Performance Enhancement of PV Panel by Cooling Front Surface of PV Panel with the Use of Water as a Cooling Medium

Pranav Patel, Pavit Shah, and Alkesh Mavani

Abstract This paper introduces a cooling system in a commercial photovoltaic panel using water to examine the improved output through a reduced operating temperature. It presents an alternative cooling technique for photovoltaic (PV) panels that include a water flow over panel surfaces. Solar radiation and operating temperature are two main parameters that affect the effectiveness of a photovoltaic panel. For these conditions, the electrical efficiency of the solar panel will be degraded as the operating temperature of the solar panel rises. Water flowed over the panel at a constant flow rate. The average temperature fall of the front and back surfaces is 3.54 °C and 2.79 °C, respectively, mainly the front water flow over the solar panel. Front cooling provides a 9.64% enhancement inefficiency on average. The average temperature fall of the front and back surfaces is 3.54 °C and 2.79 °C, respectively, mainly to front water flow over the solar panel. Front cooling provides a 9.64% enhancement in efficiency on average.

Keywords Efficiency · PV module · Temperature drop · Water cooling

1 Introduction

While the globe struggles with energy scarcity, global warming, and the degradation of energy and the environment, there is a need for green technologies to substitute fossil fuels, water, and other natural resources. PV (photovoltaic solar energy) is one of the alternative energy sources. The photovoltaic solar cell, as its name implies, is a semiconductor device that creates energy when exposed to light. A photovoltaic cell changes only a small portion of the irradiance into electrical energy (less than 20%). PV cells' electrical efficiency diminishes as the temperature goes up [1–25]. The

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power produced of conventional flat-panel PV modules can be enhanced by cooling because it stops the PV cells from reaching temperatures that induce significant harm. The effectiveness and power output of a PV module is found to be inversely proportional to temperature [13–20]. Solar energy is just one of many alternative energy sources accessible. Solar energy is an almost endless source of energy. Solar power has the ability to supply all of the world's present and future energy needs on a consistent basis. As a result, it is one of the most viable energy sources. The sun's power absorbed by the earth is around 1.81×10^{11} MW, which is greater than the current consumption rate of all commercial energy sources on the planet [10]. As a result, solar energy may provide all of the world's current and future energy needs on an ongoing basis. Cooling can enable typical flat-panel PV modules to create more electricity because it prevents the solar cells from reaching the temperature where lasting damage occurs.

Effect of Operating Temperature on Solar Panel:

Because of the absorption and reflection caused by the glass cover and PV module in conventional photovoltaic (PV) setups, over 80% of solar radiation is transformed into heat, resulting in a massive gain in PV cell operating temperature [2]. Like all other semiconductor devices, solar cells are sensitive to temperature. Increasing temperature diminishes the bandgap of a semiconductor, altering many of the properties of the material. The decrease in a semiconductor's bandgap with rising temperatures can be seen as increasing the energy of the material's electrons. Therefore, it takes less energy to sever the bond. The reduction of bond energy in the bond model of a semiconductor also decreases the bandgap. Raising the temperature, therefore, reduces the difference in the band. Within a solar cell, the open-circuit voltage is the parameter most influenced by an increase in temperature. The P–V characteristic is the interaction between the electrical power consumption of a solar PV module, P, and the output voltage, V, while solar radiation, E, and cell temperature, Tm, stay unchanged. If any of those two elements, Tm or E, alters, then all features change as well. The effect of temperature increase is shown in Fig. 1.

2 Objectives

The major goal of this project is to investigate passive water cooling systems in order to improve efficiency. To conduct experimental research on passive water cooling settings in order to improve panel efficiency and performance.

3 Research Gap

According to the literature review, water cooling is the most effective approach for panels [1–25]. Only a few researchers have experimented with passive water cooling.

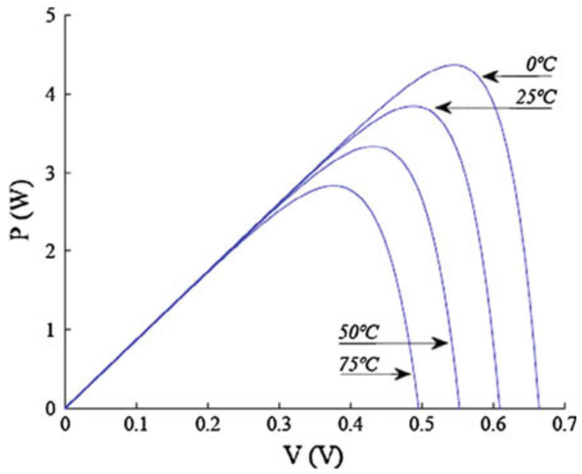

Fig. 1 Temperature variation P–V characteristics across 0° and 75 °C [3]

We can reduce the operating temperature of PV panels and increase their efficiency at a lower cost by using an effective passive water cooling technology. Flowing water on the front surface can be a good technique to keep cool.

4 Methodology

In this section, experimental setup and procedure are discussed. A non-contact type infrared thermometer was used to measure the front and back surface temperatures, and a solar power meter was used to monitor the sun's radiation. For the experimental study, two regular PV panels, manufactured in Topsun Energy Ltd. were used. The panel's specifications are listed in Table 1. Current and voltages were measured by using a digital multimeter.

The solar panel should be at an angle that is equal to the latitude of the location where it is installed. For Gandhinagar, the latitude is 23°, so the panel was kept at 23° of inclination angle, and then, the experiment was performed.

Table 1 PV panel specifications

Model	TEL24P320
Rated maximum power (P_m)	320 W
Rated operating voltage (V_m)	37.20 V
Rated operating current (I_m)	8.61 A
Open-circuit voltage (V_{OC})	45.28 V
Short-circuit current (I_{SC})	9.20 A

4.1 Experiment Setup and Procedure

For getting maximum solar radiation, solar PV panels were kept at the latitude angle of Gandhinagar (23°) in the south direction. We have used a PVC pipe of 2-m length and 1-inch diameter and fixed it above the panel. We have made 40 holes of 1.5 mm diameter on the surface of that pipe in a straight line. These numbers of holes were required for water uniformity on the front surface of the panel. So for every cell column on the panel, there are three holes provided. The 500 L water tank was used as storage tank. The valve is used for water flow control, and a 2 m long pipe is used for the water supply on the panel. The readings are taken at every half-hour interval. The water was supplied over the surface 5 min before reading and flowed for only 10 s every time. The water flow rate was constant at a rate of 8 ml/s. The big size PVC pipe pieces are used as collectors under the panel to make sure there is no water wastage. But there is a slight loss of water due to evaporation because of high surface temperature. To acquire a more precise temperature, eight temperature readings were taken for both the front and back surfaces of the panel. One of the two panels was utilized as a reference panel with no cooling mechanism and the other as a modified panel. The fill factor, which was 0.78 for the solar panel, was also taken into account when calculating the PV panel's efficiency (Fig. 2).

5 Results and Discussion

In this section, detailed data and observations of this experimental research are given. The experiment was performed on the terrace of LDRP-ITR, Gandhinagar. The reading was taken from 9:00 A.M to 4:00 P.M. The observation table was prepared which is given below. A detailed discussion is given below.

As can be seen in Figs. 3 and 4, the PV panel's front and back surface temps were nearly identical to the reference panel in the early hours. In the case of the reference panel, however, as the solar energy increased, the front and back surface temperatures increased as well. Front cooling via water flow improves the performance of the solar PV panel. 3.54 °C is the average difference in temperature of the front surface. Due to the cooling effect, the panel surface temperature is lower than the reference panel for the first two to three hours. After that, due to high front surface temperature, the difference of temperatures between with and without cooling is lesser at 12 P.M and 2 P.M.

The solar radiation increased with time and was maximum between 1:00 and 2:00 PM. The average difference in back surface temperature is obtained by 2.79 °C. But from Fig. 4, we can see that the PV panel with front cooling gives a lower back surface temperature than without the cooling panel.

The power output of the PV panel grows in tandem with the rise in solar radiation over time. The results for power output and efficiency are shown in Fig. 5 and 6. The power output of both panels rose as solar radiation increased over time. Because the

Fig. 2 Experiment setup

front-cooled panel had a lower surface temperature, it produced more power than the reference panel. 308.67 W and 274.54 W are the average power outputs of a PV panel with cooling and a reference panel, respectively.

The efficiency of solar panels with cooling is always better than that of solar panels without cooling, as shown in Fig. 6.

The panel efficiency is highest during the initial hours, as shown in the graph. However, when the working temperature rises over time, so does the efficiency. However, the reference panel's average efficiency is 17.43%, whereas the panel with front cooling has a 19.11% efficiency.

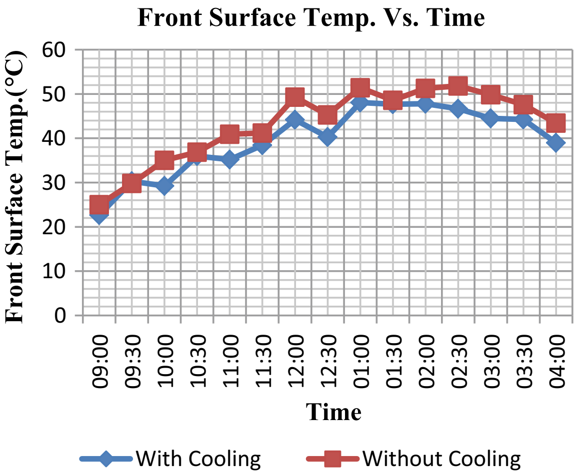

Fig. 3 Front surface temperature versus time

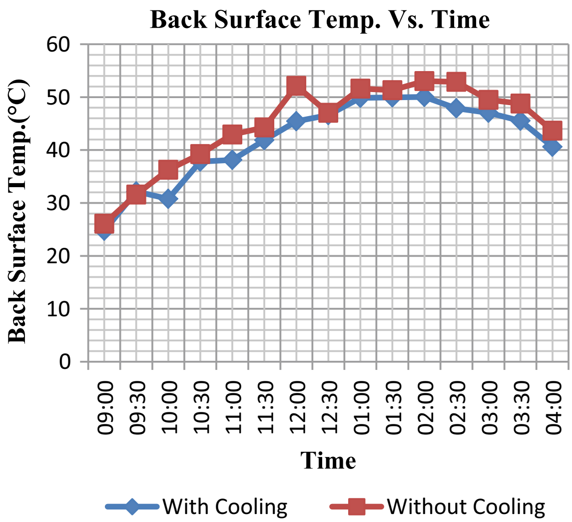

Fig. 4 Back surface temperature versus time

6 Conclusion

Finally, it is feasible to assert that the suggested water cooling approach has a positive impact on the performance of PV panels, which is advantageous in PV applications. Due to the front water flow, a nearly uniform cooling effect is obtained. The available solar radiation at the site for the reference panel varies from 245 to 1001 W/m^2, while for cooling panel varies from 315 to 998 W/m^2. The results showed a significant decrease in the temperature of the PV panel.

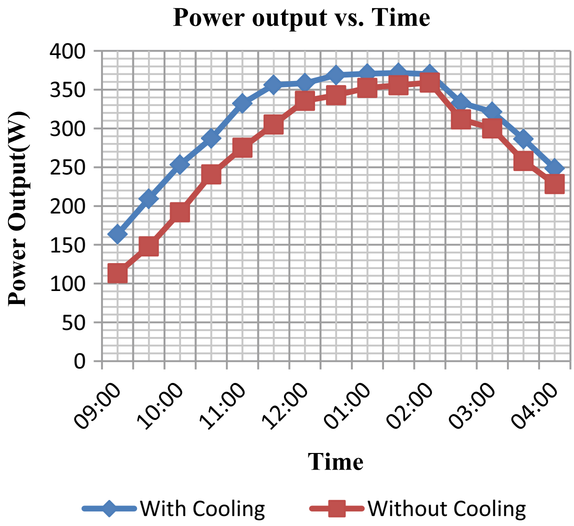

Fig. 5 Power output versus time

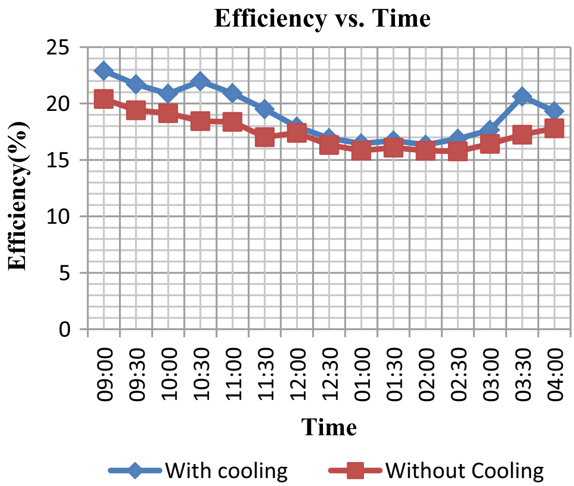

Fig. 6 Efficiency versus time

Front cooling via water flow enhances the performance of the solar PV panel. The front surface seems to have a temperature reduction of 3.54 °C, whereas the back surface has a temperature reduction of 2.79 °C.

The average percentage increase in efficiency and power achieved by front cooling is 9.64% and 12.44%, respectively. No water is wasted due to the use of water collectors (Fig. 7).

When enhancing electricity efficiency is the primary goal, water cooling has been proved to be an excellent option. As a result, the future research goal should be to achieve effective water cooling of PV panels.

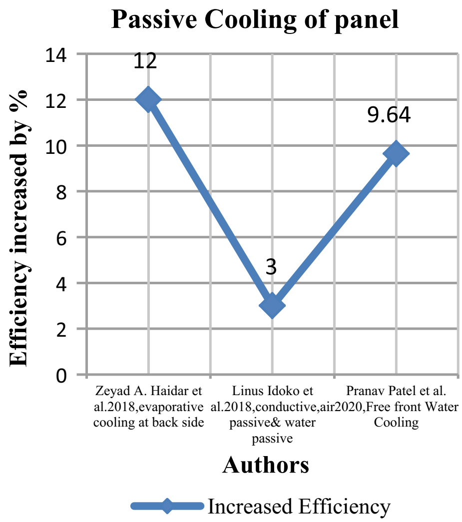

Fig. 7 Comparison of passive cooling results with other findings obtained using different methods used by various authors

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