Active and Passive Cooling Comparison of PV Panels Applied in Tropical City: Case Study Palembang, South Sumatra

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Abstract. The renewable energy generation is currently a trending topic due to the reduced availability of conventional fossil fuel while the demand for energy keeps on increasing. This condition insists on a particular action in search of renewable energy to substitute fossil fuel. One of the unlimited energy offered by nature is the energy from the sun, which also environmentally friendly. Palembang is located in equator blessed with abundant of sun rays which can be utilized maximally by eliminating things that can cause adverse effects such as overheated solar panels. Tropical weather comes with high temperature, and this heat is even more on the surface of the solar panel. The overheated solar panels lead to the reduction of power output and efficiency. Therefore, the cooling system should be applied to ensure the surface temperature is below 35°C, which an average ambient temperature for solar panels. The cooling system can be active that needs power and passive, which naturally generated from the surrounding environment. This paper discusses the comparison of the cooling system applied to solar panels, the passive (heatsink application) and active (water cooling). The active cooling system produced 8.64 Watt higher than a normally installed panel, and passive cooling is 2.7 Watt higher. The active cooling system efficiency is 0.33% more than regular panels, and passive cooling system has 1.2% more. This paper can be a reference to the choice of cooling system for solar panels installed in a city with a tropical climate.

1. Introduction

Renewable energy is now a trending topic worldwide of encountering the global problem of depleting fossil fuel and global warming due to excessive CO₂ emission. Therefore, people around the world turn to an unlimited source of power from nature, such as solar power, geothermal, wind, hydro, and biodiesel/biomass. The power from nature is known to be environmentally friendly [1]. This environmentally safe is not only in term of CO₂ emission but also to reduce earth destruction due to excessive abuse of its resources such as coal mining. Renewable energy is defined as the source energy that is not depleted when used. This energy is including direct electricity generation by photovoltaic (PV) effect. This method is the most suitable for Palembang, a city situated in equator blessed with abundant sun rays all the year-long [1][2].

The application of PV system is ideal for Palembang as a tropical city; however, the PV system is bound to some factors affecting the output power and efficiency of the system. One of the factors is surface temperature. The surface temperature of a solar panel applied in Palembang can exceed its
The tolerable temperature is 35°C. The exceeding temperature can also damage a PV cell and significantly reduce electricity production [3]-[6].

The excessive heat can be reduced by installing cooling devices in the PV system. The cooling device can be naturally called passive cooling [7]-[9] and can be a powered device called active cooling [10]-[15]. The example of passive cooling is the application of heatsink that naturally let the heat from the surface and dissipates the heat to environment [7][8]. The active cooling can be conducted by flowing the water on the surface of the solar panel by using a pump [10][11].

This paper discusses the comparison of the cooling system applied to the PV panel. The experiment is conducted by installing two panels with different cooling techniques, and one panel is installed normally without a cooling system. This paper is a literature study from two experiments with different cooling techniques taking the case of a tropical city. The data presented in this paper has partially published [7][10]. This paper is a review study of the methods applied in our research facility.

2. Materials and Method

This paper presents the comparison of two cooling methods, the passive [7] and active cooling [10]. The passive cooling considered are heatsink application and coating the surface with a thin film. The active cooling is by flowing water on the surface of the solar panel to reduce the overheated surface.

2.1. Passive Cooling Method

Electronics devices have utilized heatsink to prevent them from overheating. The high conductivity metal that forms a heatsink removes the heat and passes it to the environment. The same process is adopted for a PV module. The ribs heatsinks are installed in the backside of a PV panel, as shown in figure 1. Figure 1(a) shows the heatsink installation, and figure 1(b) shows the PV panel installation with heatsink (HS) and fan compare to the typical application as the comparison.

![Figure 1](image)

(a) Installation setting. (b) Schematic diagram.

Figure 1. Schematic installation of heatsink for passive cooling [7].

The system is equipped with a thermostat as the temperature sensor to show the surface temperature of the heatsink and standard application PV panels. The load considered in this study is a DC bulb 24 V 100/90 W. A solar meter is added to show the irradiance received by PV panels.

2.2. Active Cooling Method

The active cooling method applied in this study is a cooling water system by flowing water to the surface of the PV panel to reduce to prevent overheating. The active cooling system in this study uses a mini DC pump to flow the water on the surface of the PV panel, as shown on the setting in figure 2.
The load considered is also a DC bulb 24 V 100/90 W. Digital thermometers are attached to both panels to measure variable needed. A solar power meter is also considered to measure the irradiance received by the PV panels. The measurements were taken every 30 minutes online using CCTV.

3. Result and Discussion

This paper presents the typically installed panel and panels equipped with a cooling system. The data is taken during the dry season (August 2018) in Palembang, South Sumatra. The average temperature is 38.7°C, and the temperature of the PV panel surface can reach up to 55.5°C. The data given in this study has been partially published; therefore, this study is more a review study of comparing to the type of cooling systems. The factors affecting solar panel temperature includes wind and cloud as the shading.

3.1. Passive Cooling Method

The passive cooling system has advantages that it is naturally conducted without the required power; therefore, it is cheaper and more environmentally friendly. Figure 3 shows the experiment setting for heatsink installation; where "PV" is the typically installed panel, and "PV + HS fan" is a panel with a cooling system. Typically installed PV panel and the cooling system installed panel are placed side by side to ensure both receive the same amount of irradiance and conditions. Temperature sensor in this study is only to show the ambient temperature. The DC lamp is on during voltage and current measurement, and off during open-circuit voltage (\(v_{oc}\)) and short circuit current (\(i_{sc}\)).
Table 1 shows the effect of ambient temperature on PV panels surface temperature. This type of cooling system relies on nature; therefore, the environment change affects electricity production.
Figure 4. Output power production of typically and cooling system installed PV panels.

Figure 4 shows the output power of typically and cooling system installed PV panel. The average power of typically installed PV panel ($P_N$) is 45.72 Watt, and the maximum produced power ($P_{N\text{-max}}$) is 55.42 Watt on 12:30 PM. The PV panel ($P_{HS}$) with cooling system produced average power 53.58 Watt, and the highest maximum power ($P_{HS\text{-max}}$) produced on 01.00 PM is 64.06 Watt. Therefore, there is 8.64 Watt difference in power production.

Figure 5. The installation setting of passive cooling system.

Figure 5 shows the efficiency comparison of PV panel with cooling system and the typically installed one. The average efficiency of typically installed PV panel ($\eta_N$) is 6.28%, while the efficiency of the PV panel with the cooling system ($\eta_{HS}$) is 7.48%. The average difference is 1.2%.
3.2. Active Cooling Method
Two panels are installed to investigate the effect of active cooling on power output production and efficiency. The PV panels are installed at an angle of 15° relative to the floor to imitate rooftop installation and to ensure the water flow. This angle is also chosen to ensure self-cleaning during raining time for typically installed PV panels. Those panels are polycrystalline type of 100 Wp each. Figure 6 shows the experimental setup for active cooling PV panels.

![Experimental Setup for Active Cooling PV Panels](image1.jpg)

**Figure 6.** The installation setting of active cooling system [10].

![Irradiance Effect on PV Panels Surface Temperature](image2.jpg)

**Figure 7.** Irradiance effect on PV panels surface temperature.
Figure 7 shows the effect of irradiance received by a solar panel and surface temperature. During the peak hours, the surface temperature of the typically installed PV panel is 38.4°C to 50°C. The surface temperature of the cooled PV panel was around 32.6°C; therefore, there was 17.4°C difference between the typical and cooled PV panel.

Irradiance significantly decreased at 03:30 PM down to 486 W/m². The highest temperature on a typically installed PV panel is 64.1°C when the irradiance is 1081 W/m² at 12:00 PM. At 12:30 PM the sky was cloudy, and the irradiance dropped significantly to 537 W² and the surface temperature of the typically installed PV panel also dropped to 53.3°C. The average temperature of the cooled PV panel that is 36°C, this temperature is not much different from the ambient temperature, which is an average of 36.3°C. The most significant temperature difference between the two PV panels is 26°C at 11:30 PM, and the temperature difference between the two PV panels was 18.7°C.

Figure 8 shows the power output comparison between typically and cooled PV panels. During a cloudy moment at 12.30 PM, the produced output significantly decreased to 31.86 W for cooling PV panels and 29.87 for the typically installed panel. The average produced power for typically installed panel (P_{out-normal}) is 31.5 W, and 34.2 W for the cooled PV panel. There is a 2.7 W difference.

![Figure 8. Power output comparison between normally and cooled PV panels.](image)

The Fill Factor (FF) for the PV panels considered in this study is 0.7, and the surface panel area is 660 x 1125 mm. Fill factor is necessary for calculating efficiency. Figure 9 shows the efficiency comparison between normal and cooled PV panels. Based on figure 8, the output production is stable from 08.30 PM to 03.30 AM. The average efficiency of normally installed PV panel (η_{N}) is 3.83%, and the average efficiency of the water-cooled PV panel (η_{W}) is 4.16%. Therefore, there is a 0.33% efficiency difference. The highest η_{W} is 16.18% at 03.30 PM, and the highest η_{N} is 5.87%.
Figure 9. Efficiency comparison between normally and cooled PV panels.

The cooling system installed in PV panels is significantly increased the power output and efficiency of the solar panel. Both active and passive cooling systems are proven effective for PV panels application in a tropical city. Passive cooling has more advantage over active cooling since this type of cooling system is not required power. The fan installed in a passive cooling system requires very low voltage; therefore, it is negligible for counting the cost to provide power for the cooling system. The active cooling system is more effective if it is set automatically, to prevent wasting power during cloudy times or when the irradiance received is drop at the beginning or end of the day.

4. Conclusion
This paper presents the comparison between passive and active cooling for PV panels installed in tropical city Palembang. Both cooling systems are effective in reducing surface panel temperature and prevent overheating and the failure of any cells. The output power and efficiency of a cooled PV panels are better than the typically installed one. Passive cooling system help solar panel to produce (P_{HS}) 53.58 Watt compare to 45.72 Watt of the typically installed PV panels. Therefore, there is 8.64 Watt difference in power production. The average efficiency of typically installed PV panel (\eta_N) is 6.28\%, while the efficiency of the PV panel with the cooling system (\eta_{HS}) is 7.48\%. The average difference is 1.2\%. For an active cooling system, the average produced power for typically installed panel (P_{out-normal}) is 31.5 W, and 34.2 W for the cooled panel. There is a 2.7 W difference. The average efficiency of typically installed PV panel (\eta_N) is 3.83\%, and the average efficiency of water-cooled PV panel (\eta_{W}) is 4.16\%. Therefore, there is a 0.33\% efficiency difference.

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