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(Research Article)

Effect of dust particles size on Photovoltaic module (PV) performance

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Abstract

This study explores the effect of different size of dust particles accumulation onto the PV module performance. In which size properties of four kinds of dust particle samples (45 µm, 125 µm, 250 µm and 355 µm) is used to assess their impact on electrical and optical properties. In sieve analysis, a major portion of the very fine sand particles (73%) has been observed. The obtained results indicate that variation of physical parameters (grain size) on PV performance in terms of output electric power and light transmission. It has been concluded that small fine particles significantly deteriorate the performance of PV module, more so than coarser particles.

Keywords: Dust soiling; PV sites; Particle size; Shadow effect; Power loss; Transmittance loss

1. Introduction

Generally, solar photovoltaic panels are installed under the outside environmental conditions. However, PV panels face numerous shadow effects due to a variety of soiling effects caused by dust deposition, pollutants, passing clouds, guano, etc. The PV technology is very sensitive to partial shading (*i.e., termed as non-uniform illumination*), where only a single spot can disturb the whole module's performance [1, 2]. Deposited small dust particles play a significant role in the PV system performance. Whenever minute dust particles are deposited over the PV module surface, they reduce illumination (transmittance) intensity by absorbing and scattering light, which turns into a great loss of output power generation as shown in Fig. 1. The degree of power loss depends on its parameters, like shape, size distribution, and density [3, 4].

Figure 1 The accumulation of heavy amount of small dust particles onto a PV glass surface

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The main characteristics of deposited dust particles onto PV systems are mainly decided by the dust features (i.e., weight, shape & size, chemical, optical properties, and electrostatic properties etc.) and PV module surface property (roughness of PV glass cover). A degree of roughness plays a significant role in the friction level between small particles and glass plate. A rough surface easily allows to settle more dust particles on itself and promotes a further dust level [5, 6].

2. Effect of particle size on PV performance

Only a little dust deposition on the PV surface can have a severe negative impact on the output power generation. The minute particles have high adhesion strength to the PV glass surface. Even though they can adhere to the surface in a vertical position (high inclination) also [7]. Moreover, Appels et al. [8] exhibited in their study that the deposition of finer dust particles (2-10 μm) has a more serious effect on the power output as compared to the coarser particles. This is because the finer dust particles are to be distributed more uniformly onto a PV glass surface than coarser particles. Due to this, a minimum void space between the particles exists and, as a result, only less sunlight can pass (transmission losses) through the particles, i.e., leading to a reduction of cell performance [9, 10]. The presence of prevailing moisture in the air also promotes the accumulation of small dust particles and increases the adherence to glass cover (i.e., cementation process) [11, 12].

3. Experimental methodology

This study aims to characterize and analyze dust deposition and its adverse effect on PV system performance. As a result, the study of particle size distribution on PV module surfaces is most essential. Moreover, it can be easily seen that the different sizes of dust particles are to be settled over the front glass plate of PV device. In this context, some efforts have been made to categorize and evaluate the effect of particle size of collected dust samples from PV module surface directly. In experimental (particle size analysis) work, the dust sample was collected from the panel's surface. The settled dust particles were removed using a small fine soft brush and sealed inside the small plastic bottles. The samples were taken from December to February (i.e., critical dust deposition period in Rajasthan) for the three months of winter. For sieves analysis, the different sizes of strainers were used (i.e., S1-S12; 2mm, 1.4mm, 1mm, 710μm, 500μm, 355μm, 250μm, 180μm, 125μm, 90μm, 63μm and 45μm respectively). In an artificial dust soiling experiment, dust of different particle sizes has been uniformly deposited over a glass coupon of size (10cm ×10cm) with the help of a strainer. Now, the impact of particle size on output electrical power and transmittance has been assessed.

4. Result and discussions

4.1. Sieve analysis of collected dust samples

The sieve analysis is a series test which is performed to determine the effect of dust particle size on the PV performance. Sieve analysis was performed to assess the size and composition of the collected dust sample. For which, different sizes of sieves are used, from 355 μm (S6) to less than 45 μm (S12). Afterward, different sizes of particles were separated out by sieve analysis as presented in Fig. 2.

Figure 2 Different size of dust particle after sieved.

As a result, Figure 3 shows the conclusions of a sieve analysis which is implied by the percentage composition (%) corresponding to strainer size (S6-S12) as presented by the column chart.

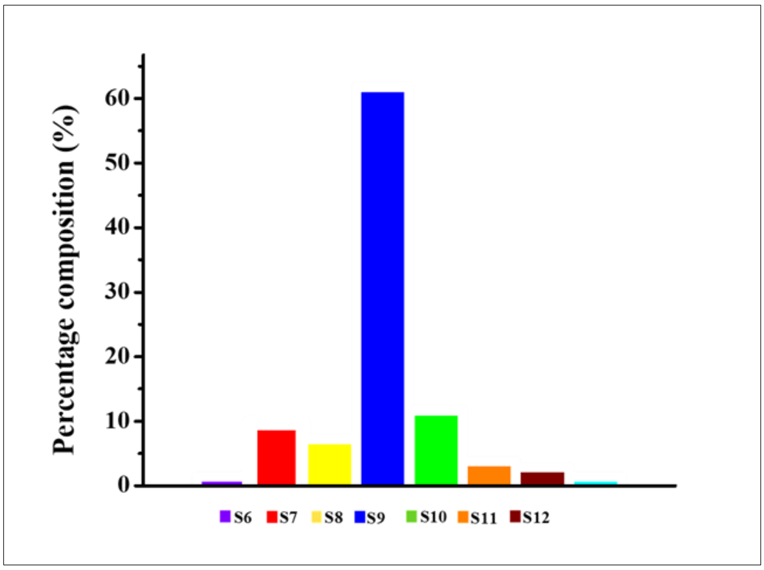

Figure 3 Particle size composition of soil samples directly collected from panel's surface.

Moreover, it is monitored that the size of collected dust particles from the panel's surface changes from the range of medium silt (16-31 µm) to medium sand (125-355 µm) particles, as shown in Table 1.

Table 1 Sediment type distribution of dust particles collected from PV module surface.

Sediment type	**Coarse silt**	**Very fine sand**	**Fine sand**	**Medium sand**
Range (µm)	38-63	90-125	180-250	355-500
Size composition (%)	8.1	73.5	17	1.4

The obtained results show that the soil sample contained a high concentration of very fine sand (73.5%) particle size and minimum of medium range (1.4%) respectively. Grain sizes of diameter from 60 to 2000 µm are carried by wind [13]. These small particles are transported by wind and correlated with the distance from which the small dust particles are carried by air, as small particles with a diameter (up to 5µm) can travel long distances and cover wide areas. Whereas particles in the range of (20-40 µm) accumulate from the local area and larger components (50 to 70 µm) of dust particles come from the local region, activities like human movement, vehicular activities, machinery and livestock [14].

4.2. Electrical analysis

In order to determine the effect of different sizes of dust particles on output power has been examined. The output power has been assessed with four different sizes of dust particles, i.e., 45 µm, 125 µm, 250 µm, 355 µm as shown in Fig.4.

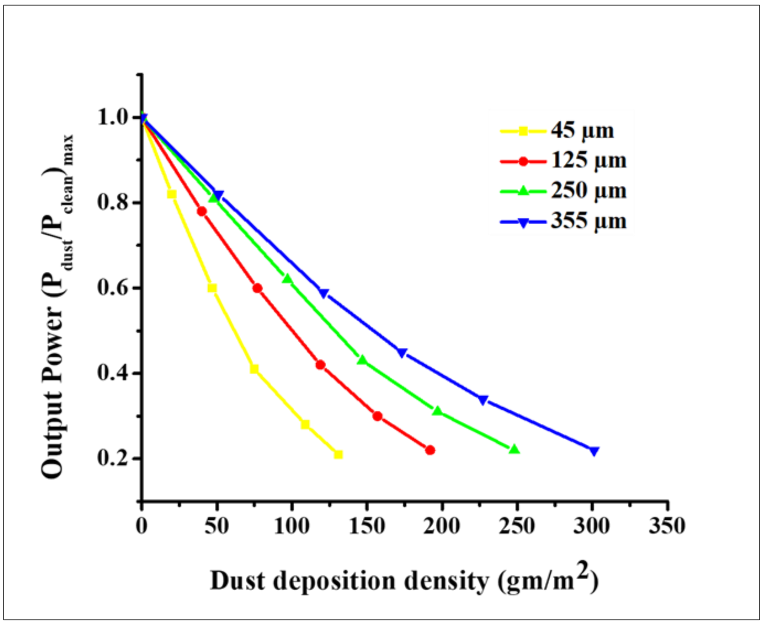

Figure 4 Effect of different sizes of dust particles deposition on PV module performance.

The maximum output power was plotted versus dust deposition density (gm/m^2) for the dust particle samples. The loss of output power was measured by comparing the maximum power output P_{max} (clean) with respect to a dust particle sample $_{Pmax}$ (dust) by using Solar Module Analyzer PROVA 210 [15]. A reduction in output power has been analyzed under the artificial lightning source (light intensity at the radiation level of 650 W/m2) in the laboratory. Generally, the output power generation reduces as the grain size of dust particles decreases. It is seen that finer dust particles lead to higher loss in output power generation than larger-sized particles, for similar mass volume [16]. Because of the fine size of dust particles, it can have the ability to uniformly distribute over the PV module surface, which prevents a extreme portion of light from passing through the transparent PV glass cover. As a result, a heavy reduction in output power has been observed, causing fine particles.

4.3. Optical analysis

Similarly, a considerable reduction in optical transmittance for different sizes of particles can be easily assessed. In the experiment, a glass coupon was artificially deposited onto different sizes of dust particles as presented in Fig. 5.

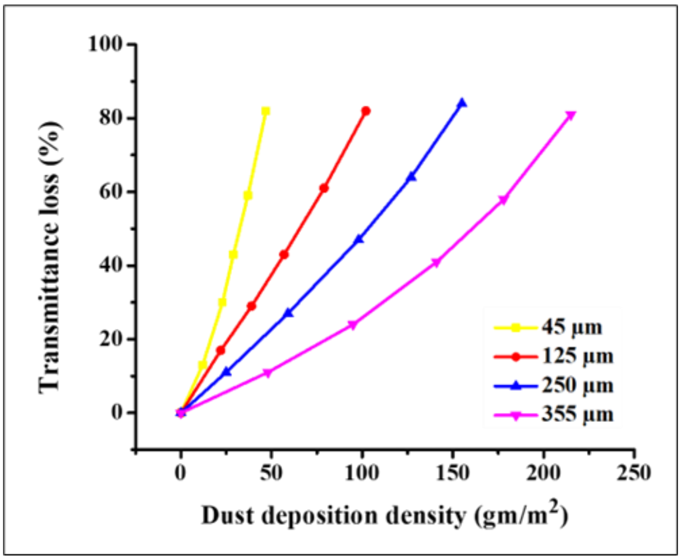

Figure 5 Effect of different size of dust particles deposition on optical performance of PV module.

A normal transmittance through the soiled glass coupon is measured and compared to the clean glass plate. The average normal transmittance intensity of light (w/m^2) was measured using a MECO solar power meter. A reduction of optical transmittance caused by dust particle accumulation can be determined by the transmittance loss (%) as follows:

$$\Delta\tau(\%) = \frac{\tau_{max}(dust\ particles) - \tau_{max}(clean)}{\tau_{max}(clean)} \ldots\ldots\ldots\ldots.(1)$$

The fall in normal transmittance is shown by a comparison of transmittance intensity observed between clean and a sample of dust particles. It is obvious from the obtained transmittance curve that the loss in transmittance is directly related to the dust particle size. Furthermore, as the dust particle deposition rate increases, the transmittance loss rises at a gradually decreasing rate until attaining its upper limit. After that, the effect of dust particle accumulation disappears. Finally, normal transmittance has been observed to quickly reduce the accumulation of quite small dust particles.

5. Conclusion

In this study, the accumulation of different sizes of dust particles on the PV module glass cover was demonstrated to reduce their performance. This means that the effect of particle size is directly correlated with the level of PV performance, which can be clearly seen in the experimental study. For dust samples, fine particles have more serious effects on the PV performance than coarser particles. Thus, it is obviously found that the output power decreases more rapidly with the settlement of fine particles onto a PV module surface. These small particles have the capability to distribute uniformly over the PV module surface, blocking a large proportion of light from passing through the PV cells. This means that there is very less void space between the small dust particles through which light can pass.

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