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PV Panel Efficiency Improvement Using PCM Cooling Technique

Anurag Shrivastava and Sanket Kansal***

ABSTRACT

The jouissance of thermal range with yield is a disappointing affliction for PV panel behaviour since greater working temperatures reduce the effectiveness of solar panels. This study looks into how a phase change material, RT 35 (Rubitherm), lowers the photovoltaic panel's operating temperature and attempts to keep it at or near ambient temperature. The effect of these material exchangers on working temperature was studied by modelling the dynamical algorithms entangled in the thermal energy transfer of the solar plate in the PCM arena. is investigated. For four different time periods of the day with various levels of irradiation and ambient variables, temperature variation is achieved. Observations will be recorded in order to compare efficiency at 25° C and a standard irradiation of 1000 W / M2.

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

1.0 Introduction

The 1839 discovery of the photovoltaic effect allows for the conversion of solar light into electricity. According to the various light wavelengths, these photons carry varied amounts of energy [1]. A semiconductor of a P-N junction, a solar cell, or the cell itself can reflect or absorb photons. By absorbing the photon in a solar cell, a photovoltaic (PV-) system can be created from a solar cell [2]. A junction produces a voltage that can force current through an external circuit. According to the conservative estimate, India only had about 430 MW of residential solar roofs in 2018, compared to more than 2500 MW in Britain, which accounted for over half of India's total solar electricity. However, over the past 20 years, technology has evolved significantly, with the top cell performance certified at over 24%. These design advancements have been successfully translated in recent years into consumer goods with cells that are currently on the market [3].

First size maximizes the defeatism of cell interconnection and exterior areas while decreasing the sum of highly doped content within the component. Optically, the cell's increased light collection and decreased reflection had a significant impact. These features have increased silicon cell performance by 24.7 percent [4]. These design advancements have been successfully translated in recent years into consumer goods with cells that are currently on the market and have an efficiency of 17–18%. This suggests that relatively thin silicon films, only a micron or two thick, should be able to achieve significant cell efficiencies [5].

**Corresponding author; Assistant Professor, Department of Mechanical Engineering, SR Institute of Management and Technology, Lucknow, Uttar Pradesh, India (E-mail: onuda@rediffmail.com)*
***HXM Practice Partner, DXC Melbourne, Victoria, Australia (E-mail: sanketkansal@yahoo.com)*

Over 90% of the silicone used to make solar cells is crystalline silicone. These design advancements have been successfully translated in recent years into consumer goods with cells that are currently on the market and have efficiency cells are exceptionally efficient, with commercial modules having an efficiency of 12 to 18 percent and laboratory cells having a record efficiency of 24.7 percent [6]. Si molecules that are amorphous have a relatively simple atomic structure. This causes the material to be seriously flawed. A wide recombination of the carrier is caused by a number of slow bonds.

$$\mathbf{V_{OC}} = \frac{kT}{q} \ln\left\{\frac{I_L}{I_0} + 1\right\} \quad \ldots (1)$$

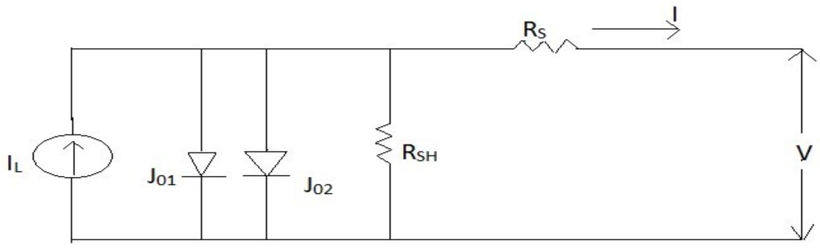
$$\mathbf{I_{Total}} = I_0 \left\{e^{\frac{qV}{kT}} - 1\right\} - I_L \quad \ldots (2)$$

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

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

These design advancements have been successfully translated in recent years into consumer goods with cells that are currently on the market and have an efficiency Making solar cells from thin, crystalline silicone films is one of the most alluring ways to produce durable, low-cost [8] panels. Crystalline silicone is a great material for solar cells and is frequently utilized in thin film technology for a number of reasons [9]. It has demonstrated high and consistent cell quality. A potential substitute for a power system composed of a network of local grid clusters is the development of affordable solar energy [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 % / ^{o}C
8	Temperature Coeff. Of Isc	0.2 % / ^{o}C

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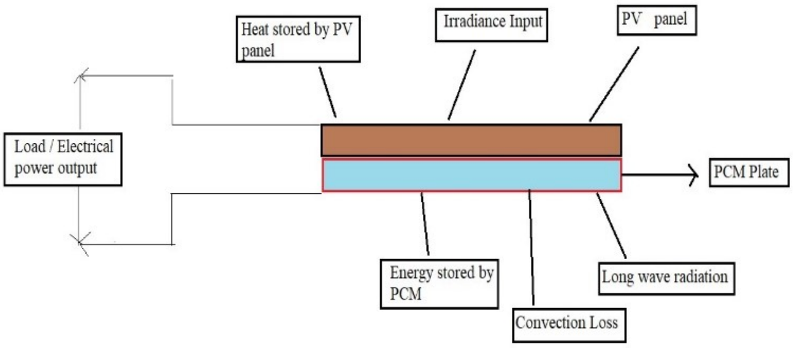
2.0 PCM Cooling Technique

Figure 2: Physical Overview of PCM Material



It is one of the most effective methods for cooling solar PV cells because it keeps PV panels at a fixed temperature for a predetermined amount of time [13]. A material class known as a phase change material, which has a large capacity to store heat, is used in this cooling technology. As a result of this heat storing capacity,

The material undergoes phase transition, changing from a solid to a liquid state [14], however, the device's heating rate won't vary during the conversion. These design advancements have been successfully translated in recent years into consumer goods with cells that are currently on the market and have efficiency cells are exceptionally efficient, with commercial modules having an efficiency at for a specific amount of time, and the operational temperature of the module is now within a range of temperature that is lower than the initial temperature and all other parameters are improving [15]. A coating of RT35 with a thickness of 0.02 m was employed as the phase-change material.

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

$$I_{reff} = \varphi * \alpha \qquad \dots (6)$$

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

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

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

By resolving the aforementioned equation (9) and using MATLAB's SIMULINK model to solve the aforementioned differential equation [16], we can observe how Phase Change Material affects the cell temperature.

3.0 Results and Discussion

Table 2: Change in Temperature After Application of Cooling Technique

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.

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

After adopting a cooling technique, we can conclude that a temperature reduction of roughly 15 oC is achieved with the use of phase change material, and improvements in efficiency and fill factor are also seen for this temperature drop. The fill factor and efficiency for 57 oC are approximately 73 and 18 percent, respectively.

4.0 Conclusion

Temperature increases result in a decrease in open circuit voltage. As we can see from the above-mentioned statistics, this variation indicates that as panel temperature rises, these design advancements have been successfully translated in recent years into consumer goods with cells that are currently on the market and have efficiency. In order to lower the operating temperature of the PV panel, we used phase change material as a cooling strategy. As a result, a variation of roughly 15 ^{o}C was attained, and the fill factor and efficiency were raised by 2 and 1 percent, respectively. Optically, the cell's increased light collection and decreased reflection had a significant impact. These features have increased silicon cell performance by 24.7 percent. Therefore, the use of phase change materials improved the overall photovoltaic system's efficiency.

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