Enhancing Photoelectric Conversion Efficiency of Solar Panel by Water Cooling

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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 cooling the back side of the photovoltaic panel using water absorption sponge which was fixed on of PV panel and maintain wet condition by circulation of drop by drop water. The objective of the present work is to reduce the temperature of the solar cell in order to increase its electrical 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 were achieved an efficiency of 8–9%. However, when the panel was operated under water cooling condition, the temperature dropped maximally by 4^0C leading to an increase in efficiency of solar cells by 12%.

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1. INTRODUCTION

As the world is facing critical 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, water based power plants is based on annual rainfall and wind power is also depends on climate changes. Solar energy is one of the comparable candidates. 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, in principle, solar energy could 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 in sunlight 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 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 this can also cause the structural damage of PV modules 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 reaches to the 80^{0}C or more where when the solar cell is a silicon series solar cell.

The various literatures showed 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 develop solar cell having improved PV conversion efficiency, among these cooling provides a good solution for the low efficiency problem. Both water and air are suitable to be used as the cooling fluid to cool the PV module in order to avoid the drop of electrical efficiency [7-12]. 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. One such technique is cooling of solar panel back side using water as the coolant. In this study, the main focus is on the comparison of the electrical efficiency of the PV panel with and without cooling. By varying the water flow rate, the electrical performance will also be investigated.

2. MATERIALS AND METHODS

A commercial polycrystalline solar cell panel with area of 36X27 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 Fig1. The cooling system consists of 5 litre capacity water cane, water hose pipe with flow regulating knob, water absorbing sponge which is fixed on back side of the panel and drain pipe for collecting the water. The solar panel is placed on 3 feet 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 Fig.2 Voltmeter and ammeter were used in range of 0-50 V and 1-10A respectively. 8 W dc bulbs 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, the water flowing in and out the water flume, and the water in the tank were 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 hour by hour and the panel temperature was also noted using digital thermometer. Readings were recorded for every one hour on 3rdMay 2014 from 8.00 am to 18.00pm without water cooling. The same procedure was repeated from 4-8th may 2014 with water cooling by varying flow rate in step of 0.5 litre/hr from one litre/hr up to 3litre/hr.

Table.1 Solar Panel Specification

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

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

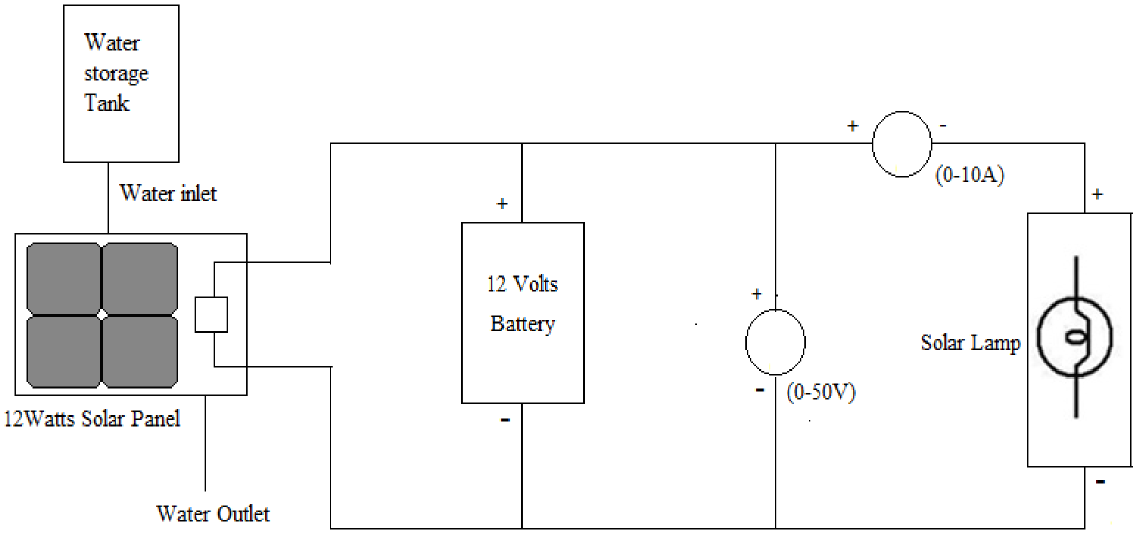

Figure 2. Output characteristics test system of solar panels with water cooling

3. 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 through the panel and water flow rate were measured and recorded.

The photoelectric conversion efficiency is calculated as:

$$\eta = \frac{Pmax}{AI}$$

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 solar irradiance is measured using solarimeter.

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 efficiency of solar panel. It might be the water absorption capacity of 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 is found that 2 litres per hour is optimal flow rate of water.

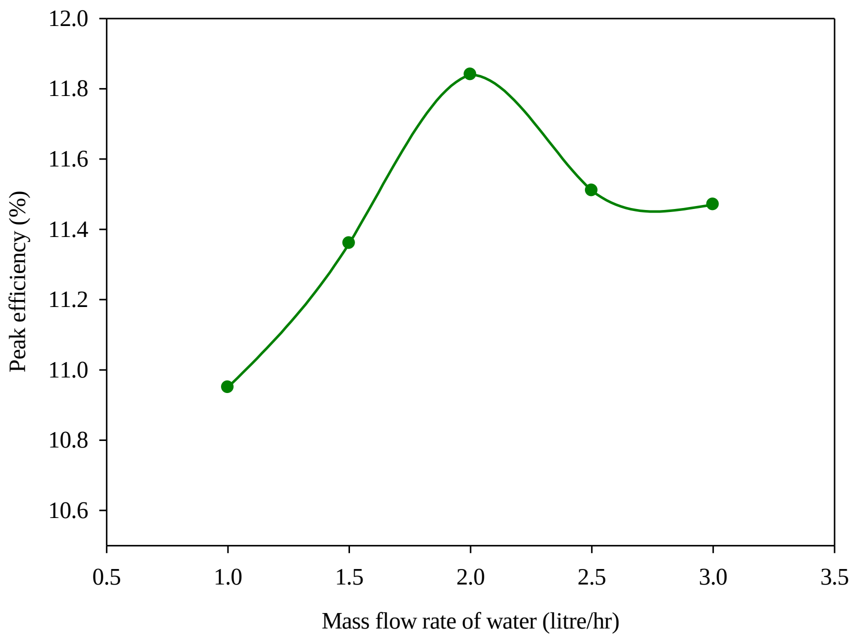

Figure 3. Peak efficiency of solar panel against mass flow rate of water

Figures 4-6 shows the comparing results between the solar panel without cooling and two litres per hour flow of cooling water one day in May. The maximal 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.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 as shown in Figure 4.

Figures 5 show that the radiation intensity is the primary factor affecting the output power of solar panel under a certain load resistance condition. As the solar radiation intensity first increases and then decreases, the output powers of solar panel also observed in same trend. The highest values of power output appear in 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, as shown in Figure 5

Figures 6 show that the radiation intensity and the temperature of the solar panel are the main factors that affecting the photoelectric conversion efficiency of solar panel. According to the data, the temperature increase of 1 K, the efficiency of solar panel with cooling increases maximally by 2.69% and averagely by 0.39% compared with ordinary one, as shown in Figure 6. The maximum efficiency of 11.84% was achieved with water of panel and corresponding maximum efficiency ordinary panel is 9.15%.

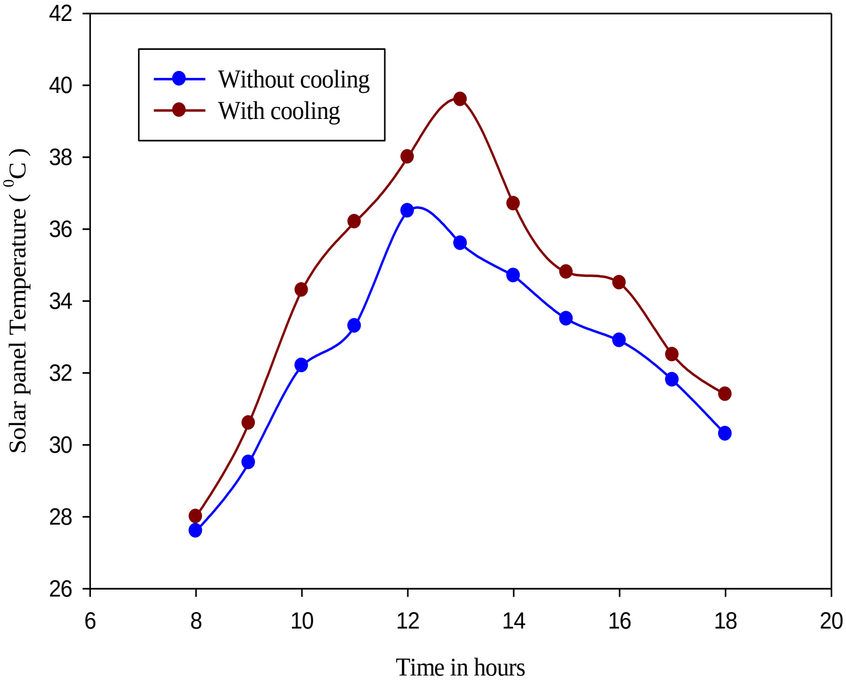

Figure 4. Comparison of temperature per hour of solar panel between cooling and without cooling

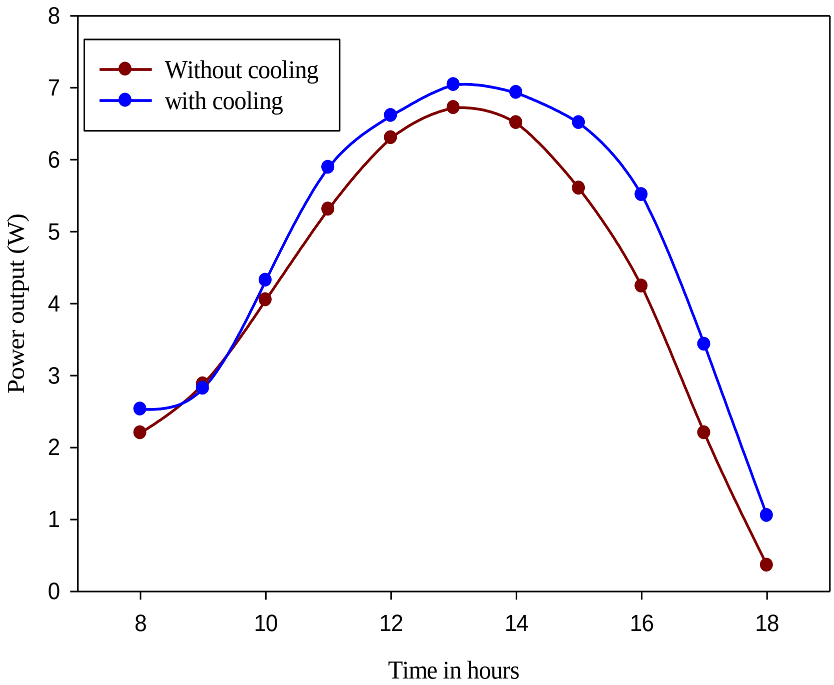

Figure 5. Comparison of power output per hour of solar panel between cooling and without cooling

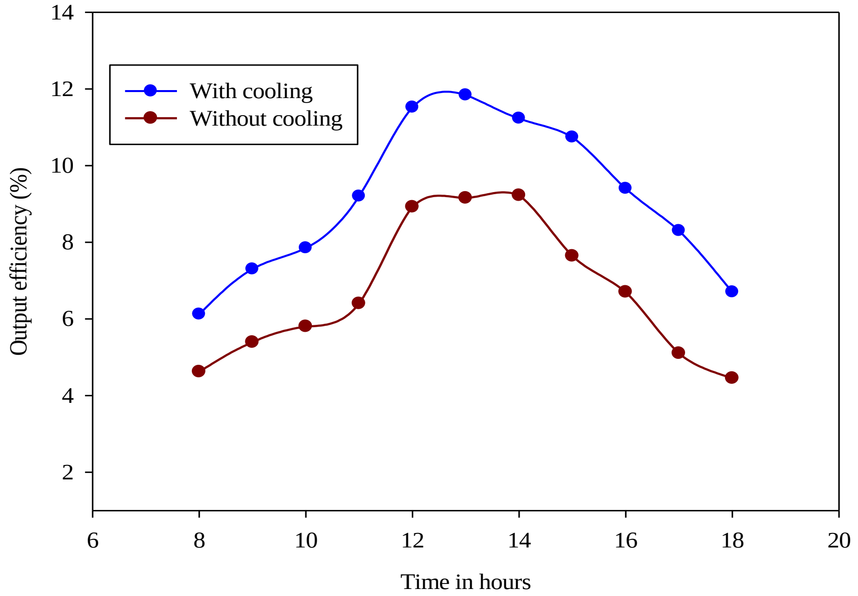

Figure 6. Comparison of temperature per hour of solar panel between cooling and without cooling

4. CONCLUSIONS

A novel sponge arrangement at back side of solar panel for cooling 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 temperature of that using water cooling reduces maximally 4^0C, the output power increases maximally by 6.4%, and the efficiency difference is 2.6%

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