EFFECT OF DUST DEPOSITION ON THE PERFORMANCE OF PHOTOVOLTAIC PANELS

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Abstract
Solar photovoltaic power plants are ideally located in regions with high levels of insolation. Photovoltaic performance is affected by high cell temperatures, contamination, mismatch and other losses associated with the balance of systems. It is critical to understand the implications of each of these losses on system performance. This paper attempts to understand the performance loss due to dust through a dynamic study of the IV performance of panels under different contamination conditions in an open-air experimental test rig. Additionally, this paper discusses the results of an indoor study simulating the performance of photovoltaic panels under different dust deposition regimes.

Keywords: Photovoltaic panel, simulations in MATLAB, solar cell, efficiency, energy sources, photovoltaic module.

Introduction

Environmental parameters such as ambient temperature and local wind and dust patterns can significantly affect system performance. The influence of ambient and cell temperatures on PV system performance has been fairly well studied theoretically and validated by wind tunnel simulations. However, the productivity loss associated with dust deposition is an issue that has not been comprehensively addressed in previous studies because it is difficult to accurately quantify. Research [1, 2] shows that productivity can be reduced by 20% each month due to dust accumulation on dirty cell surfaces. Moreover, experiments carried out in [1] show that high wind speeds contribute to the accumulation of dust on surfaces. No studies have yet been conducted to correlate the amount of dust deposition and the resulting reduction in PV system performance. Tropical regions such as southwest Central Asia are particularly vulnerable to dust accumulation in photovoltaic installations. However, the degradation of PV systems due to dust is greater in tropical regions where arrays are installed at shallower tilt angles. The settling of dust and sand on the surface of the cells can be uniform or uneven depending on the size of the photovoltaic arrays and the terrain. Smaller panels may have uniform dust accumulation, and the decrease in panel performance may be the same across multiple panels in an array. However, the dust accumulation pattern may not be the same for panels with a larger area or panels located at greater distances from each other in the module. Therefore, panel performance degradation due to dust deposition may not be uniform across the array and therefore more difficult to predict for such an installation. Ambient wind and precipitation are believed to be natural dust removers from photovoltaic surfaces. On the contrary, it can be seen that wind and rain often contribute to the deposition of dust on photovoltaic surfaces. High wind speeds increase the tendency for dust to settle on the surfaces of photovoltaic panels and cause a drop in the panel's power output. Rainfall promotes cleaning of photovoltaic surfaces when water helps remove dust particles as it flows off the surface [2]. However, if rainwater evaporates from the surface of the PV without draining, this results in greater dust adhesion to the surface. It is critical to investigate the impact of dust settling on PV system performance to understand the performance losses due to pollution alone. This would help assess the magnitude of the dust deposition problem in terms of potential losses when feeding power into the grid and estimate the economic loss to the power plant. Such an investigation would also facilitate feasibility studies of cleanup mechanisms and the development of appropriate cleanup schedules.

2.Methods and Equipment

A dual method was used to obtain the I-V curves from two identical panels: one panel with dust deposition and the other panel without dust. In the first method, I - V readings were recorded from panels placed indoors and illuminated by halogen lamps simulating sunlight. The second method consisted of recording current-voltage characteristics from identical panels installed on an open experimental stand and exposed to natural sunlight. Both panels in both installations were subjected to identical environmental conditions and differed only in dust deposits.

Electrical characteristics of solar modules PS - P 36 150 W	
Maximum power (Pmax)	37. 0 W
Voltage at (Vmm)	18 . 41 V
Open Circuit Voltage (Voc)	22.06 V
Current at (Imm)	2. 15 A
Short circuit current (Isc)	2. 63 A
Temperature coefficient Isc (KI)	0.058 A/°C
Number of cells in series (N)	36

To simulate indoor solar energy, two identical panels of the specified ratings were installed side by side parallel to the ground. The panels were placed in a dark room, and the only illumination of the panels was a pair of halogen sun lamps, the intensity of which could be varied, suspended vertically above each panel. One of the panels remained free. dust throughout the solar simulation, while dust was deposited on the surface of the other panel. The current-voltage characteristics were plotted and recorded using MECO solar module analyzers . The intensity of the lamps was measured and set using a TENMARS solar energy meter, and a CENTER infrared thermometer was used to measure the lower surface temperature, which is considered a good approximation of the operating temperature of the element. The current-voltage characteristic for the internal solar array of the simulator settings was recorded in two batches of readings. In order to eliminate the influence of an increase in the operating temperature of the cells on the performance of the panels during operation, the first set of data was recorded while varying the intensity of light incident on the panels from 200 W/m^2 to 800 W/m^2 while maintaining the temperature of the panels constant. Thus, the I-V curves thus obtained in this first set are independent of the effect of element temperature on the performance of the two panels. In the second set of recordings, the incident light intensity was again varied from 200 W/m^2 to 800 W/m^2 in increments of 100 W/m2, allowing cell surfaces to reach maximum temperatures at these insolation levels. The test results conducted on the indoor solar simulator setup were presented and discussed in the next section.

3. Results and Discussions

The indoor setup allowed for better control of the test conditions than the outdoor test bench. Because the indoor tests were conducted in a dark, enclosed room, the incident light on the panel could be adjusted to desired values and kept constant over a long period of time. Additionally, by turning off the lamps, the panels could be returned to ambient room temperature, which remained more or less constant throughout the study period. This allowed a more comprehensive study of the dust phenomenon affecting the performance of panel I - V. The indoor solar radiation simulation was repeated in an outdoor experimental tested whether similar behavior could be observed under natural solar radiation and ambient temperature conditions. In both situations, the IV characteristics of the panel that had accumulated dust were compared with those of the clean panel. Of the two panels used for the indoor simulation, one panel was completely free of dust and the second panel had a visible amount of dust deposited on the surface. In the microscopic images in Fig. Figure 3 shows dust deposits on the panels. It can be noted that almost 70% of the surface area of the second panel was covered with dust particles. In the first set of readings, I-V curves were plotted at an intensity of 400 W/m2 at two different cell surface temperatures, viz. 40°C and 50°C (Fig. 1), and in the second case - when the temperatures of both panels were close to the ambient temperature in the room. The intensity of the halogen lamps was increased in steps of 100 W/m^2, starting from 200 W/m^2 to 800 W/m^2, which was the maximum luminous intensity of the lamps. All readings were recorded when the panel temperature reached 30° C . The current-voltage characteristics obtained for two panels at 200 W/m2, 400 W/m^2, 600 W/m^2 and 800 W/m^2 are reproduced here. Table 1 above shows the records at various intensities of the average output power, short circuit currents, open circuit voltages and cell temperatures noted at that intensity.

Table 1. Indoor simulation study records.

G(W/m2)	T (°C)		P (W)		I(A)		V(V)	
	Clean	Dust	Clean	Dust	Clean	Dust	Clean	Dust
200	40.68	42.32	0.84	0.58	0.073	0.048	17.72	17.64
300	41.30	42.57	0.98	0.64	0.082	0.054	17.86	17.69
400	49.84	50.90	1.84	1.11	0.157	0.097	18.26	18.07
500	51.22	52.27	2.83	1.69	0.233	0.136	18.59	18.33
600	52.60	54.88	3.31	1.96	0.269	0.158	18.63	18.38
700	54.99	56.37	3.86	2.33	0.312	0.181	18.62	18.39
800	62.42	64.65	3.97	2.47	0.339	0.195	18.36	18.13

From the records and graphs the following observations can be made:

1. Dust deposits on the panels affect the operating temperature of the elements. It has been observed that a dusty panel performs 1-2° C higher than a clean panel at the same light incidence. This increase in element temperature due to dust further reduces the electrical efficiency of the panel. Increasing the cell surface temperature from 40° C to 50° C resulted in a slight increase in the short circuit current of both the clean and dusty panels, which was, however, accompanied by a large drop in open circuit voltage, causing an overall loss of power output due to the increase in operating temperature. Thus, the combined effect of dust deposition and increased cell surface temperatures further degrades system performance.

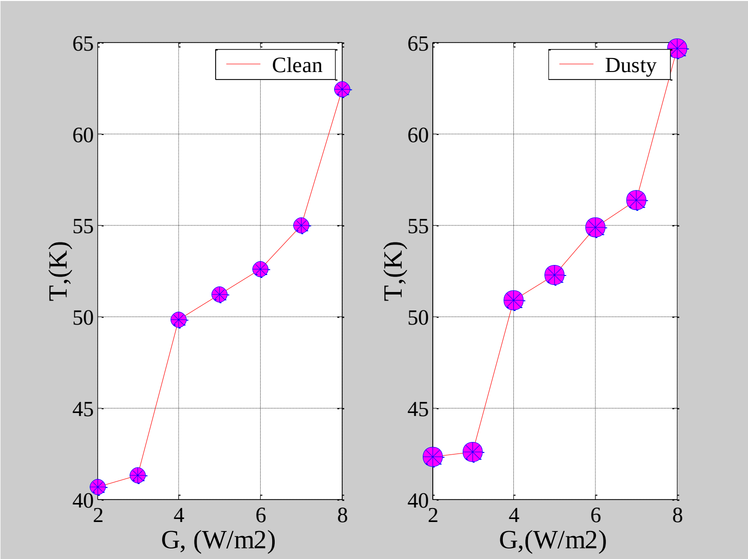

Figure 1.

2. However, dust has a significant effect on the short circuit current generated by the panels. A clean panel always produced a higher output current than a dusty panel. This difference in current outputs increased as the incident light intensity increased from 200 W/m^2 to 800 W/m^2.

Conclusion

The current power of the dusty panel decreased with increasing intensity of the incident light, as can be seen in the penultimate column of the table. Table 1, which shows the ratio of the short circuit current of a dusty panel to the short circuit current of a clean panel. Thus, dust deposition has a significant impact on the output current of PV systems.

References

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