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Performance of Photovoltaics Panel Without Cooling and with Water Cooling

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ABSTRACT: Solar energy is a promising resource for development in Indonesia. Indonesia's solar energy potential is estimated to generate over 200 GW of electricity, given the efficiency of existing solar module technology. However, utilization in solar power plants remains below 100 MW. With solar energy potential spread evenly across Indonesia, the largest potential is found in West Kalimantan Province (20 GW), followed by South Sumatra in second place (17 GW), and East Kalimantan in third place (13 GW). Therefore, accelerating the transition from coal or fossil fuels to renewable energy sources, particularly solar energy, is highly feasible in various regions across Indonesia. One method for cooling solar panels that has been implemented is a water-cooling system. This is what underlies the author to conduct research on the effect of water cooling on the performance of 3 X 100 WP solar panels. The results showed that the maximum efficiency of the solar cell was achieved on Saturday before cooling was carried out, with a figure of 28.34%. Conversely, the lowest efficiency occurred on Tuesday after the cooling process, which was 90%. The implemented air-based cooling system was able to reduce the temperature of the solar panel. The highest average temperature measured without temperature was 54.6°C on Saturday, while the lowest average temperature after temperature was recorded was 46.88°C on Tuesday. The maximum average voltage recorded was 54.22 Volts without cooling, while the lowest average voltage was 42.33 Volts after cooling was applied. For the highest average current recorded was 3.93 Amperes before cooling, while after cooling, the average was only 3.25 Amperes. The maximum average power without cooling reached 175.02 Watts, while the lowest average power after cooling was 146.43 Watts.

KEYWORDS: Energy, Photovoltaic, Panel, Cooling, Power

I. INTRODUCTION

Renewable s widely considered to be clean and non-polluting, adding no contaminants to the atmosphere. Sources of this energy include hydropower, hydrothermal and geothermal systems, wind, sunlight, waste, biomass, biofuels, and ocean waves. In the future, all forms of green energy must become the primary focus of energy development and utilization. Consequently, renewable energy should be prioritized rather than treated merely as a secondary option; after all, these are natural resources that are freely accessible and capable of sustainable renewal [1].

Solar energy plays a crucial role in the lives of all living beings, including humans, animals, and plants. For humans, sunlight is commonly used to dry food or clothing. Furthermore, solar energy contributes significantly to photosynthesis in plants, a process that produces oxygen—an element essential for the survival of humans and animals. Solar energy represents a resource with immense development potential in Indonesia, largely due to the country's location along the equator. It can be harnessed across Indonesia's vast territory of 2 million km², offering a potential yield of 4.8 kWh/m² per day equivalent to a distributable capacity of 112,000 GWp [2].

According to Syahwil & Kadir [3], solar energy is a form of energy that will not be exhausted until the end of the world. The light it produces can be converted from one form of energy into another, and the potential energy yield from sunlight is limitless. However, the amount of light reaching Earth decreases during cloudy or rainy weather, and Earth's rotation results in the occurrence of night. These factors determine the magnitude of solar energy that reaches the Earth.

A solar panel is a device that converts direct sunlight into electricity. Currently, the use of solar panels has become widespread in daily activities. Most commonly used solar panels are stationary, which limits the efficiency of sunlight absorption. To ensure optimal sunlight absorption, the device needs to move in sync with the sun's movement [4].

Harnessing daylight has emerged as a cornerstone of modern renewable energy strategy [5,6]. Photovoltaic panels actively transform solar radiation into usable power, eliminating fossil fuel consumption and cutting down carbon footprints [7,8]. Unlike less mature renewable alternatives, solar setups rely on highly validated technology that is fundamentally changing how the world generates power [9,10]. Ultimately, solar-driven power networks succeed due to their key characteristics: they are inherently regenerative, perfectly clean, non-polluting, and secure [11].

PV modules typically convert only about 20% of solar irradiance into usable electricity, while the remaining energy is dissipated as heat. This thermal accumulation elevates the module's operating temperature, which can significantly degrade its conversion efficiency. Beyond temperature alone, the specific temperature coefficient of the PV technology also dictates overall performance outcomes. Consequently, surface cooling is essential to sustain low operational temperatures. Among various methods, water cooling has emerged as a prominent technique to restore and enhance conversion efficiency. Mosty, about 80% of solar irradiance is converted into heat and only 20% is converted into electrical energy [12]. High temperature of the panel can reduce degree of its conversion efficiency [13,14]. To maintain panel temperature not exceed than maximum allowable value, it is important to perform cooling of a panel surface. Water cooling method has been proven method not only to keep panel temperature at design temperature, but also to enhance panel conversion efficiency. Water injection cooling resulted in an energy output growth [15]. Chanphavong *et al.*[16] found that conversion efficiency of cooled mono-crystalline PV module was higher than non-cooled mono-crystalline module. Mostakim *et al.* [17] observed PV panel efficiency enhancement up to 16.78 % at cooling water flow rate of 1.56 L/min. Meanwhile, Purwant & Badadhe [18] enchanced PV efficiency using direct cooling with CuO nanofluid. They found that the CuO nanofluid reduced panel temperature by up to 9.25°C, increased electrical efficiency from 16.32% to 17.60% compared to conventional water cooling.

Cooling of PV panel has been performed on the top surface of panel so far, very limited works on underneath surface cooling. Thus, the present work aims to investigate performance of 300 Wp PV panel without cooling and with cooling at underneath of the PV surface. The performances of the PV evaluated were PV temperature, output voltage, output current, power output, and conversion efficiency.

II. MATERIAL AND METHOD

Figure 1 shows the experimental setup of the present work. The 300 Wp polycrystalline photovoltaic panels converts solar irradiance (Ir) to DC current (I). Electric energy generated by the PV panel was stored in the battery. MPPT controls maximum charging condition on the battery. Converter is used to convert DC current to AC current. Meanwhile, underneath surface of the PV panel is chilled using water sprayer. Milt tester was used to measure DC voltage (V) and DC current (I) generated by the PV panel. Solar irradiation (Ir) was measured using lux meter and panel temperature (T) was measured using thermo-gun.

Figure 1. Experimental setup

The data collection was performed for 5 days from 09.15 am to 3.15 pm. The data of Ir, T, V, and I curated were then averaging in each day observation. The data were used to calculate output power of the PV panel (P) and efficiency of the panel (η) using Eq. (1) and Eq. (2).

$$P = V \times I \tag{1}$$

$$\eta = \frac{P}{A_{pv} \times I_r} \tag{2}$$

III.RESULT AND DISCUSSION

Table 1 to Table 3 present daily averaging of solar irradiation, PV temperature, voltage and current generated without PV cooling and with water cooling.

Table 1. An average PV temperature

Day	Irradiance (W/m2)	PV Temperature	
		No Cooling	With Cooling
Tue	591	51.8	46.9
Wed	596	52.6	47.6
Thu	601	53.4	48.5
Fri	611	54.1	49.8
Sat	618	54.6	50.1

Table 2. An average voltage

Day	Irradiance (W/m^2)	Voltage (V)	
		No Cooling	With Cooling
Tue	591	44.8	42.3
Wed	596	47.8	43.5
Thu	601	49.3	45.8
Fri	611	51.0	48.1
Sat	618	54.2	51.9

Table 3. An average current

Day	Irradiance (W/m²)	Current (A)	
		No Cooling	With Cooling
Tue	591	3,6	3,3
Wed	596	3,7	3,3
Thu	601	3,7	3,6
Fri	611	3,8	3,7
Sat	618	3,9	3,8

Figure 2 shows the PV surface temperature without cooling and with water cooling. An average PV surface temperature proportional to solar irradiance. PV surface temperature increased as increasing solar irradiance received by the PV panel. The temperature of the PV surface with water cooling was lower than that without cooling. Obviously, water spraying on the PV surface caused more heat was released by the PV through water spray which in turns lower the PV surface temperature.

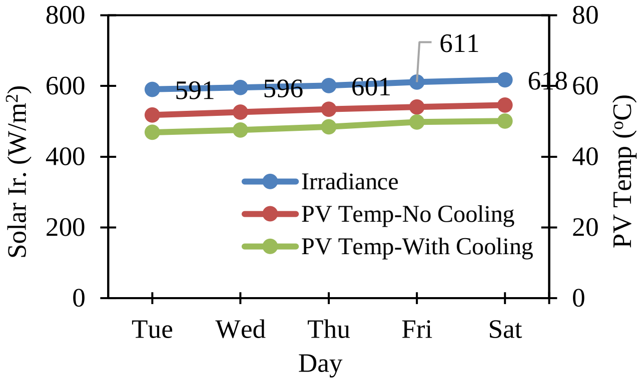

Figure 2. PV temperature

The daily average DC voltage generated by the PV module without cooling and with cooling was shown in Figure 3. The average voltage generated was proportional with the solar irradiance. The average voltage inclined when solar irradiance stepped up. The graph in Figure 3 showed that the PV surface cooling reduced voltage generated by the PV module.

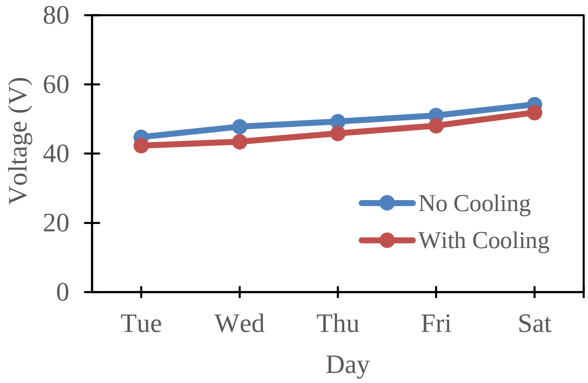

Figure 3. Voltage

Meanwhile, an effect of PV surface cooling on average DC current generated was presented in Figure 4. It can be observed that an effect of cooling on average current generated was similar with that on average voltage. An average current was lower when using PV surface water cooling.

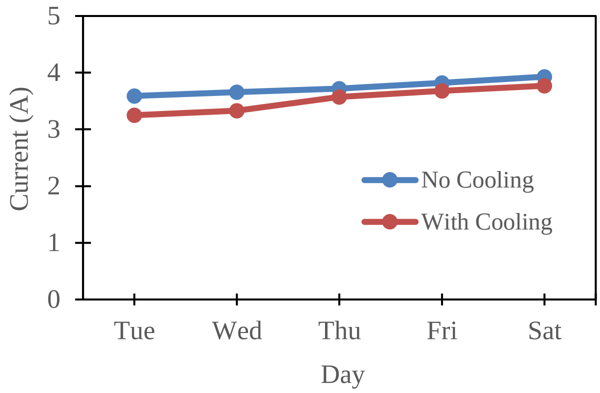

Figure 4. Current

Since the trends of the average voltage and current were proportional to solar irradiance and the power output was a function of voltage and current, the power output was also enhanced with increasing solar irradiance. Figure 5 presents an effect of PV surface cooling where the cooling reduced power output of the PV module. The highest power output of 175.0 Watt was found with no PV cooling on Saturday when the solar radiation was 618 W/m².

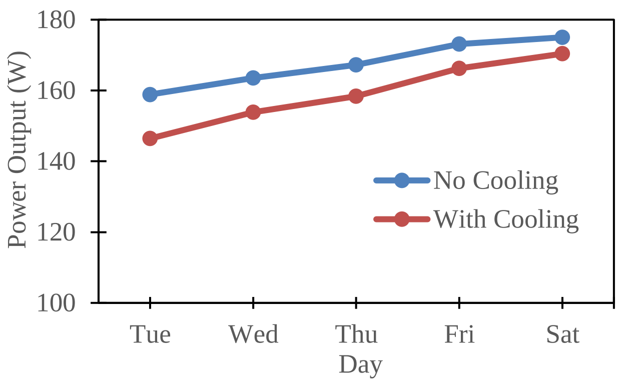

Figure 5. Power output

Meanwhile, Figure 6 displayed conversion efficiency of the PV module. Higher efficiencies of the PV module were obtained with no PV surface cooling. The highest efficiency of 28.34% was found on Friday when the solar irradiance was 611 W/m²

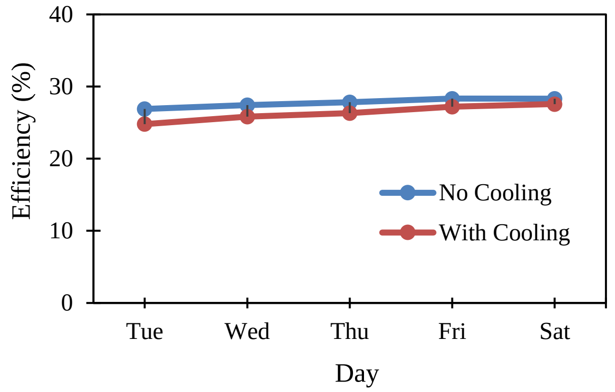

Figure 6. PV Efficiency

V. CONCLUSIONS

It can be concluded that the maximum efficiency of the solar cell was achieved on Saturday before cooling was carried out, with a figure of 28.34%. Conversely, the lowest efficiency occurred on Tuesday after the cooling process, which was 90%. The implemented air-based cooling system was able to reduce the temperature of the solar panel. The highest average temperature measured without temperature was 54.6°C on Saturday, while the lowest average temperature after temperature was recorded was 46.88°C on Tuesday. The maximum average voltage recorded was 54.22 Volts without cooling, while the lowest average voltage was 42.33 Volts after cooling was applied. For the highest average current recorded was 3.93 Amperes before cooling, while after cooling, the average was only 3.25 Amperes. The maximum average power without cooling reached 175.02 Watts, while the lowest average power after cooling was 146.43 Watts.

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