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ENHANCING THE PERFORMANCE OF PHOTOVOLTAIC PANELS BY STATIONARY COOLING

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ABSTRACT

The photovoltaic cells will exhibit long-term degradation if the temperature exceeds a certain limit thereby decreasing the PV power in general and the efficiency of the said system in particular. This decrease is resulted first of all in dropping the open circuit cell voltage. The cell manufacturer generally specifies a temperature degradation coefficient & a maximum operating temperature for the cell. The cost of photovoltaic installation is mostly dependent on the PV array area. Therefore, in order to improve the cost effectiveness of the PV array power system, electric power generated by the PV array should be efficiently utilized. The purpose of this study is to improve the performance of a photovoltaic Panel by attaching a cooling system on the backside of the PV panel. The results are compared with Conventional systems. Experimental measurements for both with & without cooling system indicate that the Current developed by the photovoltaic panel with cooling system is higher as compared to the conventional panel. Also the power & the electrical efficiency of the combined system are higher than the traditional one.

Index Terms: *Photovoltaic panel, Stationary cooling, Conventional panel, Temperature senor etc.*

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Nomenclature

P_i = Input Power in W
I_s = Solar radiation in W/m^2
A_c = Effective module cell area in m^2
P_o = Photovoltaic array output power in W
V = D.C. output voltage in Voltage (V)
I = D.C. output operating current in A
E_a= Panel efficiency

1. INTRODUCTION

Solar energy is one of the most powerful energy in the world. Almost all the renewable energy sources such as geothermal, tidal and wind energy originate entirely from the sun. There are many different applications that change the form of solar energy into other types. Solar cell or photovoltaic (PV) is the tool that transforms solar energy into electrical energy.

Photovoltaic cells are semiconductor devices that convert the sunlight into electricity. Photons below a threshold wavelength have enough energy to break an electron hole bond in semiconductor crystal, which in turn can drive a current in the circuit. The solar radiation consists of photons at a range of wavelengths and corresponding energies. Photons with wavelengths above the threshold are converted into heat in the PV cells. This waste heat must be dissipated efficiently in order to avoid excessive high temperatures, which have an adverse effect on the electrical performance of the cell.

It is well known that the efficiency of photovoltaic solar cells decreases with an increase in temperature. This decrease is resulted first of all in dropping the open circuit cell voltage. The cell manufacturer generally specifies a temperature degradation coefficient and a maximum operating temperature for the cell. The cost of photovoltaic installations is mostly dependent on the PVarray area. Therefore, in order to improve the cost effectiveness of PV array powered systems, electric power generated by the PV array should be efficiently utilized. Krauter [1] used a method of reducing reflection with a thin (1 mm) film of water running over the face of the panel. The improved optics and cell temperatures increased electrical yield 10.3% over the day (8-9% after accounting for pumping energy). In order to enhance the heat transfer from the PV module, thereby effectively reducing the operating temperature and improving the efficiency of the PV module, Abdolzadeh and Ameri [2] improved the performance of a photovoltaic water pumping system by spraying water over the top surface of PV array experimentally. They pointed out that the efficiency of a photovoltaic water pump system can be increased due to spraying water over the front of PV array. Furushima and Nawata [3] evaluated the performance of PV- power generation system equipped with cooling device utilizing siphonage. The study showed that the cooling of the PV modules increased the electrical power output and produced hot water which could be for heating purposes thereby contributing an energy efficient system. Teo et al. [4] studied hybrid PV/T solar system experimentally & used air to extract heat from the PV module rare surface. They pointed out with an active cooling; temperature dropped significantly leading to an increase in efficiency of solar cells to between 12% and 14%. Hosseini et al. [5] conducted an experimental study to compare the performance of a PV system combined with a cooling system consisting of a thin film of water running on the top surface of the panel with an additional system to use the hot water produced by the system. The results indicated that the combined system yielded higher power output and electrical efficiency and lower module temperature and reflection losses compared to conventional PV system. Gang et al. [6] experimentally studied the performance of a novel heat pipe photovoltaic/ thermal system and validated the model output with measured data. The experimental results showed an improvement in the system efficiency with cooling with water circulation.

The purposed study aims to investigate the possibility of improving the performance of a photovoltaic cell by attaching the cooling system to the backside of the PV panel.

2. SYSTEM DESCRIPTION & DATA COLLECTION

This experimental set-up was designed to investigate how the temperature affects the efficiency and power output of PV panel during operation. Figure 2.1 shows the experimental setup, composed of two similar but separate PV solar photovoltaic panels each with area of 0.351 m^2. The maximum output voltage and current are 17.7V, 2.09A respectively and with maximum power output of 37W at irradiance of 1000 w/m^2 and cell temperature of 25°C. One of the panel is modified by attaching the small water bags at the backside of the panel. The other panel is a conventional PV as a reference panel. The photovoltaic panels are positioned east west.

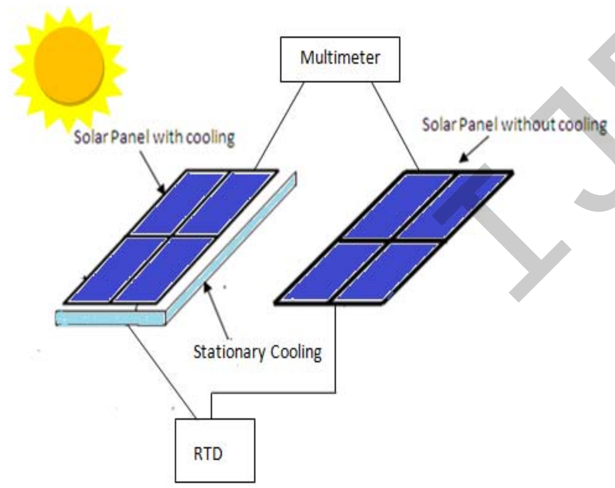

Figure: 2.1 Schematic diagram of experimental setup

The panels tilt angle are set to 21 deg with respect to the horizontal, which is the local latitude of Nagpur (Latitude 21.1500° N, Longitude 79.0900° E), India, so as to face in the south direction. Sensors (model PT100) were installed at the top & back side of both the PV panel in order to measure the photovoltaic panels' temperature. Also current & voltage were measured by Omega type multimeter. The experiments were conducted from 9.00 am to 3.00 pm for 15 days & recorded the data for every 5 min.

Figure: 2.2: Experimental setup (consists of Panel with cooling & without cooling)

Figure: 2.3: Panel with Stationary cooling (water bags)

2.1 Mathematical Methodology

Incident solar radiation on the PV panel gives the input power (in W) to the system which is given by

$P_i = I_s \times A_c$

The D.C. output power from the PV panel is given by

$P_o = V \times I$

Panel efficiency (E_a) is the measure of how efficient the PV panel is in converting sunlight to electricity.

$E_a = P_o / P_i$ **[7]**

3. RESULT & DISCUSSION

Solar PV panel with stationary cooling & without cooling were constructed in order to determine the system that will produce the higher power output. They were both placed in the sun close to each other to have the same sky condition as practicable enough. Readings were taken on both the systems simultaneously for comparison. The effect of the stationary cooling on the power generation of photovoltaic panels is investigated.

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Figure 4.1 shows the effect of the stationary cooling on PV panel's output power. The average output power for PV panels with cooling is 40.35 W and the average output power for the PV panels without cooling is 35.77 W. Therefore, one can see 13% improvement in power generation for the case of using PV Panel with cooling. The improvement was peak from 11:00A.M. to 1:00PM.

Figure 4.2 shows how the application of stationary cooling increases the photovoltaic cell temperature. The maximum temperatures for the PV array without cooling & with cooling are 70 °C, and 79 °C, respectively. As it can be seen from experimental results, the maximum module temperature equipped with stationary cooling is always higher than the conventional module temperature. However, it is obvious that the operation module temperature with stationary cooling is always below the maximum working temperature defined by the module manufacturer (90°C) so this temperature rise is supposed to be not harmful to generation characteristics. It is clear that the temperature of the PV panels increases consequently due to the increased incident solar radiation & constant mass attached at the backside of the panel. It is well known that, increasing PV panel temperature will result in decreasing panel power output. However, results shows that stationary cooling, leads to increases the PV panel output power. Therefore it is evident that the positive effect of stationary cooling is more sensible than the negative effect due to rising panel temperature.

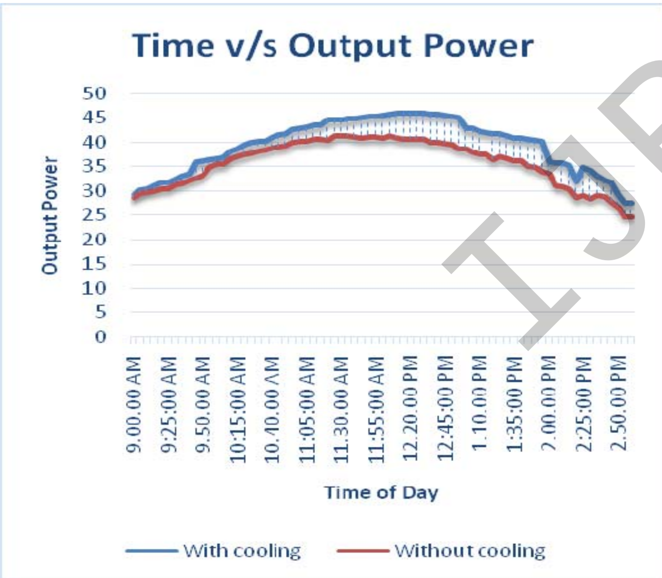

Figure: 4.1: Comparison of module output power with and without cooling during the test day.

Variation of output voltage and current of the system affected by the stationary cooling are presented in Figure 4.3 & 4.4. It can be seen in Figure 4.3 & 4.4 that due to the use of stationary cooling, voltage begins to drop but the current increases. This reduction of output voltage was due to rising the operating PV cells temperature. Experimental results indicate that the current of the panels which is temperature independent, increases due to the light intensity increases. The output power of a solar cell is dependent on both irradiance and cell temperature. The increase of radiation on the PV module leads to increase the temperature of water bags, which further increases the temperature of the panel more than the temperature of conventional panel, which is its largest disadvantage of using PV modules with stationary cooling. However, results show that the positive effect of stationary cooling on the photovoltaic panel performance is more than the negative effect due to increase in panel temperature.

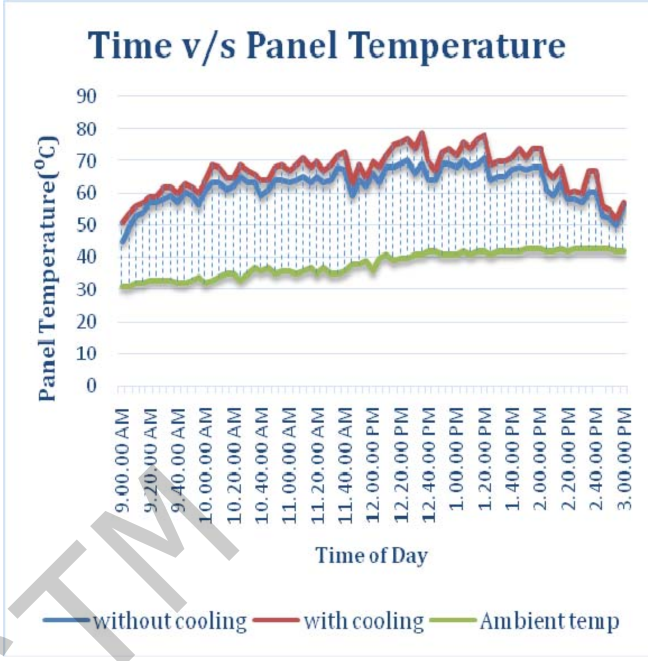

Figure: 4.2: Comparison of module temperature with and without cooling during the test day.

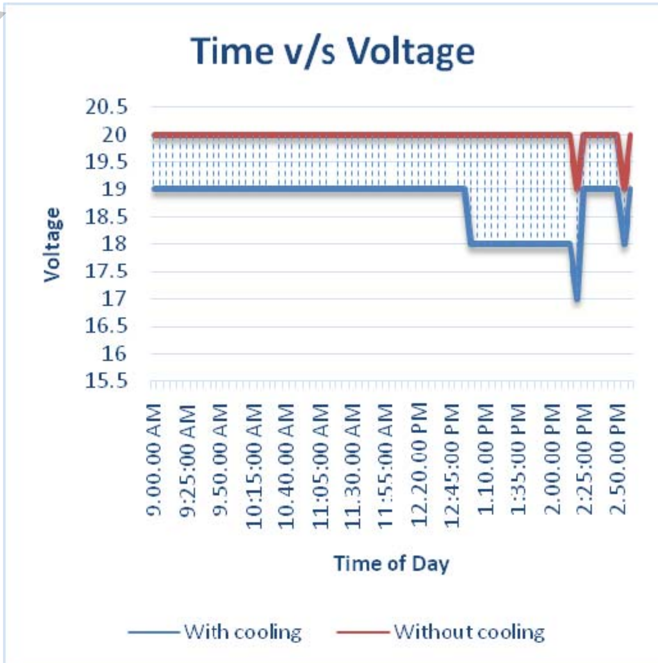

Figure: 4.3: Variation of module Voltage with and without cooling during the test day.

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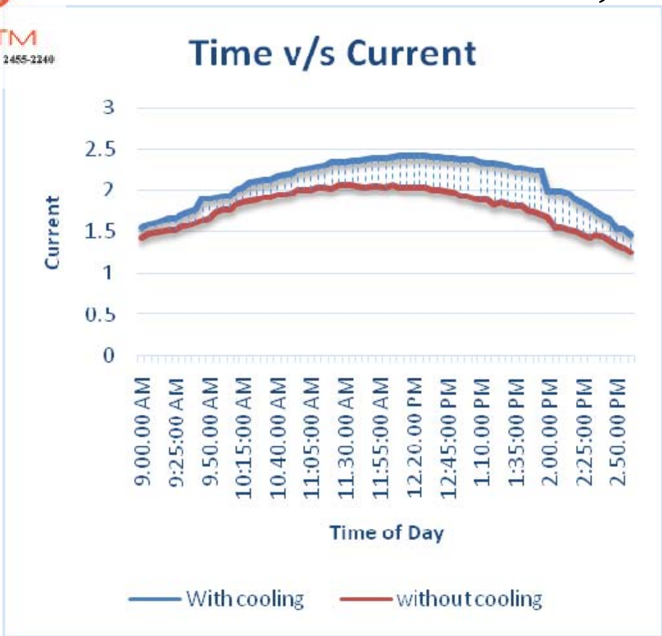

Figure: 4.4: Variation of module Current with and without cooling during the test day.

4. CONCLUSION

The described tests in this paper show that the output power from photovoltaic cells with stationary cooling is higher than without cooling. It is shown that, by attaching the water bags at the backside of the panel increases the temperature of the panel which decreases the voltage but increases the current of the panel and consequently increases power output of the panel. The research indicates that the operation module temperature with stationary cooling is always below the maximum working temperature defined by the module manufacturers; so this temperature rise is supposed to be not harmful to generation characteristics.

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