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PCM Cooling Technique Applied for Improvement of PV Panel Efficiency

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ABSTRACT

As a renewable and sustainable energy source, photovoltaic (PV) panels have made a big impact on the world's transition to clean energy. Nonetheless, one of the difficulties PV systems encounter is the efficiency loss brought on by high working temperatures. The jouissance of thermal range with yield has a discouraging effect on PV panel behavior since greater operating temperatures reduce solar panel effectiveness. This study looks into how phase transition material RT 35 (Rubitherm) lowers a solar panel's working temperature and tries to keep it at or near room temperature. By simulating the dynamical algorithms involved in the thermal energy transfer of the solar plate in the PCM arena, the impact of these material exchangers on operating temperature was examined. There are four distinct times of the day that are set aside for temperature variations along with different quantities of ambient light and radiation. Measurements will be recorded in order to compare efficiency at 25°C with a standard irradiation of 1000 W/M2.

Keywords: *Cooling, Arithmetic, Dynamic, Equations, Voltage.*

1.0 Introduction

High temperatures have a major effect on solar systems' efficiency. Consequently, the literature employs a variety of cooling techniques to reduce PV panel temperatures and increase power output. According to the literature, these cooling methods can be classified as heat pipe, phase change material, thermoelectric, jet impingement, evaporation, spray, fin, and photovoltaic/thermal systems. Selecting the PCM ought to start with determining the system's operating temperature. The PCMs are made in both commercial and laboratory environments, and are available in extraordinarily broad temperature ranges. The three categories of PCMs are etics, inorganic compounds, and organic chemicals. Some of the functionalities needed for storage are absent from the majority of PCMs.Finding the system's operational temperature should be the first step in choosing the PCM..The PCMs are made in both commercial and laboratory environments, and are available in extraordinarily broad temperature ranges. The three categories of PCMs are etics, inorganic compounds, and organic chemicals. Some of the functionalities needed for storage are absent from the majority of PCMs. For system design, it is crucial to choose the material that has the necessary features and is closest to the lowest cost. The photovoltaic effect was discovered in 1839 and has since allowed for the conversion of solar light into electricity. Because of the variations in light wavelengths, these photons have distinct energy [1]. A semiconductor in a P-N junction, a solar cell, or the cell itself can all reflect or absorb photons.

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A photovoltaic system absorbs photons in a solar cell. Recent years have seen some technological advancements in Si-based photovoltaic systems, mostly centered on increasing efficiency and streamlining the production process to lower silicon material use. Nonetheless, several obstacles pertaining to the broader use of commercially accessible photovoltaic technologies are contributing to the delayed adoption of innovative installed photovoltaic capacities. The first concern is to the comparatively high initial cost of PV systems in certain economies, which is particularly apparent in less robust economies.

Typically, the total cost of home photovoltaic systems falls between 1,0 and 3,0 euros per watt. A solar cell can be used to produce a system [2]. An external circuit can be forced to conduct current through a junction's voltage. In 2018, India's home solar roofs accounted for less than half of the country's total solar electricity production, with an estimated 430 MW, compared to over 2500 MW in Britain. However, in the previous 20 years, technology has evolved significantly; the greatest cell performance available today is certified at over 24 percent. These latest design advancements have been successfully integrated into consumer goods containing cells that are currently available on the market [3]. These developments have not only increased efficiency but also made it easier to incorporate solar technology into a variety of consumer and business items.

Advanced Materials: Through improved light absorption and charge carrier generation, the adoption of innovative semiconductor materials, such as perovskite-based compounds or multi-junction cells, has led to increased efficiency.

Improved Manufacturing Techniques: Innovations in manufacturing processes, including thin-film deposition methods, nanostructured materials, and precise doping techniques, have enabled the production of high-performance cells with reduced defects and improved electrical properties.

Optimized Cell Designs: Increased light trapping mechanisms, reduced optical losses, and better electron-hole separation have all contributed to increased conversion efficiencies and better overall performance in a variety of environmental settings.

The effective incorporation of these most recent design developments into consumer goods shows that high-efficiency PV technologies are both practically applicable and ready for the market. Nowadays, consumers may choose from a large variety of solar-powered items, such as outdoor lights, portable chargers, and residential and commercial solar arrays, all of which have better energy conversion and less negative environmental effects.

First size reduces the total amount of highly doped content inside the component while increasing the defeatism of external regions and cell connections. A significant optical effect was produced by the cell's enhanced light collection and decreased reflection. These enhancements have resulted in a 24.7% increase in silicon cell performance [4]. These design advancements have been successfully applied to consumer goods in recent years, resulting in the market availability of 17–18% efficient cells. This implies that sizable cell efficiencies should be achievable with relatively thin silicon films, only a micron or two thick [5].

Over 90% of the silicone used in the manufacturing of solar cells is crystalline silicone. Commercial modules have an efficiency of 12 to 18 percent, while laboratory cells have a record efficiency of 24.7 percent. These design advancements have been successfully adapted into consumer items in recent years, as evidenced by the amazing efficiency of the cells that are currently on the market. [6]. The atomic structure of amorphous silicon molecules is extremely simple. This causes the content to include important errors.A number of slow bondings cause the carrier to recombinate extensively.

$$\mathrm{V_{OC}} = \frac{\mathrm{kT}}{\mathrm{q}} \ln\left\{\frac{\mathrm{I_L}}{\mathrm{I_0}} + 1\right\} \qquad \ldots 1$$

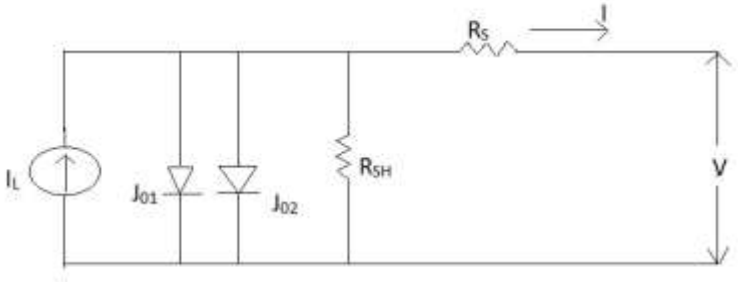
$$I_{Total} = I_0\left\{e^{\frac{qV}{kT}} - 1\right\} - I_L \quad ...2$$

$$F.F = \frac{V_M I_M}{V_{OC} I_{SC}} \quad ...3$$

$$\eta = \frac{V_{OC}\, I_{SC}\, F.F}{P_{Rad}} \quad ...4$$

These design advancements have been successfully used in recent years to consumer goods that incorporate commercially accessible efficient cells. One of the most promising methods for producing long-lasting, reasonably priced solar panels is the incorporation of thin, crystalline silicone films into the cells [8]. Because of these qualities, crystalline silicone is a well-liked choice in thin-film technology and a great material for solar cells that use thin films [9]. It has proven to have better cell performance. The growth of affordable solar energy may eventually replace a power system composed of a network of local grid clusters [10].

Figure 1: Single Unit of a Solar Power Plant



From 2 MW in 1975 to 3800 MW in 2007, the yearly global PV module manufacturing has risen in terms of MW [11]. Amorphous silicon, cadmium telluride, and copper indium gallium selenide are the three primary thin film technologies. Amorphous silicon makes up roughly 65 percent of the total [12].

Table 1: Characteristics Feature of Solar Plant

Sr. No.	Factors	Value
1	Units	70
2	Maximum Generation	216.15 W
3	V_{Pmax}	24 V
4	I_{Pmax}	8.25 A
5	V_{OC}	46.3 V
6	I_{SC}	8.84 A
7	Temperature Coeff. Of Voc	-0.16 % / ºC
8	Temperature Coeff. Of Isc	0.2 % / ºC

2.0 PCM Cooling Technique

Phase change material (PCM) cooling techniques make significant use of latent heat absorption or release by employing materials that undergo a phase transition (solid to liquid or vice versa) at a specific temperature. This feature makes PCM an effective thermal management option for a variety of applications, including as raising the efficiency of photovoltaic (PV) panels.It is among the best techniques for cooling solar PV panels since it maintains the panels' temperature at a set level for a predefined period of time [13]. This cooling technology makes use of a material class called as phase transition material, which has a great ability to retain heat. The material experiences a phase transition from a solid to a liquid state as a result of this heat-storing ability [14], but the heating rate of the apparatus won't change throughout the transformation.These design developments have been effectively applied in recent years to consumer goods that feature efficient, currently-available cells. cells have a very high efficiency, while commercial modules have an efficiency for a certain period of time.

$C_{PV}\frac{dT_{PV}}{dt}$ = Effective Irradiance (I_{reff}) – Radiation (Q_R) – Power (P_E) – Convection (Q_{CV}) – Heat stored by PCM Plate (Q_H) …5

$$I_{reff} = \varphi * \alpha \qquad \ldots 6$$

$$Q_R = \varepsilon_P \sigma \left[{T_{PV}}^2 + {T_S}^2\right][T_{PV} + T_S] \qquad \ldots 7$$

$$T_S = 0.037536\left[{T_{amb}}^{1.5}\right] + 0.32\,[T_{amb}] \qquad \ldots 8$$

$$\frac{dT_{PV}}{dt} = \left\{\frac{\varphi * \alpha - \sigma \epsilon_P\{({T_{PV}}^2 + {T_S}^2)(T_{PV} + T_S)\} - C_{FF}\left(\ln\frac{K_1\ \varphi}{T_{PV}}\right) - Q_H - Q_{cv}}{C_{PV}}\right\} - \frac{\text{Conduction}}{C_{PCM}} \qquad \ldots 9$$

We can see how Phase Change Material impacts the cell temperature by calculating the aforementioned equation (9) and the aforementioned differential equation [16] using MATLAB's SIMULINK model.

3.0 Results and Discussion

Table 2: Temperature Change Following the Use of a Cooling Technology

Sr. No.	I_R	T_{PV} (Before Cooling)	T_{PV} (After Cooling)	P_{max} (Before Cooling)	P_{max} (After Cooling)
1	1200	27	26	211.69	211.89
2	840	72.04	59	154.20	157.76
3	840	66.51	52.97	147.85	167.98
4	820	57.45	45. 37	156.68	170.81
5	858	62	48	164.43	180.58

Table 3: Characteristic Quantities of Solar Unit before Application of Cooling Process

Sr. No.	I_R	T_{PV}	V_{pmax}	I_{pmax}	P_{max}	V_{oc}	I_{sc}	F. F	η
1	1200	27	29.39 V	7.65 A	212.68 W	38.14 V	7.98 A	0.83	0.214
2	840	74.08	25.07 V	6.86 A	152.2 W	28.84 V	7.74 A	0.78	0.189
3	840	68.41	25.75 V	6.45 A	156.05 W	34.54 V	7.70 A	0.77	0.188
4	820	59.35	25.86 V	7.45 A	158.38 W	32.77 V	7.56 A	0.76	0.192
5	868	62	25.33 V	7.68 A	171.33 W	34.53 V	7.76 A	0.74	0.195

As can be seen from the above table, the performance of the panel degrades as the temperature rises. For example, the fill factor at 65°C is approximately 72%, while the efficiency is approximately 18%. By controlling this degradation, the efficiency may be increased to approximately 17.5°C. Using a cooling approach, we can determine that phase change material reduces temperature by about 15 oC, and that this temperature drop also results in gains in efficiency and fill factor. At 57 oC, the fill factor and efficiency are roughly 73 and 18%, respectively.

Table 4: Characteristic Quantities of Solar Unit after Application of Cooling Process

Sr. No.	I_R	T_P	V_{pmax}	I_{pmax}	P_{max}	V_{oc}	I_{sc}	F. F	η
1	1200	28	29.38 V	8.39 A	214.68 W	37.14 V	8.85 A	0.823	0.249
2	840	58	25.86 V	7.2 A	165.66 W	34.61 V	7.682 A	0.764	0.245
3	840	52.95	26.48 V	7.19 A	162.98 W	36.28 V	7.629 A	0.798	0.256
4	820	47.35	34.4 V	7.08 A	165.71 W	35.4 V	7.583 A	0.776	0.267
5	858	49	36.05 V	7.59 A	175.58 W	38.05 V	7.452 A	0.7673	0.297

4.0 Conclusion

The temperature rises with an open circuit voltage reduction. Even when the panel temperature rises, The previously described results demonstrate that these design advancements have been successfully implemented into consumer goods with efficient cells that are now on the market. To lower the PV panel’s operating temperature, we used phase-change material as a cooling method. This resulted in a variation of about 15 oC and increases in the fill factor and efficiency of 2 and 1 percent, respectively. A significant optical effect was produced by the cell’s enhanced light collection and decreased reflection. These advancements have resulted in a 24.7% increase in silicon cell performance. Phase transition materials were consequently introduced, increasing the overall efficiency of the solar system.

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