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Enhancing the Efficiency of Solar Cell by Air Cooling

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Abstract

The main objective of the present work is to investigate an effect of the temperature on the performance of the solar cell. In order to accomplish this study, solar panel has been tested under three different conditions such as, solar panel without cooling, solar panel placed in grass field and solar panel with air cooling. During testing, solar cell parameters such as open circuit voltage, short circuit current, surface temperature, panel temperature and ambient temperature have been observed. The results obtained clearly show that solar panel with air cooling has generated the maximum open circuit voltage and short circuit current while comparing to other two test conditions. For every 15 minutes, solar panel has been made to cool with air so as to decrease the temperature rise of the solar panel. Based on the test results, it could be concluded that solar panel integrated with air cooling system is expected to achieve higher electrical efficiency owing to improved power generation. The present work could be beneficial to understand the effect of temperature on the cell parameters and performance of the solar panel.

Keywords: Air Cooling, Electrical Efficiency, Solar Cell, Solar Radiation, Temperature Rise

1. Introduction

The need of renewable energy has gradually come to be considered a way to weaken the negative effects brought about by global warming and climate change. The renewable energy sources, such as Photovoltaic energy, wind energy and fuel cells are able to reduce considerable carbon dioxide emission[1,2]. When the PV modules are operated in an outdoor environment, due to frequent changes in the environmental temperature and irradiation intensity, it gives rise to critical thermal-related factors which affects their performance and reliability of PV modules.

Generally Photovoltaic directly converts solar radiation into electricity with efficiency in the range 9-12% depending on solar cell type. More than 80% of solar radiation falling on PV cells is not converted to electricity but either reflected or converted to thermal energy[3]. This leads to an increase in the PV cell's working temperature and consequently, a drop of electricity conversion efficiency.

Due to increase in the temperature of PV cells by 1 K, there is a reduction of electrical efficiency by 0.4–0.5%. In order to increase electrical efficiency of the PV, it is desired to remove the accumulated heat from the PV surface and use this heat appropriately. In order to achieve higher electrical energy efficiency, the operating temperature is maintained by cooling of PV panel and hence, the PV's electrical efficiency is increased[4–7].

In this paper, a poly crystalline silicon panel of 60 Wp is used for the experimental purpose. The experiment is conducted in three different cases, the results are obtained and compared. The result shows that by cooling of solar cell it gives the higher efficiency when compared to without cooling of solar cell.

2. Electrical Power and Electrical efficiency of a PV Module

In general, electrical power of a PV module is given by Equation (1).

$$P = V_{oc} \times I_{sc} \tag{1}$$

In general, electrical efficiency of a PV module is given by Equation (2).

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$$\eta_e = \frac{V_{oc} I_{sc} FF}{A_m G} \quad (2)$$

Where:

P - Electrical Power of PV module
η_e – Electrical efficiency of PV module
V_{OC}, I_{SC} – Open Circuit Voltage and short circuit current of PV module
A_m – Total area of PV module (m^2)
G – Incident solar radiation (W/m^2)
Area of the Panel = 0.3762 m^2
FF-Fill Factor (Constant-0.7199)

3. Experimental Work

A solar panel of 60Wp with Open circuit voltage (V_{oc}) – 21.6V, Short circuit current (I_{sc}) – 3.86A, Maximum power voltage (V_{mp}) – 17.2V and Maximum power current (I_{mp}) – 3.49A is taken for the experimental analysis. The solar panel is mounted on a fitting and the solar panel is analyzed in three different cases, they are the solar panel without cooling, the solar panel with air cooling and solar panel placed in grass field (without cooling) and the readings are noted from that readings power and electrical efficiency is calculated for all the cases. The readings are taken for 12 hours (6 am to 6 pm).The Figure 1 shows the experimental setup for solar panel without cooling. Figure 2 shows the experimental setup for solar panel placed in a grass field (without cooling) and Figure 3 shows the experimental setup for solar panel with air cooling.

3.1 Experimental Values

The solar panel is analyzed under different ambient conditions and different irradiations, the open circuit voltage (V_{oc}), short circuit current (I_{sc}) are measured by

Figure 1. Experimental setup for solar panel without cooling.

Figure 2. Experimental setup for solar panel placed in grass field (without cooling).

Figure 3. Experimental setup for solar panel with air cooling.

using multimeter and the surface temperature (T_1), panel temperature (T_2) and atmospheric temperature (T_3) are noted by using temperature indicator. The experimental values are listed in the Tables 1, 2 and 3. The Table 1 gives the experimental values of solar panel without cooling, Table 2 gives the experimental values of solar panel placed in a grass field (without cooling) and Table 3 gives the experimental values of solar panel with air cooling. The power and efficiency are calculated by using Equations 1 and 2.

4. Results and Discussion

The Figure 4(a) shows the variation of solar radiation and panel temperature with reference to time for solar panel without cooling. If the solar radiation increases from morning to noon and at noon highest solar radiation occurs and decreases from noon to evening, proportional to solar radiation the panel temperature also increases.

Figure 4(b) shows the variation of open circuit voltage and short circuit current with reference to time for solar panel without cooling and Figure 4(c) shows the variation of power and efficiency with reference to time for solar panel without cooling. In theoretical, the temperature have influence the open-circuit voltage of the solar panel under any solar irradiation. When the solar radiation intensity rises, the short circuit current I_{sc} will increase due to the increase in the minority carrier concentration and hence

Table 1. Experimental values of solar panel without cooling

S. No.	Time	G (W/m^2)	V_{oc} (V)	I_{sc} (A)	T_1 (°C)	T_2 (°C)	T_3 (°C)	Power (W)	η_e %
1	6AM	32	13.9	0.03	23	22	23	0.417	3.46
2	7AM	139	16.6	0.11	24	22	23	1.826	3.49
3	8AM	479	17.7	0.28	25	26	27	4.956	2.75
4	9AM	621	18.6	1.05	39	43	33	19.53	8.35
5	10AM	812	18.7	2.45	51	53	39	45.815	14.99
6	11AM	973	17.8	2.78	53	58	42	49.484	13.51
7	12PM	1005	17.6	2.77	63	58	43	48.752	12.89
8	1PM	988	17.6	2.68	59	56	45	47.168	12.69
9	2PM	848	17.2	2.28	55	54	43	39.216	12.29
10	3PM	719	17.7	1.69	54	49	46	29.913	11.05
11	4PM	560	17.1	0.37	37	37	38	6.327	3.00
12	5PM	212	16.5	0.18	34	35	33	2.97	3.72
13	6PM	50	13.4	0.02	29	30	29	0.268	1.42

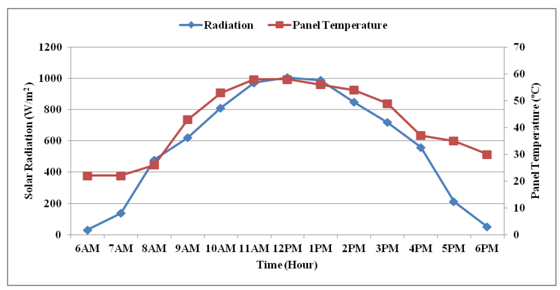
Table 2. Experimental values of solar panel placed in grass field (without cooling)

S. No.	Time	G (W/m^2)	V_{oc} (V)	I_{sc} (A)	T_1 (°C)	T_2 (°C)	T_3 (°C)	Power (W)	η_e %
1	6AM	32	12.9	0.03	20	22	21	0.387	3.21
2	7AM	80	16.9	0.15	22	23	22	2.535	8.42
3	8AM	290	17.2	0.35	25	25	26	6.02	5.51
4	9AM	559	18.3	0.87	37	34	32	15.921	7.57
5	10AM	756	18.7	1.8	49	40	34	33.66	11.83
6	11AM	897	18.4	1.72	43	39	35	31.648	9.37
7	12PM	908	18.2	0.75	40	39	36	13.65	3.99
8	1PM	898	18.1	0.59	48	39	42	10.679	3.16
9	2PM	801	17.6	0.59	44	36	35	10.384	3.44
10	3PM	595	17.4	0.35	34	34	32	6.09	2.72
11	4PM	432	16.8	0.21	31	32	30	3.528	2.17
12	5PM	190	15.9	0.11	30	30	29	1.749	2.44
13	6PM	50	11.6	0.01	27	27	27	0.116	0.61

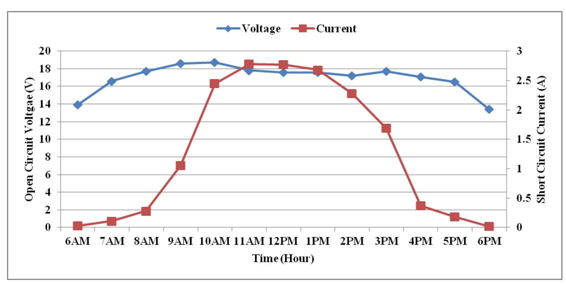
the open-circuit voltage V_{oc} will rise[1]. But the experimental results show that the output voltage of the solar panel increases with increase in the temperature and attain maximum value after that the temperature still increased and the voltage start to decreased, but the output current increases slightly when the temperature rises. In similar way, the temperature increased, the efficiency increased to reach its maximum value, after that the temperature still increased and the efficiency start to decreased.

Table 3. Experimental values of solar panel with air cooling

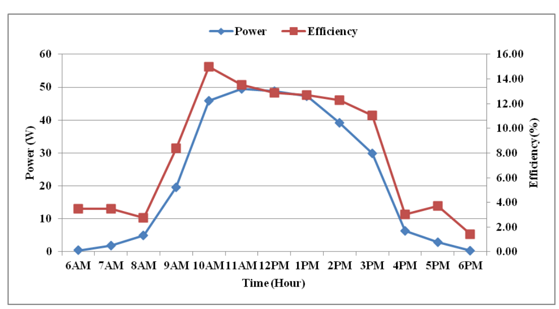
S. No.	Time	G (W/m^2)	V_{oc} (V)	I_{sc} (A)	T_1 (°C)	T_2 (°C)	T_3 (°C)	Power (W)	η_e %
1	6AM	34	13.8	0.79	31	31	28	10.902	85.23
2	7AM	165	18.6	1.01	32	31	30	18.786	30.26
3	8AM	433	19.1	1.57	36	35	33	29.987	18.40
4	9AM	611	19.5	2.23	41	43	35	43.485	18.91
5	10AM	919	18.2	3.8	47	41	38	69.16	20.00
6	11AM	1066	18.1	2.8	46	41	40	50.68	12.63
7	12PM	1070	18	2.56	45	40	39	46.08	11.44
8	1PM	1005	17.8	2.77	45	39	38	49.306	13.04
9	2PM	947	17.7	1.79	43	38	36	31.683	8.89
10	3PM	724	17.5	1.57	40	36	34	27.475	10.08
11	4PM	534	17.3	1.42	39	36	33	24.566	12.22
12	5PM	246	17.3	0.78	36	34	32	13.494	14.58
13	6PM	50	17.2	0.72	31	33	29	12.384	65.83



(a)



(b)



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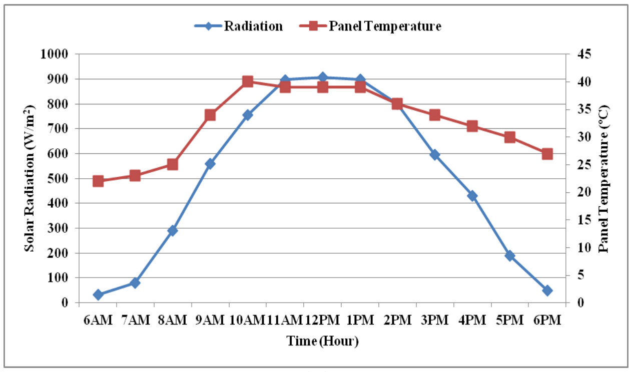
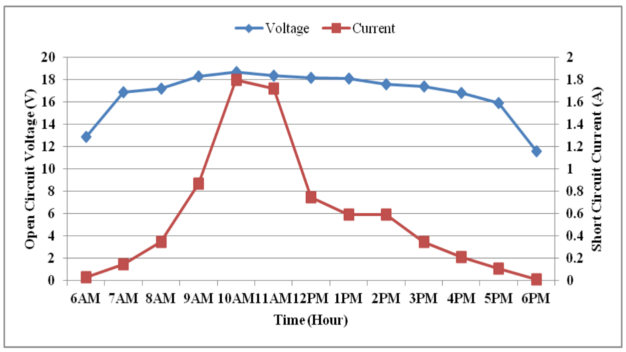
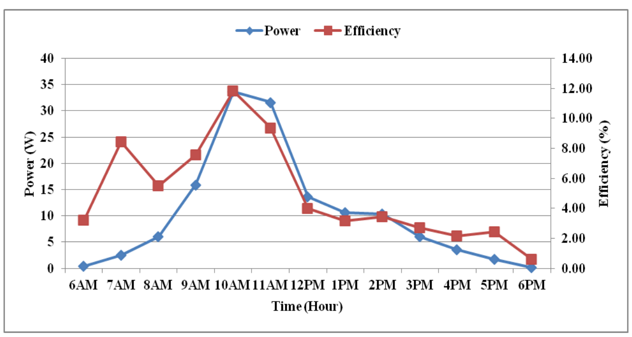

Radiation
Panel Temperature
Solar Radiation (W/m²)
Panel Temperature (°C)
6AM 7AM 8AM 9AM 10AM 11AM 12PM 1PM 2PM 3PM 4PM 5PM 6PM
Time (Hour)

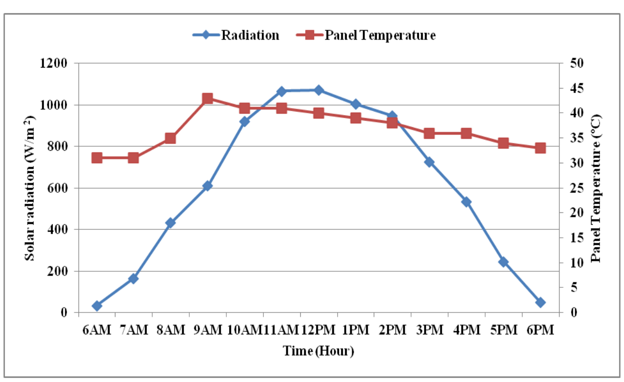
(d)


Voltage
Current
Open Circuit Voltage (V)
Short Circuit Current (A)
6AM 7AM 8AM 9AM 10AM 11AM 12PM 1PM 2PM 3PM 4PM 5PM 6PM
Time (Hour)

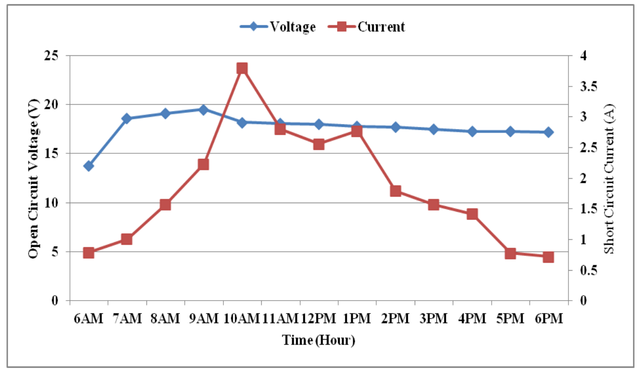
(e)


Power
Efficiency
Power (W)
Efficiency (%)
6AM 7AM 8AM 9AM 10AM 11AM 12PM 1PM 2PM 3PM 4PM 5PM 6PM
Time (Hour)

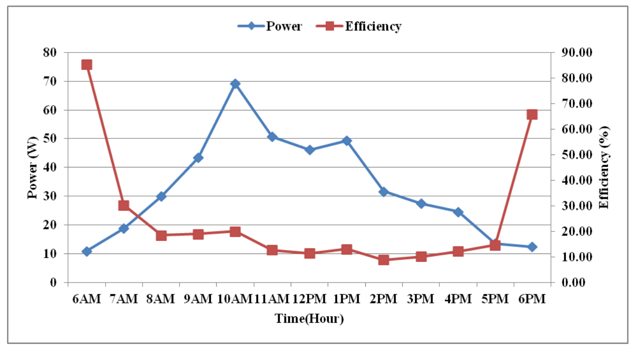
(f)


Radiation
Panel Temperature
Solar radiation (W/m²)
Panel Temperature (°C)
6AM 7AM 8AM 9AM 10AM 11AM 12PM 1PM 2PM 3PM 4PM 5PM 6PM
Time (Hour)

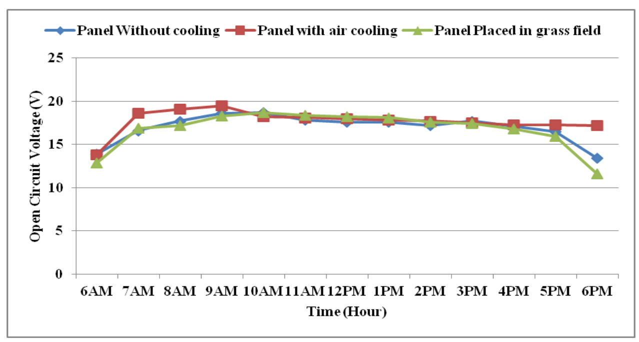
(g)


Voltage
Current
Open Circuit Voltage (V)
Short Circuit Current (A)
6AM 7AM 8AM 9AM 10AM 11AM 12PM 1PM 2PM 3PM 4PM 5PM 6PM
Time (Hour)

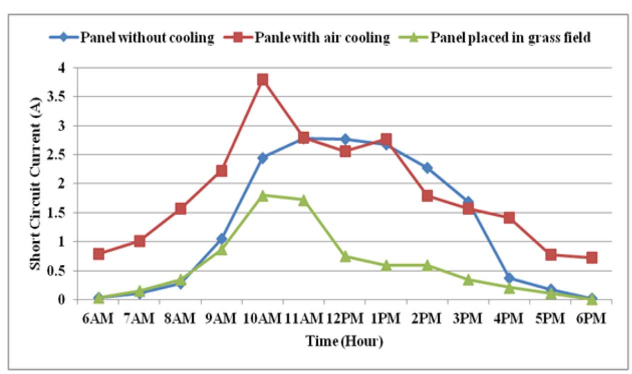
(h)


Power
Efficiency
Power (W)
Efficiency (%)
6AM 7AM 8AM 9AM 10AM 11AM 12PM 1PM 2PM 3PM 4PM 5PM 6PM
Time(Hour)

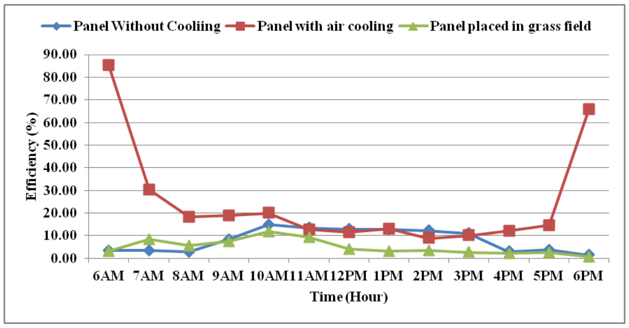
(i)


Panel Without cooling
Panel with air cooling
Panel Placed in grass field
Open Circuit Voltage (V)
6AM 7AM 8AM 9AM 10AM 11AM 12PM 1PM 2PM 3PM 4PM 5PM 6PM
Time (Hour)

(j)


Panel without cooling
Panle with air cooling
Panel placed in grass field
Short Circuit Current (A)
6AM 7AM 8AM 9AM 10AM 11AM 12PM 1PM 2PM 3PM 4PM 5PM 6PM
Time (Hour)

(k)



(l)

Figure 4. **(a)** Variation of solar radiation and panel temperature with reference to time for solar panel without cooling. **(b)** Variation of open circuit voltage and short circuit current with reference to time for solar panel without cooling. **(c)** Variation of power and efficiency with reference to time for solar panel without cooling. **(d)** Variation of solar radiation and panel temperature with reference to time for solar panel without cooling. (Panel placed in grass field). **(e)** Variation of open circuit voltage and short circuit current with reference to time for solar panel without cooling. (Panel placed in grass field). **(f)** Variation of power and efficiency with reference to time for solar panel without cooling. (Panel placed in grass field). **(g)** Variation of solar radiation and panel temperature with reference to time for solar panel with air cooling. **(h)** Variation of open circuit voltage and short circuit current with reference to time for solar panel with air cooling. **(i)** Variation of power and efficiency with reference to time for solar panel with air cooling. **(j)** Comparative analysis of variation of open circuit voltage with respect to time. **(k)** Comparative analysis of variation of short circuit current with respect to time. **(l)** Comparative analysis of variation of efficiency with respect to time.

The Figure 4(d) shows the variation of solar radiation and panel temperature with reference to time for solar panel without cooling (panel placed in grass field). If the solar radiation increases from morning to noon and at noon highest solar radiation occurs and decreases from noon to evening, proportional to solar radiation the panel temperature also increases.

Figure 4(e) shows the variation of open circuit voltage and short circuit current with reference to time for solar panel without cooling (panel placed in grass field) and Figure 4(f) shows the variation of power and efficiency with reference to time for solar panel without cooling (Panel placed in grass field). As in the case of solar panel without cooling, the temperature has effect on open circuit voltage and efficiency. For getting higher efficiency the temperature has to be maintained. For maintaining the temperature, the panel is placed in a grass field. When compared to the normal floor the grass farm is cooler. The observation is made in solar panel placed in grass field, the temperature is maintained to get high open circuit voltage but with low short circuit current. In similar way, the temperature has effect on power and efficiency of solar panel in grass field.

The Figure 4(g) shows the variation of solar radiation and panel temperature with reference to time for solar panel with air cooling. If the solar radiation increases from morning to noon and at noon highest solar radiation occurs and decreases from noon to evening, proportional to solar radiation the panel temperature also increases.

Figure 4(h) shows the variation of open circuit voltage and short circuit current with reference to time of solar panel with air cooling and Figure 4(i) shows variation of power and efficiency with reference to time of solar panel with air cooling. As in the case of solar panel without cooling, the output voltage and efficiency of the solar panel increases with increase in the temperature and attain maximum value after that the temperature still increased and the voltage and efficiency start to decreased. The observation from the solar panel placed in the grass field is the temperature maintained at a level to get high open circuit voltage but with low short circuit current, it leads to create a problem in current collection. For rectifying these drawbacks, the solar panel is cooled with air. For cooling a DC fan is used. The cooling is made for every 15 minutes in order to maintain the temperature of the panel. In this case the temperature of the panel is maintained to get high voltage, current and efficiency.

The Figure 4(j) shows the comparative analysis of variation of open circuit voltage with respect to time. Figure 4(k) shows comparative analysis of variation of short circuit current with respect to time and Figure 4(l) shows the comparative analysis of variation of efficiency with respect to time. From these analyses, the solar panel with air cooling arrangement would give the high open circuit voltage, short circuit current and efficiency over the whole day, because the panel is cooled to maintain the temperature.

5. Conclusion

In the present work, the poly crystalline solar panel was tested in three different cases. The result was discussed and compared with other cases. From the observation, the solar panel with air cooling could give the higher open circuit voltage, short circuit current and better efficiency over the whole day, because the panel temperature rise was reduced by cooling air.

6. References

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