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Solar panels output optimization using Phase Change Material (PCM) and heatsink applied in open-pit mining

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Abstract. Solar energy can be utilize to power a system located far from the electricity sources such a mobile tower applied in open-pit mining in PT Bukit Asam Tbk. However, the tropical weather in an open-pit mining can increase the surface temperature of a Photovoltaic (PV) panel, lead to overheating and the reduction of the efficiency and the reduced electricity power. This condition requires a cooling system to reduce the temperature. This paper presents the application of Phase Change Material (PCM) and heatsink as the cooling system for a PV panels. The PCM installed are in two sizes aluminum hollows, a 0.0025 m^3 and 0.00625 m^3. The experiment was conducted in 2 batches, 14-29 February 2020 for the installed 0.0025 m^3 aluminum hollow, and 1-14 March 2020 for 0.00625 m^3. The application of a 0.00625 m^3 can reduce the PV panel's surface temperature up to 3-5ºC. The generated current using PCM 0.00625 m^3 is 0.034 A for I*sc* and 0.014 A I_{load} higher than without cooling system. The application of a aluminum hallow with the size of 0.00625 m^3 gives 9-20% efficiency, and the efficiency gives 8-15%. The experimental results show that the use of a hollow aluminum with a size of 0.00625 m^3 can reduce the surface temperature of the PV panel and increase the power and efficiency of the PV panels.

1. Introduction

The industrial revolution has increased the need for energy sources for both business and non-commercial activities. As the scientists have predicted, the availability of widely used fossil fuels are becoming depleted by time. In Indonesia, 95% of the energy consumption still uses fossil fuels, and about 50% of the fossil energy is oil, whereas the rest is gas and coal. Consumption of fossil fuel leads to environmental pollution and greenhouse CO. Among other floods, drought and global warming are impacts of these pollutants. This condition leads people to find energy alternatives that are more natural and easy to replenish. The new renewable energy trend is expected to improve the quality of life for people [1-6].

However, electricity generation by solar energy is effected by many external factor including sun position relative to the photovoltaic (PV) panel position, overheating and shading [6-9] and the overheated PV surface [10-18]. Recent studies using phase change materials (PCMs) have attracted many researchers to the surface of solar cells as a cooling system [19-21].

This paper discusses the comparative analysis of PV panels installed in a mobile tower used in open-pit mining. The first panel is equipped with a PCM and heat sink as a cooling device using an aluminum hallow with a size of 0.0025 cm^3, and the second panel uses an aluminum hallow with a size of 0.00625 m^3. The third PV panel is installed without a cooling system as a benchmark for the cooled PV panel. This research took place in the South Sumatra Open-Pit mine. The compared PV panels supply electricity to the mobile tower used in the pit. It is critical that this renewable technology continues to grow due to its high potential for use in everyday life [22,23].

2. Proposed method

This paper proposes the use of PCM for a passive cooling system combined with a heat sink. Three PV panels are installed, two cooling panels with a different hollow aluminum size and the third one is normally installed. The aluminum hollow sizes considered in this study are 0.0025 m^3 and 0.00625 m^3.

2.1. Phase Change Material (PCM)

PCM is a phase change material that allows thermal energy to be absorbed, processed, and released. PCM is also referred to as a latent heat storage unit. The use of certain PCMs depends very much on the temperature of the phase change, where latent heat can be used as a whole. When properly applied to a system, PCM can make considerable energy savings. When PCM reaches temperature changing phase (melting temperature), PCM absorbs large amounts of heat at almost constant temperatures. PCM continues to absorb heat until all materials are converted into liquid phases, without significant temperature changes. If the heat temperature decreases around the environment, the liquid PCM begins to freeze and release the stored latent heat. Large amounts of PCM are available in any temperature range up to 190°C. Therefore, the use of paraffin wax in solar cells is one alternative for reducing the surface temperature of too high solar panels. The heat sink is used as a heat transfer metal to help spread heat to the PCM. Thus, the expected surface area of the object's heat transfer is faster than the cooling process.

2.2. Proposed cooling system

This research is implemented for PV panels to supply mobile towers in PT. Bukit Asam Tbk which is located in Tanjung Enim, South Sumatra. The PT. Bukit Asam Tbk open-pit mining site and its surrounding area is 7700 ha. The region is located at $103^o45' - 103^o50'$ East Longitude and $3^o42'30' - 4^o47' - 30'$ South Latitude. Mobile tower shown in Figure 1 is required to allow data communication from a wireless network on a vast mining site, but traditional energy supply for the mobile tower is not feasible. Solar energy is suitable for this type of situation because it receives plenty of solar rays.

This mobile tower is critical to the implementation of the FMS (Fleet Management Systems), which enables the transmission of data on speed units, working tonnage units, heavy-duty equipment conditions, fuel and working conditions, and the disposal or front of the excavation process. Updated data is sent to the dispatcher or operator. The PV panels to power the mobile tower is shown in Figure 2.

Figure 1. The mobile tower deployed in the open-pit mine.

Figure 2. The PV panels to power mobile tower deployed in the open-pit mine.

2.3. PV panels efficiency

Efficiency is the parameter used to show the effectiveness of PV panel application using a proposed method. Efficiency is the ratio between the output produced and the energy input received by the PV panel. Therefore, the efficiency of a PV panel is given by

$$\eta = \frac{\rho_{max}}{\rho_{in}} x100\%, = \frac{I_{mp} \cdot V_{mp}}{P_{in}} x\ 100\%, = \frac{I_{sc} V_{oc} FF}{P_{in}} x\ 100\%, \quad (1)$$

where *Imp* and *Vmp* are the generated current and voltage when the PV panel supplies a load, and *Isc* is the current during short circuit and without load, and *Voc* is the voltage measured during open circuit without any load attached.

3. Results and discussion

3.1. Experimental setup

The experiment was carried out using three solar panels installed on the mobile network. The PV panels used are monocrystalline types with 50 WP (W-peak) each. Two panels installed using PCM paraffin and heatsink systems with 0.0025 m^3 of hollow aluminum size measurements were taken from data (14-29 February 2019) and from 1-14 March 2020 to 0.00625 m^3 of hollow aluminum. Another PV panel is installed without the use of a PCM and heatsink system. Data is collected every day from 9.00 a.m. to 3.00 p.m. The circuit is equipped with a thermal camera to detect the temperature of each device in detail. The solar charger is used to limit the incoming and outgoing currents of the battery as a source of energy from installed solar cells.

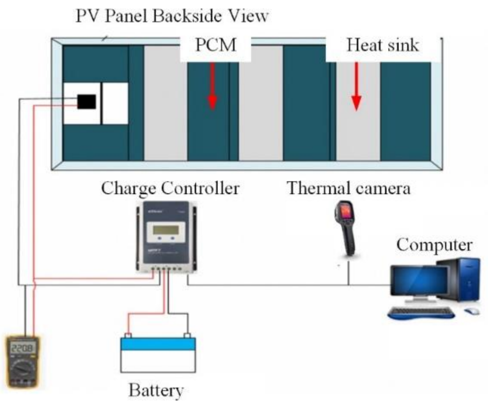

Figure 3. Experimental setup.

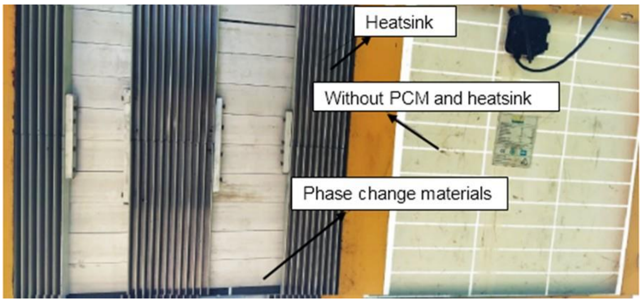

Figure 4. The installation of PCM and heat sink compared to the panel without cooling system.

Figure 3 shows the experimental setup of the PV panels attached to the mobile tower shown in Figure 1. Figure 4 shows the back of the PV panel when the cooling system is installed (left), and the cooling system is not installed (right). Both PV panels are installed side by side; therefore, both panels received the same amount of irradiance.

3.2. Experimental results

The experiment was initially scheduled for 30 days, but the weather was challenging in February and March when South Sumatra had medium cloudy and sunny conditions.

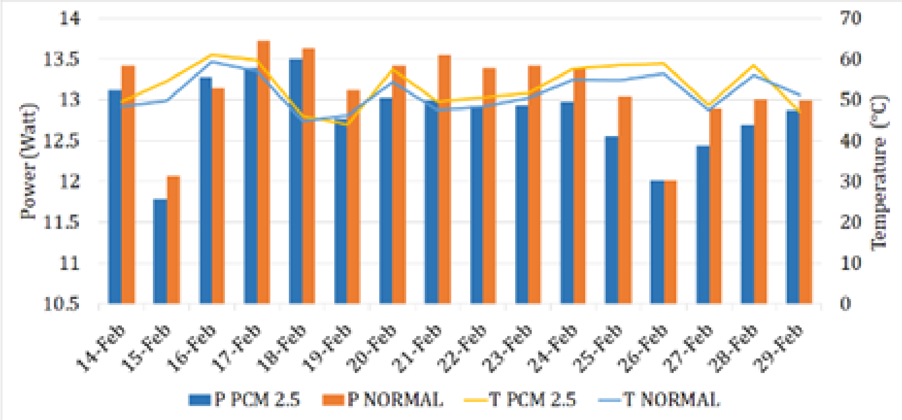

Figure 5. Temperature effect on output power with the application aluminum hollow 2.5 m^3.

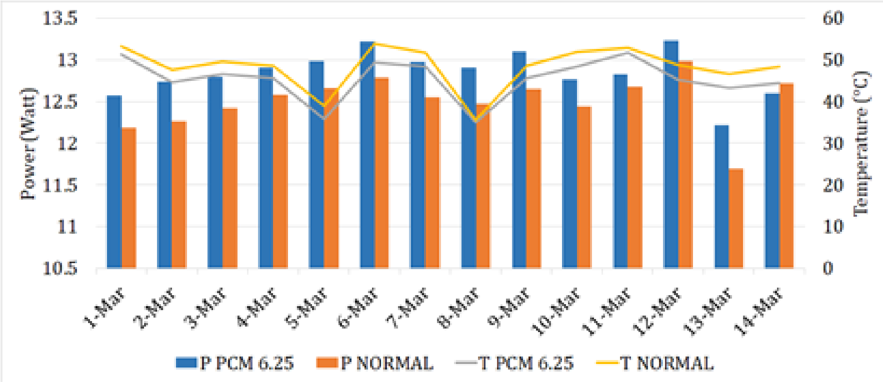

Figure 6. Temperature effect on output power with the application aluminum hollow 6.25 m^3.

Figure 5 shows the temperature conditions that could affect the output power generated by the PV panel. Weather conditions are observed every day in order to compare the effect of the temperature measured with the application of a 0.0025 m^3 aluminum Hallow PCM system and heat sink compared to the condition without the use of a 0.0025 m^3 Hallow aluminum PCM system and heat sink. Power generated by a 0.0025 m^3 PCM system (P PCM 2.5) is less than normal power without a 0.0025 m^3 PCM system (P NORMAL). The temperature measured using the 0.0025 m^3 PCM system (T PCM 0.0025) is higher than the temperature without using the 0.0025 m^3 PCM system (T NORMAL).

Figure 6 shows the comparison of the produced power between the application of the PCM cooling system and the 0.00625 m^3 aluminum hallow heat sink and the standard application of the PV panel. T Normal is defined as temperature without a cooling system, and T PCM 0.00625 m^3 is the temperature at which the cooling system is used. P PCM 0.0025 is the power produced with the application of 0.00625 m^3 PCM cooling system. The cooling system reduces the PV panel temperature to 3-5°C for the application of a 0.00625 m^3 aluminum hollow. Therefore, the overheated temperature can be properly reduced by using a PCM with a 0.00625 m^3 hallowed aluminum heat sink. Figures 7 and 8 show the cooling system's effect when using a 0.0025 m^3 and 0.00625 m^3 aluminum hallow. The application of an aluminum hallow with a size of 0.0025 m^3 is not sufficient to reduce the overheated PV panel.

The power generated by the use of a cooling system with an aluminum hollow of 0.00625 m^3 is higher than without a cooling system, while the power generated by the use of a cooling system with an aluminum hollow of 0.0025 m^3 is lower than the power generated without a cooling system. The average temperature with a hollow aluminum cooling system of 0.0025 m^3 PCM is 53°C and without 51°C and with a hollow aluminum cooling system of 0.00625 m^3 PCM is 45°C and without 48°C.

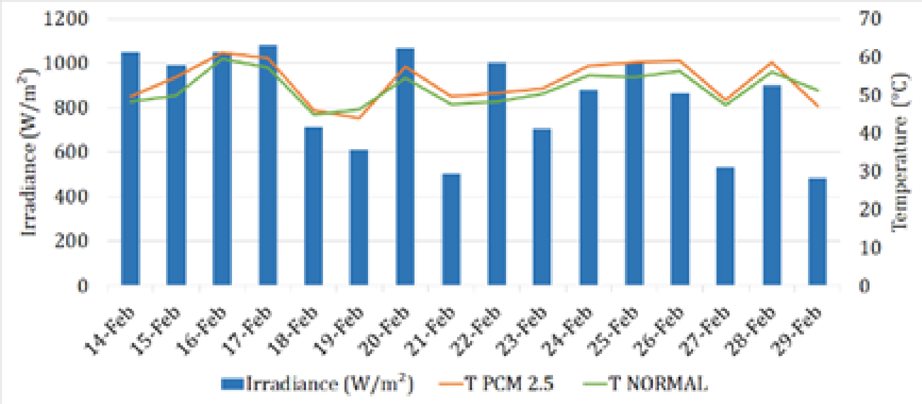

Figure 7. Irradiance effect on temperature using 0.0025 m^3 hollow aluminum.

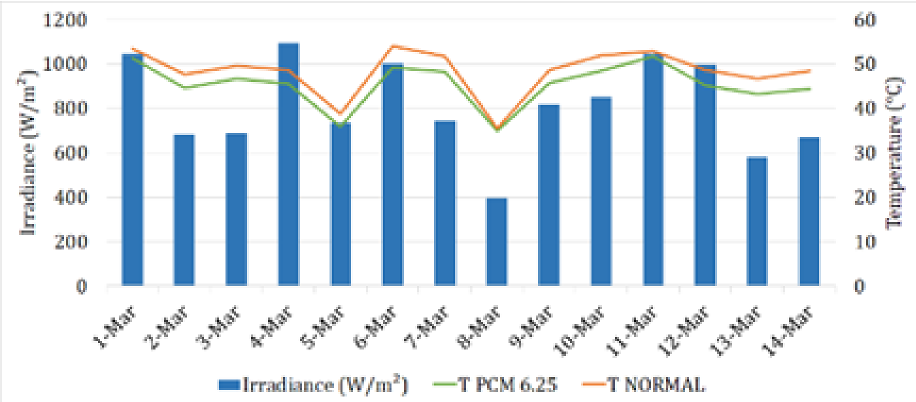

Figure 8. Irradiance effect on temperature using 0.00625 m^3 hollow aluminum.

Figures 7 and 8 that weather determines the irradiance value generated on the PV solar cell. This condition means that the lower the solar cells' irradiance, the lower the current produced by the solar cells.

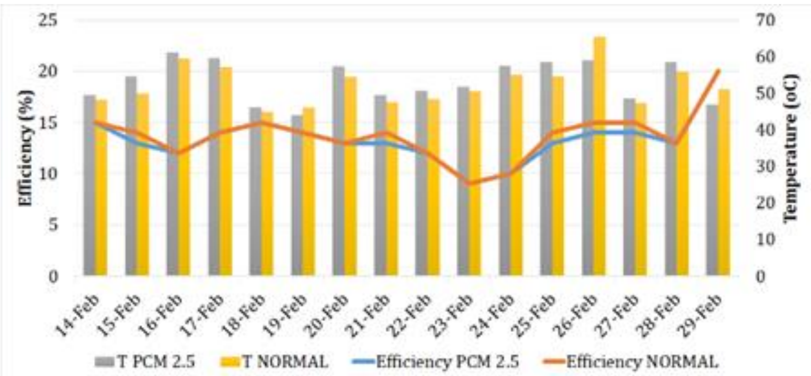

Figure 9. Comparison of efficiency using a 0.0025 m^3 PCM system and without cooling system.

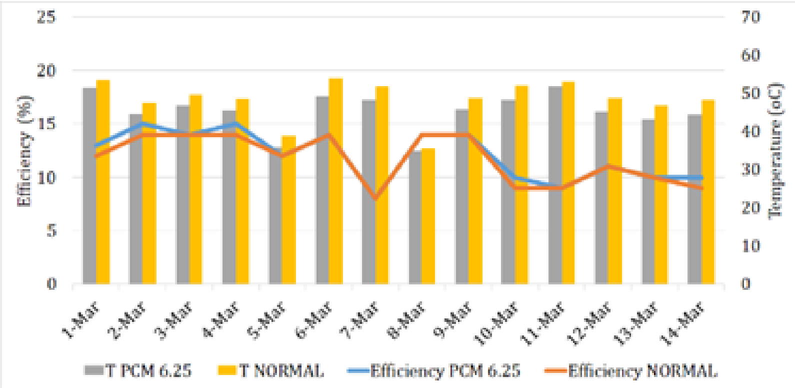

Figure 10. Comparison of efficiency using a 0.00625 m3 PCM system and without cooling system.

Figures 9 and 10 provide the efficiency comparison of the cooling system's performance and without the cooling system, where Efficiency PCM 0.0025 is the efficiency of application PCM 0.0025 m^3 and Efficiency PCM 0.00625 is the efficiency of application PCM 0.00625 m^3. Figure 10 shows that using an aluminum hallow with a size of 0.0025 m^3, the highest efficiency is 20%, and the lowest is 9%. The efficiency obtained by using a cooling system with an aluminum hallow solution of 0.00625 m^3 is 15% the highest and 8% the lowest.

The experimental results show that the application of a hollow aluminum with a size of 0.0025 m^3 is not sufficient to optimize the performance of the PV panel to power the PT Bukit Asam Tbk mobile tower. The application of a hollow aluminum with a size of 0.00625 m^3 can reduce the surface temperature of the PV panel and increase the power and efficiency of the PV panels.

4. Conclusion

This paper presents the application of PCM and heatsink as the cooling system for a PV panels. The PCM installed are in two sizes aluminum hollows, a 0.0025 m^3 and 0.00625 m^3. The experiment was conducted in 2 batches, 14-29 February 2020 for the installed 2.5 m^3 aluminum hollow, and 1-14 March 2020 for 0.00625 m^3 aluminum hollow. The application of a aluminum hallow with the size of 0.0025 m^3 gives 9-20% efficiency, and the efficiency gives 8-15%. The experimental results show that the application of a hollow aluminum with a size of 0.0025 m^3 is not sufficient to optimize the performance of the PV panel to power the PT Bukit Asam Tbk mobile tower. The use of a hollow aluminum with a size of 0.00625 m^3 can reduce the surface temperature of the PV panel and increase the power and efficiency of the PV panels.

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