



# Proceeding Paper Phase Change Material for the Cooling of Solar Panels—An Experimental Study<sup>†</sup>

Bilal Hussain<sup>1</sup>, Huzaifa Waseem Malik<sup>1</sup>, Fakhar Ul Hasnain<sup>2</sup> and Muhammad Irfan<sup>1,\*</sup>

- <sup>1</sup> Department of Mechanical Engineering, Capital University of Science and Technology, Islamabad 45750, Pakistan; bh9143500@gmail.com (B.H.); huzaifa.malik@cust.edu.pk (H.W.M.)
- <sup>2</sup> Department of Mechanical Engineering, Kyungpook National University, Daegu 37224, Republic of Korea; fakhar948@gmail.com
- \* Correspondence: m.irfan@cust.edu.pk
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**Abstract:** Solar panel efficiency decreases with an increase in the panel surface temperature. This study utilized the Phase Change Material (PCM) based cooling approach along with Aluminum fins to reduce the temperature of the PV panel. The PV panel surface temperature and efficiency are the target parameters we investigated. The results were compared with conventional PV panel values at inclination angles of 30°, 45°, and 60° with respect to the ground. The experimental results show that the PV panel efficiency increased by 6.85%, 6.82%, and 4.2% for the inclination angles of 30°, 45°, and 60°, respectively. The corresponding maximum temperature drops were 13.1 °C, 12.9 °C, and 8.5 °C.

Keywords: phase change material; PV panel cooling; efficiency; solar energy

## 1. Introduction

A solar cell, also known as a photovoltaic (PV) cell, converts solar energy into electricity. It consists of a p-n junction diode. A single silicon solar cell can generate a maximum open circuit voltage of approximately 0.5–0.6 Volts. When integrated into a larger solar panel system, it yields significant renewable energy. Roughly 23% of solar irradiance is intercepted by environmental factors like dust, ozone, and water vapor, while approximately 29% is reflected back into space. Only 48% of solar energy traverses the atmosphere and becomes absorbed by the solar panel surface. Consequently, the silicon solar panel converts around 20% of solar energy into electrical energy [1]. An increase in the temperature of the PV panel causes a reduction in the photovoltaic panel's efficiency by approximately 0.5% to 0.6% per degree rise in temperature. Chavan et al.'s study used a 40 W panel with three systems, including conventional PV, PV-PCM fins, and a water circulation system. PV-PCM achieved 4.24% higher electrical efficiency [2]. Prakash et al. used HS36-hydrated salt as a PCM for PV cooling to enhance panel performance. PV-PCM reduced the surface temperature by 25.4% and increased the electrical efficiency by 17.5% [3]. Homlakorn et al. employed organic eutectic PCM in a finned container for PV module cooling. Out of three proposed proportions of acid, a 60:40% wt mixture yielded a 7.06 °C reduction in temperature, a 0.454 W increase in power, and a 4.226% efficiency improvement [4]. This current study utilized a combination of PCM and an Aluminum fin structure to cool down the PV panel in the atmospheric conditions of Islamabad, Pakistan, for various inclination angles with respect to the ground.

### 2. Experimental Setup

Two identical PV panels, each with a 30 W power rating, were used in the experimental setup, as shown in Figure 1. Monocrystalline solar panels were utilized due to their higher efficiency compared to other panel types. The PV panel optimum operating voltage, open



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**Copyright:** © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). circuit voltage and short circuit current were 19.5 V, 22.9 V and 1.70 A, respectively. The PV panel dimensions were 650 mm  $\times$  350 mm  $\times$  25 mm.



**Figure 1.** (Left) The experimental setup; (**Right**) The schematic of the PCM container installed in the PV-PCM system showing dimensional details (All dimensions are in mm).

One panel called the PV-PCM system, was cooled by the PCM-fin cooling system, while the other panel did not cool but served as the reference for result comparisons. In the PV-PCM system, an Aluminum container containing PCM and fin structures was attached to the back of the PV panel. The PCM chosen for this study was CaCl<sub>2</sub>.6H<sub>2</sub>O with a density of 1706 kg/m<sup>3</sup> and a melting point of 29 °C, which was suitable according to the environmental conditions of the location. The dimensional details and the container structure are shown in Figure 1. The height of the PCM container was 40 mm, which was dictated by the mass of the PCM and the PV panel dimensions. The mass of the PCM was calculated such that it was sufficient to absorb the total solar energy available throughout the day in the form of latent energy. This helped to maintain the PV panel temperature at the PCM phase change temperature of 29 °C, which was close to the optimum operating temperature of the PV panel (25 °C). K-type thermocouples were used to record the temperature of the PCM, while an infrared thermal gun was used to record the PV panel's surface temperature.

#### 3. Result and Discussion

Each experiment was performed three times, and the average results were used for the purpose of analysis. The efficiency of the conventional PV panel can be calculated as [5]:

$$\eta_{PV} = \eta_{ref} \left[ 1 - \beta \left( T_{PV} - T_{ref} \right) \right] \tag{1}$$

where  $\eta_{ref}$  is the reference efficiency of the standard PV system and  $\beta$  is the thermal expansion coefficient of the PV system, which is 0.0045/K [5]. Similarly, the efficiency of the PV-PCM system can be calculated as

$$\eta_{PV-PCM} = \eta_{ref} \left[ 1 - \beta \left( T_{PV-PCM} - T_{ref} \right) \right]$$
<sup>(2)</sup>

Efficiency enhancement is calculated as [5]

Enhancement (%) = 
$$\left| \frac{\eta_{PV} - \eta_{PV - PCM}}{\eta_{PV}} \right| \times 100$$
 (3)

Figure 2 presents the trends of the panel surface temperature and panel efficiency of the conventional and PCM-cooled systems for all three angular orientations. From

the experimental results plot, it can be seen that the PCM-cooled system exhibited lower surface temperatures and higher efficiencies compared to the conventional PV system for all three angular orientations of the PV panels. At the start of the experiments, both the conventional and the PV-PCM systems were approximately at the same temperatures . As time progressed during the day, the surface temperature of the PV panels increased for both systems; however, the PV-PCM system temperature was lower than the conventional system. This is because the heat was being stored in the PCM filled in the container attached to the PV panel of the PV-PCM system. Consequently, the efficiency of the PV-PCM system was also higher compared to the conventional system. The PCM melted as it stored energy during the process. As time passed, the entire PCM was melted, and no more latent heat could further be stored. Therefore, the surface temperature of PV-PCM started rising at a faster pace and eventually approached that of the conventional panel. Similar trends were also observed for the panel efficiencies. It can be also observed that the panel efficiency for the 30° orientation was highest and continuously decreased as the angle increased to 60°.



**Figure 2.** Panel surface temperature and panel efficiency at different angular orientations. (**a**) Angular orientation =  $30^{\circ}$ ; (**b**) Angular orientation =  $45^{\circ}$ ; (**c**) Angular orientation =  $60^{\circ}$ .

Table 1 presents the maximum values of the temperature difference between the conventional and PV-PCM systems at 11:30 a.m. for all three angular orientations of the PV panel. The corresponding maximum efficiency enhancement values (in percentages) are also tabulated.

Table 1. Performance parameters for various orientations of the PV panel.

Parameters —	Orientation Angle		
	<b>30</b> °	$45^{\circ}$	<b>60</b> °
Temperature difference, ΔT (°C) Efficiency Enhancement (%)	13.1 6.85	12.9 6.82	8.5 4.2

#### 4. Conclusions

This study analyzed the performance of the PCM-based cooling system integrated with fins to cool down the PV panel and ultimately enhance electrical efficiency. It was observed that the utilization of PCM decreased the PV panel surface temperature, which consequently increased the efficiency of the panel. The experimental result shows that PCM-based cooling decreased the PV panel's surface temperature by 13.1 °C, 12.9 °C and 8.5 °C compared to the conventional PV panel for the inclination angles of 30°, 45°, and 60°, respectively. The corresponding increase in the PV panel's efficiency were 6.85%, 6.82%, and 4.2%.

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