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Influence of dust deposition on photovoltaic (PV) module performance at the different sites

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Abstract

This research paper has been designed to investigate the effect of small dust pollutants on a solar photovoltaic panel output power capacity under different environmental conditions. The impact of the various dust pollutants on photovoltaic (PV) modules has been assessed and analyzed. The results show how dust accumulation influences the PV module's performance through output power. The panel performance gradually decreases with increasing dust accumulation on PV glass plate. Consequently, A significant amount of power loss (12.52% - 16.29%) has been recorded at the different PV sites. In which, a maximum level of power loss (16.29%) was obtained for the lime-stone site.

Keywords: Dust deposition; Small particles; PV sites; Shadow effect; Dust pollen

1. Introduction

Currently, the deposition of minute dust particles onto the front glass plate PV module is a great challenge for the performance and life of the device. These small (fine and coarser) dust particles are to be transported with the wind by various sources such as sand storms (especially in desert areas), vehicle activities, the construction of buildings, industrial pollution (i.e., cement, limestone, bricks etc.), stone crusher factories as shown in Fig.1. Dust can be measured to be minute solid particles with a size of less than 500μm [1, 2]. The little dust particles can greatly disturb the performance of PV solar module in two types: (1) through the direct deposition of dust on the flat surface of the PV modules, and (2) the presence of dust in the local region around the PV site. In both cases, the accumulated dust particles will affect the PV output negatively. Because the solid dust particles absorb or disperse part of the sunlight significantly. The level of power degradation depends on the mass, shape, and size of dust particles deposition on the flat surface of PV module [3]. Moreover, the rate of dust deposition on PV units depends on the local atmosphere, wind blow speed, and geographic conditions [4, 5].

1.1. Effect of environmental dust deposition on PV module

Generally, PV modules are installed in outside environmental conditions, where these face many obstacles in power production regularly. When small sold dust particles deposited over the flat smooth glass cover, these interfere with sunlight by the optical effect of absorbing, attenuating, and scattering, incident sun radiation [6]. In this regard, a noteworthy work is stated by Sayyah et al., 2014 [7]. In which output power loss caused by dust accumulation is regarded as geographical location, local atmospheric conditions.

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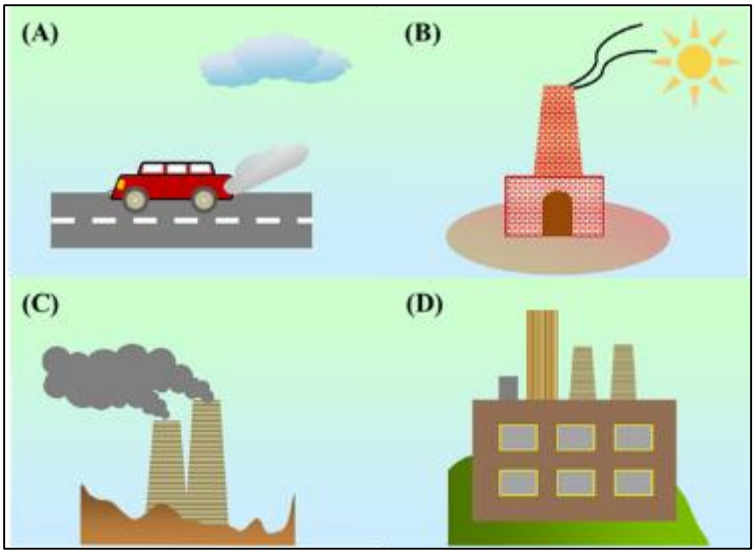

Figure 1 Different places of pollutants deposition: (a) transport activities; (b) bricks-kiln; (c) lime-stone industries; and (d) construction sites

2. Methodology

In order to determine the effect of accumulated dust particles onto the front glass cover of the PV module which the different type of locations are selected in the vicinity of the roadside (PS#1); brick-kiln (PS#2); lime-stone industry (PS#3); and construction site (PS#4). The study site was located near Jaitaran village, Pali District (Rajasthan). The performance data (Particle size analysis, gravimetric study, and power loss) were carefully detected every month and then analyzed it for the seasons, i.e., Winter (November to February), Summer (March to June), and Rainy (July to October).

3. Result and discussions

3.1. Particle size analysis

The obtained results of the composition analysis of particle size attributed that the collected dust particle samples PS#1, PS#2, PS#3, and PS#4 contain major concentrations of < 31 µm (i.e., Medium and coarse silt) diameter particle size as presented in Table 1. All dust samples were sieved with a mesh size no. 31 µm to 125 µm. These collected dust samples were analyzed for the winter (November to February) i.e., critical dust deposition period in a year. It depicts the main proportion of dust particles size made up in the range of fine coarser dust particles (particle size below the range 63 µm). Moreover, PS#3 dust contains coarser dust-sized particles which will hamper more sunlight radiation.

Table 1 Particle size distribution of collected dust sample

Sediment type	Size (µm)	PS#1 (%)	PS#2 (%)	PS#3 (%)	PS#4 (%)
Medium silt	16-31	45.66	50.22	52.77	41.71
Coarse silt	31-63	15.21	9.99	26.21	18.01
Very fine sand	63-125	37.31	35.98	20.23	36.49
Fine sand	125-250	1.82	3.81	0.79	3.97

3.2. Dust gravimetric analysis

The collected dust samples were weighed by using an Amici tools high precision electronic balance (8068 series, resolution 0.001 gm) and then, dust samples weight (dust gravimetric density) was determined using the equation:

$$w = (w_2 - w_1)/a$$

Where, is dust density (g/m^2), w_1 is the initial weight of butter paper, w_2 is the final weight of butter paper with dust sample, and is the total area of the PV module (m^2) [8]. Afterward, data were analyzed for the three seasons i.e., Winter, Summer, and Rainy in a year. In context, average dust deposition is determined for an every season as depicted in Figure 2 below.

It is practically observed that a peak level of dust deposition has been seen close to the lime-stone industry and meanwhile minimum along the roadside. Because the lime-stone industry emits more coarser size (very small) of dust particles. Moreover, it is also seen that the availability of privileged moisture in the air promotes more dust deposition over the front glass plate in all sites.

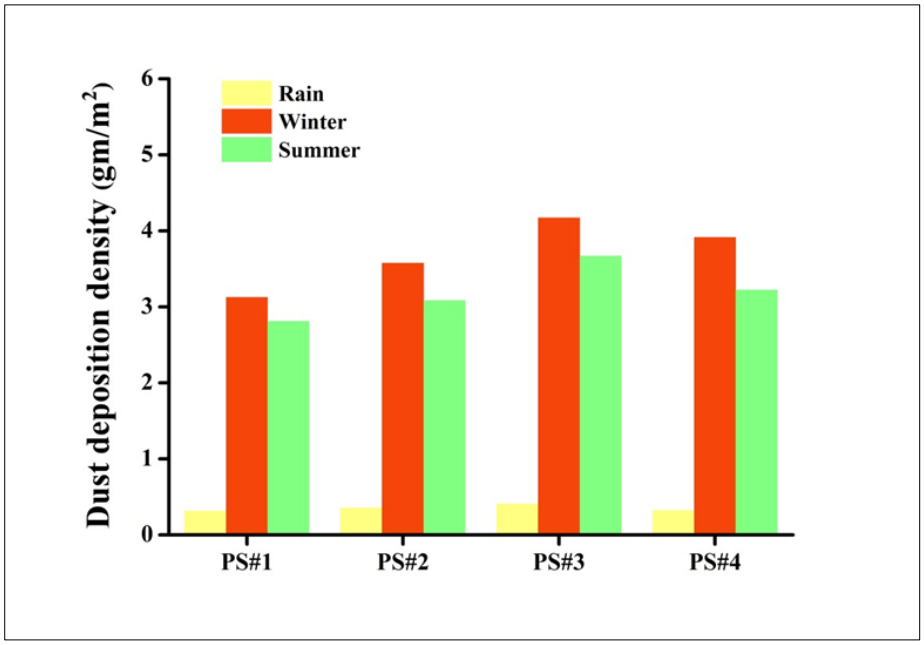

Figure 2 Effect of dust deposition onto the solar photovoltaic plate at the different sites under different types of environmental conditions

3.3. Output power analysis

An electrical study (power loss %) is performed to demonstrate the impact of dust deposition on smooth PV glass plates. The experimental work is accomplished by fixing the dirtied glass plates to a standard solar PV module as shown in Fig.3. The output electrical data (average power loss %) is estimated every month and then analyzed for the three seasons in a year. The data were measured under the natural sunlight for the determination of power output. The output DC power has been recorded with clean module glass plate (reference PV module) and then with an exposed (dirted) glass plate by using a Solar Module Analyzer PROVA 210 detailed as follows [9, 10] as shown by Eqn. 1.

$$Power\ loss\ (\%) = \frac{P_{out}(clean) - P_{out}(dirt)}{P_{out}(clean)} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

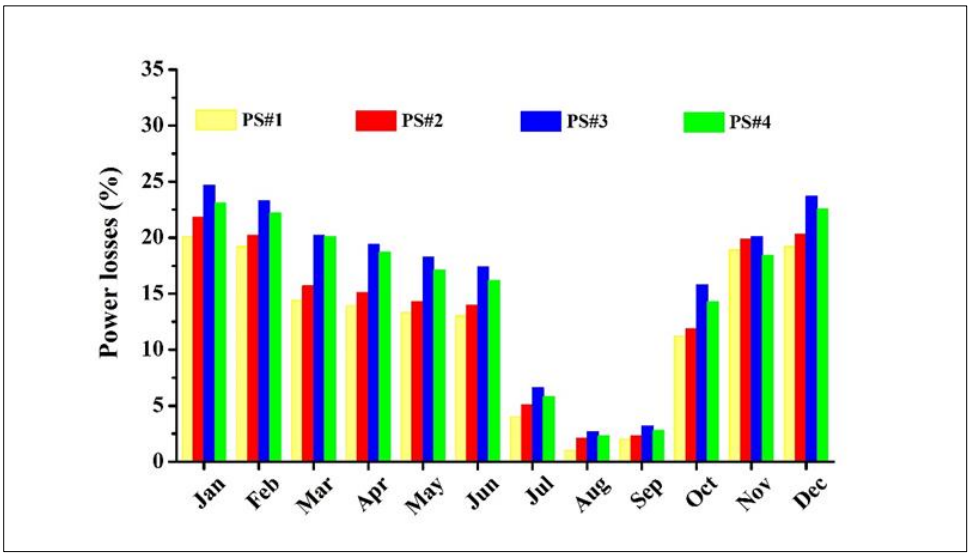

Figure 3 Effect of dust deposition on the output power losses (%) at different surrounding locations

It can be clearly seen that the accumulation of small pollutants on the front glass cover of the PV module blocks the sunlight and hence the result in power loss. Figure 3, depicts the power loss (%) caused by the deposition of small dust pollutants on the PV cover at different sites. According to observations, the collected dust sample PS#3 (lime-stone industry) leads to maximum power loss meanwhile minimum along to roadside (PS#1).

Table 2 Average seasonal power loss (%) at the various previous sites

PV Site	Rain	Winter	Summer	Annual
PS#1 (%)	4.55	19.35	13.65	12.52
PS#2 (%)	5.35	20.55	14.78	13.56
PS#3 (%)	7.08	22.95	18.83	16.29
PS#4 (%)	6.3	21.58	18.03	15.30

4. Conclusions

This research study has been conducted to demonstrate the impact of different pollutants which emitted from various local PV sites. The outcome of this study shows that maximum power loss (%) has been detected in winter due to presence of high levels of moisture in air.

Moreover, Based on the obtained results, it is concluded that a considerable amount of power loss has been recorded corresponding to PV site PS#3 (lime-stone) i.e., fine lime-stone dust powder is more prone to output power production.

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