

Effect of Water Cooling on the Energy Conversion Efficiency of PV Cell

Saira Iqbal^a, Samia Afzal^b, Atta Ullah Mazhar^{c*}, Hazeema Anjum^d, Anab
Diyyan^e

^{a,b,c,d,e}*Mechanical Engineering Department, NFC Institute of Engineering & Fertilizer Research, Faisalabad,
Pakistan*

^a*Email: atta_mazhar@yahoo.com*

Abstract

By receiving the solar irradiance, the photovoltaic solar cell generates electricity. During the absorption of solar radiations, there is a considerable increase in cell operating temperature, that effect upon the electrical efficiency of photovoltaic (PV) cell. On the back side of PV panel, water absorption sponge is fixed, the adverse effect can be avoided and wet condition is maintained with the help of passage of water by wipe. Main purpose of this effort is to increase the electrical conversion efficiency by reducing the solar cell's temperature. Experiments were performed in order to observe the effect of cooling on the efficiency of PV solar cell. It was found that there is a linear relationship between temperature and efficiency of the PV module. From the statistical data it was found that the water cooling drops the temperature of PV panel by 4-5°C, which significantly increase the efficiency from 7 to 12%.

Keywords: Water Absorption Sponge; Energy conversion efficiency; Water cooling.

1. Introduction

An option asset for force era is required other than the utilization of fossil fuels, water and wind due to the reason that world is facing many problems like deficiency of energy and energy resources, global warming and environment detraction. In future, there will be no fossil fuel because they are limited, annual rain fall is basic source of hydro power plant and climate changes also effect on wind power. For interchange energy source solar energy is also used as a compatible candidate. For the sake of infinite source of energy, solar energy is also used. Deflected power by the earth from the Sun is about 1.8×10^{11} MW which is greater than the utilization rate from all the viable energy resources that is present on earth. All the present and the future needs can be fulfill by

the solar energy. This is the reason that it is one of the most arising source of the nonconventional energy sources[1-4].The machine that changes over the energy specifically from the Sunlight to electrical energy by utilizing the procedure of photovoltaic is called PV cells. **Charles Fritts** was the first person who built the solar cell, by using a thin layer of gold with the junction of coating selenium (semiconductor), in 1883.A slender film that was intermediate between two layers was formed in 2009. Perfect change in effectiveness is in the scope of 15% of a typical Photo voltaic module. The operating temperature of PV system is raised by using the heat and this heat is transformed from the resting energy. The efficiency and the power rate of photovoltaic modules is affected by it and it can also be the cause of structural distortion of the photo voltaic cells that lowers its conversion efficiency and shorting its life range. The increase in temperature cause the decrease in output power of PV module. When we used a silicon series solar cell, the photovoltaic cell's temperature is 80⁰C normally. The temperature of a cell effects on its efficiency. The conversion efficiency of PV module reduced from 0.2-0.5% by increase in temperature of 1K. Air and water both are reasonable to cool the PV module keeping in mind the end goal to maintain a strategic distance from the drop of electrical proficiency [7-12]. photovoltaic cell's working depends not only upon the maximum power, maximum power voltage, open circuit voltage, maximum power current, short circuit voltage, tolerance related value %,but also negatively affected by angle of irradiance, shading, dust storms, relative humidity, suspension in air and ambient temperature[13,14]. The improvement of PV/T system is stimulated by several obstacles. The main aspect is that the higher efficiency can be provided by the PV/T system instead of Thermal collector system and a PV cell. With expanded the effectiveness, the benefit time of the framework can additionally be abbreviate [15]. To investigate a proficient innovation by the examination of working of PV cells with the help of various technologies and cooling tower, many efforts have done. By using water as a coolant solar panel's back is cooled in this technology. The focal point of this study is to observe the effect of water cooling of the panel on its efficiency and compare it with that of without cooling.

2. Methodology

To consider and determine the facts regarding materials and methods a test was conducted with a polycrystalline solar panel (solar) having 36 x 27 cm² of area. **Table 1** shows the characteristics of the solar panel. The setup thus formed for carrying out the experiments consisted of 12 W solar panel with power rating, 12V battery, Voltmeter, Ammeter, Solar lamp and Cooling system. A view of the entire setup is given below in **Figure1**. Following are the components of a cooling system; Water cane (5 liters), hose with a knob to regulate the flow, a sponge which absorbs the water and a pipe used for water collection.

The circuit is established by connecting the voltmeter with the solar panel along with the ammeter. Discharge of battery is made possible with the help of an 8 W bulb. For better performance the solar panel is tilted at an angle of 45 degree on relatively higher stand preferably of 3 feet height. The voltmeter used had a range of 0-50V and the ammeter used had a range of 0-10A. Load job was done by a bulb. In order to measure the intensity of solar radiation, a device named pyranometer was used. For the purpose of monitoring temperatures of ambience, water and solar panels, thermometers were used of digital nature. First and foremost of all is the providence of water done through water cane wherefrom the water goes into the sponge via hose. Knob serves as a flow controller. To achieve complete success and best performance the system was placed towards the western

direction to gain direct sunlight and to cater for humid winds, during late afternoon. (Real experiment timings and flow to be mentioned). Similarity in weather conditions served as a positive factor for gaining accurate results.

Table 1: Specifications of PV module used in the experimentations.

Peak Power	12 W
Type	Poly-Crystalline
Open Circuit Voltage	21.3
Maximum Power Voltage	17.5
Maximum Power Current	0.68A
Operating Temperature	-40°C to 85°C
Number of cells	36
Dimensions	32 x 27

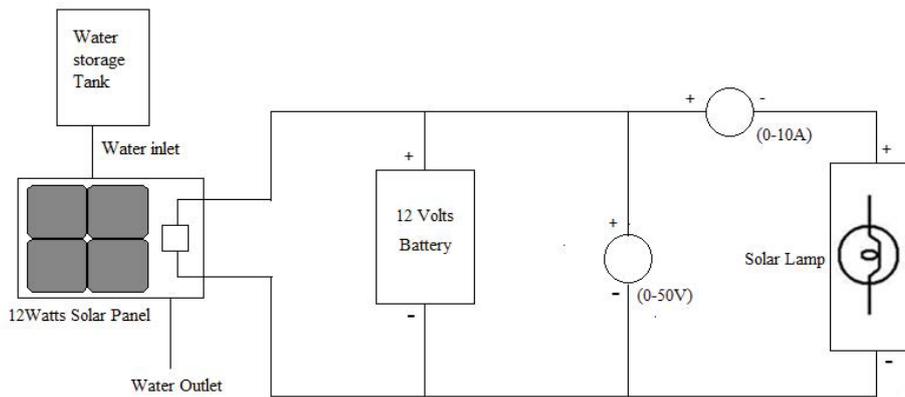


Figure 1: Output characteristics test system of solar panels with water cooling.

3. Result and discussions

The output power i.e. readings of both the measuring devices (voltmeter and ammeter) was measured to calculate the conversion efficiency of PV panel. Temperature along the surface of the panel and real time solar radiation intensity. Ambience temperature, water flow temperature at inlet and outlet as well as the water flow was also measured .the conversion efficiency of photoelectric module can be calculated as:

$$\eta = P_{\max} / A * I$$

Here η shows the energy conversion efficiency %. P_{\max} is the maximum amount of power output of the PV panel. A (m^2) is the active area of panel under test. “ I ” is the amount of solar irradiance which is incident over the solar panel. With the help of ammeter and voltmeter readings, we can estimate the maximum power generated.

$$\eta_e = [1 - \beta (T_c - T_o)] \tag{1}$$

$$\eta_e = \int VI dtAc \tag{2}$$

The following equation describes the electrical efficiency of a PV module.

$$\eta_o = Vmp ImpG \tag{3}$$

The thermal efficiency of the panel can be calculated by the equation

$$\eta_{th} = m \cdot Cp \int (T_{out} - T_{in}) dtAc \tag{4}$$

Following equation gives the total efficiency of a hybrid PV/T system.

$$\eta_{total} = \eta_{th} + \eta_e = m \cdot Cp \int (T_{out} - T_{in}) dt + \int VI dtAc \tag{5}$$

In equations (1) and (4) the electrical and thermal efficiencies are described.

The expressions formed disclose that solar irradiation and the factors which are influenced by it such as PV current, PV voltage and the temperatures at inlet and outlet are all proved to be functions of time, integrating the equation with time. **Figure 2** shows the variation of peak efficiency of PV cell with the change in mass flow rate of water in Lit/hr. Figure clearly depicts that flow rate beyond 2 lit/hour causes a drag to the peak efficiency of the panel.

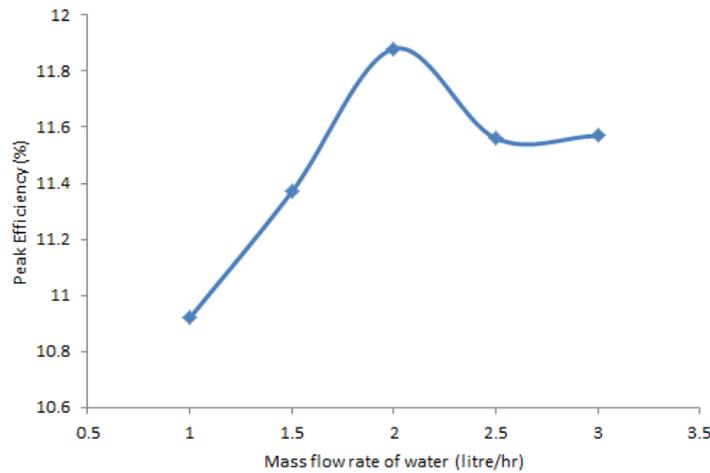


Figure 2: Peak efficiency of solar panel against mass flow rate of water.

The distinguishing result among the solar panels with and without cooling is given in **Figure (3) - (5)** revealing the fact about average air temperatures and Intensity of radiations. The maximal and average wind speeds are (readings). Comparison between temperatures of solar panels is given in **Figure (3)**. It has been made obvious that temperature with water cooling reduces by 4°C keeping the flow rate at 2 liters /hour. Averagely by 1.7°C as compared to panel without cooling.

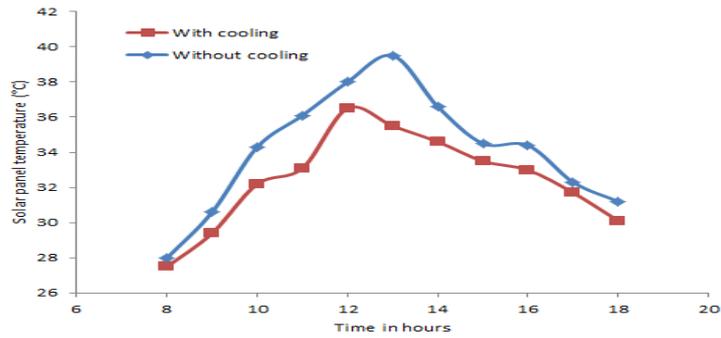


Figure 3: Comparisons on solar panel temperature between cooling and without cooling.

Comparison of power output is given in **Figure (4)**, as irregular trend is followed by power output i.e. it abruptly decreases after certain point. In between **12:00 and 13:00 hrs**, the power output gives away its maximum value and this value with cooling becomes **6.4%** at maximum and **4.3%** averagely.

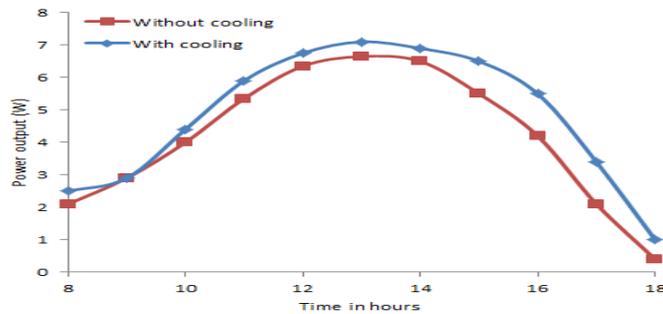


Figure 4: Comparisons on power output per hour of solar panel between cooling and without cooling.

Comparison of output efficiencies is given in **Figure (5)**. Hourly assessment of output efficiencies shows that with cooling it increases maximally at a rate of **0.39%** at average and **2.69%** at maximum at compared to ordinary panel **11.84%** was the maximum efficiency achieved with water cooling and 9.15% for ordinary panel.

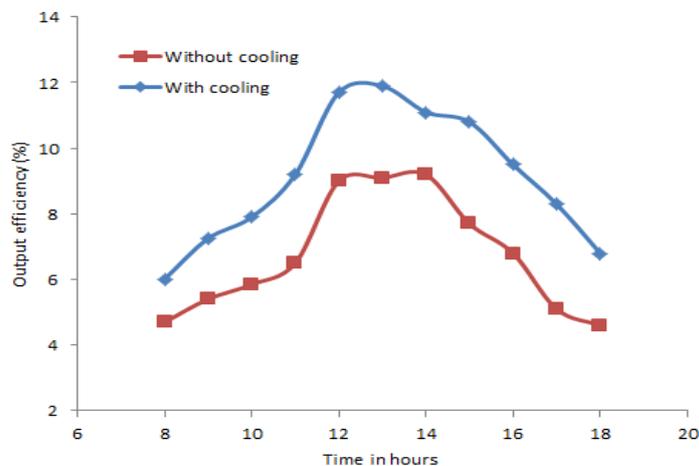


Figure 5: Output efficiency v/s time of PV module with cooling and without cooling.

4. Conclusions

Arrangement of novel sponge at the back of the panel concludes that it gives better results indicating that increased photoelectric conversion efficiency can be obtained by decreasing the temperature under cooling conditions. The conclusions depicting better performance of cooling system over ordinary panels include the fact that cooling reduces temperature by 4°C maximally. Maximal increase of 6.4% in output power and 2.6% increase in output efficiency. For enhancement of photoelectric conversion efficiency, very cheap water sponges can be utilized as a mean to cool the solar panel. Life of a sponge is 6 months and it has simple attachment and replacement.

References

- [1] L. Zhu, Y. Wang, Z. Fang, Y. Sun, Q. Huang. "An effective heat dissipation method for densely packed solar cells under high concentrations." *Solar Energy Mat Solar Cells*, vol. 94, pp. 133-140, 2010.
- [2] S. A. Abdulgafar, O. S. Omar, K. M. Yousif. "Improving the Efficiency of Polycrystalline Solar Panel via Water Immersion Method." *International Journal Innovative Research in Science, Engineering and Technology*, vol. 3, pp. 83-89, 2014.
- [3] H.G. Teo, P.S. Lee, M.N.A Hawlader. "An active cooling system for photovoltaic modules." *Applied Energy*, vol. 90, pp. 309–315, 2012.
- [4] X. Tang, Z. Quan, Y. Zhao. "Experimental Investigation of Solar Panel Cooling by a Novel Micro Heat Pipe Array." *Energy Power Engineering*, vol. 2, pp. 171-174, 2010.
- [5] S. Mehrotra, P. Rawat, M. Debbarma, K. Sudhaka. "Performance of a Solar Panel with Water Immersion Cooling Technique." *International Journal Science Environ Technology*, vol. 3, pp. 1161 – 1162, 2014.
- [6] Z.J. Weng, H. Yang. "Primary Analysis on Cooling Technology of Solar Cells under Concentrated Illumination." *Energy Technology*, vol. 29, pp. 507-517, 2010.
- [7] S. Dinesh, Borkar, Sunil, V. Prayagi, J. Gotmare. "Performance Evaluation of Photovoltaic Solar Panel Using Thermoelectric Cooling." *International Journal Engineering Research*, vol. 3, pp. 536-539, 2010.
- [8] B. Gardas, M.V. Tendolkar. "Design of Cooling System for Photovoltaic Panel for Increasing its Electrical Efficiency." *International J Mechanical Prod Engineering*, vol. 1, pp. 63-67, 2012.
- [9] M. Rodriguez, D. Horley, P. Gonzalez-Hernandez, J. Vorobiev, P.N. Gorley. "Photovoltaic solar cells performance at elevated temperatures." *Solar Energy*, vol.78, pp. 243–250, 2005.
- [10] A. Royne, C. Dey, DR. Mills. "Cooling of photovoltaic cells under concentrated illumination: a critical review." *Solar Energy Materials Solar Cells*, vol. 86, pp. 451–453, 2005.
- [11] L. Zhu, F. Robert, Boehm, Y. Wang, C. Halford, et al. "Water immersion cooling of PV cells in a high concentration system." *Solar Energy Materials Solar Cells*, vol. 95, pp. 538-535, 2011.
- [12] D. Chapin, C. Fuller, G. Pearson. "Hybrid photovoltaic and thermal solar-collector Designed for Natural circulation of water." *Applied Energy*, vol. 83, pp. 199-210, 2006.
- [13] A. Joshi, A. Tiwari, G. Tiwari, I. Dincer, B. Reddy. "Performance evaluation of a hybrid photovoltaic

- thermal (PV/T) (glass-to-glass) system.” *International Journal Thermal Science*, vol. 48, pp. 154, 2009.
- [14] S. Dubey, G. Sandhu, G. Tiwari. “Analytical expression for electrical efficiency of PV/T hybrid air collector.” *Applied Energy*, vol. 8, pp. 697-705, 2009.
- [15] T. Chow. “A review on photovoltaic/thermal hybrid solar technology.” *Applied Energy*, vol. 87, pp. 365-9, 2010.
- [16] N. Rott. “Note on the history of the Reynolds number.” *Annual Review of Fluid Mechanics*, vol. 22, pp. 1-11, 1990.
- [17] V. Gnielinski. “New equations for heat and mass transfer in turbulent pipe and channel flow.” *International Chemical Engineering*, vol. 16, pp. 359-368, 1996.