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Output Power Loss of Photovoltaic Panel Due to Dust and Temperature

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Abstract- Due to increase in power consumption and greenhouse problem all over the world, an alternative source is necessary for generating clean and environmental friendly electric power. In this regard, solar energy could be a good choice of power generation, since the cost of solar panels decreasing rapidly in the past few years. Moreover, solar energy has also become more efficient as compared to other source of energy systems. The performance of solar photovoltaic (PV) panel depends on the incoming light to panel surface and it is governed by environmental parameters, mainly dust and temperature. Dust shading creates a barrier in the path of incoming sun light, which reduces the amount of sunlight falling on photovoltaic panel surface, and hence power output and performance of panel reduces significantly. The increase in temperature above maximum power point temperature results in power output loss of panel. This paper presents the phenomena of performance degradation of PV panel due to dust shading and temperature.

Keywords Photovoltaic panel; Fossil fuel; Dust; Sun light.

1. Introduction

The price of fossil fuel and natural gases are increasing rapidly, which is responsible for increase in power generation cost all over the world. The uses of fossil fuels also responsible for greenhouse problem which harms and pollutes the surrounding environment. Therefore, an alternative source, such as solar energy is necessary for generating clean and environmental friendly electric power. Solar energy could be a good choice of power generation, since the cost of solar panels decreasing rapidly in the past few years. Solar energy is available in abundance in nature and it is considered as one of the easiest and cleanest means of source among all other available renewable energy sources. The energy of sun i.e. solar radiation is converted in to electricity by means of photovoltaic effect. Photovoltaic power generation is a method of producing electricity using solar cell. A solar cell converts incoming solar energy in to electrical energy [1]. The photovoltaic (PV) module consists of number of solar cells. A PV panel consists of number of PV modules. The efficiency of solar photovoltaic system mainly depends on incoming sunlight which falling on the PV panel surface. If the amount of incoming sun light falling on PV panel surface increases the efficiency of PV system also increases and vice versa.

On the other hand, the dust particles on panel surface creates a barrier in the path of sunlight, that falling on panel surface. Due to this, part of solar cell in the panel will be shaded, which degrades the performance of PV panel. Further, due to dust accumulation on panel surface, short circuit current and open circuit voltage decreases. However, short circuit current decreases more significantly than the open circuit voltage of PV panel [2-4]. The effect of dust accumulation on PV panel performance is shown in the Figure 1. In addition to dust deposition on panel surface, temperature is a vital environmental parameter, which also affects the performance of PV panel.

As the temperature of PV cell increases its open circuit voltage, fill factor and conversion efficiency decreases. Moreover, the increment in short circuit current is very small due to rise in temperature. Hence, the performance of PV cell reduces due to rise in its surface temperature [5-7]. A study shown that, the reduction in the cell temperature by 22ºC leads to 10.3% of energy gain in the PV module [8]. One more study reveals that for every 1K increase in surface temperature the reduction in open circuit voltage was 0.45% and the increase in short circuit current was 0.09% [9]. Similarly, one more study reported that the reduction in open circuit voltage was 2mV for every 1°C increase in surface temperature of silicon solar cell [10]. From these studies it can be concluded that the reduction in open circuit voltage is more severe than increment in short circuit current. This reduces fill factor of the PV panel, which degrades its performance. In this paper the effect of dust shading and surface temperature on the performance degradition of PV panel is presented.

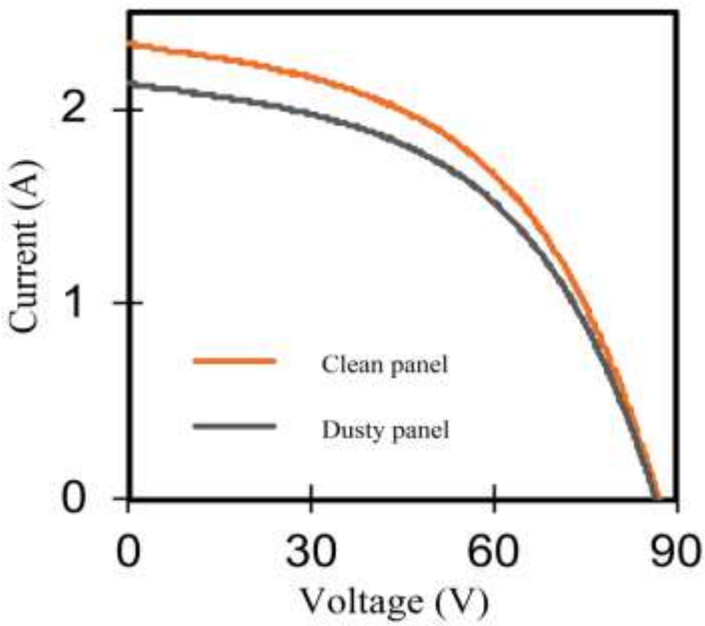

Fig. 1. I-V characteristics of PV panel

2. Effect of dust on PV panel performance

This study is carried out using an indoor solar panel set-up with the help of solar simulator. To determine the effect of dust shading, red soil is used to accomplish shading of solar cells in a string of PV module. Soil of size less than 35µ was used for this purpose. The solar module consists of 36 single crystal silicon solar cells. The typical value of open circuit voltage is 18 volts. Initially a single cell is shaded with the dust and output parameters, such as current, voltage and power readings are measured. The cells of a string are shaded in steps and its respective readings are noted. Table 1 gives the readings of the output parameters of the panel.

Table 1. Measured voltage, current and power with shading of cells

No of shaded cells	Voltage (Volt)	Current (amp)	Power (Watt)
0	17.2	0.27	4.644
1	7.6	0.14	0.836
2	2.9	0.04	0.116
3	2.5	0.03	0.075
4	1.7	0.02	0.034
5	1.1	0.01	0.011
6	1.1	0.01	0.011
7	0.8	0	0
36	0	0	0

The reading in the Table 1 indicates that, as the number of shaded cells increases in a string the respective power output of PV panel decreases, significantly. The relation between number of shaded cells and the power output of PV panel is plotted, which is shown in Figure 2.

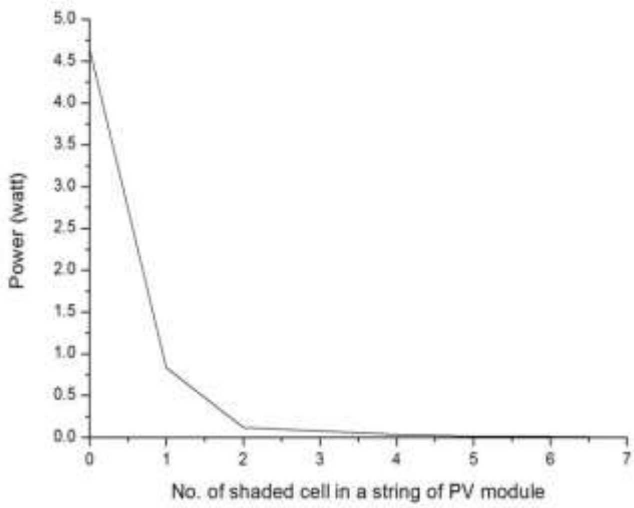

Fig. 2. Relation between power output and number of shaded cell in string of PV module

A close look at the Figure 2 shows that the power output of PV panel drops drastically with the shading of one solar cell (i.e. by shading the first cell) in a string. This is because the shaded cells block the incoming light to the panel surface and generate less charge carrier compared to unshaded solar cells. This reduces the power output of the panel, which degrades the performance of PV panel.

3. Effect of Temperature on PV Panel Performance

Using the above mentioned set-up, the effect of temperature on PV panel is monitored by increasing surface temperature, and its respective power output is recorded. The increase in surface temperature is achived using infrad red lights. , The maximum power output of PV panel is achieved at 31.7°C (is designated as 'maximum power point temperature'). By keeping the surface temperature constant at 31.7°C, the output current and output voltage is recorded by increasing load on PV panel, which is given in Table 2. Similarly, under same loading condition output current and output voltage of PV panel is noted by increasing surface temperature by keeping intial temperature at 31.7°C. Table 3 gives the respective output readings of PV panel with increasing surface temperature.

A comparison between Table 2 and Table 3 indicates that the power output and output voltage of panel is decreasing, though there is an increase in surface temperature, which corroborates with the literature review. The percentage reduction in output voltage and power output due to increase in surface temperature of PV panel are presented, respectively in Table 4 and Table 5 (which are derived from Table 2 and Table 3).

Table 2. Output voltage and current at maximum power point temeprature (i.e. 31.7°C)

Output voltage (Volt)	Output current (amp)	Output power (Watt)
17.50	0.270	4.73
17.90	0.1950	3.49
18.00	0.1740	3.13
18.08	0.1621	2.93
18.18	0.1401	2.55
18.20	0.1274	2.32
18.34	0.1050	1.93
18.41	0.0782	1.44
18.43	0.0608	1.12
18.44	0.0498	0.92
19.30	0.0275	0.53
19.50	0.0164	0.32
19.60	0.0055	0.11
19.70	0	0

Table 3. Output voltage and current under increasing surface temperature

Output voltage (Volt)	Output current (amp)	Output power (Watt)
17.50	0.270	4.73
17.02	0.203	3.46
16.94	0.1842	3.12
16.86	0.1720	2.90
16.71	0.1496	2.50
16.66	0.1380	2.30
16.48	0.1160	1.90
16.40	0.0860	1.40
16.30	0.0674	1.10
16.26	0.0554	0.90
16.19	0.0308	0.50
16.11	0.0186	0.30
16.06	0.0062	0.10
15.89	0	0

Table 4. Difference in output voltage (as obtained from Table 2 and Table 3)

T_i (°C)	V_m (Volt)	V_i (Volt)	$V = V_m - V_i$ (Volt)	% V (Volt)
0	17.50	17.50	0	0
6.2	17.90	17.02	0.88	2.74
7.1	18.00	16.94	1.06	3.20
8.1	18.08	16.86	1.22	3.66
10	18.18	16.71	1.47	4.51
10.6	18.20	16.66	1.54	4.8
12.9	18.34	16.48	1.86	5.83
13.7	18.40	16.4	2.01	6.28
15	18.43	16.3	2.13	6.86
15.7	18.44	16.26	2.18	7.08
16.6	19.30	16.19	3.11	7.48
17.6	19.50	16.11	3.39	7.94
18.2	19.60	16.06	3.54	8.23
20.4	19.70	15.89	3.81	9.20

Note:

T_i= Increase in surface temperature (in °C) of PV panel from maximum power point temperature (i.e. 31.7°C)

V_m= Output voltage (in Volt) of PV panel at maximum power point temperature

V_i= Output voltage (in Volt) of PV panel under increasing surface temperature condition

V= Difference in output voltage of PV panel under two different conditions

% V= Percentage reduction in output volateg of PV panel due to increase in surface temperature

Table 5. Difference in output power (as obtained from Table 2 and Table 3)

T_i (°C)	P_n (Watt)	P_i (Watt)	P= P_n- P_i (Watt)	% P (Watt)
0	4.725	4.725	0	0
6.2	3.49	3.46	0.03	0.86
7.1	3.133	3.12	0.013	0.42
8.1	2.93	2.9	0.03	1.03
10	2.55	2.5	0.05	1.96
10.6	2.32	2.3	0.02	0.87
12.9	1.93	1.9	0.03	1.55
13.7	1.44	1.4	0.04	2.78
15	1.12	1.1	0.02	1.79
15.7	0.92	0.9	0.02	2.17
16.6	0.531	0.5	0.031	5.84
17.6	0.32	0.3	0.02	6.25
18.2	0.11	0.1	0.01	9.09
20.4	0	0	0	0

Note:
T_i= Increase in surface temperature (in °C) of PV panel from maximum power point temperature (i.e. 31.7°C)
P_n= Output power (in Watt) of PV panel under normal operating temperature condition
P_i= Output power (in Watt) of PV panel under increasing surface temperature condition
P= Difference in output power of PV panel under two different conditions
% P= Percentage reduction in output power of PV panel due to increase in surface temperature

4. Conclusions

Renewable energy, such as solar energy, is becoming more attractive especially in remote areas where the access for other power sources is difficult. The output power of solar energy system depends on solar radiation and surface temperature of PV panel. The present study shows that the reduction in solar radiation due to dust shading degrades the output power of PV panel. Hence, dust shading is one of the important factors one should consider while designing and installing the solar system. The complete shading of solar cell creates current mismatch phenomena. This current mismatch creates hotspot heating of PV panel. If the heating is prolonged for a long period, it can permanently damage the solar cell crystal, which reduces the life span of PV panel. Therefore a regular maintenance and cleaning operation of PV panel is necessary for improving its life cycle and performance.

To recapitulate, it is observed that the increase in surface temperature of PV panel degrades its output power. Further, the output voltage also reduces significantly with the increase in surface temperature. The reduction in output voltage varies from 0 to 9.2% with increase in surface temperature from 0 to 20.4%, where as the output power reduces from 0 to 9.09%. Since this study is carried out on a 100W PV panel, the recorded degradation in output voltage and power is meagre when compared to the efficiency of PV panel. However, the effect of surface temperature cannot be neglected in large PV arrays.

References

[1] Kothari D.P, Singal K.C, Rakesh R. *Renewable Energy Source and Emerging Technologies*. New Delhi: PHI Learning Private, 2009.

[2] El-Shobokshy MS, Mujahid A, Zakzouk AK. *Effects of dust on the performance of concentrator photovoltaic cells*. IEE Proceedings I-Solid-State and Electron Devices. 1985 Feb;132(1):5-8.

[3] Klugmann-Radziemska E. *Degradation of electrical performance of a crystalline photovoltaic module due to dust deposition in northern Poland*. Renewable Energy. 2015 Jun 30;78:418-26.

[4] Alonso-García MC, Ruiz JM, Herrmann W. *Computer simulation of shading effects in photovoltaic arrays*. Renewable energy. 2006 Oct 31;31(12):1986-93.

[5] Mahfoud A, Mekhilef, S, Djahli F. *Effect of Temperature on the GaInP/GaAs Tandem Solar Cell Performances.* International Journal of Renewable Energy Research (IJRER), 2015; 5(2): 629-634.

[6] Molenbroek E, Waddington DW, Emery KA. *Hot spot susceptibility and testing of PV modules*. InPhotovoltaic Specialists Conference, 1991, Conference Record of the Twenty Second IEEE 1991 Oct 7 (pp. 547-552). IEEE.

[7] Touati FA, Al-Hitmi MA, Bouchech HJ. *Study of the Effects of Dust, Relative Humidity, and Temperature on Solar PV Performance in Doha: Comparison Between Monocrystalline and Amorphous PVS.* International journal of green energy. 2013 Aug 9;10(7):680-9.

[8] Krauter S. *Increased electrical yield via water flow over the front of photovoltaic panels*. Solar energy materials and solar cells. 2004 May 1;82(1):131-7.

[9] Schwingshackl C, Petitta M, Wagner JE, Belluardo G, Moser D, Castelli M, Zebisch M, Tetzlaff A. *Wind effect on PV module temperature: Analysis of different techniques for an accurate estimation.* Energy Procedia. 2013 Dec 31;40:77-86.

[10] Migan G.A. *Study the operating temperature of a PV module*. Project Report 2013 MVK160 Heat and Mass Transfer, Lund Sweden.