



Feasibility analysis for enhancement of output power of the PV panels by use of PCM (Phase Change Material) based cooling technique

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Abstract

In this paper, analysis has been done to enhance the power output from a regular Solar PV Panel, by placing a layer of PCM (Phase Change Material) behind the back sheet of the Solar PV Panel. The power output (V-I Curve) for a regular Solar PV panel, without any thermal dissipation measures has been presented. Then the mathematical model in MATLAB software is made, which shows the effect of the atmospheric parameters (mostly temperature) on the power output of the PV Panel. Output current and voltage dependence, of a PV Panel, on temperature of that Panel has also been discussed and proved with the help of V-I graph. Hence the positive effect of applying the PCM layer on PV Panel is calculated in terms of power output increase, by increase in thermal dissipation, by the use of MATLAB/Simulink Model.

Keywords

Enhancement of Power Output, Thermal dissipation, Mathematical Model.

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1. Introduction

With the depletion of Non-Renewable sources of energy, and the negative impacts caused by the same, the world is in desperate need to produce energy through the renewable sources on large scale. The most trending renewable sources of energy known to us are Hydro-energy, solar-energy and wind-energy. Generation of solar energy has massive scope in India. The geographical location of the India stands to benefit it for generating solar energy. The reason being India is a tropical country receiving solar radiation throughout the year, which amounts to 3,000 hours of sunlight. This is equal to

5,000 trillion kWh energy (approx.). Almost every parts of India receive 4-7 kWh of solar radiation per square meters. This is equal to 2,300–3,200 sunlight hours per year [1].

The Output voltage and current of the PV Panel also depends upon the atmospheric factors like temperature and wind. For our research work we have neglected the effect of wind as it is negligible in comparison to the effect of temperature.

Effect of Temperature on Output Power of the Solar Photovoltaic Module

Solar cells perform better in cold climate rather than in hot. Panels are rated at 25°C which can be different from the real outdoor situation. For each degree rise in temperature above 25°C panel output decays by about 0.25% (approx.) for amorphous cells and about 0.4-0.5% (approx.) for crystalline cells. Hence, in hot summer days PV panel temperature can reach 70°C or more. Which means that the panels will put up to 25% less power as compared to what they are rated at 25°C. Thus a 100W panel will produce 75W in May/June in most parts of India where temperature reaches 45°C and beyond in summer [2].

Cooling Techniques to Increase Efficiency of SPVM

Various cooling methods have been employed to increase the efficiency of the solar panels.

Generally, cooling methods can be broadly classified under two categories: Active Cooling, which utilise energy (pump, fan, etc.) and Passive Cooling, which utilize natural convection/conduction to extract heat from the system. Most of the cooling methods today make use of Active water and air cooling, as these are the simplest techniques employed for cooling. However, Passive cooling methods are self-operating, more reliable and more economic than active cooling methods. This is because of the absence of any moving parts. It can be divided into three main groups: Air or Water passive cooling, and Conductive cooling. The main disadvantage of Active thermal cooling is that it requires electricity and hence results in higher costs, as compared to passive cooling. Passive thermal cooling does not require any mechanical heating device and are Environmental friendly. Their cost of operation is also low and they help in storing natural energy resources without any pollution as they do not produce any greenhouse gases while operating.

Use of Phase Changing Material (PCM) based Solar PV Modules

A **phase change material (PCM)** is a substance with a high heat of fusion, having a specific melting and solidifying temperature. Large amount of energy can be stored and released with the help of PCM.

Cooling the PV panels with Phase Changing Material (PCM) is preferable because it does not need any additional energy for cooling. Ideal PCM for cooling PV panel should have high latent heat of fusion, high thermal conductivity, and should be chemically stable, non-corrosive, non-toxic, melt temperature lying in the operating temperature of the PV panel and minimum sub cooling. One of the most important tasks is to ensure high thermal conductivity of PCM [3].

With the removal of the excess heat out of the PV panel we can achieve lower temperature of the PV cell and higher production of electricity.

This work will be focusing on the temperature reduction of PV modules, through the use of a phase change material (PCM) for storing thermal energy, with the advantage of having a much higher heat capacity than the conventional heat storage methods, particularly due to high latent heat of fusion during melting. This allows a more compact cooling system in terms of heat storage, thermal mass and volumetric storage. This objective of this study is to attain the PV Panel power output enhancement by the use of PCM based PV Panels with higher thermal dissipation capacity.

2. Mathematical Model (of a PV Module)

We have modelled a Solar PV Module in Matlab, which shows the dependence of Output Current and Voltage on Panel Temperature. With the help of Simulink Model, we have traced the V-I characteristics of a PV Panel, at different temperatures. The characteristics which are to be traced have two important parameters, one is Short circuit current (I_{SC}) and the other is Open circuit voltage (V_{OC}).

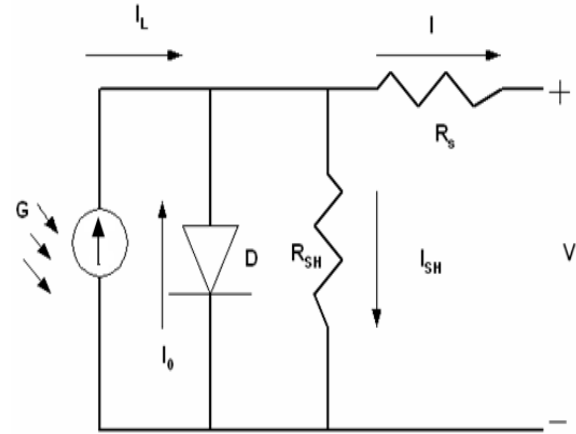


Figure 1. Circuit diagram of PV module

Exponential equations for circuit diagram of the PV model [4]:

$$k = 1,38 \times 10^{-23} \text{ J/K};$$

$$T_R = 300^\circ \text{ K};$$

T – Photovoltaic panel temperature;

V – Imposed Voltage (V);

I_{SCR} – Short circuit current;

I_O – Dark saturation current, Shows temperature dependency (Amp.);

I_{OR} – Saturation current;

K – Short circuit temperature coefficient; 0,0017 (Amp./°C);

C – Solar irradiance (Watt/m²);

R_S – Series resistance of cell (in ohms);

R_{SH} – Shunt resistance of cell (in ohms).

For generating the highest power output at a given irradiance and temperature, the operating point should such correspond to the maximum of the (V-I) curve.

$$I = I_p - I_o \left[\exp \left(\frac{q(V + IR_s)}{nkT} \right) - 1 \right] - \frac{q(V + IR_s)}{R_{sh}} \quad (2.1)$$



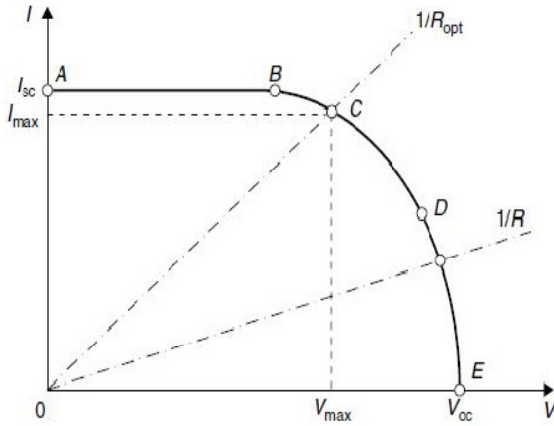


Figure 2. Representative current-voltage curve for photovoltaic cells

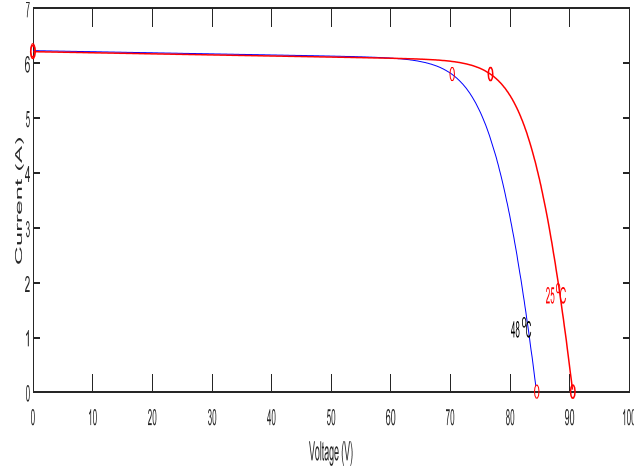


Figure 5. I-V curve obtained from Model.

$$V = \frac{kT}{q} \ln \left(\frac{I_p}{I_o} + 1 \right) \quad (2.2)$$

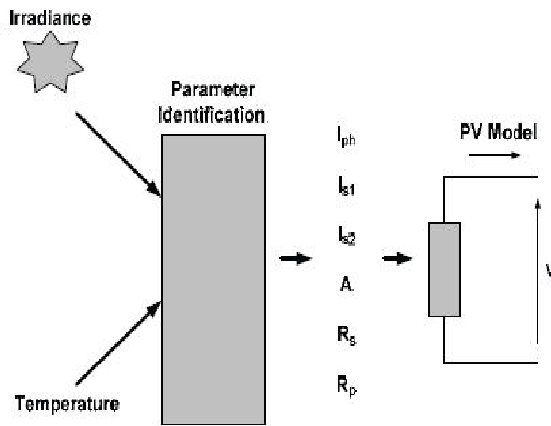


Figure 3. Modelling of a PV panel.

3. Simulink Model

The following is the Simulink model of basic circuit of PV module.

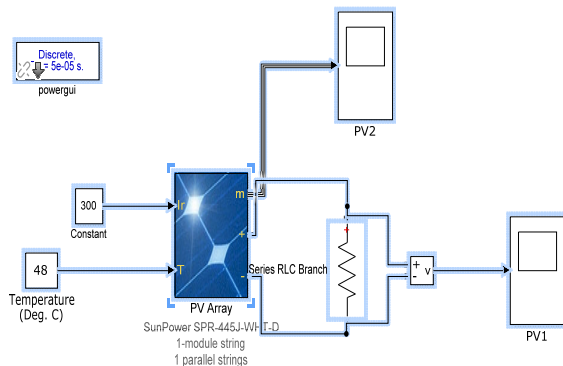


Figure 4. Simulink Model of PV module.

Here, from these curves we can see the change in output power when temperature is decreased.

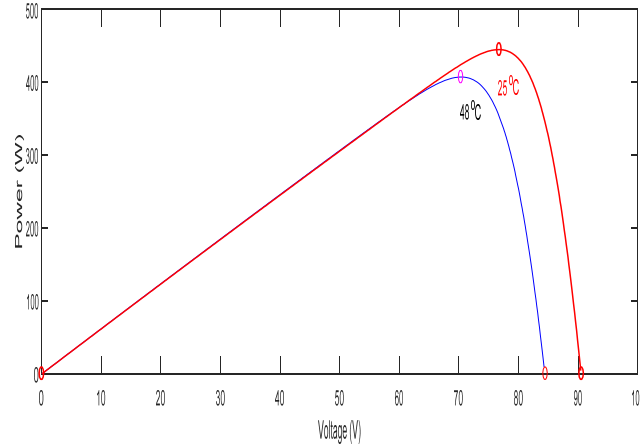


Figure 6

Figure 6 is showing the temperature dependence of P-V curve ranging from 25°C TO 48°C.

4. Conclusion

An accurate photovoltaic module electrical model is presented and demonstrated in MatLab/Simulink for a typical SunPower SPR-445J-WHT-D photovoltaic panel. Such a simple PV model can be easily simulated in MatLab/Simulink modelling and simulation platform. Especially, SimPower System tool in MATLAB, now we have a basic PV module which can be used for all solar power analysis. Given solar irradiance to be constant we have observed the effect of panel temperature on output current and voltage. The model returns the I-V and P-V graphs. It is observed that increase in temperature decreases efficiency of the panel. So, we have used a Phase Changing Material (PCM) which is a passive cooling technique. It reduces the panel temperature and thereby increases its efficiency. It is seen that an increase of almost 14%



can be obtained by the above mentioned technique. Therefore, simulation results show that a photovoltaic panel output power increases as module temperature decreases.

Hence, in India, this technique can be employed on industrial scale to increase the power output of the Solar Plant.

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