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Characterization of Dust on Solar PV of Tropical Zone of India

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ABSTRACT: Solar energy plays a major part in clean energy generation all over the globe due to faster technology advancements. Performance of solar cells in clean and dusty conditions is investigated in this paper. The dust of tropical region in India is characterised and experimented with. The experiments are carried out in artificial illuminance in indoor conditions. UV-Vis and SEM analysis characterises the samples and produces the effect of wavelength and particle size on the PV performance.

KEYWORDS: Dust, tropical region, UV-Vis, SEM, PV performance.

I. INTRODUCTION

The economic development has always been intimately associated with increasing energy usage and growth. Renewable energy can help decouple that correlation, contributing thereby to sustainable development. In this context, photovoltaic (PV) solar energy conversion is a clean and practical technology with huge potential. Solar PV technology is well proven for producing electricity, where the global production has been increasing 370 times than that in 1992. However, it is not yet widely deployed; PV efficiency optimization and cost reductions could significantly expedite the uptake of novel solar technologies. Moreover, for an optimal management and analysis of expected PV performance, the location sites become increasingly important.

Renewable energy is gaining attention all over the world in recent years as clean energy technology. Utilization of solar energy for energy generation is gaining pace in this field, with the upcoming technologies. Since, PV power generation is influenced by various factors such as temperature, wind, humidity, dust deposition, etc. efficiency optimization and cost reductions can improve the uptake of utilization of solar technologies. India's solar grid capacity is 9.23 gigawatts (GW) as of January 2017; 56.66 % of which was achieved in the previous year. However, influence of dust on PV panels reduces the efficiency to 85% [1]. Some of the main challenges to deploy solar energy on a large scale in India are the different climatic conditions.

II. LITERATURE SURVEY

Influence of external resistances obstruct irradiation reaching the panel cells and thus affect performance of solar panels. Sulaiman S A et al analyzed the effects of particles or dirt accumulation on the power output of PV. The study concluded that opaque particles affect mostly on the panel performance [12]. Tilt of the panels and its effect on dust assimilation was observed Mani M and Pillai R [1]. An approach to mitigate the impact of dust has been evolved for various climatic zones in Ref. [1].

Review on the impact of depositions on the PV system performance and the challenges in the related research has been given by Mani M. and Pillai R. in [2]. Similar research was carried out by Maghami M R et al in addition to some cleaning methods to enhance the PV performance [3]. Drop in the efficiency of the PV system is mainly due to the accumulated dust on the surface of panels which may vary depending on the geographical locations. Study on physical properties of dust and their influence on the panel output has been done for various locations all over the world. Efficiency reduction by 26% was observed in Qatar [4] and 32% in Saudi Arabia [5]. In Kuwait reduction of 17%

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efficiency was recorded due to sand in 6 days [6]. Daily efficiency reduction in Poland was observed to be 0.8% subjected to environmental dust [7] at 37° tilt. A decrease of output from 7.2 % to 5.6% was recorded in California which increased again to 7.1% after the rainfall [8]. Pertaining to the climatic conditions in Mexico, performance reduction of 15% without rainfall has been estimated [9]. Dust accumulation for two weeks caused output reduction of 10.8% in Indonesia [10]. Study of effect of other parameters like humidity, precipitation, and wind velocity has been carried out in [10]and [11]. Despite the same research carried out, the effect of dust on the panel is location based. Depending on the various climatic conditions prevailing in India, the effect would be varying in different regions. The objective of this work is to characterize and analyse the effect of various dust particles from tropical regions in India.

III.METHODOLOGY

Investigation of physicochemical properties of dust and their impact on PV performance is tested by experiments conducted at indoor conditions. The modules are poly-crystalline, detailed specifications shown in Table 1. The radiation measurement is done using Ambient Weather TM-206 Solar Power Meter (Pyranometer) by Ambient Weather by placing it along the panel surface also ideal for checking solar panel efficiency and gives measurements in both W/m² or BTU (ft²*h). The PV output current and voltage were measured by using digital multi-meter & ECOSENSE, which is a Solar PV research System. Experiments done with the help of this system demonstrates the I-V and P-V characteristics of PV module with varying radiation and temperature level, which experimentally determines the effect of variation on PV module power & also the effect of dust on module output power. Samples used for determining the module performance were cement, sand, laterite and dust. The dust was collected from panel depositions of a solar farm.

Table 1 : PV module specification

Peak Power (0-4.99Wp) P _{max} (Wp)	40
Maximum Voltage V _{mpp} [V]	17.84
Maximum Current I _{mpp} [A]	2.25
Open Circuit Voltage V _{oc} [V]	21.95
Short Circuit Current I _{sc} [A]	2.44
Module Efficiency (%)	12.94

The experiments conducted in this study consists of three parts. The first part of the analysis included collection of dust from the solar panel accumulated for over four months and other samples for study purpose. The samples collected are tested for wavelength and SEM analysis. Wavelength of a particle gives a measure of light absorbed which may lead to increase in the panel surface temperature. The impact of the sample wavelength and the particle size obtained was studied on the panel output performance. The second part includes the experimental investigation of artificially sample deposition and its effect on PV panel output performance by distribution of the samples homogenously on the module. The experiment is done indoor with a fixed system module using halogen lamps of 1000 watt to create artificial illuminance. The sample depositions on module was studied in comparison with clean module at the same time. The temperature of the module was tried to be maintained at 25°C to 40°C as more temperature leads to decreased output efficiency. The steps followed in the procedure are: (a) connect the PV system and the controller, (b) prepare the samples at different quantities (0.25g, 0.5g, 1g and 2g), (c) spread the samples individually on the module, (d) measure the readings of the pyranometer and the controller, (e) repeat the steps by increasing the sample quantity, and (f) measure the changed power output.

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IV. RESULTS

Morphology of all selected samples is showed in the Fig 1 – 4 by micrograph Scanning Electron Microscopy (SEM). Collected dust particles are not in form of cake, but they are evenly spread on carbon strip. Fig 1 having the smallest particle size of 13.80 μm to 19.10 μm .

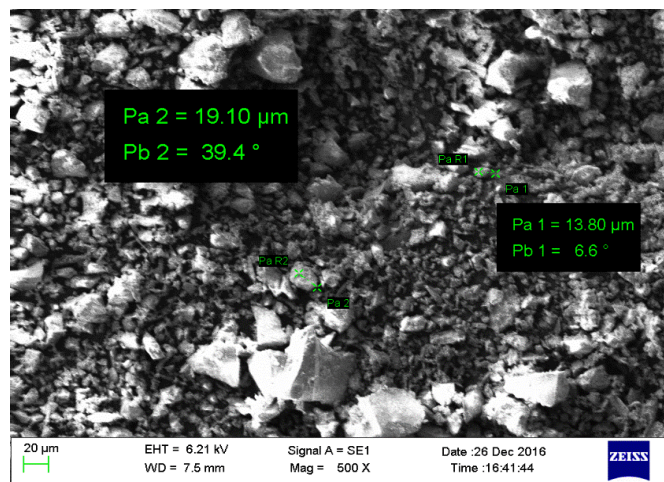


Fig 1. : SEM result of Cement

The particles are with rough surface, granular with edges, some particles are hardly visible. Laterite micrograph shows particle range (Fig 2) between 9.845 to 93.85 μm , having rounded edges and are granular in shape.

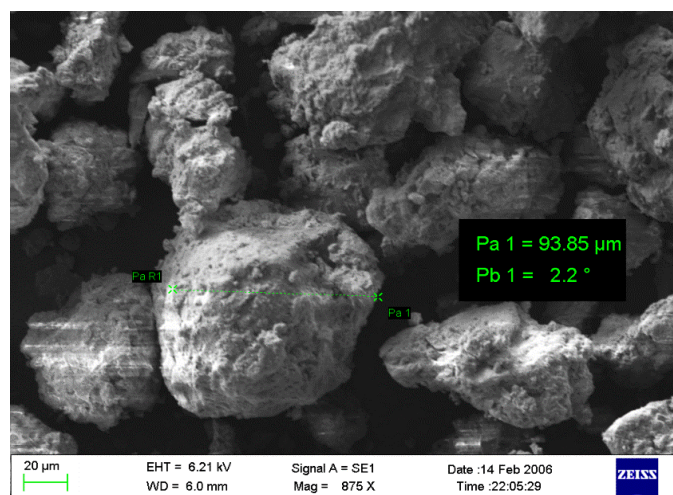


Fig 2. : SEM result of Laterite

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The dust sample collected (Fig 3) from the solar panels, are of uniform size nearly of 18.31 to 28.78 μm .

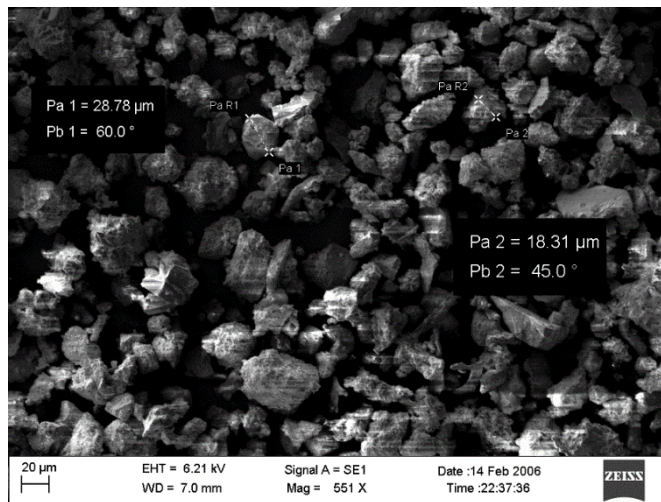


Fig 3. : SEM result of Dust collected from Panels

In Fig 4 the particles are evenly distributed with the largest size amongst the selected samples. The range of particles size is 148.6 to 307.3 μm having granular round edges.

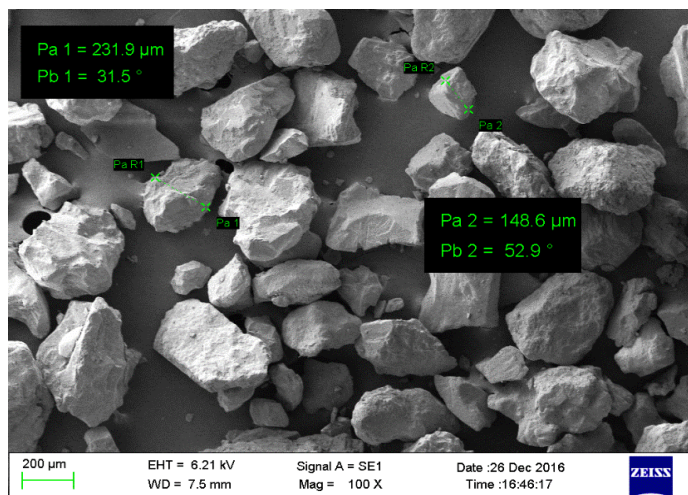


Fig 4. : SEM result of Sand

The micrograph of the particles show a mixture of round and edgy granular particles with rough texture. Some elongated particles are also visible randomly in the microscopy of Fig 3. Based on the particle size from the SEM analysis the power generation of the PV module was evaluated (Fig 5). The power generation reduces as the particle size of the sample decreases' the reason being the surface area of smaller particles is more which hinders the radiation reaching the module.

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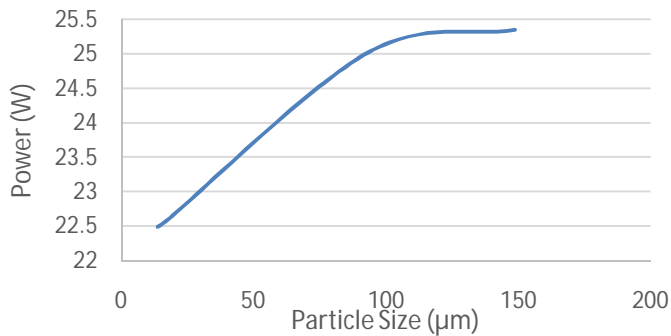


Fig 5. : Graph of Particle size versus Power

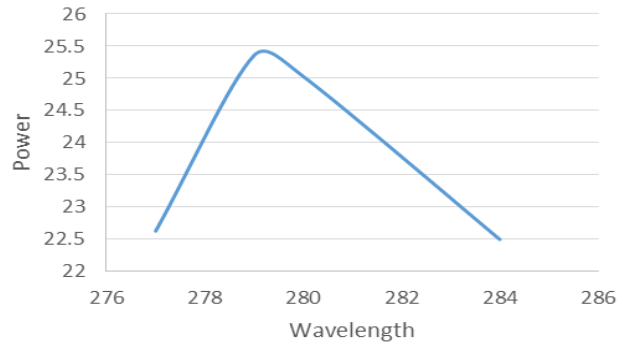


Fig 6. : Graph of Wavelength versus Power

The graph Fig 5 shows the effect on power produced with respect to particle size. The power generation decreases as the particle size decreases. The wavelength versus absorption graph shows wavelength range of 275 to 290 nm. In **Error! Reference source not found.** initially as the wavelength increases the power increases up to a certain limit 279.5 nm and further decreases after this limit.

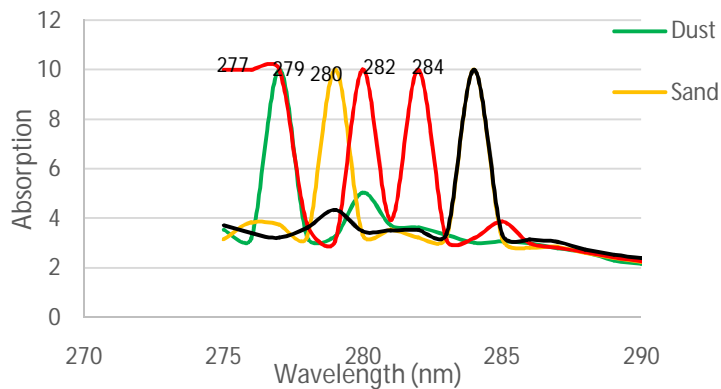


Fig 7. : Graph of Wavelength versus absorption

Panel dust having the lowest wavelength of 277 nm and cement particles having the maximum of 284 nm (Fig 7).

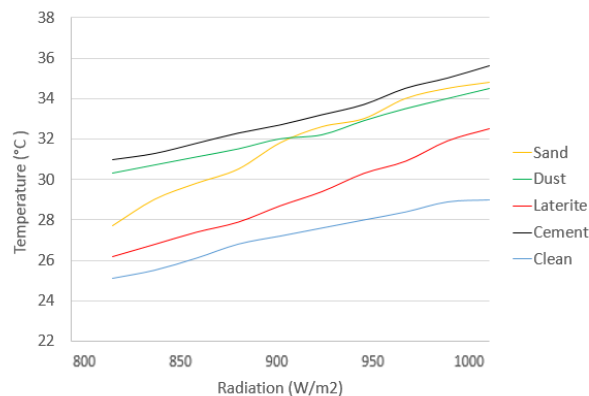


Fig 8. : Graph of temperature variation due to sample deposition

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In 0 the graph shows the correlation and comparison between radiation and surface temperature for the samples studied. The absorbance of the radiation by particles depend on their wavelength and particle size. Except for cement, as the wavelength of the particles decrease the temperature of the surface increase. In case of sand, the surface temperature increases rapidly, whereas the remaining samples tend to increase temperature evenly. Observations also show that as the particle size decrease the temperature of the surface increases.

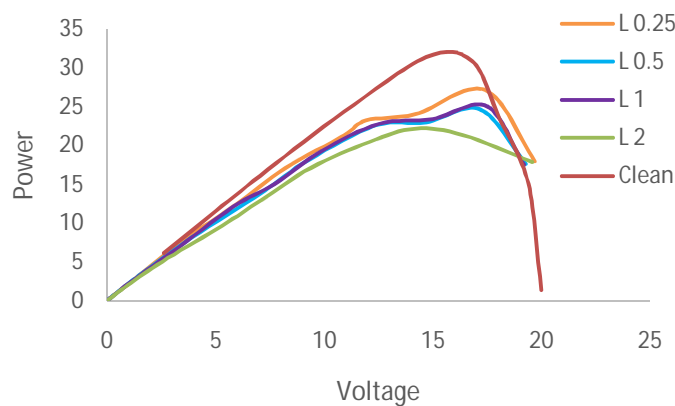


Fig 9. : Effect on power v/s voltage due to variation in laterite density

In Fig 9the power – voltage graph of cement shows efficiency reduction from 25.4% to 28.3% whereas the reduction in efficiency remains constant after sample density of 1 gram. The Fig 10power-voltage graph sand shows the maximum reduction of 18.85% to 25.81%. For 0.25 g sand the percentage reduction was 25.81 which is highest for lowest density distributed over the surface. Fig 12determines the power-voltage characteristics of natural dry dust collected form the panel. The minimum percentage reduction was 18.85 from 0.25 g & the maximum reduction was 34.93 from 2 g. Fig 10shows the power – voltage graph of laterite depicting the efficiency reduction from 13.46% to 29.38%. Dust and laterite show more variation of power peaks for different sample densities. Fig 12. shows the comparison of power-voltage graph for all the samples tested with a constant weight of 0.5 g. The graph shows that cement has the highest percentage of efficiency reduction of 25.454% followed by 21.159% by laterite, 20.69% by natural dry dust & the minimum by 18.585% of sand.

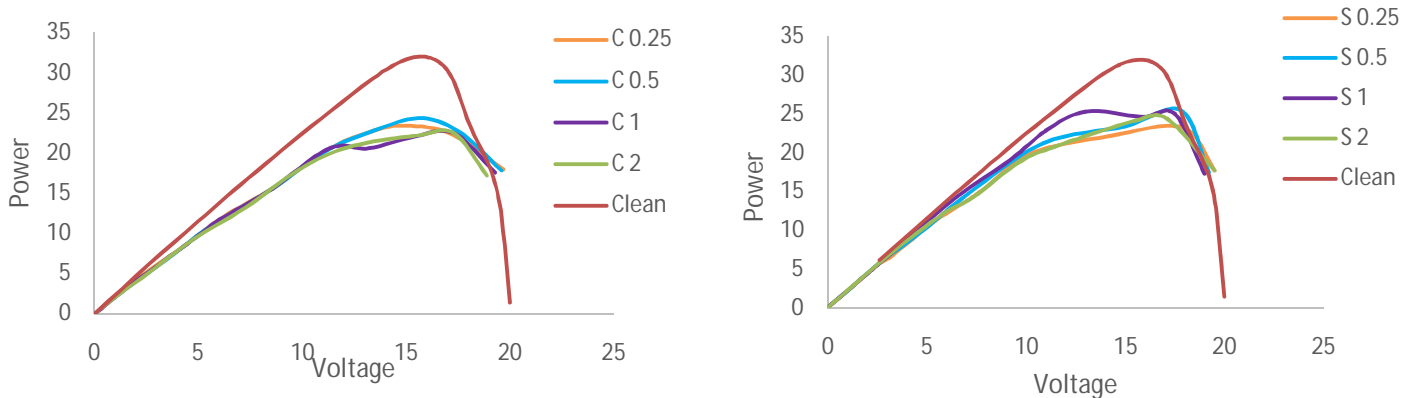


Fig 10. : Effect on power v/s voltage due to variation in cement density Fig 11. : Effect on power v/s voltage due to variation in laterite density

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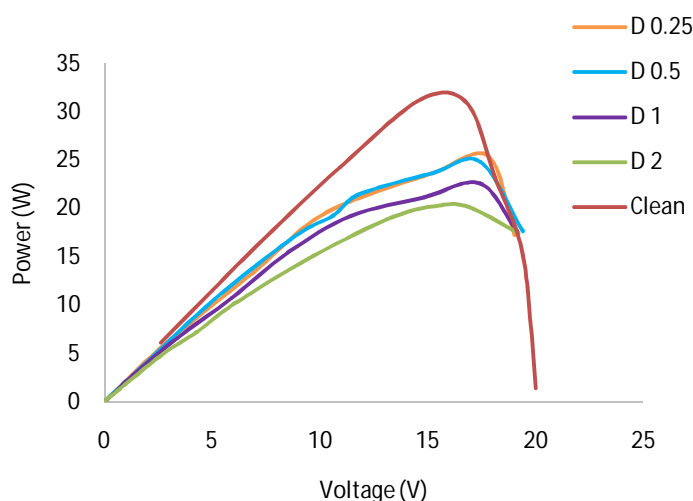


Fig 12. : Effect on power v/s voltage due to variation in Dust density

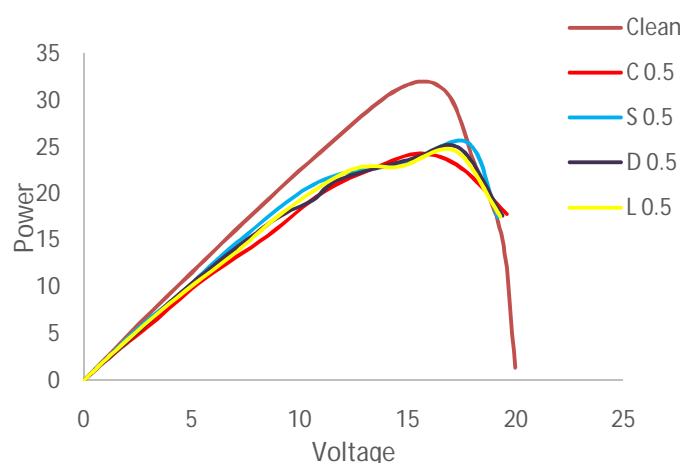


Fig 13. : Comparison of power v/s voltage for the studied samples

V. CONCLUSION

Accumulation of dust over solar panels reduces the overall efficiency of the system due to obstruction of radiation and/or increase in the surface temperature. In this study, the structural and physical characteristics dust particles collected from PV panels were investigated and their influences on the photovoltaic performance were evaluated. UV-Vis and SEM were used to physically characterize the samples of cement, laterite, sand and dust collected from panel surface accumulated over a duration of four months in India. The main result show that dust particles have mainly an average size of about 81.98 μm and are granular. The panel dust contain a mixture of cement and laterite as the panels from where the sample was collected is located on laterite soil and near a cement industry; proof of which is the SEM results.

The second part of the study compares the output of the module after the homogeneous distribution of sample over the surface of the panel. The smaller the size of the particles, more will be the effect on the efficiency of the panel; due to the increase in surface area of particles. Wavelength of the particles also affect the panel efficiency up to a certain extent for a certain range. To further investigate dust characteristics, we believe that this original study could serve as a reference for the characteristics of the India dust, and work is in progress to design a mitigation process based on these results.

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