 30.06.2024

* Corresponding Author

Abstract: Energy that can be obtained from natural resources and constantly replenished by nature is called "renewable energy". To harness solar energy and convert it into electricity, a device known as a solar panel is utilized. However, solar panels encounter certain drawbacks, including reduced efficiency as the panel temperature rises and the partial absorption of sunlight due to its reflection by the top glass layer. This study aims to optimize solar panel efficiency by innovatively integrating a cooling system with water treatments and an aluminum foil reflector to enhance energy output. The study focused on a 700 mm × 510 mm × 30 mm monocrystalline solar panel. Initial efficiency improved significantly after implementing the cooling and reflector system. Based on measurement data, incorporating the reflector, revealed an average temperature of 61.3°C and solar radiation of 871.10 W/m². The cooling duration of 40.64 seconds was achieved with a water pump flow rate of 0.29 lt/s. Notably, the combined approach yielded substantial efficiency enhancements, with the solar panel reaching peak efficiency levels of 10.36%.

Keywords: *Efficiency, Reflectors, Solar panel, Water treatments*

Cite this paper as: Laurensia, M., & Halim, L. Optimizing solar panel efficiency utilizing reflectors and water treatment techniques. *Journal of Energy Systems 2024; 8*(2): 116-129, DOI: 10.30521/jes.1352390

1. INTRODUCTION

Solar panels are equipment capable of transforming solar energy into electrical energy [1]. However, solar panels have a drawback, which is relatively low efficiency [2]. Typically, monocrystalline solar panels have an efficiency of 16-18% [3]. For every increase in temperature on the solar panel, the efficiency decreases by 0.38% [4]. Several factors can affect the decrease in power output from solar panels, including dust and shading on the solar panels, light reflection, orientation, weather conditions, and temperature [5]. The efficiency of solar panels can be negatively affected by two temperature factors: The solar panel's temperature and the surrounding ambient temperature [6].

According to Ref. [7], cooling solar panels using water treatment methods is effective. The cooling process uses an on/off system, where the pump is activated when the solar panel reaches its maximum temperature. By implementing this process, the power consumed by the pump can be minimized. Additionally, [8,9] state that water treatment methods can increase solar panel efficiency by up to 47%. However, the radiation produced by the sun also affects the efficiency results [10]. The higher the radiation value generated by the sun, the more optimally the surface of the solar panel can function [11]. According to the research [12], employing mirror reflectors on both sides of the solar panel can result in a 24% increase in efficiency. Furthermore, mirror reflectors enhance efficiency while minimizing costs as much as possible [13,14].

This research aims to optimize solar panel efficiency by combining the water treatment cooling method and reflectors to achieve optimum efficiency. Additionally, the water treatment system in this research considers the pump's power consumption to ensure that the power used by the pump does not exceed a specific limit. Both systems are used because the combination of reflectors and water treatment methods can increase solar panel efficiency. By utilizing these two factors, the issues that can cause a decrease in solar panel efficiency can be addressed effectively.

In this research, temperature and light reflection are the main parameters that impact solar panel efficiency. To improve the efficiency of the solar panel, which can be negatively affected by light reflection and temperature, the reflected sunlight from the panel is redirected using an aluminum foil reflector. In order to improve the efficiency of the solar panel, which can be negatively impacted by light reflection and temperature, the reflected sunlight from the panel is redirected using an aluminum foil reflector In order to improve the efficiency of the solar panel, which can be negatively impacted by light reflection and temperature, the reflected sunlight from the panel is redirected using an aluminum foil reflector [12]. However, the efficiency is enhanced by implementing the water treatment method to mitigate the impact of temperature on the solar panel. This method involves cooling the solar panel by circulating water over its surface.

2. METHODOLOGY

This research aims to explore solar panel systems comprehensively, encompassing the design of a sunlight absorption-enhancing system and the incorporation of a cooling mechanism through water treatments tailored explicitly for monocrystalline panels. The objective is to elevate the efficiency of these panels. This research also considers the temperature difference of solar panels before and after the application of the cooling system. This research also evaluates the comparison of solar energy absorption by panels before and after the installation of reflectors. Lastly, the project intends to compare the efficiency of solar panels before and after the implementation of the cooling system with water treatments and the use of reflectors.

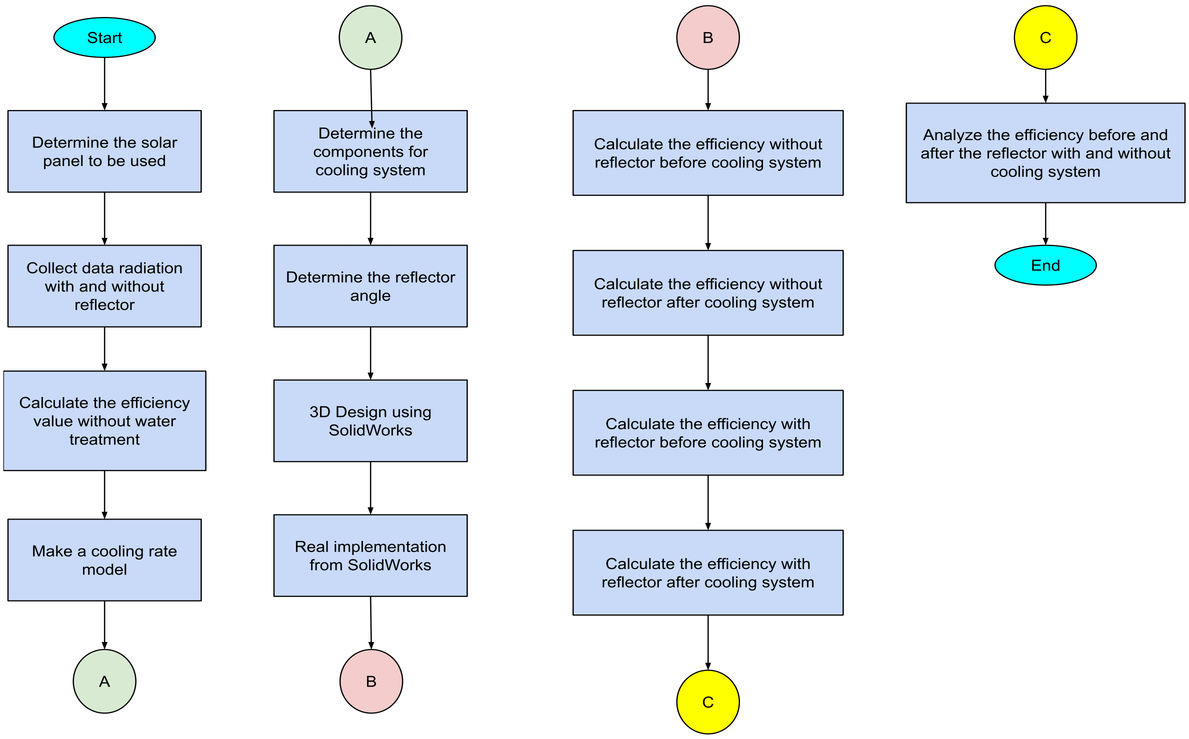

Figure 1. Research methodology

To achieve the objectives of this research, several stages are conducted, as shown in Fig. 1, with the following explanations:

1) The type of solar panel is determined before the research begins. This is necessary because the temperature effect on solar panels varies. In this research, monocrystalline solar panels are used.
2) Radiation data without a reflector and with a reflector is collected for one week each. The average radiation without a reflector and radiation with a reflector is used to create a sunlight simulator using halogen lamps.
3) The fill factor and efficiency are calculated. By collecting radiation and temperature data, the simulation efficiency of the solar panel is determined. The calculated fill factor and efficiency values are obtained without any treatment.
4) The cooling rate model calculates the required duration for the solar panel cooling process.
5) The components and specifications needed for the cooling process are determined to minimize the power consumption generated by the solar panel. This allows for an increase in the efficiency of the solar panel. The components can be determined after obtaining the cooling rate model calculations.
6) The appropriate reflector angle is determined based on the direction of incoming sunlight.
7) The cooling system and reflector placement are designed using SolidWorks to facilitate installation.
8) The system is created according to the 3D design previously made on SolidWorks.
9) The fill factor and efficiency of the solar panel system without a reflector and cooler are measured after the heating process using a halogen simulator, and the maximum temperature is reached.
10) The fill factor and efficiency of the system with the solar panel placed in a water tank without a reflector and the system with the solar panel without a reflector flowing with water are measured after the heating process, reaching the maximum temperature, and the cooling process is performed.
11) The fill factor and efficiency of the solar panel system with a reflector and without a cooler are measured after the heating process using a halogen simulator, and the maximum temperature is reached.
12) The fill factor and efficiency of the system with the solar panel and reflector placed in a water tank and the system with the solar panel and reflector flowing with water are measured after the heating process, reaching the maximum temperature, and the cooling process is performed.
13) The efficiency of the method without a reflector and a cooler, the method without a reflector with water treatments, the method with a reflector without a cooler, and the method with a reflector using water treatments is analyzed to determine the best solar panel efficiency among all the methods conducted.

The solar panel used in the research conducted at *6°19'51.5"S 107°07'52.8"E* is a monocrystalline solar panel measuring 700 mm × 510 mm × 30 mm.

2.1. Solar Panel

Monocrystalline solar panels can be used for 25 to 30 years [15]. Additionally, monocrystalline solar panels perform more efficiently at higher temperatures than polycrystalline solar panels [16]. Therefore, monocrystalline solar panels were used in this research due to their higher efficiency than polycrystalline panels, as shown in Fig. 2.

Figure 2. Monocrystalline solar panel type SP-50-M36.

Polycrystalline solar panels typically exhibit efficiency levels ranging from 13% to 16%, whereas monocrystalline solar panels generally offer efficiency levels ranging from 16% to 18% [3,17,18]. Fig. 3 shows the graph of the efficiency of solar panels type.

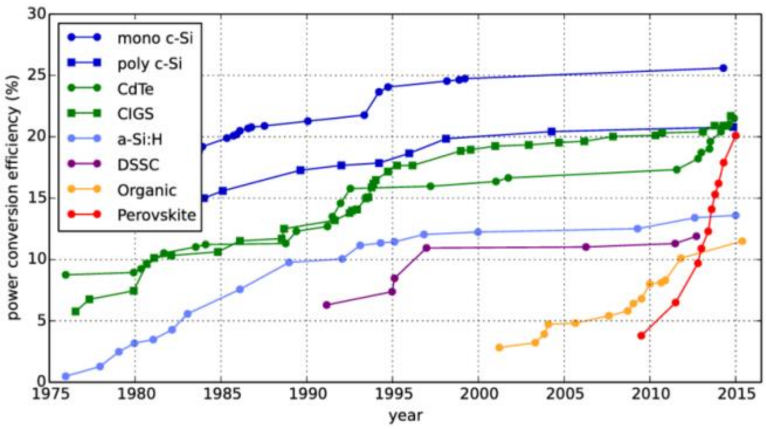

Figure 3. Efficiency chart based on types of solar cells after Ref. [19].

2.2. Reflector

One of these issues of solar panel efficiency is the reflective nature of the solar cell's glass cover, which reflects sunlight, preventing the radiation from being absorbed by the solar cell [20]. To address this, reflectors can be utilized. Two materials can be used as reflectors for solar panels: Mirrors and Aluminum foil [21]. Mirror reflectors have a reflectivity rate of up to 99%. However, if mirror reflectors are used, there are some disadvantages associated with mirrors, such as their high cost. Aluminum foil reflectors have a lower reflectivity rate than mirrors, which is 88% [22]. However, aluminum foil is cheaper compared to mirrors. With a thickness of 0.3 µm, aluminum foil is also lighter in weight than mirrors.

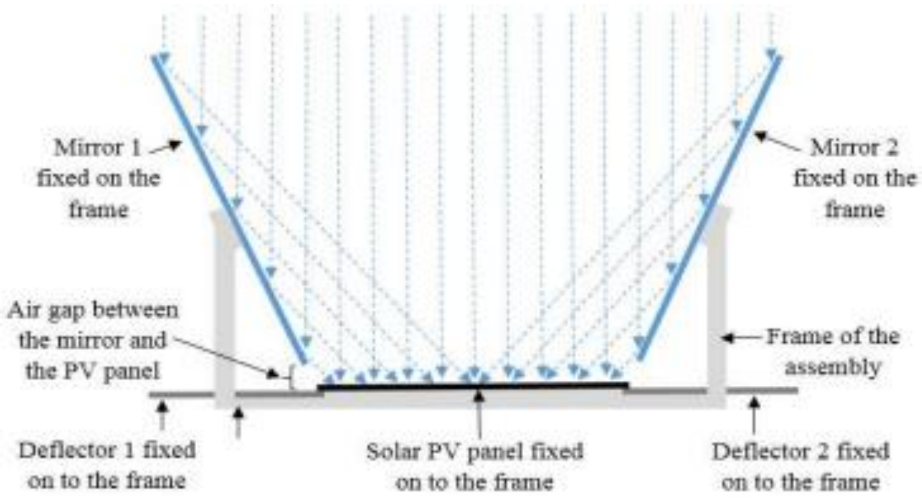

Figure 4. Design of solar panel with reflector [23].

From Fig. 4, a reflector is added to capture more light so that the rays reflected by the mirror can be received by the solar cells on the solar panel [23].

2.3. Fill Factor and Efficiency

The fill factor is a variable needed to determine the magnitude of efficiency in a solar panel. The fill factor indicates the quality of the solar panel [24]. The fill factor equation can be expressed as Eq. (1).

$$Fill\ Factor = \frac{V_{mp}\ I_{mp}}{V_{oc}\ I_{sc}} \tag{1}$$

V_{mp} = *voltage reached when maximum power is obtained (V)*
I_{mp} = *current reached when maximum power is obtained (A)*
V_{oc} = *voltage of the solar panel when open circuit (V)*
I_{sc} = *maximum current of the solar panel when short circuit (A)*

Efficiency is the output generated from a power source as the maximum possible input to be considered efficient. The larger the system's efficiency, the better it utilizes the resources it consumes. The efficiency of a solar panel can be expressed as Eq. (2).

$$Efficiency = \frac{V_{oc}\ I_{sc}\ Fill\ Factor}{SI\ A} 100\% \tag{2}$$

The efficiency of a solar panel is also influenced by several factors, such as sunlight being obscured by clouds, solar radiation, temperature, and dust or shading on the surface of the solar panel. Factors other than temperature and solar radiation can be mitigated by selecting the appropriate location for solar panel installation.

2.4. System Design

2.4.1. Solar simulator

In this research, a solar simulator is needed to simulate the heat and light conditions received by the solar panel [25]. The main component required for the simulator is a lamp. Several types of lamps have been used in research, including xenon lamps, mercury lamps, LEDs, and various other lamps [26]. Halogen lamps are used in solar simulators because they are easily available in the market, have high light intensity, affordable price usability, and their light spectrum is similar to sunlight.

Color temperature is a metric employed to describe the color attributes of light. It is denoted in Kelvin (K), spanning from 1000 K to 10000 K. Sunlight is commonly associated with a color temperature of approximately 5600 K. In contrast, halogen lamps typically possess an average color temperature of roughly 3200 K. Halogen lamps emit radiation with wavelengths that closely resemble those of sunlight, spanning from 360 nm to 2500 nm. Color temperature serves as a parameter to describe the visual perception of light's color characteristics and is measured in Kelvin (K), with a range of 1000 K to 10000 K. Sunlight is typically associated with a color temperature of approximately 5600 K, while halogen lamps exhibit an average color temperature of around 3200 K.

2.4.2. Reflector and water treatment system

Fig. 5 is the top view of the solar panel cooling (i.e. water treatment) system and reflector. There are 36 halogen lamps used in the simulation. Each halogen lamp has a power of 50 W, resulting in a total power usage of 1800 W.

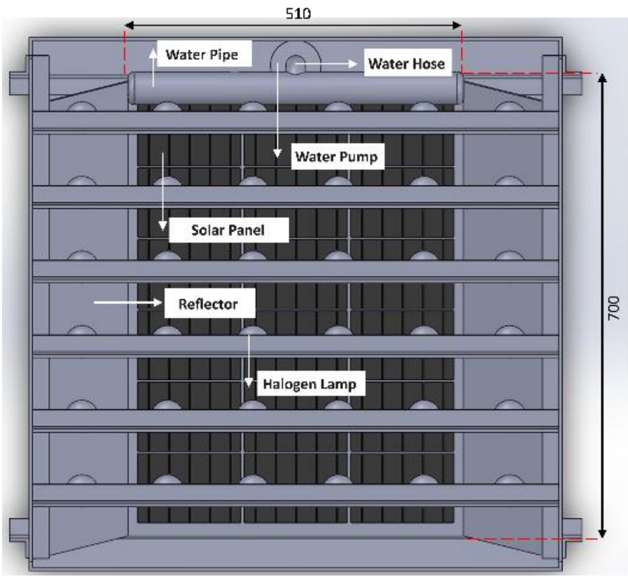

Figure 5. Top view of the cooling system with reflectors.

Each frame row contains an equal number of halogen lamps, precisely six lamps, to ensure uniform light distribution on the solar panel to achieve the desired radiation based on the previously obtained data, 871.1 W/m². Each row of halogen lamps is connected in series. The water pipe serves the purpose of circulating water from the pump to the surface of the solar panel, and the water then returns to the water tank through the same pipe [27].

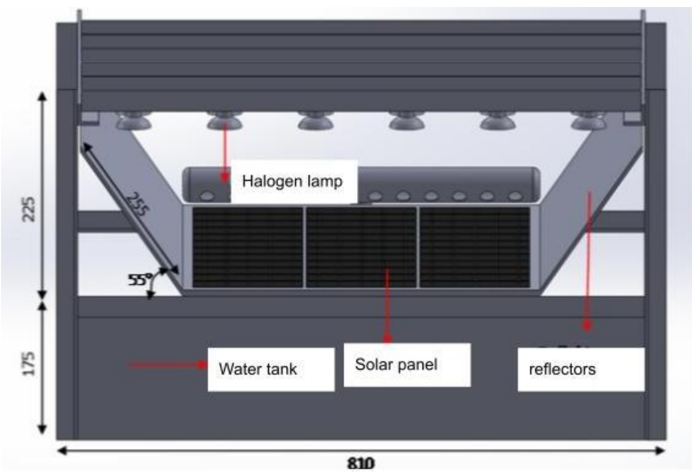

Figure 6. Front view of the cooling system with reflectors.

Based on the cooling system shown in Fig. 6, the left and right reflectors are installed at a 55° angle, as shown in Fig. 7. The 55° angle is chosen as it represents the maximum angle achieved with the halogen lamps mounted above the solar panel. Furthermore, research findings [28] indicate that angles above 50° increase the effectiveness of the solar panel by up to 26.5%. On the contrary, if the reflector inclination exceeds 55°, the reflector will obstruct the halogen lamps, resulting in suboptimal light emission on the solar panel. This research focuses on a specific type of reflector called a parabolic trough reflector. Therefore, it can be concluded that the reflector used in this research can also be applied to solar panels on a larger scale, with the reflector's inclination ranging from 55° to 75°, to achieve maximum efficiency from the solar panel. The size of each reflector section is 325 mm × 700 mm. The length of the front pole for mounting the halogen lamps is 255 mm. The halogen lamps are positioned at 9.5 cm from the solar panel.

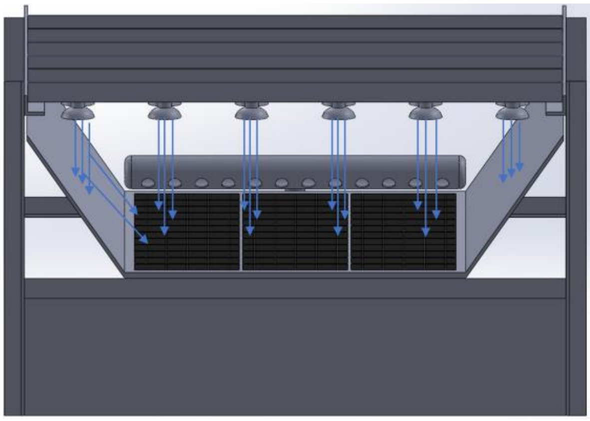

Figure 7. The direction of reflective bounce to solar panel.

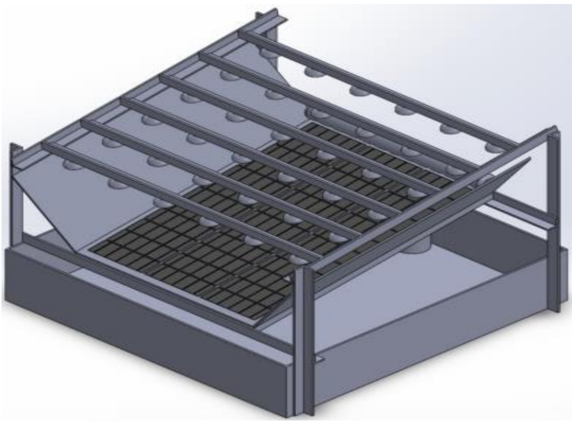

Figure 8. Isometric view of the cooling system with reflectors.

Fig. 8 illustrates the overall design of a solar panel cooling system with various main components. The water pump is placed inside a tank using a submersible pump type. The pump initiates its operation when the temperature on the solar panel reaches the maximum temperature threshold of 61.3°C.

3. RESULTS AND DISCUSSION

The system design outcomes are subsequently put into practical implementation, yielding more reliable and accurate testing results, as shown in Fig. 9.

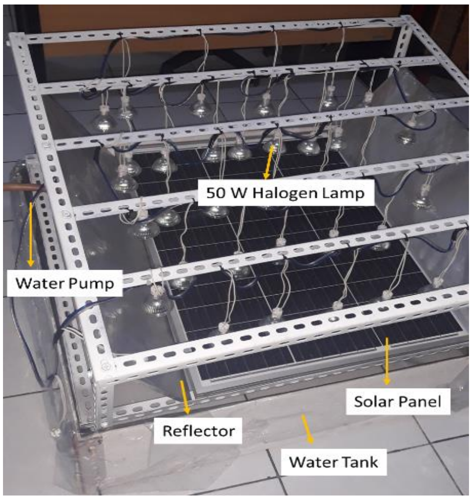

Figure 9. Implementation of the cooling system solar panel with reflectors.

The essential elements for the system comprise a solar panel, a 50 W halogen lamp, a gypsum water tank, an Aluminum foil reflector, pipes, and a water pump. The water pump is responsible for circulating water from the water tank onto the surface of the solar panel through perforated pipes. The above design uses 34 halogen lamps as simulators for sunlight, with a total power consumption of 1360 W for the lamps. The halogen lamp arrangement is 9.5 cm from the solar panel.

The operational procedure of the solar panel cooling system is as follows:

1) Once activated, the water pump initiates water extraction from the water tank.
2) The water pump is linked to a hose that transports the water to the surface of the solar panel via a pipe.
3) The water cascades onto the surface of the solar panel through the interconnected pipe.
4) The water then flows back into the water tank. These four operations are repeated in a continuous cycle until the surface temperature of the solar panel stabilizes.

The electrical schematic of the solar panel cooling system and its sensor is shown in Fig. 10.

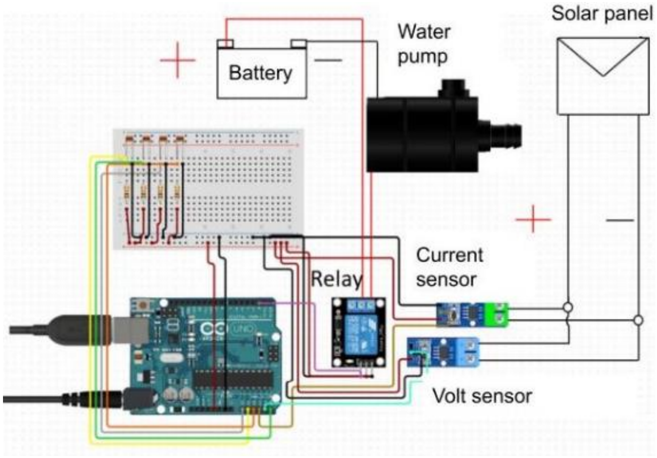

Figure 10. Schematic of solar panel cooling system.

3.1. System without Reflector and Water Treatment

The electrical schematic of the solar panel system without the cooling system is shown in Fig. 11.

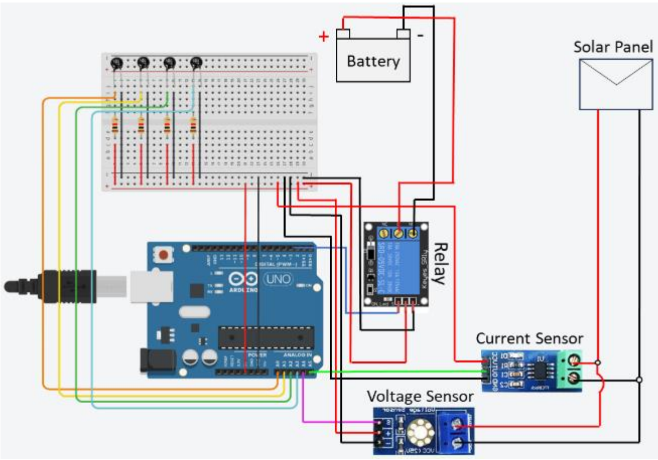

Figure 11. Schematic of solar panel without cooling system.

Initially, the sensors used for measurements are connected through an Arduino. Then, the Arduino is powered on. After that, the halogen lamp is turned on to emit radiation to simulate the solar radiation and heat the solar panel until it reaches a temperature of 57.3°C. Current and voltage are measured every 5 seconds using voltage and current sensors from when the halogen lamp is turned on until the solar panel reaches a temperature of 57.3°C. It takes approximately 5.1 minutes for the halogen lamp to reach a temperature of 5.7°C; at that point, the measured radiation is 869.61 W/m^2. Current measurement is performed using predetermined resistor (load) values. The measurement result without a reflector and cooler is shown in Table 1.

Table 1. Results without reflector and cooling System.

Load (Ohm)	Voltage (V)	Current (A)	Power (W)	Temperature (°C)
5.2	8.94	1.72	15.38	56.5
10.3	13.27	1.289	17.11	57.3
22	16.59	0.754	12.51	57.4
32.8	17.35	0.529	9.18	58.1
52	18.04	0.347	6.29	59.1
59.2	18.35	0.31	5.59	59.2
68.9	18.47	0.268	4.95	59.4
78.8	18.52	0.235	4.35	59.6
88.6	18.69	0.211	3.49	60.3
98.3	19.07	0.194	3.7	61.1

Without the cooling system, the solar panel can generate a maximum output power of 17.11 W, with an output voltage of 13.27 V and an output current of 1.289 A, as observed during measurements with a resistor value of 10.3 **Ω**. This power output is a reference for comparing the power output of water treatment methods without a reflector. A solar panel's efficiency and fill factor can be calculated using Eqs. (1,2) which results:

$$Fill\ Factor = \frac{13.27 \times 1.289}{18.48 \times 1.88} = 0.49 \quad (3)$$

$$Efficiency = \frac{18.48 \times 1.88 \times 0.49}{863.3 \times 0.357} \times 100\% = 5.52\% \quad (4)$$

3.2. System with Solar Panel Placed on Water Tank without Reflector

The steps are similar to the previous measurement method. The initial step in setting up the system with the solar panel positioned above the water tank is to ensure that the water tank is filled with water at a temperature of 25.5 °C and a water level of 165 mm.

Table 2. Results without reflector above the water tank.

Load (Ohm)	Voltage (V)	Current (A)	Power (W)	Temperature (°C)
5.2	8.99	1.73	15.56	55.3
10.3	13.24	1.295	17.27	56.8
22	16.68	0.758	12.64	57.5
32.8	17.42	0.531	9.25	58.2
52	18.15	0.349	6.33	59.1
59.2	18.41	0.311	5.73	59.4
68.9	18.53	0.269	4.99	59.6
78.8	18.67	0.237	4.42	59.9
88.6	18.78	0.212	3.98	60.0
98.3	19.27	0.196	3.77	60.3

Table 2 presents the average voltage, current, and power values obtained from three data collection trials using the solar panel. When the solar panel is positioned on the water tank, it can generate a maximum output power of 17.27 W, with an output voltage of 13.34 V and an output current of 1.295 A, measured with a resistor value of 10.3 Ω. The efficiency and fill factor of the solar panel can be calculated using Eqs. (1,2) which results:

$$\textit{Fill Factor} = \frac{13.27 \times 1.289}{18.48 \times 1.88} = 0.49 \qquad (5)$$

$$\textit{Efficiency} = \frac{18.79 \times 1.89 \times 0.49}{863.3 \times 0.357} \times 100\% = 5.6\% \qquad (6)$$

The efficiency calculation results show that the solar panel system placed inside the water tank without a reflector increased by 0.08% compared to the energy calculation without a cooling system and a reflector. However, it can be stated that the cooling system by placing the solar panel above the water tank is not effective because there is no significant increase in efficiency compared to the system without cooling using a solar panel without a reflector.

3.3. System using the Top Surface Method: Solar Panel without Reflector with Water Flow

The top surface method is a water treatment technique where cooling is achieved solely through water flow over the solar panel's surface without reflectors. For this method, the water tank is initially filled with water at a temperature of 25.5 °C, ensuring a water level of 165 mm. Additionally, the solar panel starts with an initial temperature of 26.5°C. Then, 34 halogen lamps are turned on to emit radiation with a value of 869.61 W/m² until the solar panel temperature reaches 57.3°C. Once the temperature of the solar panel reaches 57.3°C, the water pump is triggered by the relay, initiating the flow of water onto the surface of the solar panel. Once the relay activates the water pump, the current and voltage are measured every 5 seconds using current and voltage sensors. When the temperature reaches 29.5°C, the relay will turn off the water pump.

Table 3. Results without reflector with water flow.

Load (Ohm)	Voltage (V)	Current (A)	Power (W)	Temperature (°C)
5.2	9.31	1.791	16.67	33.2
10.3	14.73	1.43	21.06	34.1
22	18.72	0.851	15.93	35.3
32.8	19.45	0.593	11.53	35.9
52	20.96	0.403	8.45	36.0
59.2	21.25	0.359	7.62	36.4
68.9	21.49	0.312	6.71	36.8
78.8	21.67	0.275	5.96	37.2
88.6	22.5	0.254	5.72	37.3
98.3	21.42	0.218	4.67	37.4

In Table 3, the recorded data represents the solar panel surface's output values without a reflector but with water flow. The maximum power output achieved by the solar panel under these conditions is 21.06 W, with corresponding output voltage and current values of 14.73 V and 1.43 A, respectively, as measured using a 10.3 Ω resistor. The efficiency and fill factor of the solar panel can be calculated using Eqs. (1,2) which results:

$$Fill\ Factor = \frac{14.73 \times 1.43}{20.65 \times 1.83} = 0.56 \tag{7}$$

$$Efficiency = \frac{20.65 \times 1.83 \times 0.56}{863.3 \times 0.357} \times 100\% = 6.8\% \tag{8}$$

When comparing the efficiency of a solar panel without a reflector and cooling system to that of a solar panel without a reflector but with a water treatment cooling system, there is an observed improvement in efficiency of 1.28%.

3.4. Solar Panel System using Reflector without Cooling System

The sensors used for measurement are connected through an Arduino. Then, the Arduino is powered on. After that, the halogen lamp is turned on until a temperature of 61.3 °C is reached. The time taken by the halogen lamp to reach a temperature of 61.3 °C is 5 minutes, and the radiation obtained at that temperature is 869.7 W/m^2. Current measurement is performed using predetermined resistors.

Table 4. Results using reflector without water flow.

Load (Ohm)	Voltage (V)	Current (A)	Power (W)	Temperature (°C)
5.2	10.02	1.872	18.22	57.4
10.3	14.98	1.526	23.99	58.2
22	16.41	0.952	19.94	58.9
32.8	17.43	0.702	16.16	59.5
52	18.67	0.549	15.672	60.3
59.2	19.56	0.384	8.73	61.2
68.9	19.86	0.325	7.28	61.6
78.8	19.93	0.297	6.95	62.2
88.6	20.06	0.223	4.41	62.5
98.3	20.14	0.181	3.22	63.4

The efficiency and fill factor of the solar panel can be calculated using Eqs. (1,2) which results:

$$Fill\ Factor = \frac{14.98 \times 1.526}{20.13 \times 1.87} = 0.607 \tag{9}$$

$$Efficiency = \frac{20.13 \times 1.87 \times 0.607}{869.3 \times 0.357} \times 100\% = 7.35\% \tag{10}$$

The data presented in Table 4 shows an increase in efficiency of 1.83%. This indicates that using a reflector is an effective approach to enhancing the efficiency of a solar panel.

3.5. Solar Panel Placed using Reflector on Water Tank

The water container, with dimensions of 810 mm × 810 mm × 175 mm, is filled with water up to a height of 165 mm at a temperature of 25.5 °C. Then, the solar panel is placed with an inclination angle of 10°. The time required to heat the solar panel until a temperature of 61.3 °C is reached is 5.4 minutes using a submersible water pump with a water flow rate of 17.14 liters per minute or 0.29 lt/s. The solar panel is heated using a set of halogen lamps with an average radiation of 871.1 W/m^2.

Table 5. Results using reflector on water tank.

Load (Ohm)	Voltage (V)	Current (A)	Power (W)	Temperature (°C)
5.2	10.01	1.874	18.26	56.7
10.3	15.02	1.528	24.04	57.5
22	16.74	0.954	20.02	58.8
32.8	17.58	0.706	16.35	59.2
52	18.68	0.550	15.73	59.9
59.2	19.50	0.385	8.77	59.9
68.9	19.79	0.327	7.37	60.3
78.8	20.01	0.299	7.04	61.1
88.6	20.06	0.223	4.41	61.8
98.3	20.05	0.180	3.18	62.3

The data in Table 5 shows the results of the solar panel placed on the water container (water tank). The maximum power output achieved by the solar panel is 24.04 W, with an output voltage of 15.02 V and an output current of 1.528 A, as measured with a resistor value of 10.3 **Ω**. The efficiency and fill factor of the solar panel can be calculated using Eqs. (1,2) which results:

$$Fill\ Factor = \frac{15.02 \times 1.528}{20.21 \times 1.86} = 0.611 \qquad (11)$$

$$Efficiency = \frac{20.21 \times 1.86 \times 0.611}{869.7 \times 0.357} \times 100\% = 7.39\% \qquad (12)$$

The efficiency calculation shows that the solar panel system placed inside the water container with a reflector increased by 0.04%. Compared to the solar panel system placed inside the water container without a reflector and with a reflector but without a cooling system, an increase of 1.79% is obtained.

3.6. System using the Top Surface Method for Solar Panel with Reflector and Water Treatment

In order to implement the system with the method of water flow over the solar panel, fill the water container with water at a temperature of 25.5 °C, a water height of 165 mm, and an initial solar panel temperature of 26.5 °C. Then, activate 34 halogen lamps to generate radiation at 871.10 W/m^2 until the surface temperature of the solar panel reaches 61.3 °C. Once the temperature of the solar panel reaches 61.3 °C, the water pump is triggered by the relay, initiating the flow of water onto the surface of the solar panel. Using current and voltage sensors, measure the current and voltage every 5 seconds. In another condition, when the temperature reaches 29.5 °C, the relay will turn off the water pump.

Table 6. Results with reflector and water treatment.

Load (Ohm)	Voltage (V)	Current (A)	Power (W)	Temperature (°C)
5.2	9.83	1.832	17.45	29.5
10.3	17.82	1.802	33.45	29.8
22	20.05	1.21	32.21	30.2
32.8	20.81	0.803	21.15	31.3
52	21.85	0.584	15.62	32.4
59.2	22.41	0.405	9.71	32.7
68.9	22.55	0.336	7.79	33.1
78.8	22.46	0.312	7.67	33.6
88.6	22.43	0.241	5.05	34.4
98.3	22.65	0.206	4.17	34.9

Based on the data presented in Table 6, when the cooling system is applied, the solar panel achieves a maximum power output of 33.45 W. The corresponding voltage and current output are measured at 17.82 V and 1.802 A, respectively, using a resistor value of 10.3 **Ω**. By analyzing the data, the efficiency and fill factor of the solar panel can be calculated using Eqs. (1,2) which results:

$$Fill\ Factor = \frac{17.82 \times 1.802}{22.28 \times 1.823} = 0.78 \quad (13)$$

$$Efficiency = \frac{22.63 \times 1.82 \times 0.78}{869.7 \times 0.357} \times 100\% = 10.36\% \quad (14)$$

After conducting six experiment scenarios to calculate the efficiency of three different methods, which are without cooling, placing the solar panel above a water tank, and flowing water over the surface of the solar panel with and without a reflector, the following efficiencies were obtained: 5.52% without a reflector, 5.6% with the solar panel above a water tank, and 6.8% without a reflector but with water flow. With the addition of a reflector, the efficiencies improved to 7.35% without water flow and 7.39% with water flow. Notably, when water flowed over the surface of the solar panel, reducing its temperature from 61.3°C to 29.5°C, a significant efficiency increase of 10.36% was achieved. The efficiency of the solar panel showed no notable alteration when no cooling method was employed and when the solar panel was positioned within a water tank. This lack of significant change could be attributed to the relatively ineffective nature of placing the solar panel inside a water tank. However, when comparing it to the approach of flowing water over the surface of the solar panel, the efficiency witnessed a noticeable increase of 4.48% compared to the efficiency without using a reflector and cooling system.

Research data from [27] shows that implementing a cooling system results in an efficiency of 7.01% for the solar panel. In addition, research [29] demonstrated that the implementation of solar tracking dual-axis using fuzzy logic and cooling system results in an increase of the solar panel efficiency to 7.46%. As represented in the result of [30], the efficiency of a solar panel using a mirror reflector and cooling method has increased by 20%. However, when the cooling system is combined with a reflector, the efficiency of the solar panel experiences an approximate 3.35% increase, reaching a value of 10.36%, and the efficiency using this method has increased by 48% compared to the cooling system method only. Therefore, it can be concluded that using a reflector and a water treatment cooling system can improve the efficiency of the monocrystalline solar panel type SP-50M36.

4. CONCLUSION

The research focuses on the effectiveness of incorporating a reflector and a water treatment cooling system in enhancing the efficiency of the monocrystalline solar panel. The captured solar radiation increased from 869.61 W/m² to 871.10 W/m² by using a reflector on the side of the panel. Furthermore, implementing the water treatment cooling system resulted in a significant temperature reduction of the solar panel, from a maximum of 57.3°C without a reflector and 61.3°C with a reflector to a final temperature of 29.5°C for both cases. This cooling process led to remarkable efficiency improvements, with the solar panel achieving efficiencies of 6.8% with water treatment cooling, 7.35% with the addition of a reflector, and a peak efficiency of 10.36% when combining the reflector and cooling system.

REFERENCES

[1] Mohammad, A. and Mahjabeen, F. Revolutionizing Solar Energy: The Impact of Artificial Intelligence on Photovoltaic Systems. International Journal of Multidisciplinary Sciences and Arts 2023; 2: 117–127, DOI: 10.47709/ijmdsa.vxix.xxxx
[2] RHODES, C. J. Solar energy: principles and possibilities. Science Progress (1933-) 2010; 93: 37–112.
[3] Walker, A. Solar energy: technologies and project delivery for buildings. John Wiley & Sons, 2013.
[4] Hafemeister, D. Sustainable Energy—Without the Hot Air. American Association of Physics Teachers, 2010.

[5] Hosenuzzaman, M., N. A. Rahim, J. Selvaraj, and M. Hasanuzzaman Factors affecting the PV based power generation. In: 3rd IET International Conference on Clean Energy and Technology (CEAT) 2014; IET, pp. 1-6.
[6] Deivakumaran, S., Y. L. Chua, and Y. Y. Koh Active cooling system for solar panels with silver nanofluid and water. IOP Conference Series: Earth and Environmental Science 2023; 1–10, DOI: 10.1088/1755-1315/1205/1/012012
[7] Schiro, F., A. Benato, A. Stoppato, and N. Destro Improving photovoltaics efficiency by water cooling: Modelling and experimental approach. Energy 2017; 137: 798–810.
[8] Peng, Z., M. R. Herfatmanesh, and Y. Liu Cooled solar PV panels for output energy efficiency optimisation. Energy conversion and management 2017; 150: 949–955.
[9] Sumarno, R. N. and K. Kinasih Rooftop Solar Power Plant Design on Campus Cafe. In: The 1st Lawang Sewu International Symposium 2022, pp. 159–166.
[10] Buni, M. J. B., Al-Walie, A. A. K., Al, K. A. N. and Al-Asadi, K. A. N. Effect of solar radiation on photovoltaic cell. International Research Journal of Advanced Engineering and Science 2018; 3: 47–51.
[11] Suyanto, H., Pasra, N., and Mauriraya, K. T. Optimization Analysis of Output of Photovoltaic Types on The Effect of Solar Temperature and Radiation. In: The 4th International Conference on Green Technology and Design 2022, pp. 17–26.
[12] Wijesuriya, D. T. P., Wickramathilaka, K., Wijesinghe, L. S., Vithana, D. M., and Perera, H. Y. R. Reduction of solar PV payback period using optimally placed reflectors. Energy Procedia 2017; 134: 480–489.
[13] Sharma, A. and Bajpai, V. K. Enhancement of power generation efficiency of PV system using mirror reflector. International Journal of Ambient Energy 2022; 43: 8036–8045, DOI: 10.1080/01430750.2022.2088615
[14] Ahmed, S., Mia, M. M. A., Acharjee, S., and Ansary, M. A. A. More efficient use of photovoltaic solar panel using multiple fixed directed mirrors or aluminum foils instead of solar trackers in rural perspective of Bangladesh. International Journal of Scientific and Technology Research 2014; 3: 294–298.
[15] Sodhi, M., Banaszek, L., Magee, C., and Rivero-Hudec, M. Economic Lifetimes of Solar Panels. In: Procedia CIRP; 2022: Elsevier B.V., pp. 782–787.
[16] Akbarudin Rahman, R. and Putranto, H. Performance Comparative Analysis of Monocrystalline and Polycrystalline Single Diode Solar Panel Models using the Five Parameters Method 2019.
[17] Karellas, S., Roumpedakis, T. C., Tzouganatos, N., and Braimakis, K. Solar Cooling Technologies. New York: Taylor & Francis Group, LLC, 2019.
[18] Saga, T. Advances in crystalline silicon solar cell technology for industrial mass production. NPG Asia Materials 2010; 2: 96–102, DOI: 10.1038/asiamat.2010.82
[19] Neukom, M. Martin Neukom: Charge Carrier Dynamics of Methylammonium Lead-Iodide Perovskite Solar Cells, From Microseconds to Minutes, 2016.
[20] Singh, M. and Sharma, G. Simplified Mirror Techniques for Improving Solar Cell Performance 2022.
[21] Kumar, M., Reddy, B. V., and Reddy, P. V. Experimental Comparison of Solar Paraboloid Collector with and without Mirror in Aluminum Foil as Reflectors. International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) 2018; 8: 1117–1124.
[22] Richards, B. S. and Howard, I. A. Luminescent solar concentrators for building integrated photovoltaics: opportunities and challenges. Energy & Environmental Science 2023; 16: 3214–3239, DOI: 10.1039/D3EE00331K
[23] Win, T. N. Comparison of Power Output from Solar Panel with Reflector and without Reflector.
[24] Keyhani, A. Design of smart power grid renewable energy systems. John Wiley & Sons, 2016.
[25] Tawfik, M., Tonnellier, X., and Sansom, C. Light source selection for a solar simulator for thermal applications: A review. Renewable and Sustainable Energy Reviews, 90: 802–813, DOI: 10.1016/j.rser.2018.03.059
[26] Soetedjo, A., Nakhoda, Y. I., Lomi, A., and Suryanto, T. A. Solar simulator using halogen lamp for PV research. In: Proceedings of Second International Conference on Electrical Systems, Technology and Information 2015 (ICESTI 2015); 2016: Springer, pp. 239–245.
[27] Cedric, S. Peningkatan Efisiensi Panel Surya Monocrystalline dengan Menggunakan Metode Water Treatments. 2020
[28] Kim, M. K., Abdulkadir, K. O., Liu, J., Choi, J.-H., and Wen, H. Optimal Design Strategy of a Solar Reflector Combining Photovoltaic Panels to Improve Electricity Output: A Case Study in Calgary, Canada. Sustainability 2021; 13: 6115.
[29] Euy Gun, S. Monocrystalline Solar Panel Efficiency Enhancement using Water Treatments and Solar Tracking Dual-Axis Methods with Fuzzy Logic. Parahyangan Catholic University, Bandung, 2022.
[30] Arshad, R., Tariq, S., Niaz, M. U., & Jamil, M. Improvement in solar panel efficiency using solar concentration by simple mirrors and by cooling. International Conference on Robotics and Emerging Allied Technologies in Engineering; 2014: IEEE Computer Society, 292–295. 10.1109/iCREATE.2014.6828382