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Enhancing Photoelectric Conversion Efficiency of Solar Panel by Water Cooling

M Mohamed Musthafa*

School of Mechanical Engineering, SASTRA University, Thanjavur-613401, Tamilnadu, India

Abstract

Photovoltaic solar cell generates electricity by receiving solar irradiance. The electrical efficiency of photovoltaic (PV) cell is adversely affected by the significant increase of cell operating temperature during absorption of solar radiation. This undesirable effect can be partially avoided by fixing a water absorption sponge on the back side of the photovoltaic panel and maintain wet condition by circulation of drop by drop water through sponge. The objective of the present work is to reduce the temperature of the solar cell in order to increase its electrical conversion efficiency. Experiments were performed with and without water cooling. A linear trend between the efficiency and temperature was found. Without cooling, the temperature of the panel was high and solar cells achieved an efficiency of 8–9%. However, when the panel was operated under water cooling condition, the temperature dropped maximally by 4°C leading to an increase in efficiency of solar cells by 12%.

Keywords: Photovoltaic cell; Solar panel cooling; Photo-electric conversion efficiency; Water absorption sponge

Introduction

As the world is facing the problem of energy deficit, global warming and detoriation of environment and energy sources, there is need for an alternative energy resource for power generation other than use of fossil fuels, water and wind. Fossil fuel get depleted in next few decades, hydro power plants are depends on annual rainfall and wind power is also depends on climate changes. Solar energy is one of the comparable candidate for alternate energy source. Solar energy is a very inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8×10^{11}MW which is larger than the present consumption rate on the earth of all commercial energy sources. Thus solar energy could be supply all the present and future energy needs of the world on a continuing basis. This makes it one of the most promising of the unconventional energy sources [1-4].

A solar cell is a device that directly converts the energy from sunlight in to electrical energy through the process of photovoltaics. The first solar cell was built around 1883 by Charles Fritts, who used junctions formed by coating selenium (a semiconductor) with an extremely thin layer of gold. In 2009, a thin film cell sandwiched between two layers of glass was made.

A typical PV module has an ideal conversion efficiency in the range of 15%. The remaining energy is converted into heat and this heat increases the operating temperature of PV system which affects the electrical power production of PV modules and this can also cause the structural damage of PV modules leads to shorting its life span and lowering conversion efficiency. The output power of PV module drops due to rise in temperature, if heat is not removed [5]. The temperature of the solar cell generally reach to the 80°C or more when the solar cell is a silicon series solar cell.

The various literatures reveal that cell temperature has a remarkable effect on its efficiency. The temperature increase of 1K corresponds to the reduction of the photoelectric conversion efficiency by 0.2%-0.5% [6]. Various studies have been conducted in order to improve the PV conversion efficiency, among these cooling provides a good solution for the low efficiency problem. Both water and air are suitable as the cooling fluid to cool the PV module in order to avoid the drop of electrical efficiency [7-12].

Performance of a solar-photovoltaic (PV) system not only depends on its basic electrical characteristics; maximum power, tolerance rated value %, maximum power voltage, maximum power current, open-circuit voltage, short-circuit current, maximum system voltage, but also is negatively influenced by several obstacles such as ambient temperature, relative humidity, dust storms and suspension in air, shading, global solar radiation intensity, spectrum and angle of irradiance [13,14].

There are several reasons which motivate the development of the PV/T system. One of the main reasons is that PV/T system can provide higher efficiency than individual PV and thermal collector system. With increased the efficiency, the payback period of the system can also be shorten [15]. Many efforts have been made to find an efficient cooling technology by analyzing the performance of solar cells using different technologies and various cooling liquids. The technique used in this study is the cooling of solar panel back side using water as the coolant. The main focus of this work is on comparison of the electrical conversion efficiency of the PV panel with and without cooling at optimum flow rate.

Materials and Methods

A commercial polycrystalline solar panel with an area of 36×27 cm^2 was tested. PV panel specifications are listed in Table 1. The experimental setup is consists of 12W power rating solar panel, 12V battery, volt meter, ammeter, solar lamp and cooling system. The photographic view of experimental set up is shown in Figure 1. The cooling system consists of 5 litre capacity water cane, hose with flow regulating knob, water absorbing sponge and drain pipe for collecting

***Corresponding author:** Musthafa MM, School of Mechanical Engineering, Sastra University, Thanjavur-613401, Tamilnadu, India, Tel. 91 4362 304118; E-mail: mdm_712003@yahoo.co.in

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Peak power	12W
Type	Poly-crystalline
Open circuit voltage	21.3V
Maximum power voltage	17.5V
Maximum power current	0.68A
Operating temperature	-40°C to 80°C
Number of cells	36
Dimensions	32×27 cm

Table 1: Solar panel specification.

Figure 1: Photographic view of experimental setup without and with water cooling.

the water. The solar panel is placed on 3 feet mild steel stand with a tilt angle of 45°. The solar panel is connected to the positive and negative terminals of the battery through the voltmeter and ammeter. Battery is discharged with bulb load. Schematic diagram of output characteristics test system of solar panels is shown in Figure 2 Voltmeter and ammeter were used in range of 0-50 V and 1-10A respectively. 8 W dc bulb was used as the load. A solarimeter was used to measure the real-time solar radiation intensity (W/m^2). Temperatures of the solar panel, ambience and the water in the tank was monitored with digital thermometer.

The water is supplied from the five litre capacity water cane to the sponge which is fixed on the back side of the solar panel through the hose. The flow rate of water is controlled by knob in the hose pipe line. The setup is placed towards south in the direct sunlight and the readings of ammeter and voltmeter are noted in hour by hour and the panel temperature was also noted using digital thermometer. Readings were recorded for every one hour on 3rd May 2014 from 8.00 am to 18.00 pm without water cooling. The same procedure was repeated from 4-8th May 2014 with water cooling by varying the flow rate from one litre/hr up to 3 litre/hr in step of 0.5 litre/hr. Weather conditions on those days are more or less same.

Results and Discussion

In order to find electrical conversion efficiency of the solar panel, the following parameters were measured, such as the output power in terms of voltmeter and ammeter reading, the panel surface temperature and real time solar radiation intensity(W/m^2). In addition that ambience temperature, the inlet and outlet temperature of water flow and water flow rate were measured and recorded.

The photoelectric conversion efficiency is calculated as:

$$\eta = \frac{P_{max}}{AI}$$

where $\eta_=$ the photoelectric conversion efficiency (%), P_{max}(W) is the maximum power generated from the PV panel, A(m^2) is the surface area of the panel, and I(W/m^2) is the solar irradiance incident on the panel. The maximum power generated is estimated by voltmeter and ammeter readings.

The theoretical cell electrical efficiency (ηe) and this parameter are functioned of the cell temperature [16].

$$\eta e=\eta o[1-\beta(Tc-To)] \qquad (1)$$

$$\eta e=\int VI\ dtAc\int G(t)dt \qquad (2)$$

The electrical efficiency of the PV module can be described as following equation:

$$\eta o=Vmp\ ImpG \qquad (3)$$

The thermal efficiency can be computed with the following equation [17]:

$$\eta th=m\cdot Cp\int(Tout-Tin)\ dtAc\int G(t)dt \qquad (4)$$

The total efficiency of the hybrid PV/T system is:

$$\eta total=\eta th+\eta e=m\cdot Cp\int(Tout-Tin)dt+\int VI\ dtAc\int G(t)dt \qquad (5)$$

The electrical and thermal efficiencies are presented in Equation (2) and (4). It can be seen that the solar irradiation is a function of time and those parameters which are affected by the solar irradiation, such as inlet and outlet temperatures, PV voltage and PV current, are also functions of time. That is the reason to integrate the equation with time.

Figure 3 represents peak output efficiency of solar panel against mass flow rate of cooling water. As seen from Figure 3, two litres per hour mass flow rate of cooling water gave better performance of solar panel. It might be the water absorption capacity of the sponge. This describes that beyond two litres of water flow per hour is not stay in the sponge results in decrease in peak efficiency of the panel. It concludes that 2 litres per hour is an optimal flow rate of water for conducting the test.

Figures 4-6 shows the comparing results between the solar panel without cooling and two litres per hour flow of cooling water. The average air temperature, the radiation intensity, the maximal and average wind speeds are 39.6^{0}C, 1070 W/m^2, 4.32 m/s and 0.61 m/s, respectively. The daily net radiation is 24.9 MJ from 8:00 to 19:30 hours

Figure 4 represent comparison on temperature of solar panel between cooling and without cooling. From the result, it is observed that the temperature of the solar panel with water-cooling reduces maximally by 4^{0}C and averagely by 1.7^{0}C at two litres per hour flow rate of water compared with ordinary one.

Figure 5 show that comparison of power output per hour of solar panel between cooling and without cooling. As seen from the Figure 5, the output power of solar panel first increases and then decreases. The highest values of power output appears in the time range between 12:00 to 13:00. The output power of the solar panel with cooling increases maximumly by 6.4% and averagely by 4.3% compared with ordinary one.

Figure 6 shows comparisons on output efficiency per hour of solar panel between cooling and without cooling. From the experimental result it is found that the efficiency of solar panel with cooling increases maximally by 2.69% and averagely by 0.39% compared with ordinary one. The maximum efficiency of 11.84% was achieved with water cooling of the panel and corresponding maximum efficiency ordinary

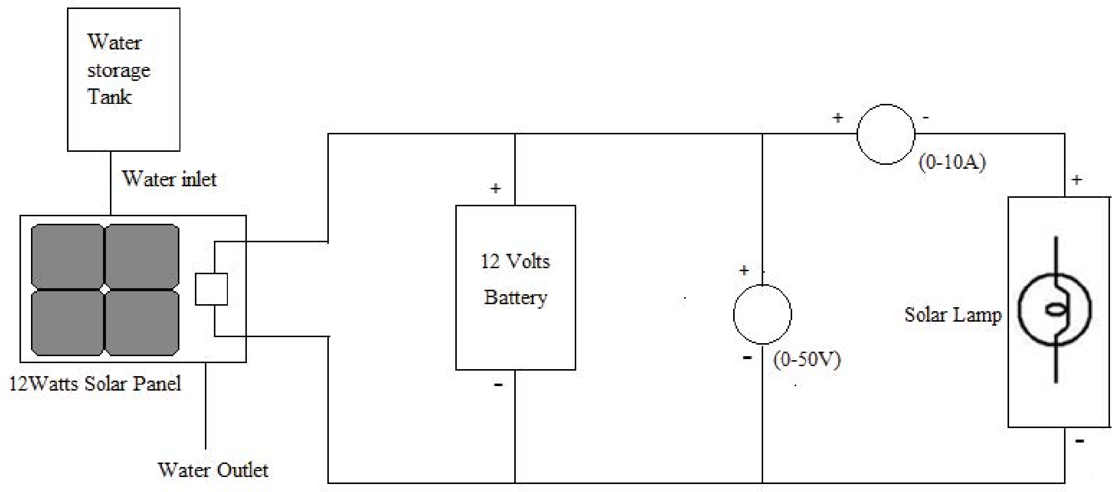

Figure 2: Output characteristics test system of solar panels with water cooling.

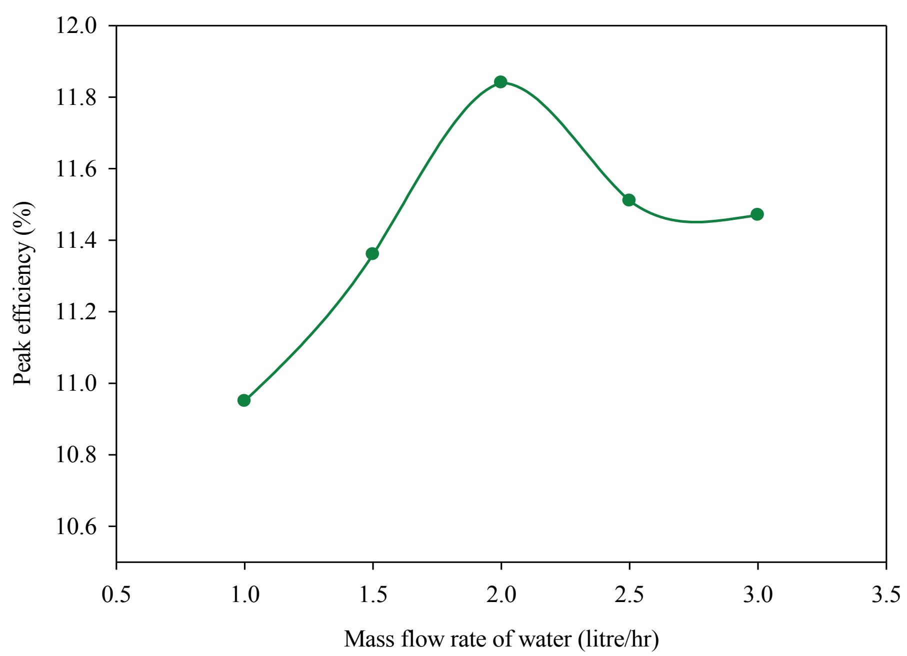

Figure 3: PeaTk efficiency of solar panel against mass flow rate of water.

panel is 9.15%.

Conclusions

A novel sponge arrangement at back side of solar panel for cooling is proved better results. The results indicate that under cooling condition, the temperature can be reduced to effectively increase the photoelectric conversion efficiency of solar panel.

Compared with the ordinary solar panel, the water cooling

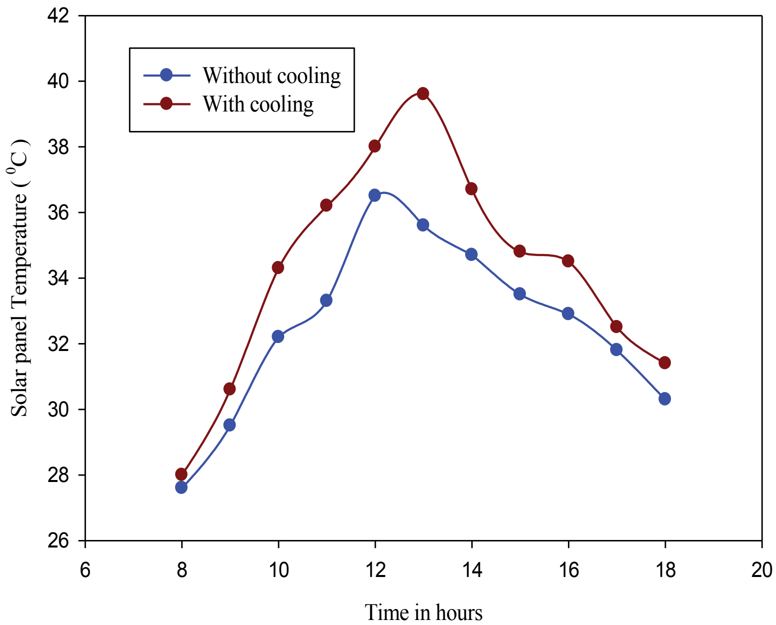

Figure 4: Comparisons on solar panel temperature between cooling and without cooling.

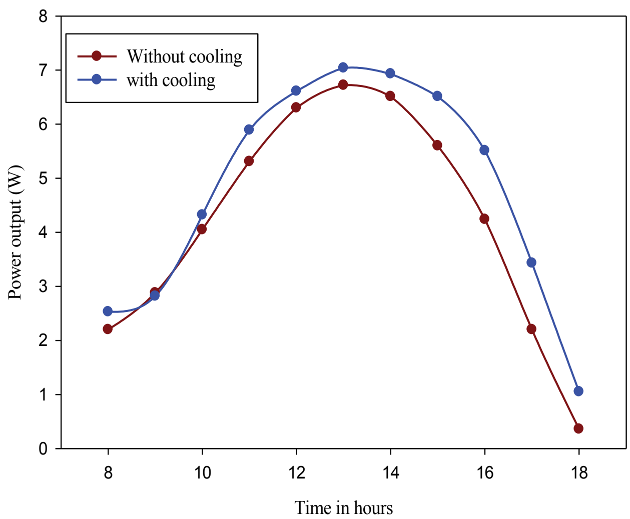

Figure 5: Comparisons on power output per hour of solar panel between cooling and without cooling.

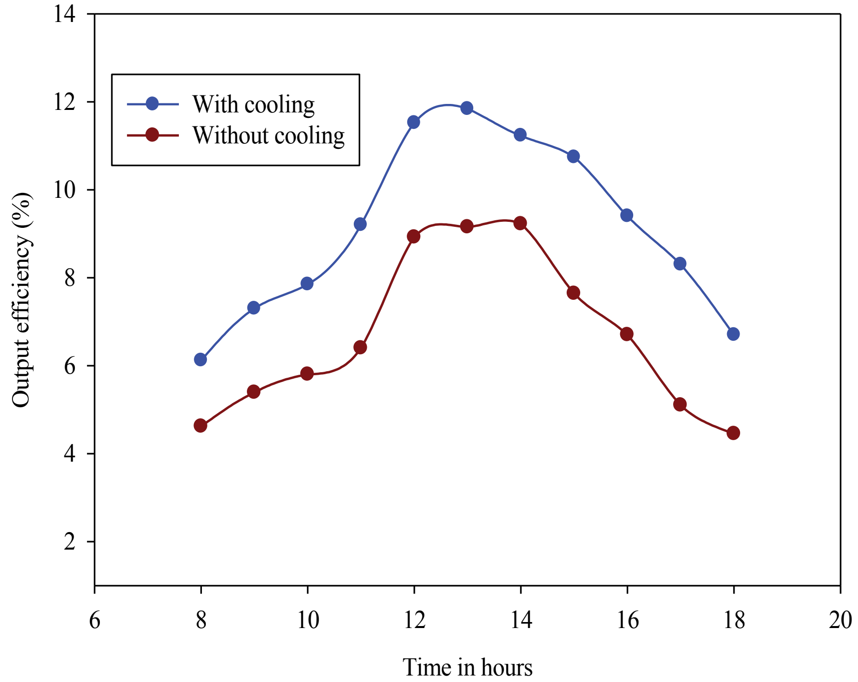

Figure 6: Comparisons on output efficiency per hour of solar panel between cooling and without cooling.

arrangement reduces cell temperature maximally by 4^{0}C, the output power increases maximally by 6.4%, and increase in output efficiency by 2.6%.

The very low cost of water absorption sponge may be used as component for solar panel cooling for enhancing photoelectric conversion efficiency.

Simple attachment and life of the sponge is also six month.

Replacement of the sponge is easy and quick.

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