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Performance Evaluation on PV Panels with Cooling Optimization utilizing Phase Changing Materials

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Abstract. The performance of solar panels is very dependent on the absorption of solar radiation. Some of the absorbed energy is converted into electricity, while the rest transformed into heat. However, PV-panels may experience intense heat that causes heat radiation in PV-panels increases. This radiation on the PV panel has a negative impact on the output of electrical energy produced and has the potential to reduce the performance of the solar panel. Therefore, it is necessary to design a PV-Panel cooling system to maintain the temperature of the panel so as not to exceed its effective working temperature. The cooling media which is currently claimed to be relatively more effective than water or air coolers is a cooling medium based on Phase Change Material (PCM). PCM can absorb, store and release energy in the form of latent heat. The purpose of this study is to maintain the PV-panel temperature so as not to exceed the effective working temperature using PCM as a cooling medium. Currently, three PV-panels underwent a performance test. Two of them equipped with PCM-tallow based cooling systems, and PCM-paraffin, while the other one using no PCM and serves as a benchmark for the whole PV-panel cooling performance test result. Tests are carried out from 08:00 to 18:00 local time in bright air conditions. The variables used include the temperature distribution of the top of the panel, the middle panel, and the bottom panel. The results showed that the use of PCM-tallow and PCM-paraffin could maintain the temperature of solar panels below 50 °C, relatively better than the PV-panels that use air as a cooler.

1. Introduction

Electricity generation from photovoltaic (PV) solar panel installations is estimated to have increased up to 50% per year worldwide. In 2012 the use of PV panels reached almost 100 TWh with total installed capacity increased by 43% or 29.4 GW [1]. Currently, numerous new buildings have integrated PV panel during their design phase [2]. This PV panel also has weaknesses as it depends on the intensity of solar radiation. Therefore, the material of the solar cell must be appropriate, and the operating temperature must be maintained [3]. While in operation, only 15-20% of the solar energy received by PV panels can be converted into electricity, while the rest dissipated as heat. This heat will be absorbed by the PV device itself, causing the working temperature to reach the optimum value. On the other hand, the conversion efficiency of PV panels decreases 0.4-0.65% for every degree of increase in surface temperature of PV [4]. Therefore, it is necessary to regulate the surface temperature of PV in order to obtain optimal electrical efficiency.

Brinkworth et al. [5], and Moshfegh and Sandberg [6] have tried to implement a method to maintain the temperature of solar panels, so they do not exceed the maximum value. The method conducted with a passive cooling system. In this system, a single channel or back air duct mounted on

the back of the PV panel, due to heat absorption resulting in natural circulation of air inside the channel, which causes the surface temperature of the PV panel, not to exceed the maximum value.
Yun et al. [7] conducted a ventilated PV panel attached to the walls of the building that serves as a pre-heating device in winter and as a natural ventilation system in the summer while controlling the surface temperature of PV. The result is a maximum ventilated PV panel surface temperature at 55.5 ° C compared to a standard PV panel surface temperature that reaches 76.7 ºC without ventilation, and 15% ventilated PV panel efficiency. Unlike Moharram [8] the method used an active cooling method. The trick is to use a pump to drain the water. Water flows over the surface of the solar panel. This system managed to reduce the surface temperature of the PV panels significantly and efficiency increases by 10.3%.

Recently a phase changing material (PCM) based method for cooling PV panels has attracted much attention from researchers. The PV-PCM system is a hybrid technology integrating PV and PCM panels into a single PV panel to increase the efficiency of higher solar energy conversion [9]. PCM is capable of absorbing heat in the form of latent heat followed by a solid-liquid phase change at an almost constant temperature range and then dissipate heat as desired.
There are tons of literature available describes PCM applications as heat energy storage materials [10]–[14]. Hasan et al. [15] review the use of several PCM candidates in the building-integrated PV (BIPV) system to regulate the surface temperature of PV panels. PCM selection must meet several criteria suitable for use in BIPV systems, i.e., including melting temperature, latent heat, and thermal conductivity and different configuration designs for PV-PCM integration. The study also evaluated the characterization of the use of organic, inorganic and eutectic PCM in the PV panel, and studied the effect of the use of five PCM candidates on the regulation of PV surface temperature and PV panel performance by using three types of insulation material.

Based on the description above it can be concluded that the importance of maintaining the performance of the solar panel and can be achieved in various ways such as passive cooling system, active system, and utilization of PCM. Therefore this study aims to keep the temperature of the PV solar panel from passing the maximum temperature using PCM as a cooling medium.

2. Methodology

2.1. Materials

In this study, the type of PV solar panel used is Photovoltaic Module 50 Watt, with nitride multicrystalline silicon cells. The panel has a length of 839 mm, a width of 537 mm, and a thickness of 50 mm. The specifications of the solar panel shown in Table 1. PCM-Tallow and paraffin are used to cool solar panels. The PCM is inserted into a container (Figure 1) and placed at the bottom of the PV solar panel. Tallow [16] and paraffin [17] used in this study had a melting point about 39 ºC and 46.7 ºC respectively.

Table 1. PV solar panel specifications used in the study

Type	Silicon nitride monocrystalline
Maximum power (Pmax)	50 W
The voltage at Pmax (Vmp)	17.5 W
Current at Pmax (Imp)	2.9
Warranted minimum Pmax	45 W
Short-circuit current (Isc)	3.2 A
Open-circuit voltage (Voc)	21.8

Figure 1. PCM position inside the container

2.2. Experimental procedure

Testing was carried out in the open field campus of the Faculty of Engineering, University of Samudra, Aceh Province, Indonesia. In this study, three PV panel units were equipped with PCM for PV-PCM testing. As a reference, a standard PV panel is used. Tests will be carried out on sunny days starting at 08:00 until 18:00 hours. The variables measured include temperature distribution on the surface of the PV panel. The data retrieval process uses a K-type thermocouple mounted on the surface of the solar panel and connected to the data acquisition of the Agilent 34970A type. The data then recorded every 5 seconds. Information from this data acquisition equipment is connected to a computer device to display data in graphical form. Overall data collection is carried out between 08:00 to 18:00 hours West Indonesian Time (WIB). Figure 2 describes the experimental setup.

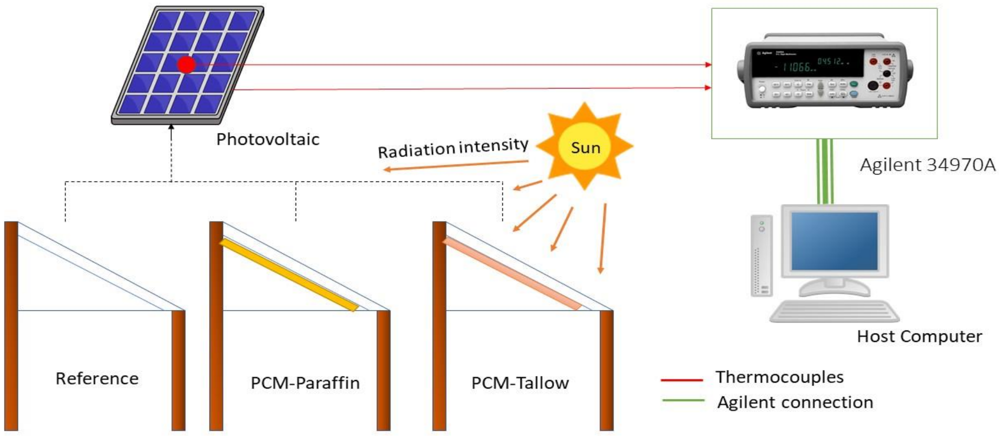

Figure 2. Experimental Setup

3. Results and Discussions

3.1. The intensity of solar radiation

Figure 3 shows that the intensity of solar radiation ranges from 376 W / m^2 at 8:00 WIB to 40 W/m^2 at 18.00 WIB. The solar radiation intensity experienced a peak at 14:00 WIB which was 973 W/m^2 where the ambient temperature was 30 ºC. This condition is excellent to be used as a reference for experimental studies on solar panels because it allows the availability of relatively higher heat on the panel surface and the heat absorption process by PCM is also more optimum.

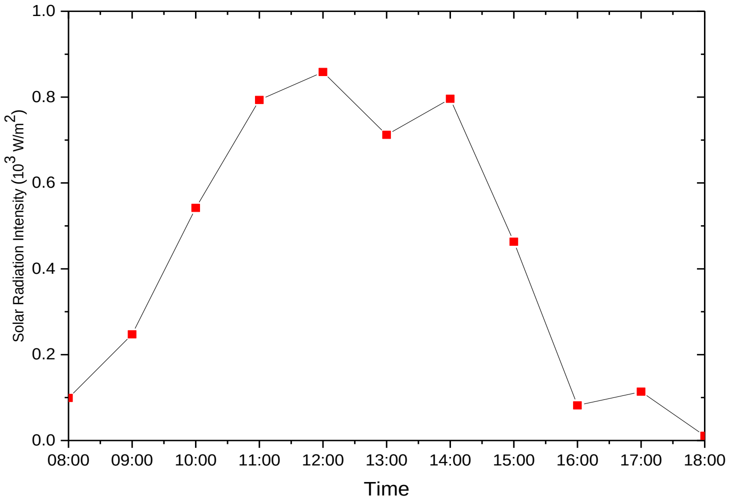

Figure 3. The intensity of solar radiation

3.2. The temperature profile of PV solar panels with PCM

Figure. 4 shows the average temperature profile of the front surface of PV-PCM solar panels. The graphics show that the average temperature of the front surface of solar panels using PCM decreases compared to PV panels without using PCM (reference). It occurred due to the excess heat developed at the PV panel surface reabsorbed by PCM. Later on, the PV panel surface temperature becomes lower compared to PV panels without using PCM. The maximum surface temperature of the solar panel without using a PCM is 65 ºC, and it happened at 12:15 WIB, while the maximum temperature achieved by PCM with tallow and paraffin only differ by about 3° C and 12° C compared to PV panels without PCM. The effect of using both PCM-tallow and PCM-paraffin continued to occur until 17.00 WIB and ultimately ended at 18.00 WIB where the surface temperature of the whole PV solar panels return to uniform. This event occurs because the intensity of solar radiation has decreased significantly.

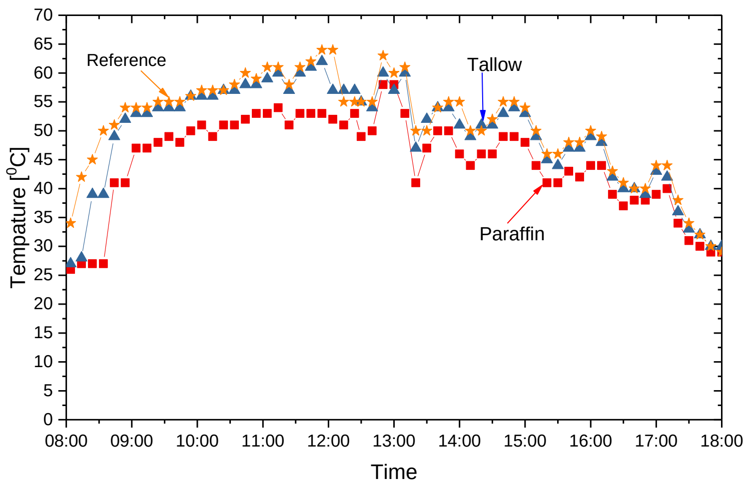

Figure 4. The average surface temperature profile on the front of the PV-PCM solar panel

Figure 5 is the average temperature profile of the PV-PCM solar panel's rear surface. The graph shows that the average surface temperature of solar panels using PCM also decreases compared to the reference panel. The magnitude of this temperature decrease is lower than the front surface temperature. The maximum temperature of the back of the solar panel without PCM is 55 ºC at 12.00 WIB, while the maximum temperature of the back surface of the solar panel uses PCM-Tallow and PCM-paraffin 48 and 42 ºC at 13:00 WIB. The average decrease in temperature that occurs in the front of the solar panel due to the addition of PCM is 2 - 6 ºC.

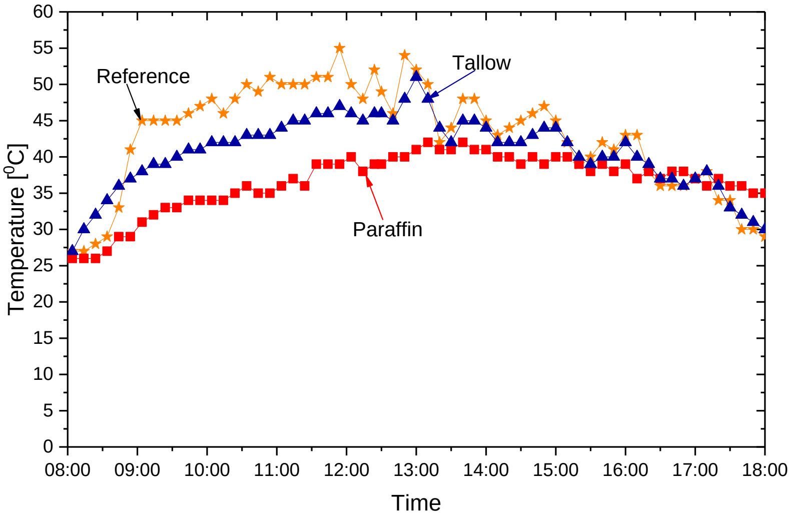

Figure 5. The average temperature profile of the back surface of the PV-PCM solar panel

4. Conclusions

Research on the utilization of PCM for cooling applications in PV solar panels has been successfully implemented. The test results show a comparison of the effective working temperature of PV solar panels with and without PCM. The experiment found that the addition of PCM to PV solar panels resulted in a decrease in the temperature of PV solar panels. Overall, from this study, both measurements were carried out on the front, and the back surface of the solar panel show that the addition of PCM capable in maintaining the performance of the solar panel through mitigating excess heat produced during the operation time.

5. Acknowledgments

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References

[1] I. Energy Agency, "World Outlook Energy 2015," 2040.
[2] A. Karthick, K. K. Murugavel, and P. Ramanan, "Performance enhancement of a building-integrated photovoltaic module using phase change material," *Energy*, vol. 142, pp. 803–812, Jan. 2018.
[3] M. Jun Huang, "The effect of using two PCMs on the thermal regulation performance of BIPV systems," *Sol. Energy Mater. Sol. Cells*, vol. 95, no. 3, pp. 957–963, Mar. 2011.
[4] E. Skoplaki and J. A. Palyvos, "On the temperature dependence of photovoltaic module electrical performance: A review of efficiency/power correlations," *Sol. Energy*, vol. 83, no. 5, pp. 614–624, May 2009.

[5] B. J. Brinkworth, R. H. Marshall, and Z. Ibarahim, "A validated model of naturally ventilated PV cladding," *Sol. Energy*, vol. 69, no. 1, pp. 67–81, 2000.
[6] B. Moshfegh and M. Sandberg, "Flow and heat transfer in the air gap behind photovoltaic panels," *Renew. Sustain. Energy Rev.*, vol. 2, no. 3, pp. 287–301, 1998.
[7] G. Y. Yun, M. McEvoy, and K. Steemers, "Design and overall energy performance of a ventilated photovoltaic fa??ade," *Sol. Energy*, vol. 81, no. 3, pp. 383–394, 2007.
[8] K. A. Moharram, "Enhancing the performance of photovoltaic panels by water cooling," *Ain Shams Eng. J.*, vol. 4, no. 4, pp. 869–877, 2013.
[9] M. J. Huang, P. C. Eames, and B. Norton, "Thermal regulation of building-integrated photovoltaics using phase change materials," *Int. J. Heat Mass Transf.*, vol. 47, no. 12–13, pp. 2715–2733, Jun. 2004.
[10] A. M. Khudhair and M. M. Farid, "A review on energy conservation in building applications with thermal storage by latent heat using phase change materials," *Energy Convers. Manag.*, vol. 45, no. 2, pp. 263–275, Jan. 2004.
[11] A. I. Fernandez, M. Martínez, M. Segarra, I. Martorell, and L. F. Cabeza, "Selection of materials with potential in sensible thermal energy storage," *Sol. Energy Mater. Sol. Cells*, vol. 94, no. 10, pp. 1723–1729, Oct. 2010.
[12] J. Jeon, J.-H. Lee, J. Seo, S.-G. Jeong, and S. Kim, "Application of PCM thermal energy storage system to reduce building energy consumption," *J. Therm. Anal. Calorim.*, vol. 111, no. 1, pp. 279–288, Jan. 2013.
[13] J. C. Kurnia, A. P. Sasmito, S. V. Jangam, and A. S. Mujumdar, "Improved design for heat transfer performance of a novel phase change material (PCM) thermal energy storage (TES)," *Appl. Therm. Eng.*, vol. 50, no. 1, pp. 896–907, Jan. 2013.
[14] M. Amin, F. Afriyanti, and N. Putra, "Thermal properties of paraffin based nano-phase change material as thermal energy storage," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 105, no. 1, p. 12028, Jan. 2018.
[15] A. Hasan, S. J. McCormack, M. J. Huang, and B. Norton, "Characterization of phase change materials for thermal control of photovoltaics using Differential Scanning Calorimetry and Temperature History Method," *Energy Convers. Manag.*, vol. 81, pp. 322–329, May 2014.
[16] Hamdani, S. Rizal, M. Riza, and T. M. . Mahlia, "Mechanical properties of concrete containing beeswax/dammar gum as phase change material for thermal energy storage," *AIMS Energy*, vol. 6, no. 3, pp. 521–529, 2018.
[17] R. Thaib, S. Rizal, Hamdani, T. M. I. Mahlia, and N. A. Pambudi, "Experimental analysis of using beeswax as phase change materials for limiting temperature rise in building integrated photovoltaics," *Case Stud. Therm. Eng.*, vol. 12, pp. 223–227, Sep. 2018.