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Influence of Dirt Accumulation on Performance of PV Panels

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Abstract

Accumulation of dirt or particles like dust, water, sand and moss on the surface of solar photovoltaic panel obstruct or distract light energy from reaching the solar cells. This is a major problem since the light obstruction materials pose as external resistances that reduce solar photovoltaic performance. The present work was performed to analyze the effects of accumulation of such dirt or particle son the output performances of solar panel. Experiments using different obstruction materials were conducted under controlled conditions using spotlights to simulate source of solar radiation. It was found that the external resistance could reduce the photovoltaic performance by up to 85%.
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1. Introduction

In 2011 the world's energy demand was still fulfilled by non-renewable sources of energy; i.e. 93% of the overall source of energy [1]. Nevertheless, due to increasing prices of fossil fuels and also due to the alarming environmental issues related to fossil fuel, renewable energy is getting more attention. It has been projected that by 2040 more than 50% of the global energy is going to be in the form of renewable energy [2]. Solar energy, being a major source of renewable energy, is crucial in meeting future energy demand.

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Equatorial countries like Malaysia have a potentialin utilizing solar energy as its future source of electrical power. The Department of Meteorology of Malaysia reported that the mean recorded daily solar radiation of the country ranged between17.4 MJ/m²and 21.2 MJ/m², which is good fora solar energyindustry. As a result, Malaysia has managed to attract investors based on their good location and attractive economics policies. The investments in the industry increased threefold between 2005 and 2010 [3].

Solar photovoltaic (PV) system uses solar cells to convert energy from sun radiation into electricity. The system is made up by a set of panels, a battery, a charge control and the load. Normally mounted on roofs and wired into a building by an inverter, solar PV panels converts the direct current energy received from solar panels into electric current. The common types of solar PV cells are monocrystalline silicon cells, multi crystalline silicon cells, thick film silicon, and amorphous silicon.Deterioration in the efficiency of a solar PV panel throughout its life cycle is not desired, since the capital cost for the system is high while the life-span of the system is limited to about 25 years. Furthermore, it takes about six years [4] for the solar PV module to generate the equivalent amount of energy consumed in its manufacturing processes. A major factor in the drop of efficiency of solar PV panels is the accumulated dust on the panel. The nature of the problem may vary by geographical locations. For example, in Malaysia the humid ambient condition promotes growth of fungus and moss on the PV panel.

There were a wide range of studies carried out on the impact of dust worldwide although with different setting, environment and time frame. In a pioneer workon the impact of dust on solar PV [5], degradation in performance of up to 4.7% was recorded with an average loss in incident solar radiation of less than 1%. A study near Riyadh in Saudi Arabia [6] revealed that dust accumulation caused a 32% reduction in the performance of solar PV within a period of eight months. Nearby, Wakim [7] in Kuwait City recorded a reduction in PV power by 17% due to sand accumulation after six days. Wakim also indicated that the influence of dust on PV performance would be higher in spring and summer as compared to that in autumn and winter. Prior to the work of Wakim, Sayigh [8] observed that about 2.5 g/m²/day of dust were collected in Kuwait between April and June (spring and summer). In a following work by Sayighet al. [9] on the effect of dust accumulation on tilted glass plates showed a reduction in plate-transmittance ranging from 64% to 17%, for tilt angles ranging from 0° to 60°, respectively, after 38 days of exposure. They also observed a reduction of 30% in useful energy gain was observed by the horizontal collector after three days of dust accumulation.

In an indoor study using halogen lamps to represent the source of radiation energy by El-Shobokshy and Hussein [10], it was revealed that cement particles (at 73 g/m²) would result in significant drop in the PV short-circuit voltage; i.e. by 80%. Interestingly, it was found that the smaller the particle size of a fixed deposition density, the greater would be the reduction in solar intensity received by the solar PV panels. This was probably due to the greater ability of finer particles to minimize inter-particle gaps and thus obscuring the light path more than that for larger particles, which was verified in another work of similar nature [11].

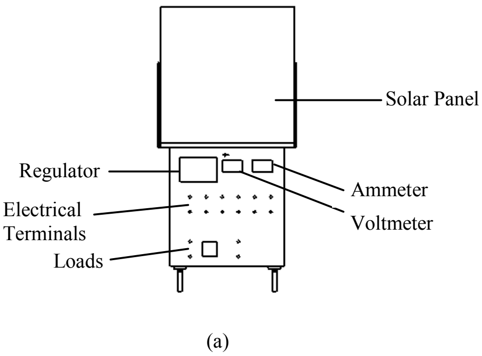
An experiment to investigate the effect of wind velocity and airborne dust concentration on the drop of PV cell performance by usingaeolian dust deposition on photovoltaic solar cells by Goossens et al. [12] showed that significant drop on the performance of such cells. In another work [13], it was found that 4 g/m²of dust layer on the solar panel decreased the output power of solar panel by 40%.Likewise, Nimmo and Seid [14] found that there could be up to 40% of degradation in the output power of photovoltaic due to accumulation of dust. In mitigating the problem of dust,Waagner Biro Gulf, an infrastructure consultancy, proposed cleaning of solar panels by using sewage water [15]. A different mitigation approach was reported, in which NASA produced a self-cleaning solar panel technique that worked by a mechanism that sensed the presence of dust on solar panels [16].

Google [17] did a study involving a flat panel and a tilted panel and found significant impact of cleaning on the former, implying that dirt tends to accumulate about twice more on flat panels as compared to on tilted panel. Another study on the effects of dust on solar PV panel in Palo Alto, California [18], reported that the dirt on solar PV panels caused a 2% reduction in output current relative to that for clean panels. Like the other reports, these two studies in California did not reveal the amount of dust involved. Differently, in an experiment [19] in Roorkee, India, it was discovered that dust accumulation on a glass plate tilted at 45° would reduce transmittance of solar radiation by an average of 8% after an exposure period of 10 days.

Despite the many studies on the impact of obscuring elements on solar PV panels, there were no similar study found in hot and humid tropical countries, where the nature of such elements would be different. For example, the effect of moss grown on the panels was never studies. Thus, the objective of this work was to assess the influence of dirt accumulation on the efficiency of solar PV panels particularly those pertaining conditions in tropical countries like Malaysia. The study, which was conducted indoor, involved artificial lighting by mean of spotlights to overcome the variation that may be experienced under the sunlight. Although solar PV is still new in the country, the findings from this study could be useful for future owners or operators to consider when venturing into this technology.

2. Experiment Setup

Figure 1 shows schematic of the experiment test rig comprising a solar photovoltaic panel (rated 50 W), a set of spotlight and the electrical circuit system. The solar panel module comprised arrays of silicon mono-crystal cells. The dimensions of the panel component structure were 635 mm by 535 mm by 35 mm (thickness). The system was installed in an indoor lab and the radiation energy was delivered by the spotlight system. Spotlights were used in this study in order to overcome inconsistency in the solar radiation resulted from the presence of clouds. The number of spotlights and their positions were varied depending on the requirements of experiments. The radiation energy from the light was measured by using Delta-OHM HD 9221 photo-radiometer, which was placed on surface of solar panel only at the time of measurements of irradiation. Output voltage and current from the solar PV panel were measured by using ProskitMT-1210 digital multi-meter.The system's load was simulated and varied by using light bulbs and a motor, each with different resistance and power ratings.



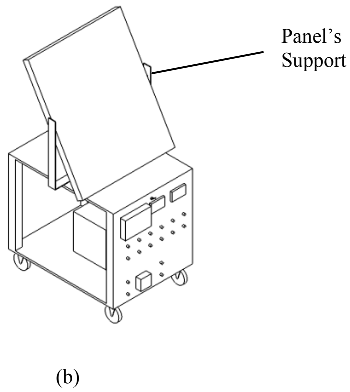


Fig. 1.Schematic of the experiment:(a) front view (b) isometric view.

Preliminary tests were performed at different conditions to determine the suitable number of spotlights that could result in acceptably homogeneous radiation of light energy over the panel area. Each of the spotlights was rated at 100 W. Readings of light radiation intensity were taken at five points on the panel. Lamp configurations using one, two and six spotlights were tested to decide the number of optimum spotlights to be used. It was observed that with the use of six spotlights, the magnitude of the light radiation increased and became close to natural light condition. The variations in results were significant when only one or two spotlights were used, particularly with shorter distance between the lamps and panels (typically less than 400 mm).

The suitable distance between the spotlights and the solar PV panel was also studied by varying the distance and followed by measurements of light radiation intensity. Shown in Figure 2 is the variation of intensity of light radiation measured using six spotlights with distance between panel and light source. The measurements of light intensity using photo-radiometer were varied at five positions as indicated in the figure. In general, it is shown in Figure 2 that the magnitude of the light radiation decreased with increase in the distance between the spotlight and the solar panel. The difference resulted from measuring the light intensity at different spots is shown to be small. This implies that the light radiation under such a configuration would be indifferent to the points of measurement of irradiation, and hence would be able to simulate the natural solar radiation.

External resistances were introduced by evenly spreading talcum, dust and sand on the solar PV panel. Two more experiments were conducted to study the performance of solar PV performance when the panel was covered by moss and by water droplets. For the study on the effect of moss, a layer of naturally accumulated moss on a thin PVC panel was used. In this case the same experiment was conducted but with the moss-filled PVC panel placed on the PV panel. To offset the effect of the PVC panel, measurements were made before and after the PVC panel was cleaned up from the moss. The influence of water droplets was considered since the country receives frequent precipitation all year round and the presence of such droplets on the solar PV panel could affect the amount of light energy transmitted on the solar cells. For the study on the effect of water droplets, water was sprayed almost evenly onto the solar PV panel. Experiments were conducted using two different intensities; i.e. 300 W/m² and 250 W/m². Experiment with water droplets was, however, not performed using the 300 W/m² intensity because the droplets were observed to evaporate fast due to heating by the lights.

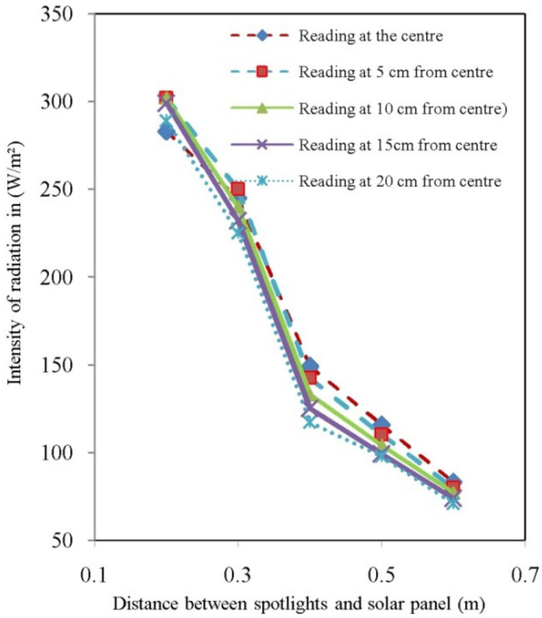


Fig. 2.Variation of light intensity with distance between light source and solar panel using 6 spotlights.

3. Results and Discussions

Shown in Table 1 is the output power of different loads and cases (layers of light obstructions) for light radiation of 310 W/m²; i.e. the higher light intensity. It is shown that the electrical power output was reduced significantly (by up to 83%) when external resistances obscured light path of the solar panel. The experiment was done by using a clean panel and a panel covered with talcum, dust, sand and moss. For light radiation of 310 W/m², the output power of the solar panel reduced by between 9% and 31% due to the effects of presence of talcum, between 60% and 70% due to dust, between 70% and 80% due to sand, and between 77% and 83% due to moss.

The *I-V* characteristics at radiation intensity of 310 W/m² is shown in Figure 3. The maximum no load voltage (V_{NL}) and maximum short circuit current (I_{sc}) were observed for to be 18.88 V and 0.71 A, respectively. It is shown in the figure that V_{NL} and I_{sc} reduced significantly due to the presence of talcum, dust and sand. The maximum power observed was 8.9 W for light radiation of 310 W/m² when a clean solar panel was used, but reduced tremendously due to the presence of talcum, dust, sand and moss. This implies that regular cleaning would be very important in order to ensure worthiness of adopting the readily known high-cost solar PV technology.

Table 1. The output power for different loads resulted from light radiation of 310 W/m². Percentage in bracket shows the reduced of output power relative to clean solar panel.

Testing Loads	Power (W)				
	Clean	Talcum	Dust	Sand	Moss
Short Circuit	0	0	0	0	0
12V Bulb 21/5 W	3.45	2.37 (-31 %)	1.02 (-70%)	0.68 (-80%)	0.66 (-81%)
12V Bulb 10W	8.68	6.65 (-11%)	2.37 (-73%)	1.87 (-78%)	1.44 (-83%)
12 V Festoon Bulb 10W	8.89	7.41 (-17%)	2.83 (-68%)	2.20 (-75%)	1.68 (-81%)
12V Motor 18W	8.15	7.38 (-9%)	3.09 (-62%)	2.37 (-71%)	1.81 (- 78%)
12 V Bulb 8W	3.16	3.01 (-5%)	2.75 (-13%)	3.12 (-1%)	2.65 (-16%)
No Load	0	0	0	0	0

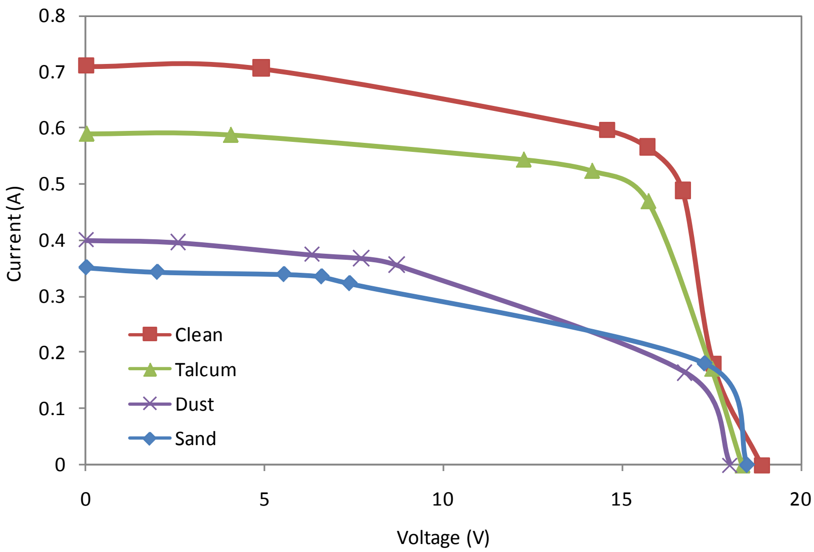


Fig. 3. *I-V* characteristic at radiation intensity of 310 W/m².

Shown in Table 2 is the output power of different loads cases for light radiation of 250 W/m². It is shown in the table that the output power of the solar panel reduced by between 25% and 31% due to the effects of presence of talcum, between 65% and 74% due to sand, between 65% and 74% due to dust, between 15% and 86% due to moss, and between 0.5% and 4.3% due to water droplets. Clearly it is shown that when covered with water droplets from rain or mist would result in negligible effect on output power of the solar PV. On the other hand, unlike water, other particles, particularly moss, which are opaque prevent light radiation from penetrating on to solar cells.

Figure 4 shows the *I-V* characteristics for radiation intensity of 250 W/m². The maximum no load voltage (V_{NL}) and maximum short circuit current (I_{sc}) were observed for to be 18.33 V and 0.52 A, respectively. Like in Figure 3 it is shown that V_{NL} and I_{sc} reduced significantly due to the presence of opaque particles, and thus implies the importance of regular cleaning of solar PV panels.

Table 2. The output power for different loads resulted from light radiation of 250 W/m². Percentage in bracket shows the reduced of output power relative to clean solar panel.

Testing Loads	Power (W)					
	Clean	Talcum	Dust	Sand	Water	Moss
Short Circuit	0	0	0	0	0	0
12V Bulb 21/5 W	1.76	1.32 (-25 %)	0.60 (-66%)	0.60 (-66%)	1.68 (-4.6%)	0.31 (-82%)
12V Bulb 10W	4.63	3.18 (-31%)	1.34 (-71%)	1.24 (-73%)	4.48 (-3.2%)	0.77 (-83%)
12 V Festoon Bulb 10W	5.14	3.59 (-30%)	1.57 (-69%)	1.43 (-72%)	5.05 (-1.8%)	0.91 (-82%)
12V Motor 18W	5.78	4.18 (-28%)	1.69 (-71%)	1.53 (-74%)	5.77 (-0.17%)	0.83 (-86%)
12 V Bulb 8W	2.94	2.71 (-7.8%)	3.03 (3.1%)	2.66 (-9.5%)	3.10 (5.4%)	2.51 (-15%)
No Load	0	0	0	0	0	0

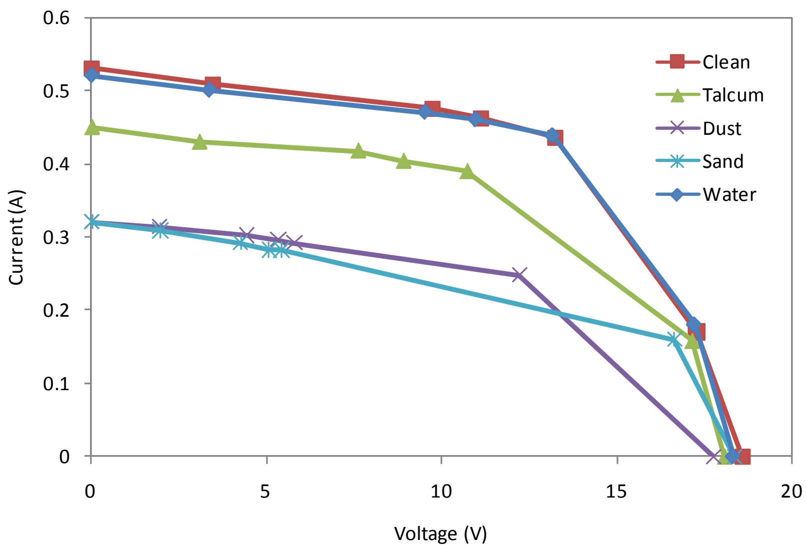


Fig. 4. *I-V* characteristic at radiation intensity of 250 W/m².

4. Conclusions

This study shows that opaque particles tremendously affect the performance of solar PV, in particular moss, which could reduce the output power by up to 86%. To overcome these problems, a proper maintenance operation for the solar panels would be necessary. Particles like dust and sand can be reduced naturally when washed away by rain but for moss proper cleaning would be required. The study also concludes that water droplet from rain would not significantly affect the performance of solar panel.

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