A Review of Experimental Study about Thermal Behavior of PV Panel Incorporating Metallic Tubes Filled With PCM

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ABSTRACT

This experimental research aims to maintain high photovoltaic efficiency(PV) by keeping them at a low operating temperature. The commercially available phase change material (PCM) RT24, encapsulated in copper pipe, was added as a heat sink to the rear side of the PV panel for this purpose. The key principle of using the copper tube as PCM encapsulation is to create a fin effect on the back of the PV panel to enhance the rate of heat transfer from the PV panel to ambient air. The experimental study revealed that this method can reduce the maximum temperature of PV panels and increase the efficiency of them.

Keywords: *Review, Experimental Study, PV Panel, PCM*

1. INTRODUCTION

A PV cell's electrical conversion efficiency is influenced greatly by its surface temperature.[1] A 1-K increase in a standard PV cell's surface temperature typically decreases the conversion efficiency by 0.08 %-0.1 %, decreasing power output by 0.45 % over the 25 C nominal cell operating temperature.[1,3] Different approaches and techniques for PV cell cooling have been suggested and implemented like the hybrid PV thermal system and passive cooling. The use of phase change material (PCM) incorporated at the rear of the PV panel is one of the passive cooling techniques.[4,5] PCMs are organic and inorganic materials which, depending on the melting temperature, undergo reversible phase changes.[6] If the absorption surface temperature is higher than the melting point of the PCM and vice versa, PCMs undergo the melting phase and keep the surface temperature close to the melting point until the whole PCM is melted. In the current study copper tubes of appropriate length and diameter are filled with

PCM. At the rear of the PV panel, the PCM-filled copper tubes are attached. The key principle for the use of PCM-filled copper tubes is that they can also create the fin effect when connected to the backside of a PV panel, which can help improve the convective heat transfer from the back of the PV panel, especially when the PCM is fully melted. This idea attempts to help boost natural convection from the back of the PV. In this research, only the PV panel's thermal reaction is studied due to PCM-filled copper tubes.

2. EXPERIMENTAL SETUPAND PROCEDURE

For this research, a PV panel of the monocrystalline type was selected because it is the purest one. The high purity of silicon allows one of the highest efficiency rates for this kind of solar panel. Monocrystalline panels have a high output of power and occupy less space. Another value to note is that, compared to polycrystalline plates, they appear to be slightly less influenced by elevated temperatures. Table I tabulates the electrical and physical properties of the PV panel.

Table 1. Properties of the PV module.

Maximum power (P max)	50 W
Voltage at P max (V max)	17.3 V
Current at P max (Imax)	2.9 A
Open-circuit voltage (Voc)	21.6 V
Short-circuit current (Isc)	3.18 A
Module efficiency (%)	15.5%
Dimensions (h* w* t)	630*510*18 (mm)
Weight (kg)	3.5 kg

Commercially available PCM RT24 was used for the current study. Properties of RT24 are tabulated in Table II.

Table 2. Thermophysical properties of the PCM used for the current study.

PCM category	Organic
Melting point (ºC)	۲۴
Latent heat (kJ/kg)	۲۵۰
Thermal conductivity (W/m2 K)	۰/۲
Specific heat capacity (kJ/kg K)	۲/۰

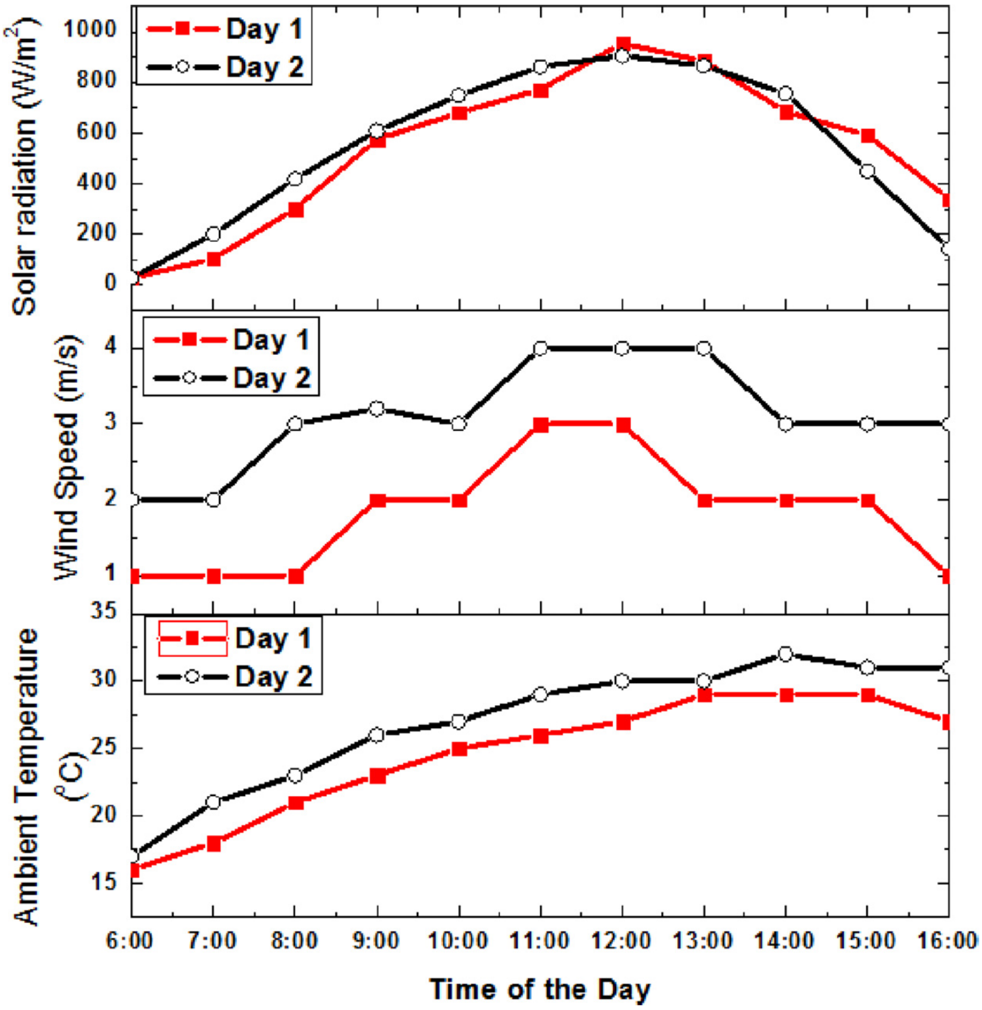

Fig. 1. Ambient temperature, wind speed, and solar radiation during experimental days.

The details reported in Fig.1 For each hour, is the average and ranges from 6:00 am until 4:00 pm. It can be noted from Fig.1 that during day 2 the ambient temperature was 2ºC–3ºC greater than that of day 1. Similarly, on day 2, the wind rate was still higher relative to day 1. Fluctuations of solar radiation were detected on day 1 because of some clouds. Solar radiation was also lower on day 1 compared to day 2. The recorded temperature of the PV panel with and without PCM was recorded every 30 s and averaged over each hour.

3. RESULTS AND DISCUSSION

1) Effect of the PCM-filled copper tubes on the PV panel front surface temperature:

The temperature difference between the front surface for the two consecutive days of conventional PV and PV with PCM is seen in Fig.2.

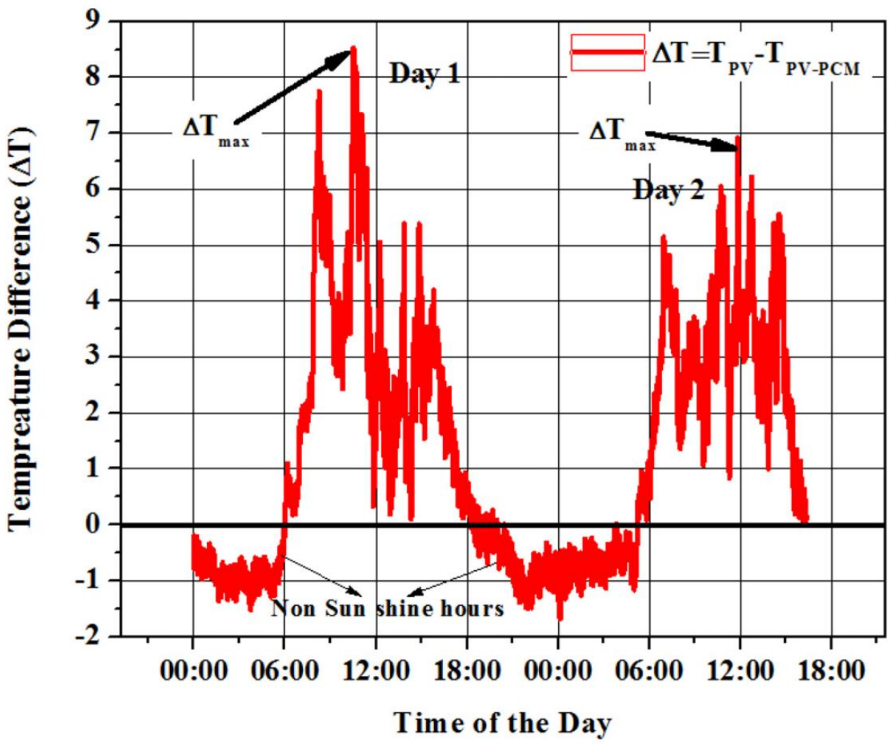

Fig. 2. Temperature differences between the PV with PCM and the PV (front surface of the PV panel).

Observations from Fig.2 reveal that during both days, ΔT is always positive during sunshine hours, which shows that the PV panel with PCM is cooler than the conventional one. The PV panel with PCM shows higher temperatures than the PV panel without PCM only during non-sunshine hours, and ΔT becomes negative during the overnight. This negative temperature behavior (Fig.2) is because, during the night, PCM releases absorbed heat, making the temperature of the PV-PCM panel marginally higher than that of the PV panel without PCM.

The front surface temperature of the PV panel is seen in Fig.3 with and without the PCM. In Fig.3, the phase change effect can be seen from 8:00 to 11:00 am on day 1. After 11:00 am until 4:00 pm when the PCM is completely melted, the PCM filled copper tubes act like fins and drain heat from the PV panel faster than the PV panel without these tubes. Therefore, the PV panel is primarily cooled from 8:00 to 11:00 a.m. due to the phase change effect of the PCM, while the PV panel is cooled from 11:00 a.m. to 4:00 p.m. due to the presence of copper tubes serving as fins. The key benefit of using the suggested cooling strategy is that the PV panel can easily use the fin effect for its cooling during sunshine hours with the presence of the PCM-filled copper tubes along with the latent heat effect.

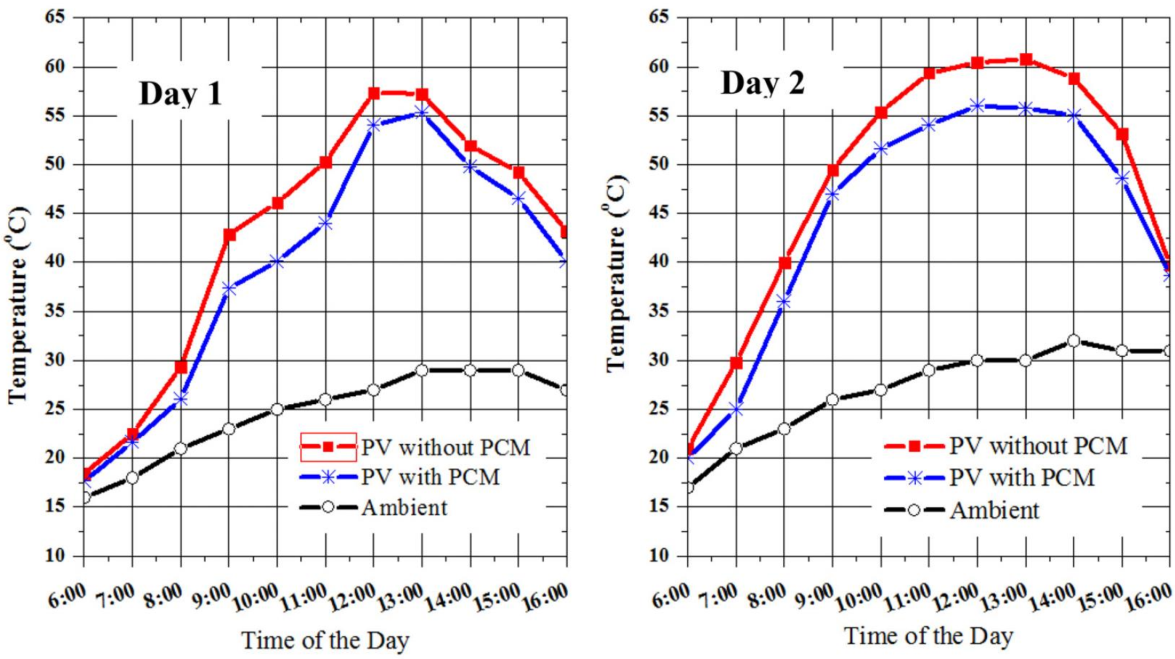

Fig. 3. Average temperature of the PV panel with and without PCM (front surface of the PV panel).

2) Effect of the PCM-filled copper tubes on the PV panel back surface temperature:

In Fig.4, the back surface temperature of the PV panel with and without PCM is seen along with the temperature of the copper tubes filled with PCM. In contrast to the back surface of the PV panel without PCM, the back surface of the PV panel with PCM was found to be much cooler on both days. The effect of the phase change on the temperature of the PV panel was observed between 8:00 and 11:00 am on day 1, while it lasted from 7:00 to 9:00 am on day 2. The PV back surface was cooled by the fin effect created by the presence of the copper tubes the rest of the time.

The PV-PCM system of rectangular PCM containers previously used by different authors[2,8,9] blocked the natural convection from the PV panel when the PCM was fully melted, and the PV-PCM panel displayed higher temperatures during the afternoon than the traditional panel.[7] The current concept assisted in enhancing the natural convection as observed clearly in the temperature profile shown in Figs.3 and 4.

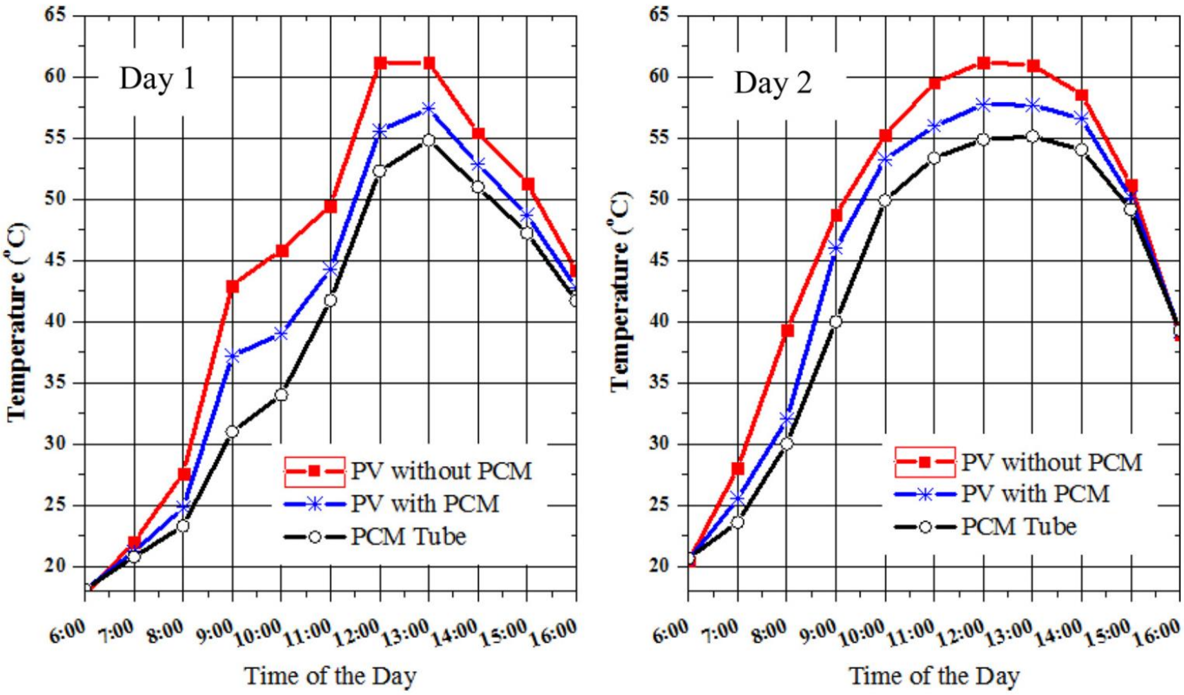

Fig. 4. Back temperature of the PV panel with and without PCM, along with the PCM tube temperature.

3) Effect of the PCM-filled copper tubes on efficiency of the PV panel:

Fig.5 demonstrates the performance of the PV panel with and without a PCM. It can be observed that during day 1 until 11:00 am the performance was dramatically improved, mostly due to the influence of PCM, and then dropped until 1:00 pm, then further improved until 4:00 pm due to the increased natural convection from the back of the PV panel with the presence of copper tubes filled with PCM. On average, the PV panel productivity rose by 1.5% during day 1 and by 1.9% during day 2. Overall, the increase in performance was observed on both experimental days because of the addition of the PCM-filled copper tubes.

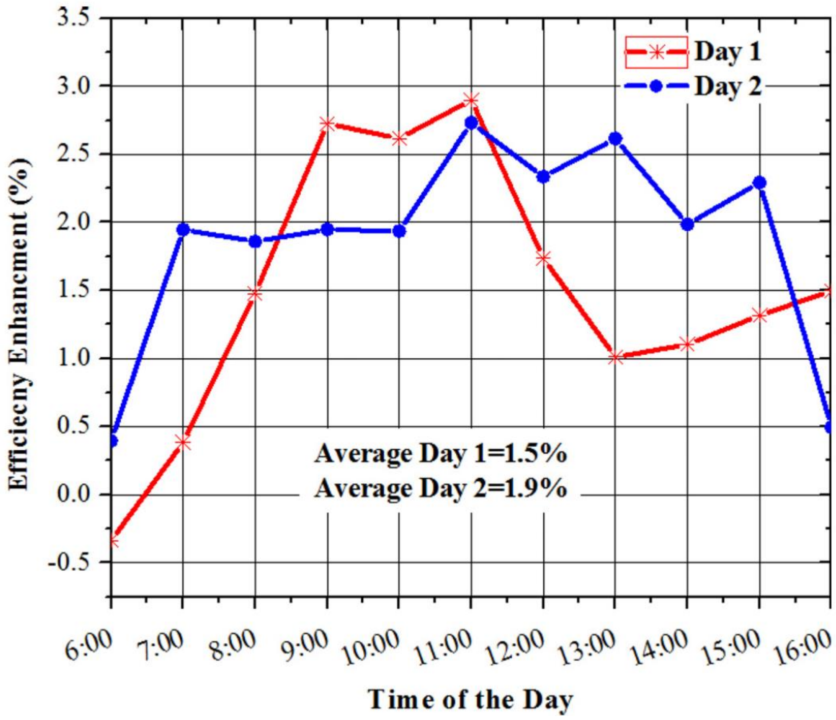

Fig. 5. Improvement in the efficiency of the PV panels during days 1 and 2 with PCM.

4. CONCLUSIONS

An experimental study to cool down the PV panel operating temperature using phase change material has been presented in this article. Commercially available PCM RT24 was encapsulated in copper tubes. Based on the experimental results the PV cell surface and the back surface temperature of the PV-PCM panel was lower compared with the conventional PV panel. On average, electrical efficiency was improved up to 3%. The current configuration showed that heat can be effectively removed from PV panels through the fin effect generated by the copper tubes even in the absence of latent heat.

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