Effects of Cement Dust on the Performance of Solar PV Module

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Abstract: Photovoltaic (PV) modules are one of the source through which solar energy is trapped for power generation. Worldwide accumulation of dust over the PV module causes a serious concern on the performance output. This paper deals with the artificially sprayed cement dust of different masses on three different PV modules with fixed tilt angle of 20° in a single day. Measurements of current, voltage and solar radiation are recorded manually every 30 minutes from 7.00am – 16.00pm. The performance of the solar panel with dust density of 0.359 mg/cm2 is less affected than the other two dust densities of 0.828 mg/cm2 and 1.040 mg/cm2. The results showed the average efficiency loss in the PV module of cement dust density 1.040 mg/cm2 is about 3.02% whereas the average efficiency loss in 0.828mg/cm2 is about 1.90% and in 0.359 mg/cm2 is about 0.68%.

Keywords : Photovoltaic (PV) module, solar energy, cement dust density, tilt angle, efficiency.

I. INTRODUCTION

Renewable energy has become a vital source in providing a green environment. Many developed and developing countries are involved in researches based on renewable energy sources. Out of all solar energy power generation systems, photovoltaic (PV) modules are getting much interest of researchers for its easy installation and maintenance. The PV based solar projects are more suitable for countries like India, where the average daily solar insolation varies from 4-7 kWh/m2. But the dust pollution deposition over the PV module has increased the demand for water and also made the maintenance costlier. The dust travelling in the air settles on the glass surface of the PV module and reduces the intensity of light energy falling over the solar cells. Output performance decreases with high deposition of dust density over the PV panels. There have been various studies conducted to investigate the effect of dust on Solar PV. The problem of dust depends on dust type, composition and its size. The deposition of the dust mainly depends on the location of the PV module [1]

Studies were conducted in indoor as well as outdoor environment for artificial and natural dust, for mono-crystalline and poly-crystalline silicon cells. Experimental study by Elminir et al. involving 100 glass samples with different tilt and azimuth angle was conducted and results showed the dust deposition density varies from 15.84 g/m2 for tilt angle 0° to 4.48 g/m2 for tilt angle of 90°and orientation of 135° deviation from north [2].

The effect of tilt angle is directly related to the amount of dust density settling on the PV panel [3]. Kaldellis and M. Kapsali studied the effect of three dust namely red soil, limestone and ash on the PV panel. A theoretical model was proposed for describing the energy yield decrease in the PV generator operating in urban natural pollution [4]. Sayigh conducted a study to understand the effect of dust over the flat plate collectors. The study was based on the varying the tilt angle of the collector and observing the density of dust settled on the panel [5]. Sayigh et al .also studied the effects of dust on glass plates tilted at various angles for 38 days of exposure located in Kuwait. The results for tilt angles ranging from 0°–60°are found out to be at a transmittance rate of 14 – 17% reduction [6].

Shobokshy and Hussein conducted an experiment by dispersing dust particles of mean diameter of 80 µm uniformly over the panels and observed the output reduction of 84% and short circuit current by about 82% for a dust accumulation of about 250 g/m2[7]. Quasem et al. tested the spectral transmittance for different tilted glass surface and found that for dust density of 8.5 mg/cm2, amorphous silicon showed a 33% reduction whereas the crystalline silicon and copper indium gallium di selenide (CIGS) showed a 28.5% and 28.6 % respectively[3].

Dorobantu et al. studied the effect of surface impurities on the PV module. A 10% increase in internal temperature of the cell was found using a thermo-vision camera. Catelani et al. conducted a study on characterisation of photovoltaic panels with effects of dust and applied a statistical method for optimizing the maintenance activity of the solar PV plant by using a Clean PV module as reference [8]. Mekhilef et al. studied the impact of dust accumulation, humidity level and the air velocity on the PV module [9].
Goossens and kerschaever conducted an experiment on

solar PV module performance with four wind velocities and four concentrations of Aeolian dust with a tilt angle of 10°. The experimental results showed drop in performance of the solar PV at high wind velocity, due to the accumulation of air borne dust. Whereas, the effect is much lower in the lesser wind velocities [10]. Experimental work performed by Benatiallah et al. shows the settlement of dust on PV module triggers a fall of the electric parameters of the module, the power delivered by module decreases of 69-97 % according to sand density, as well as the efficiency falls in the range of 66-96 % and the current decreases by range of 72 to 93% [11]. A frame work was drawn to understand the various factors that influence the settling of dust by monto et al. [12].

The specification of the solar panel used in the experiment is showed in table 1. This study concentrates on the cement dust pollution from cement industries and construction activities around the PV generators. The main objective of the study is to find out the efficiency degradation in PV panel with varying thickness of the cement dust on the glass surface.

Table 1. The Solar module used in the experimental study

Specifications	Value
Short Circuit Current (ISC)	0.62A
Open Circuit Voltage (VOC)	10.60V
Current Maximum (IMax)	0.57A
Voltage Maximum (VMax)	8.7 V
Power Maximum (PMax)	5W
Fill factor (FF)	0.69

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II. MATERIAL AND METHODS

The Experiment is carried out in two pairs of identical mono-crystalline PV module with capacity of 5W, are placed in an open environment, facing south with 20° tilt angle as shown in the fig.1. The complete experiment setup is fabricated and performed in CO2 research and green technologies center, VIT University, Vellore. Out of four panels first panel P1 is kept clean and rest of the three panels P2, P3 and P4 are sprayed with cement dust of <75µm (200 mesh size) at a height of 1m from the top.

With P1 taken as reference P2, P3 and P4 are coated with three different concentrations of cement dust. Manually, a series of solar radiation (IG), Voltage (VOC) and Current (ISC) measurements are noted every 30 minutes from 7.00am – 6.00pm in all the four panels simultaneously. Before every reading, panel P1 is cleaned with cotton piece. Voltage (VOC) and Current (ISC) are recorded using an electronic multi-meter (SEW electronics Ltd) and solar global radiation (IG) is measured using a pyranometer. Previous day before experiment some cotton pieces are kept in a dehumidifier and after 24 hours the initial weight of the cotton is recorded as M1, after the experiment the cotton piece (M1) is used toclean the surface of the dust coated panel.

Now, after cleaning again the cotton is kept in dehumidifier for period of 24 hours and then the final weight of the cotton piece is measured (M2). The mass of the cement dust accumulated on the surface of the module is measured by finding the difference in mass of cotton piece after cleaning (M2) and before cleaning (M1). After cleaning the surface of PV module final mass (M2) of cotton is measured after 24 hours of dehumidifying. The mass of cement dust is calculate using a formula

$$M_{Final} = M_{After\ Cleaning} - M_{Before\ Cleaning}$$

Here the (Mfinal) shows the mass of the cement dust accumulated on the panel. It is measured in weighing balance (accuracy of 0.01 mg) and expressed in mg. With collector area (AC), i.e the surface area of the panel is 0.03465m2, the density of the dust can be calculated.

Figure 1: Experimental setup of the cement dust Solar module kept at 20°

III. RESULTS AND DISCUSSION

For studying the effect of dust on the PV module, output power of module, capacity factor (CF) and efficiency are calculated. Previous studies reported were done for

constant solar radiation in indoor as well as in outdoor with short duration. But in this study the readings are recorded for the whole day from morning 7.00am – evening 6.00pm.The CF value determines the power loss in the dust coated Solar PV module

Table 2: Cement dust density measured on the surface of PV panel

Cement dust particle size of <75 µm (200mesh)	Panels	Cement dust density (mg/cm2)
	P1	Clean
	P2	0.359
	P3	0.828
	P4	1.040

Table 2. Shows the dust density measured over the surface of the panel. The maximum power (W) is calculated using a fill factor (F.F) with Voltage (VOC) and Current (ISC). The Power output for clean and dust coated panels is calculated and curve is drawn in fig. 2. Here the average power produced for clean panel during the experiment is 2.55W but for cement dust density of 0.359 mg/cm2 it is 2.45W and whereas for the 0.828 mg/cm2 and 1.04 mg/cm2 dust density it is 2.29W and 2.10W respectively.

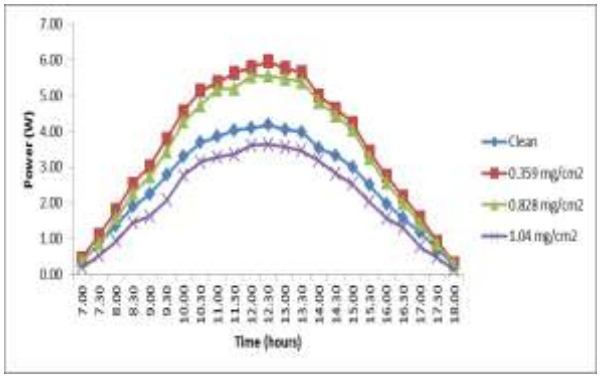

Figure 2: Power curve of the PV module for different cement dust density kept at 20° tilt angle with time

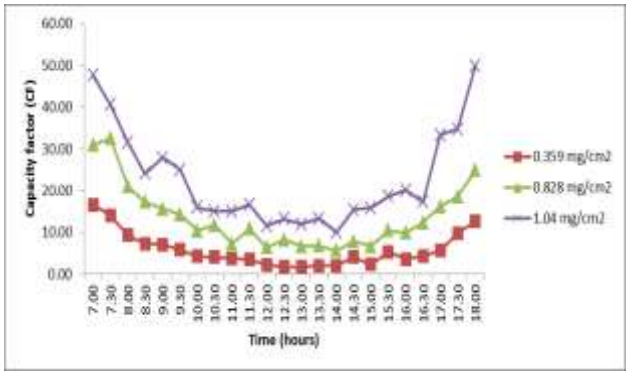

Figure 3: Capacity factor of the PV module for different cement dust density kept at 20° tilt angle with time

The capacity factor is calculated using a formula

Capacity factor (CF) %=

$$\left(\frac{P_{Clean\ panel} - P_{Dust\ coated\ panel}}{P_{Clean\ panel}}\right) \times 100$$

Where the Pclean panel means the power maximum (PMax) from the clean panel and similarly PDust coated panel for the power maximum (PMax) from the cement dust coated panel. The capacity factor indicates the power loss in the dust coated panel when compared to clean panel. The Capacity factor (CF) for the cement dust density of 1.04 mg/cm2 reaches maximum of 50%, but for density of 0.828 mg/cm2 it is reaching a maximum of 31% and for 0.359 mg/cm2 it is less than 18%. By comparing the average value of capacity factor for different dust density of the panels, it is observed that for 0.359 mg/cm2 it is around 4.02%, whereas for 0.828 mg/cm2 and for 1.04 mg/cm2 it is 10.37% and 17.60% respectively. Panel performance is mainly determined by the efficiency it produces compared to the clean panel.

The efficiency of the panel is found out using the formula

$$\eta = \frac{P_{Max}(I_{Max} \times V_{Max})}{I_G \times A_C}$$

Where $P_{Max} = (I_{SC} \times V_{OC}) \times Fill\ factor\ (F.F)$

$A_C = Area\ of\ the\ Collector = 0.03465cm^2$

$I_G = Global\ radiation\ \left(\frac{W}{m^2}\right)$

The efficiency of the clean panel is observed to be 13.82% whereas for the dust densities of 0.359 mg/cm2, 0.828 mg/cm2 and 1.04 mg/cm2 it is 13.01%, 11.92% and 10.64% respectively. The maximum efficiency recorded for the clean panel is nearly 14.98% but for other cement dust coated panels P2, P3 and P4 it is 13.60%, 12.53% and 11.66% respectively. When comparing with the clean panel, the average efficiency difference in cement dust coated panels with densities of 0.359 mg/cm2 is 0.81% and for 0.828 mg/cm2, 1.04 mg/cm2 it is around 1.90% and 3.18% respectively.

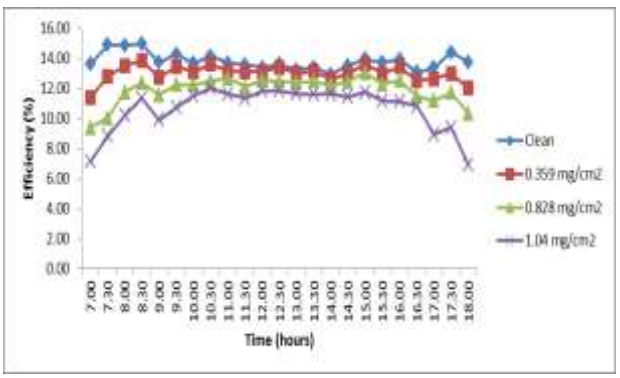

Figure 4: Efficiency curve of the PV module for

different cement dust density kept at 20° tilt angle with time

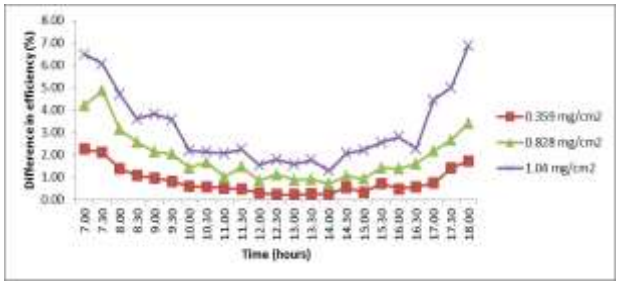

Figure 5: Difference in efficiency curve of the PV module for different cement dust density kept at 20° tilt angle with time

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IV. CONCLUSION

The study deals with the cement dust pollution over the solar PV panels and results shows as the cement dust density increases over the panels, the performance drops considerably. Interestingly the results shows drop in performance of solar PV panel with maximum for 1.04 mg/cm2 of 3.01% but for 0.828 mg/cm2 and 0.359 mg/cm2 it is 1.90% and 0.81%. The disadvantage of cement dust settling over the solar panels as it forms a permanent layer when it is mixed with rain or water drops. It dries and reduces the solar radiation intensity reaching the solar cell. So the usage of water for cleaning the panels is also increased. In Future, studies can be carried out in designing and creating a cleaning mechanism for cement dust on solar panels with minimal usage of water.

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