# STUDIES ON IMPROVEMENT OF SOLAR PV PANEL PERFORMANCE

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## ABSTRACT

*The renewable energy systems are getting popularity due to depletion of conventional fuels and ill effects related to burning of these fuels. Among the energy sources which are renewable, solar energy is popular as it is easily available and various methods are used to convert solar energy into useful energy. The solar PV system produces electrical energy using sun light and its performance is influenced by the cell temperature. The higher cell temperature reduces the power production and hence various cooling methods are developed. In this work, we have developed a cooling system which reduces the solar PV panel temperature significantly and improves the solar PV system power production. This system uses water for cooling the solar panel. The water is environment friendly, easily available and low cost. From the experimental work, we suggest that the water cooling is effective in minimizing the solar PV panel surface temperature and the energy improvement is about 14.2 %.*

*Keywords: renewable energy, photovoltaic, cooling, performance.*

## INTRODUCTION

The energy requirement is increased exponentially in recent years due to industrial activities, increase in automotive, population, etc. However, the conventional energy sources which are used for energy production decreases significantly. The energy source availability increases energy security and helps in countries industrial activity. The availability of conventional energy sources is reducing globally, and it may exhaust in near future and hence most of the countries started to use energy sources which are non-conventional, particularly solar energy. This help to reduce conventional energy source and helps in sustainability [1]. It is suggested that the burning of fuel causes climate change and recent advancements in renewable energy conversion devices reduces cost of these energy conversion devices [2]. The energy resources help in economic growth and enhancement of lifestyle of people in any country. An estimation shows that the world's energy consumption may increase by 50 %, during 2005 to 2030 and China and India will be major consumers of energy in the future [3]. The industrial and commercial applications need internal combustion engines (ICEs) for various applications and product developments. The use of conventional fuels in ICEs will increase global warming and greenhouse gas emissions. The solar energy does not cause any impact as related to traditional fuels [4]. The depletion of ozone layer may impact human being, animals and plants and hence it is necessary to adopt non-conventional energy sources such as solar energy [5].

The functional principle of PV cells or solar cells is based on the PV effect. Solar cells are made of semiconductors materials such as silicon, which captures solar energy. Most of the sunlight is trapped and transmitted by the antireflection coating consisting of metal oxides like titanium, etc. P stands for positives, and the P-type semiconductor has a greater number of holes and a smaller number of electrons. As the majority charge carriers compared to the minority charge carriers, holes are primarily responsible for the flow of electric current. Since N is a negative number, the bulk of charge carriers in N-type semiconductor are electrons. The N-type semiconductors could donate electrons, and the N-type layer is typically highly doped. To ensure that most of the depletion region arises on the P side, the P-type layer is gently doped.

From the N-type layer begin, electron moves toward the holes in the P-type region close to the junction when the N-type and P-type layers are brought together, as a result, the depletion region, where the electrons fill the holes, is created surrounding the connection. Due to the potential differences developed at the junction and electric field build in, negative charge ion is in P-type region where hole was once present, and positive charge ion in the N-type location where electron was there [7, 8].

The electrical energy is obtained from solar cell using sunlight when the sunlight falls on the solar PV panel. The flow of electron creates electric current and develops direct current. The 0.6 V is the maximum open circuit voltage developed by a common single-junction silicon solar cell [9]. Fig. 1 represents the working principle of solar cell. The chief components of PV panel are shown in Fig. 2.

The single solar cell produces low current and cells are joined to get higher current. To improve the output voltage or current, solar cells are stacked in different configurations. The solar panels are made up of these solar cell combinations. The voltage is raised by connecting the cells in series, but the current is kept constant. Parallel solar cell connections cause an increase in electric current while maintaining a steady voltage. The current and voltage can be raised by interconnecting the solar cells in series and parallel.

It is reported that as light intensity rises, solar cells' open-circuit voltage, short-circuit current, and higher output power do too. Consequently, it is clear that a solar cell will perform better at generating power at higher light intensities. It is also reported that the temperature of the cell is directly impacted by solar radiation since it rises along with solar radiation. The rise in temperature became the primary factor in the fall in the cell's output as a result. The output current rises as solar radiation increases till the temperature of cell disturbed and subsequently current value declines. The increase in current has just a small impact on the resulting voltages; however, the increase in cell temperature has a bigger impact. The resultant power and efficiency of the cell are reduced as a result of the low current and voltages [10, 11].

Various cooling methods are developed to minimize solar PV panel's temperature as the panel temperature due to higher solar radiation and higher ambient

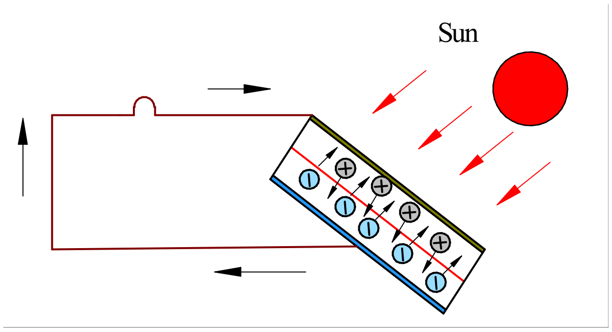

Fig. 1. Energy conversion principle in solar cell.

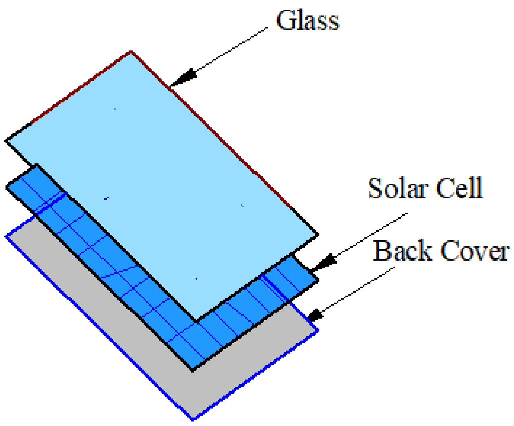

Fig. 2. Major parts of solar PV panel.

condition. The cooling system should be simple, low cost and environmentally friendly [12]. It is suggested that the fins can be used to enhance the heat transfer from panel and to cool solar PV panel as the fins increases heat transfer area which directly increases the heat transfer. Various materials are used for construction of fins. It is suggested that the fin made of aluminium provides effective heat transfer and cooling of the panel. The shape and size of the fin also affects the heat transfer [13, 14]. The fins with variable cross section provide effective heat transfer and cooling. This fin reduces the temperature of panel by 6 % and increases power output significantly [15]. It is suggested that the continuous cooling method is preferred than the non-cooling method [16]. The heat pipe can be used for the cooling of the solar PV panel [17]. From the above discussion, it is found that the potential of solar PV system is high, and it is most widely used in many countries. The output of the solar PV system is impacted by overheating of the panel during summer and higher ambient temperature also varies the output of the solar PV panel.

This work is concentrated on studying the impact of solar radiation on the solar panel during summer and developing a low-cost simple cooling system. The solar PV system performance can be enhanced by the water cooling as compared with the normal solar PV system.

## EXPERIMENTAL

### Materials and methods

A solar PV panel of capacity 40 W was used in this work. One panel was attached with sponge on its back end and water was supplied from the top. It flows downward direction due to the gravity. The performance of this system was compared with other panel which does not have any cooling. The experiments were conducted from morning to evening. A pyranometer was used for measuring solar radiation and a multi-meter was used for the measurement of power developed. Table 1 represents the technical details of solar panels used in this work.

Fig. 3 represents the experimental setup. A thermal imaging camera was used for measuring the temperature profile of the solar PV panel. The schematic of the experimental setup is shown in Fig. 4.

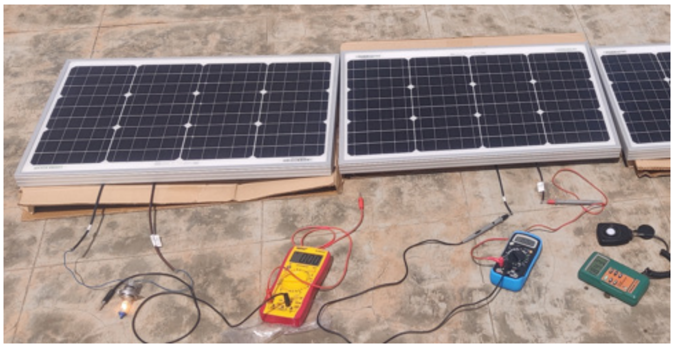

Fig. 3. Experimental setup.

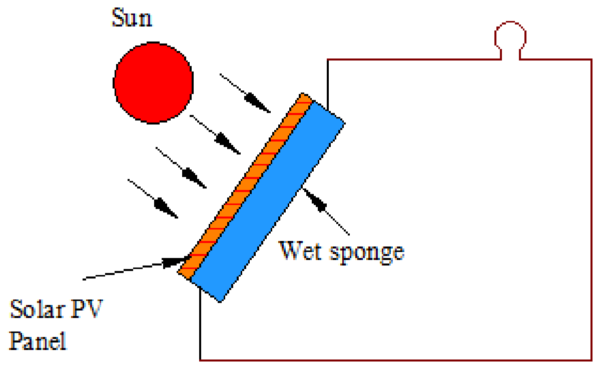


Fig. 4. Schematic of solar PV panel.

## RESULTS AND DISCUSSION

The experiments were successfully conducted to meet the objectives of this work. Fig. 5 shows the temperature of the back side of the solar PV panel during hot summer. The back-side temperature measured at 2.00 PM shows 60.3°C and the front-end temperature was 57.6°C. The backside temperature of the panel is larger than the front side as it receives heat from the terrace and the top surface is cooled by the air as the wind blows.

The water-based cooling consists of sponge which is wet by the water and used as cooling system for the solar PV panel and it was attached to the back side of the panel. The back side of the panel is cooled as its temperature is higher than the front side. Fig. 6 shows the solar radiation at different timings. It is observed that the solar radiation increases gradually and reaches peak value at 2 PM and the value decreases gradually.

Table 1. Details of solar PV panel used.

| S. No | Detail | Remark |
|---|---|---|
| 1 | Capacity | 40.00 W |
| 2 | Current at rated condition | 2.22 A |
| 3 | Voltage at rated condition | 18.00 V |
| 4 | Voltage during open-circuit | 21.60 V |
| 5 | Current during short-circuit condition | 2.410 A |
| 6 | Size in mm | 505 * 675 * 28 |

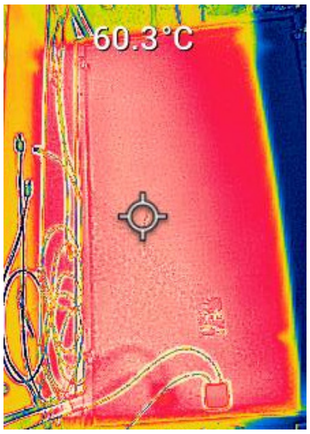


Fig. 5. Backside temperature and temperature profile of the solar PV Panel.

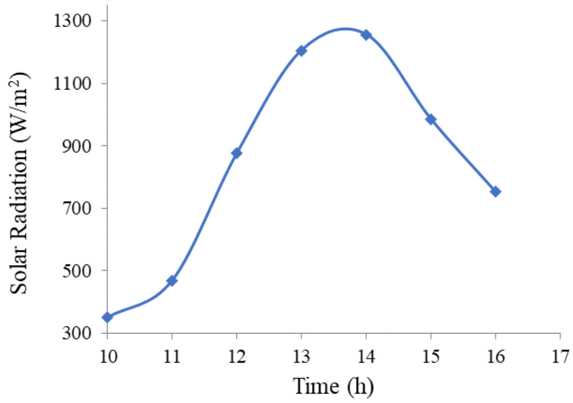


Fig. 6. Radiation intensity at different timing.

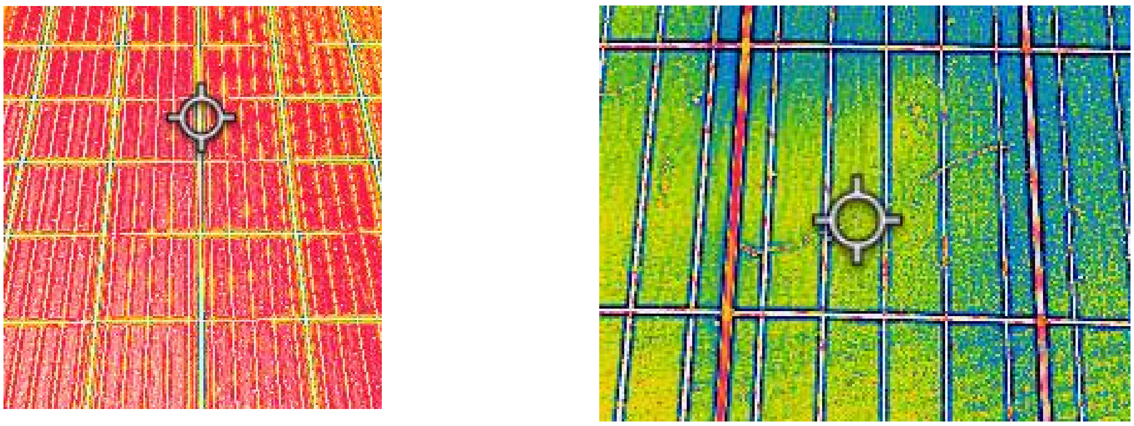

Fig. 7. a) without cooling; b) with cooling.

Fig. 7 demonstrates the solar PV panel's temperature profile both with and without a cooling device. Observations show that the solar panel with sponge water cooling system has lower temperature as compared to solar panel without cooling.

Fig. 8 represents the PV panel's top surface temperature without and with cooling. It shows that the top surface temperature of the panel increases exponentially and reach higher value during 2 PM and then decrease due to reduction in solar radiation and by the cooling effect produced by the wind. The cooling effect produced by the sponge with water is better and minimizes the temperature of the panel and the value is significant. This is due to evaporation of water in the sponge which cools the temperature of the sponge and the sponge extracts the heat from the panel. This minimizes the temperature of the panel.

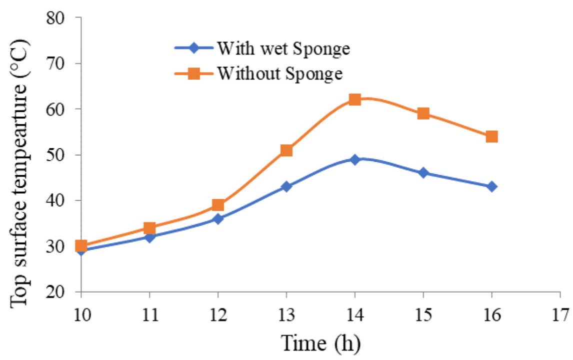


Fig. 8. Top surface temperature at different timing.

The solar PV panel's bottom surface temperature without and with cooling is shown in Fig. 9. It depicts that the bottom surface temperature of the panel increases exponentially and reaches maximum value during about 2 PM and then decreases due to reduction

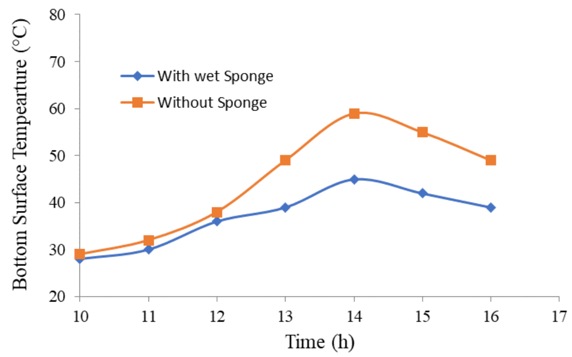

Fig. 9. Bottom surface temperature of the solar panel.

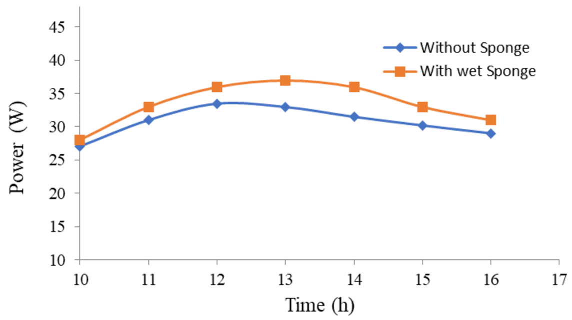

Fig. 10. Power production by the panel with and without cooling.

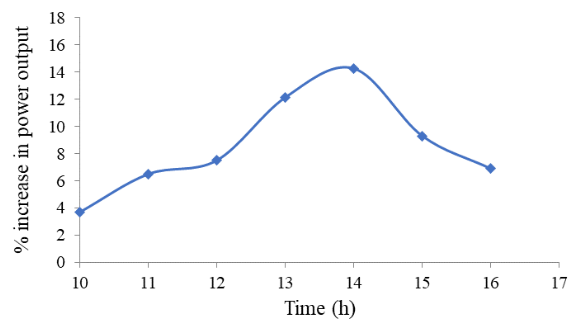

Fig. 11. Percentage increase in power output.

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Fig. 10 represents the power production by the solar PV panel with and without cooling. It shows that the power production by the solar panel gradually increase with the value of time increases and reduces gradually. The power production by the solar panel with cooling is better than the solar panel without cooling. The greater carrier concentrations caused by the higher solar cell temperature result in lower power output and higher internal carrier recombination rates [12]. The reduced bandgap of semiconductor which affects the energy production [13, 15]. The higher panel temperature may reduce the power generated by the panel and it is significant [15]. The percentage increase in the solar PV panel power output with cooling is shown in Fig. 11. It shows that the value of the percentage increase in power output increases with increase in time. It shows that the significant improvement in energy production can be obtained with water cooling.

## CONCLUSIONS

The solar PV system is commonly used in many countries as it is renewable in nature and it produces electrical energy directly from sunlight. The impact of renewable energy system on the environment is negligible as compared to conventional fuel. Also, it does affect the ozone layer and global warming. As sun radiation increases, the solar panel's temperature rises, and it is affected by ambient condition. The temperature of the panel reaches above 60° C in hot summer which decreases the power generated by this type of energy conversion device. The wet sponge used as the cooling medium in this work minimizes the temperature of the solar panel and the value is significant as the evaporation of water minimizes the solar panel's surface temperature. The use of wet sponge as cooling medium in solar panel increases the power production by about 14 %.

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