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Research Article

Cooling of Solar Photovoltaic Panel by Implementing Fins and Phase Change Material on Back Surface

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I N F O

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A B S T R A C T

The performance of solar panels is incredibly addicted to the absorption of radiation. A number of the absorbed energy is converted into electricity, while the remainder transformed into heat. However, PV-panels may experience intense heat that causes heat radiation in PV-panels to increase. This radiation on the PV panel includes a negative impact on the output of voltage produced and has the potential to cut back the performance of the solar battery. Therefore, it is necessary to style a PV-Panel cooling system to take care of the temperature of the panel to not exceed its effective working temperature. This project work aims to take care of the PV-Panel temperature to not exceed the effective working temperature using Fins and PCM as a cooling medium. The variables used include the temperature distribution of the highest of the panel, the center panel, and therefore the bottom panel. The results showed that the employment of Fin and PCM maintains the temperature of solar panels below 50ºC, relatively better than the PV-panels that use air as a cooler. An experiment is performed with and without modification of PV panel and the result shows an increase in conversion efficiency by 5–7%.

Keywords: Solar Energy, PV-Panel, Fins, Thermal Storage, Cooling

Introduction

Many countries have already started giving grants for folks that founded panels on their roofs. They heat up above their optimal working temperature and lose out on efficiency. This implies that the market needs various cooling methods for various places on earth, vicinity that also has to be explored further to seek out the foremost optimal thanks to cool them. If how to cool down the modules without economic loss then the panels would be more efficient and thus generate more renewable energy. Increasing the temperature of the solar cells causes a drop in the thermal efficiency of a PV panel. Hence our work is to cool down the solar PV panel by the integration of Fin and PCM. India receives solar power resembling over 5,000 trillion kWh annually, which is way over its total annual consumption. The daily global radiation is around

5 kWh per sq. m per day with sunshine ranging between 2,300 and 3,200 hours annually in most a part of India. Though the energy density is low and also the availability isn't continuous, it's now become possible to harness this abundantly available energy very reliably for several purposes by converting it to usable heat or through the direct generation of electricity. Photovoltaic cell covers the potential to convert solar power into electricity.[1]

The performance of the PV system is tormented by several parameters including temperature. The part of absorbed radiation that's not converted into the electricity converts into heat and causes a decrease in electrical efficiency. This undesirable effect which ends up in a rise within the PV cell's working temperature and consequently causing a drop of conversion efficiency may be partially avoided by a correct method of warmth extraction. Many researchers have investigated and proposed different methods to optimize the performance of the Photovoltaic panel and to scale back the installation costs. Hosseini et al.[2] experimentally studied the performance of a PV system combined with a cooling system consisting of a skinny film of water running on the highest surface of the panel and an extra fabricated system to use the new water produced by the system. The results showed that the ability output and electrical efficiency of the combined system were higher and lower module temperature and reflection losses compared to the traditional PV system. Furushima and Nawata[3] developed a photovoltaic system with a cooling device utilizing siphon age & evaluated the performance of a photovoltaic panel for the summer condition. The study showed that the cooling of the PV module increased the ability output and the new water produced could be used for heating purposes. To cut back the cell reflection and improve the PV performance Abdol Zadeh and Ameri[4] evaluated the performance of the photovoltaic water pumping system by spraying water over the front of the electric cell and concluded that the PV cell efficiency, subsystem efficiency & total efficiency were increased by 3.26%, 1.40%, and 1.35 % respectively at 16 m head because of spraying water over the cell. Teo et al.[5] developed a hybrid photovoltaic/thermal system consisting of a parallel array of ducts with an inlet/outlet manifold designed for uniform airflow distribution attached to the rear of the PV panel. The experimental study showed that with an air cooling, the temperature of the panel dropped significantly and solar efficiency increased between 12–14%.

Bahaidarah et al.[6] experimentally investigated the performance of the photovoltaic module by incorporating a device (cooling panel) at its rear surface. The water circulated through the warmth exchanger absorbed the warmth from the panel and the new water produced can be utilized for the domestic applications. The result showed that with an energetic cooling, the module temperature dropped significantly to about 20%, and the panel efficiency increased by 9%. Gang et al.[7] experimentally studied the performance of a unique heat pipe photovoltaic/thermal system and validated the model output with measured data. The experimental results showed improvement within the system efficiency with cooling with water circulation. Krauter[8] used a way of reducing the reflection by flowing water over the highest surface of the panel. The result showed that cell temperature dropped to 22°C and improved electrical yield 10.3% over the day. Many researchers employed air or water for active cooling of PV to realize higher electrical efficiency, but additional energy consumption for air or water circulation may reduce the online power output. Therefore, Hongbing Chen et al.[9] conducted an experimental study to check the performance of photovoltaic panels with and without fin cooling to research the effect of PV panel inclination, ambient temperature and radiation and wind velocity on the electrical efficiency and power output. The study showed that the typical power output of the PV panel with fin increased by 1.8–11.8% than without fin.

Literature Review

Many researchers have studied the use of extended surface/fins, cooling water circulations tubes, and thermal storage for cooling of a solar photovoltaic cell. Also, there is huge research going about parameters that affect the performance of solar PV cells. From literature, survey attempt has been given on benefits of different technique to cooling the solar panel to improve its performance.

Fatih Bayrak et al.[10] within the current study, the results of passive cooling on surface temperature, power output and energy-exergy efficiencies of PV panels were investigated for various fins arrangements. The efficiencies and maximum power output of the PV panel with and without fins were determined for every radiation and therefore the results were compared thoroughly. The aluminum fins placed behind the photovoltaic panels were shown to act as an efficient conductor to soak up more than heat from the solar cells and maintained PV panel temperature below the utmost allowable temperature. The best energy and exergy efficiencies values of the finned panels were calculated as 11.55%, and 10.91%, respectively.

El Mays et al.[11] assessed the performance of solar panels by using aluminum fins. The comparison of the two photovoltaic panels indicates that the quality solar PV and PV panel efficiencies are enhanced by 15.9% and 17.7%, respectively. On the opposite hand, the surface temperature of the photovoltaic panel has decreased by about 6°C.

Elsafi and Gandhidasan[12] examined the thermal and electrical performances for the compound parabolic concentrated and PV/T systems with and without fins.

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The results showed that annual thermal gain was 1% higher for PV/T with fin as compared to PV/T without fin. On the opposite hand, the annual electrical gain for PV/T with fin was 3% over PV/T without fin. The CPC-PV/T (fin) was estimated to possess quite 3% thermal and eight electrical gains compared to CPC-PV/T (without fin).

Rahman et al.[13] studied the results of varied parameters like radiation intensity, cooling fluid mass rate of flow, humidity, and dirt on the PV panel performance. It had been observed that panel temperature, dust, and humidity have a negative influence on panel efficiency. However, the panel efficiency enhanced because the radiation increased, but during this case, the panel temperature was also increased.

Krauter[14] investigated a way of reducing reflection which also provided cooling-replacing the front glass surface with a skinny (1 mm) film of water running over the face of the panel. He notes that the index of refraction (1.3) of water is superior to it of glass. Reflective losses in glass can cause losses in yield of 8–15%. The water decreased cell temperatures up to 22°C. The improved optics and cell temperatures increased electrical yield 10.3% over the day (8–9% after accounting for pumping energy). He also noted an unexpected aesthetic benefit.

Meneses-Rodriguez et al.[15] considered a unique technique to boost electrical efficiency with cooling. The authors explored the advantages of running PV cells at near their maximum theoretical temperatures (100–170°C). Theoretically, the electrical efficiency will be within the range of 10–16%. The cooling fluid would be wont to run a Stirling engine. With a sink temperature of 30°C, the authors estimate a theoretical total efficiency greater than 30%.

Ahmad Hasan et al.[16] the present article investigates the simplest way to utilize the thermal energy stored within the PCM behind the PV for domestic water heating applications. The system is evaluated within the winter conditions of the UAE to deliver heat during water heating demand periods. The proposed system achieved a ~1.3% increase in PV electrical conversion efficiency, together with the recovery of ~41% of the thermal energy compared to the incident radiation.

Hasan et al.[17] during this work, the photovoltaic panel performance has been investigated theoretically and experimentally were using an array of pin fins as a cooling system. Theoretical results were compared with experimental results of solar panels cooled by the sink, to validate the suggested thermal model. Also, the effect of the temperature of the solar cell on the panel performance has been studied experimentally. The results display that using pin fins array as a cooling technique led to call in the typical panel's temperature nearly 5.9°C and enhancement of the typical output power nearly 13.5%.

Jayashree Gotmare et al.[18] in this paper, performance enhancement of PV panels was experimented utilizing passive fin cooling under natural convection. To properly cool the PV panel, different cross-sectional fins with perforation was attached at the backside of the panel. A comparative experimental study on PV panels with and without fin cooling was disbursed to analyze the effect of operating temperature on the voltage, current and power output developed by the panel. The results showed that thanks to fin cooling temperature of the PV panel dropped significantly and the facility output was improved by 5.5% under natural convection.

Experimental Set up and Methodology

Figure 1.Experimental Set up

The experimental setup was designed to investigate the effect of fin cooling on the performance of the photovoltaic panel. Figure 1 shows the experimental setup which consists of two 40 W PV panels having an area of 0.351 m^2. The maximum output voltage and current developed by the panel are 17.2 V, 2.3 A respectively at an irradiance of 1230 w/m^2 and the ambient temperature of 31°C. For the passive cooling, fins made up of aluminum 0.8 mm thickness is used and glued evenly to the backside of the panel with thermal grease. A total of 24 fins with square cross-sections are attached alternately with a constant spacing of 40 mm to restrict the flow of air to improve the heat transfer rate from the PV panel. Perforation has been done on the fins at an equal distance by a 10 mm drill bit. The tilt angle of the panel is set to 21°C concerning the horizontal, which is the local latitude of Miraj (16.8222°N, 74.6509°E), India, to face in the south direction. The temperatures of the panels are measured by K-thermocouples which can sense the temperature from 0°C - 150°C and the readings will be shown on the digital meter. A total of 5 thermocouples are used to measure the temperatures at different locations. Two thermocouples are installed at the top and two at the backside of both the panels. Also, the current and voltage are measured multimeter. The experiment was conducted from 10.00 am–4.00 pm for 7 days and recorded the data for every 15 min. The experimental setup was designed to investigate the effect of PCM+Fin cooling on the performance of the photovoltaic panel.

Observations and Graphs

Comparison of Under Surface Temperature of P.V. Reading with Fin and without Fin

Table 1.Comparison between Fin and without fin modification

S.No.	Time	T2 (Under Surface Temp) with Fin	T2 (Under Surface Temp) without Fin	T4 (Fins Temperature)	Solar Radiation (w/m²)	Performance Improvement in %
1.	10.30	40.00	42.00	35.90	614	5
2.	10.45	41.30	43.30	42.30	768	4.84
3.	11.00	39.60	41.60	42.10	801	5.05
4.	11.15	38.50	40.50	44.30	825	5.19
5.	11.30	39.80	41.80	46.30	863	5.02
6.	11.45	38.90	40.90	43.70	887	5.14
7.	12.00	45.30	47.30	43.40	912	4.41
8.	12.15	41.00	43.00	44.00	954	4.87
9.	12.30	45.00	47.00	48.90	988	4.44
10.	12.45	45.80	47.80	48.70	1003	4.36
11.	1.00	44.50	46.50	47.10	1024	4.49
12.	1.15	45.00	47.00	52.10	1098	4.44
13.	1.30	42.00	44.00	50.00	1125	4.76
14.	1.45	41.00	43.00	42.60	1145	4.87
15.	2.00	47.60	49.60	46.60	1186	4.20
16.	2.15	47.70	49.70	48.90	1202	4.19
17.	2.30	51.40	53.40	49.90	1290	3.89
18.	2.45	47.40	49.40	38.30	1256	4.21
19.	3.00	44.30	46.30	42.10	1240	4.51
20.	3.15	34.20	36.20	41.10	1101	5.89
21.	3.30	34.50	36.50	46.80	1032	5.79
22.	3.45	38.90	40.90	43.30	1021	5.14
23.	4.00	39.60	41.60	43.60	979	5.05
24.	4.15	40.30	42.30	43.40	965	4.96

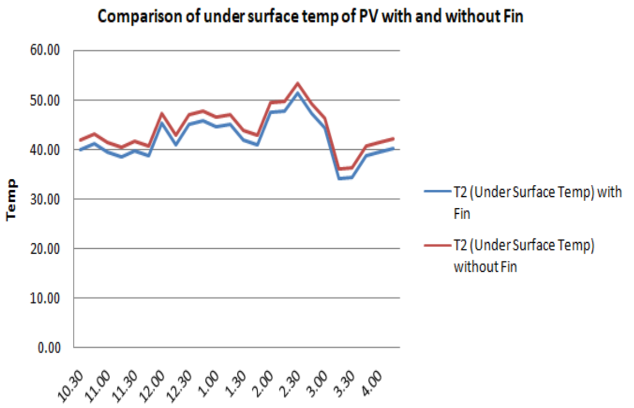

Figure 2.Comparison of under surface temp of PV with and without Fin

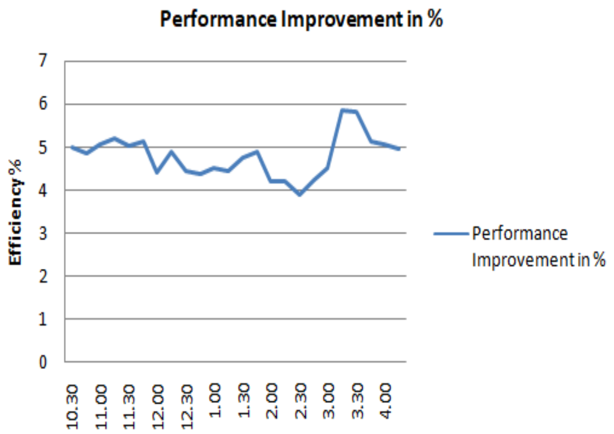

Figure 3.Performance Improvement in %

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Figure 2 shows the comparison of module surface temperature variation with and without a cooling system. The above figure shows the variation of module surface temperature with and without a cooling system. It is observed that the temperature of the module is a smaller amount compared thereto of the module without the cooling system in any respect time intervals.

Figure 3 shows the comparison of efficiency obtained by with and without an active cooling system. The above graph shows the improvement in electrical efficiency of the photovoltaic module with an active cooling system compared to that of the photovoltaic module without a cooling system.

Figure 4 shows a comparison of module surface temperature variation with and without a cooling system. The above figure shows the variation of module surface temperature with and without a cooling system. It is observed that the temperature of the module is a smaller amount compared thereto of the module without the cooling system in the slightest degree time intervals.

Figure 5 shows the comparison of efficiency obtained by with and without active cooling system the above graph shows the improvement in electrical efficiency of a photovoltaic module with the active cooling system compared to that of the photovoltaic module without a cooling system.

Comparison of under surface temperature of P.V. Reading with Fin+PCM and without Fin+PCM

Table 2.Comparison between Fin+PCM and without Fin+PCMmodification

S.No.	Time	T2 (Under Surface Temp) without Fin+PCM	T2 (Under Surface Temp) with Fin+PCM	Performance in %
1.	10.30	36.1	33.8	6.8
2.	10.45	37.3	35.1	6.3
3.	11.00	42.88	40.5	5.9
4.	11.15	44.9	42.8	4.9
5.	11.30	46.8	44.3	5.6
6.	11.45	50.2	47.3	6.1
7.	12.00	54.5	52.1	4.6
8.	12.15	51.8	50	3.6
9.	12.30	52.8	49.9	5.8
10.	12.45	52	49.6	4.8
11.	1.00	59	56.6	4.2
12.	1.15	58.2	55.8	4.3
13.	1.30	54.6	52	5.0
14.	1.45	52	51	2.0
15.	2.00	55.6	49.7	11.9
16.	2.15	55.8	53.5	4.3
17.	2.30	53.2	50.8	4.7
18.	2.45	53.5	51.3	4.3
19.	3.00	51.7	49.5	4.4
20.	3.15	50.5	48.7	3.7
21.	3.30	48.1	45.2	6.4
22.	3.45	45.4	43.3	4.8
23.	4.00	35.9	33.7	6.5
24.	4.15	44.8	42.6	5.2
25.	4.30	46.2	43.6	6.0
26.	4.45	43.5	41.5	4.8
27.	5.00	39.2	36.8	6.5

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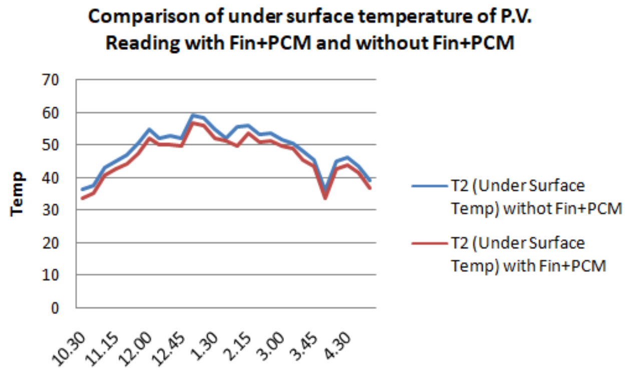

Figure 4.Comparison of under surface temperature of P.V. Reading with Fin+PCM and without Fin+PCM

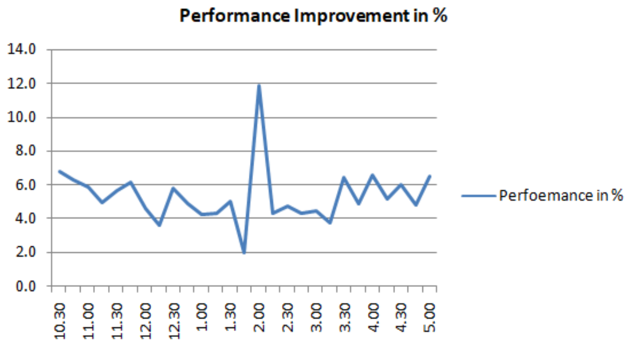

Figure 5.Performance Improvement in %

Conclusion

This work presents an experimental investigation into improving PV power generation using the Fin and PCM. Two identical PV panels were employed in the experimental assessment. The results show that the PV-Fin panel was able to reduce the panel temperature by 7–10°C compared to the naturally-cooled PV panel. Additionally, the most electrical conversion efficiency improvement of 6–7 it had been achieved by the proposed cooling approach. Also, the results show that the PV-PCM panel was able to reduce the panel temperature by 4–6°C as compared to the naturally-cooled PV panel. Additionally, the most electrical conversion efficiency improvement of 3–6 it had been achieved by the proposed cooling approach. This is often because the warmth source which was provided by the sun was situated at the highest side of the PCMTS containment where the natural convection heat transfer effect wasn't optimal. The experiment found that the addition of FIN and PCM to PV solar panels resulted in a very decrease within the temperature of PV solar panels. Overall, from this study, both measurements were meted out on the front, and therefore the back surface of the solar array shows that the addition of Fin and PCM capable of maintaining the performance of the solar array through mitigating excess heat produced during the operation time. The experimental results are a clear indication of the variation of efficiency with panel surface temperature.

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