Abstract

With the increase in surface temperature of solar cells or panels their efficiency decreases quite dramatically. To overcome the heating of solar cell surface, water top cooling technique can be used i.e. it can be placed on top of water so as to maintain its surface temperature and provide better efficiency at extreme temperatures. In this study, electrical parameters of solar cell were calculated and were observed that the cooling factor plays an important role in the electrical efficiency enhancement. Three conditions are provided for testing the solar panels at a time and analyses the temperature dependency of solar panel. (i) Roof top solar panel (ii) Floating type solar panel and (iii) Water top solar panel.

1. Introduction

Hitherto, many studies have been carried out on the cooling PV systems. Heat generated in the solar panels is one of the main issues that lead to a reduced efficiency. Many remedial measures have been proposed to overcome this issue. One significant method to overcome the heat generated in the PV module is to submerge the photovoltaic module over the water surface. But such a method may cause damage to the panel body. Another method of cooling the panel [1] by replacing the front glass
surface with a thin film of water running over the face of the panel was suggested by Krauter. Due to the presence of glass covering over the panel reflective losses may occur, which may vary from 7-15%. The water layer cause reduction of temperature up to 22 °C so that the efficiency of panel increases by 10%.

Meneses-Rodriguez et al.[2] investigated a novel method to improve the electrical efficiency with cooling. The authors explored the benefits of running PV cells at near their maximum theoretical temperatures (100-170 °C). Theoretically, the electrical efficiency can be in the range 10-16%. With a sink temperature of 30 °C, the authors estimate a theoretical total efficiency greater than 30%. Under concentrated illumination, Royne et al. [3] proposed a PV cooling methodologies, provide a set of requirements for cooling techniques, e.g. it is desirable for the temperature to be uniform across the cells during the cooling for its maximum electrical output. Also, the operating temperature does not exceed the point at which irreversible degradation occurs in the cell. The cooling method need to ensure that.

Another method for cooling the solar PV system is to use gases. Experiments using 7 different gases for cooling the PV/thermal system were performed by Gardas and Tendolkar [5] and were found that hydrogen was the best gas to maximise the power output of the system. A study on air cooling system for PV application was done by Toe et al [6] studied and found out an increase the PV efficiency from (7-8%) to (12-14%). Chinamhora et al [7] proposed a water cooling system which placed on the front and back of PV module and found that efficiency increased on clear days and not effective during cloudy days. A work on combined photo voltaic and thermal solar panels was presented by Asachi [8]-[12]. This work reduce the heat produced by PV system and also enhanced the energy output of PV and thermal collector. The present work suggests an economical topology for improving the efficiency of solar panel by utilizing the humidity at the bottom of the panel.

In this work the temperature dependency of solar panel is experimentally verified. Figure 1(a) shows the panel over the water body, where the water vapours will get deposited at the lower side of panel and the effective temperature of panel reduces. Figure 1(b) shows the panel placed on the normal way.

From the results it is very much clear that the power from the panel over the water body is greater than the panel over the normal surface.

Figure 1(a): PV panel over water body

Figure 1(b): PV panel over normal surface
2. Modelling Of Solar Panel

A Solar panel has been simulated in MATLAB/SimScape and is discussed in this section [13]. Twenty solar cells are connected in series to form a string which acts as a module. Each cell having an open circuit voltage $V_{oc} = 0.9$ V and short circuit current $I_{sc} = 0.63$ A. The combination of such modules forms a solar panel. A number of panels interconnected forms solar array, of maximum power 39.2 W at $V_m = 65.6$ V and $I_m = 0.59$ A. In order to create partial shading effect using Simulink, a diode is connected in antiparallel to each cell. This is done to avoid avalanche breakdown which would create hot spots on the solar cell which may lead to the damage of entire solar cell.

At a standard irradiance condition of 1000W/m$^2$ the solar cell produces rated power which can be observed from volt-current and volt-power characteristics. Fig.2 shows the solar cell modelling for partial shading conditions.

The irradiance value can be changed manually and the corresponding variation in irradiance can be seen. As the irradiance value decreases from 1000W/m$^2$ the panel voltage and current also reduces considerably which further results in the reduction of panel power output. In order to overcome this condition, modified maximum power point tracking method as explained in this paper can be used to track available maximum power from the panel. Fig.3 shows the Simulink model of the solar panel under partial shading conditions.

Figure 2: Modelling of solar cell for partial shading condition
Figure 3: Sim-Scape model of solar panel

Fig. 4 shows the Power - Voltage characteristics under normal irradiation conditions (1000W/m²) without partial shading. The magnitude of voltage (V_M) corresponding to maximum power (P_M) is also shown.

Figure 4: Power-voltage curve under 1000 W/m²

The Current-Voltage characteristics of the designed panel are shown in Fig. 5 at 1000W/m². Current and voltage magnitudes corresponding to maximum power is represented as I_M and V_M respectively.

Figure 5: Current-voltage curve under 1000 W/m²
3. Temperature Dependency of Solar Cell

When a solar cell is heated, it becomes less efficient. The amount of energy a solar panel can produce depends on its efficiency. The efficiency is determined by comparing how much power the solar cell produces to the amount of light that shines on it. This is measured by illuminating the solar cell with a calibrated light and measuring the current produced at different voltages. This measurement gives us current as a function of voltage which we can plot on a graph.

<table>
<thead>
<tr>
<th>Table 1: Symbols</th>
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<tbody>
<tr>
<td>Symbol</td>
<td>Quantity</td>
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<tr>
<td>P</td>
<td>Power</td>
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<tr>
<td>J</td>
<td>Current</td>
</tr>
<tr>
<td>V</td>
<td>Voltage</td>
</tr>
<tr>
<td>P_{in}</td>
<td>Power incident on cell</td>
</tr>
<tr>
<td>J_{max}</td>
<td>Current at maximum power</td>
</tr>
<tr>
<td>V_{max}</td>
<td>Voltage at maximum power</td>
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<tr>
<td>V_{oc}</td>
<td>Open circuit Voltage</td>
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<tr>
<td>J_{sc}</td>
<td>Short circuit current</td>
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<td>η</td>
<td>Efficiency</td>
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<td>FF</td>
<td>Fill Factor</td>
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</table>

The power produced by a solar cell is calculated from the current and voltage with the following equation.

\[ P = JV \]  

Where,  
P is the power produced  
J is the current and  
V is the voltage.

Somewhere along the current-voltage curve the power, P, will have a maximum value. This point is called the maximum power point and it is where we calculate the efficiency. The efficiency is given by

\[ \eta = \frac{J_{\text{max}} \cdot V_{\text{max}}}{P_{\text{in}}} \]  

Where is the efficiency \( J_{\text{max}} \) is the current at the maximum power point, \( V_{\text{max}} \) is the voltage at the maximum power point and \( P_{\text{in}} \) is the power incident on the solar cell (the power from the light shining on it). This can also be written as

\[ \eta = \frac{J_{\text{sc}} \cdot V_{\text{oc}} \cdot FF}{P_{\text{in}}} \]  

where,  
\( J_{\text{sc}} \) is the current at short circuit (when \( V = 0 \))  
\( V_{\text{oc}} \) is the voltage at open circuit (when \( J = 0 \)) and FF is the Fill factor which describes how "square" the current-voltage curve is. It is the ratio between the two rectangles drawn in the figure. When the solar cell is heated, the current,
\( J_{SC} \) will increase, but the voltage, \( V_{OC} \), will decrease. Since the voltage decreases faster than the current increases, the result is that the overall efficiency goes down.

\[
\eta \downarrow = \frac{J_{SC} \uparrow V_{OC} \downarrow FF}{P_{OUT}}
\]  

(4)

4. Experimental Setup

The experiment set up of the research work has been shown in Fig.6. Where solar panel tested in different conditions such as over an artificial water tank or the experiment made for specifically and simply rooftop. The panel is placed over the water body and the water is in contact with lower part of panel in Latitude: 10° 00' N. The temperature sensor is shown in Fig.7, where the temperature over the panel has been measured.

![Figure 6: Experimental setup](image)

Table 2: Comparison Between Panel Characteristics Under Two Different Temperature Conditions

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<tr>
<th>SL.No</th>
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The experiment set up of the research work has been shown in Fig.6. Where solar panel tested in different conditions such as over an artificial water tank or the experiment made for specifically and simply rooftop. The panel is placed over the water body and the water is in contact with lower part of panel in Latitude: 10° 00’ N. The temperature sensor is shown in Fig.7, where the temperature over the panel has been measured.

Two 100 W PV panel having $V_{oc} = 22$ V and $I_{sc} = 6.56$ A has been used for this experiment. The temperature on the solar panels that is the top surface of the panels and bottom surface of the panels have been measured along with each reading. From the readings we can see that the temperature of the panel placed over the water body is less than that of normal surface. The performance of solar panel changes under these conditions and the panel power increased considerably. The table 2 shows the open circuit voltages, short circuit currents, panel temperature and power output of solar panel when placed over the water body and placed over normal surface respectively.

From the table we can see that over 9% of increase has been achieved while placing the panel over water body. Thus by the experiments we can see that the panel temperature reduces by placing it over a water body or if there is a contact between water and panel surface. by placing the panel over the water body the water vapours collected at the inner panel surface and collect the higher temperature of the panel. As a result the net temperature of the panel reduces slightly. The reduction of temperature reflects the measurement results considerably and attained an increased power output from the cooler panel.
5. Conclusion

The proposed methodology proves to be economical and energy efficient when compared to conventional methods. Experimental results clearly show the temperature dependency of solar cells. Performances of both conventional and water top solar panels were analyzed and results prove that the power output of solar panels are improved when kept atop water bodies. This method gives way for a simple but efficient method to harness maximum solar energy.

Acknowledgement

The authors wish to thank Chairman Prof. C K Renjan, staff and management of SNGIST, teaching and non-teaching staff of Electrical department and the family members for the guidance, motivation and support in carrying out this work.

References

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