International Journal of Engineering & Technology, 7 (3.7) (2018) 669-671

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Performance Degradation of PV Module Due to Different Types of Dust Pollutants

Abhishek Kumar Tripathi[1*], M. Aruna[2] and Ch.S.N. Murthy[3]

Department of Mining Engineering
National Institute of Technology Karnataka, Surathkal, Mangalore-575025, Karnataka, India
**Corresponding author E-mail: abhinitrkl12@gmail.com*

Abstract

The deposition of dust on photovoltaic (PV) module surface is the main cause for its performance degradation in an open atmosphere. The performance degradation of the module due to dust deposition depends on the size, density and type of dust. In this paper, the effect of two different types of dust pollutants, such as red soil and lime stone on PV module performance was studied. It was found that the reduction in PV module performance due to red soil dust was more emphatic than the lime stone dust. Moreover, the dust deposition on the module surface shows a significant reduction in short circuit current and power output of PV module when compared to its open circuit voltage.

Keywords: *Photovoltaic; Dust; Short circuit current; Power output; Open circuit voltage*

1. Introduction

The generation of electric power depends on renewable and non-renewable energy sources. Non-renewable energy sources generate power but it has an adverse impact on the environment. In non-renewable power generation large amount of sulphur oxides (So_X), nitrogen oxides (No_X) and suspended particulate matter (SPM) are generated, which are responsible for pollution of the environment, and it also deteriorates the health of human being as well as other living things. The emitted gas from power plants also supports the global warming. On the other hand, due to the continuous increment in energy consumption, cost of fossil fuel and global warming all over the world, which forces the world consumers to look towards the green and renewable energy technology. Therefore, renewable energy technology is getting much more attention in both academic and industrial sector. There are different types of renewable energy sources, such as hydro, geo-thermal, wind and solar. Among these renewable sources solar energy experienced a rapid growth and popularity in last one decade, because of its huge advantages, like availability of raw material, no emission of pollutants, can be used in remote areas, no noise problem and easy to install [1-4].
The photovoltaic (PV) device is a part of solar energy system, which is able to generate electrical energy directly from the incoming solar radiance (solar energy) [5]. Whenever sunlight strikes on PV cell surface, which is made up of silicon type semiconductors, it generates electron-hole pairs inside the semiconductor material.

This generation of electron hole pairs inside the semiconductor material is the main cause for electrical power generation in solar photovoltaic system. In general, the PV module are operated in an open atmosphere, where it experiences a significant variation in environmental parameters, like wind speed, ambient temperature, solar irradiance, humidity and dust pollutants [6]. These environmental parameters affect the performance of PV panel, and among these parameters dust plays a significant role in reducing the performance of PV module.

2. Effect of Dust on PV Module Performance

The accumulation of dust on PV module surface creates a main barrier in the path of sun light that falls on the module surface. Due to this barrier, the glass transmittance of the module surface deteriorates, and thus it affects the performance of PV module. The rate of dust deposition affects PV glass cover transmittance in turn the performance of PV module. When dust particles deposit on PV module surface they absorb and scatter the incident light, as a result efficiency of PV module decreases [7].

The deposition of dust on PV module depends on environmental parameters, like ambient temperature, humidity, rainfall and wind velocity, and operational parameter, such as tilt angle and mounting height of PV module. The environmental parameters vary from place to place and therefore PV module performance reduction due to the dust deposition is not uniform for every region. Due to dust accumulation the open circuit voltage of the module experiences a negligible change compared to its short circuit current and power output [8]. One study on the module performance shows that there was a significant reduction in short circuit current and power output up to 28.6% and 30.6%, respectively after 12 days of its exposure to the atmospheric condition [9].
Due to sand dust deposition on PV module surface it was found that the reduction in short circuit current and maximum power output of PV module are respectively 40% and 34% [10]. Another study shown that the reduction in PV module conversion efficiency were 10%, 16% and 20%, respectively for 12.5 g/m^2, 25 g/m^2 and 37.5 g/m^2 dust deposition [11] Similarly, one more study reported that there was power loss of 3% to 4% of PV module due to dust deposition for 5 weeks of its exposure to the atmospheric

Copyright © 2018 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

condition [12]. Study carried out by Rajput and Sudhakar (2013) shown that due to dust deposition on PV module the power generation and efficiency of PV module was reduced to 92.11% and 89%, respectively [13].

Further one more study demonstrated that the energy loss of PV module due to red soil, lime stone and ash are respectively 19%, 10% and 6% [14]. The reduction in energy is also influenced by the color, composition and size of dust pollutants [15]. In a similar study it was reported that among five kinds of air pollutants, such as red soil, ash, sand, calcium carbonate and silica gel, sand shown a minimum reduction of 0.9V output voltage, whereas reduction due to ash was as high as 4.7V [16].

The variation in electrical parameters of PV module due to dust accumulation is also influenced by the type of PV technology, such as monocrystalline silicon (mc-Si), polycrystalline silicon (pc-Si) and amorphous silicon (a-Si). It was reported that the reduction in PV module power output due to dust effect is 77.75% for mc-Si module and 18.02% for pc-Si module [17]. It was also found that the reduction in open circuit voltage and fill factor due to dust accumulation on PV module are less affected when compared to short circuit current and power output [18]. The review of literature clearly indicates that the performance of PV module not only depends on the amount of dust but also on size and type of dust. Therefore, in this paper an attempt was made to study the effect of different dust pollutants on the performance of PV module.

3. Laboratory Set-up and Methodology

A 20W polycrystalline solar PV module was used to study the effect of dust pollutants on the module performance. The solar simulators were used to generate an artificial solar radiation inside the laboratory. These simulators could generate different range of constant solar radiation. A solar power meter TM-207 was used to measure the solar radiation falling on the module surface. During this study a constant solar radiation of 567 W/m^2 was maintained on the module surface.

Two different types of dust pollutants, such as red soil dust and lime stone dust of size less than 75µ were used. These dust pollutants were uniformly distributed on the module surface in three stages i.e. 5gm, 8gm and 11gm in mass. For every trial of theses stages i.e. dust distribution, the electrical responses of PV module, such as current, voltage and power were recorded. Two multimeters and one 320Ω rheostat were used for the measurement of electrical responses of PV module. The electrical responses were also recorded for the clean panel.

4. Results and Discussion

The electrical responses of PV module for mass distribution 5gm, 8gm and 11gm for red soil dust and lime stone dust were recorded. Based on these measured readings, the current-voltage characteristic of PV module for red soil and lime stone dust were plotted which are shown in Figure 1 and Figure 2. Similarly, the power-voltage characteristic of the module for red soil and lime stone dust are presented in Figure 3 and Figure 4. From the graphical representation, as shown in Figure 1, Figure 2, Figure 3 and Figure 4 the reduction in short circuit current (ISC), open circuit voltage (VOC) and maximum power output (PMAX) were calculated, which are presented in Table 1 and Table 2. These results in Table 1 and Table 2 indicates a significant reduction in ISC and PMAX for both the pollutants. The reduction in open circuit voltage of PV module is meager for both the pollutants. The reduction in maximum power output of PV module due to red soil and lime stone dust deposition is presented in Figure 5. As depicted in Figure 5, the reduction in maximum power output due to lime stone dust deposition is low compared to red soil dust. Hence, the performance degradation of PV module due to dust deposition is not only depends on the mass of dust but also on the type of dust.

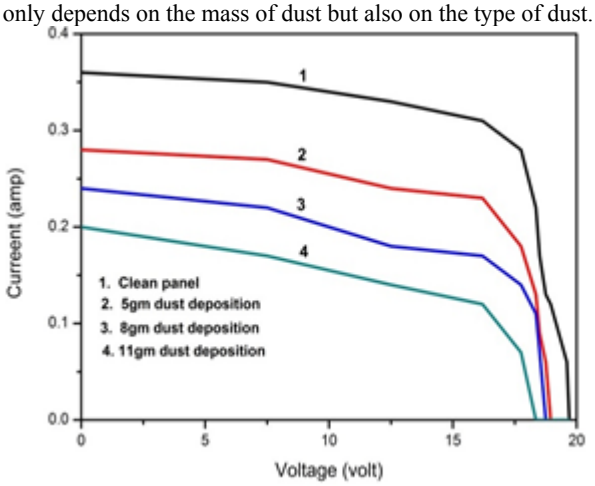

Fig. 1: I-V characteristic of PV module with red soil dust deposition.

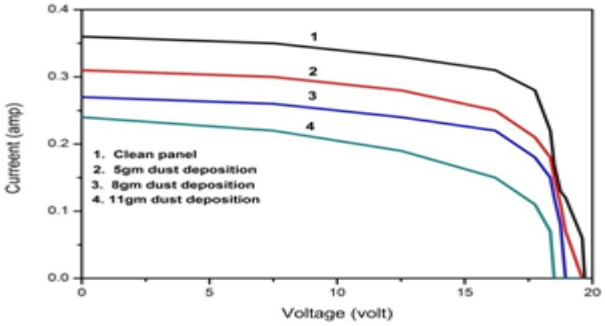

Fig. 2: I-V characteristic of PV module with lime stone dust deposition.

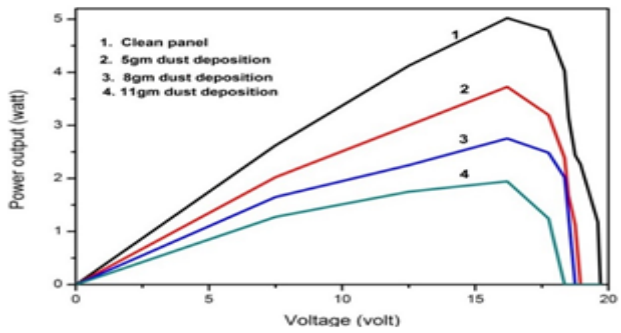

Fig. 3: P-V characteristic of PV module with red soil dust deposition.

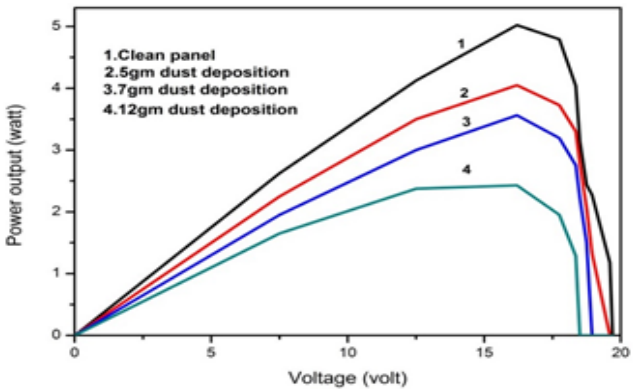

Fig. 4: P-V characteristic of PV module with lime stone dust deposition.

Table1: Effect of red soil on the panel performance (size= less than75micron)

Mass deposition (gm)	Reduction in I_{SC} (%)	Reduction in V_{OC} (%)	Reduction in P_{MAX} (%)
5	22.2	3.8	25.8
8	33.3	4.8	45.1
11	44.4	6.8	61.2

Table.2: Effect of lime stone on the panel performance (size= less than75 micron)

Mass deposition (gm)	Reduction in I_{SC} (%)	Reduction in V_{OC} (%)	Reduction in P_{MAX} (%)
5	13.8	3.0	19.3
8	25.0	4.0	29.0
11	33.3	6.0	51.6

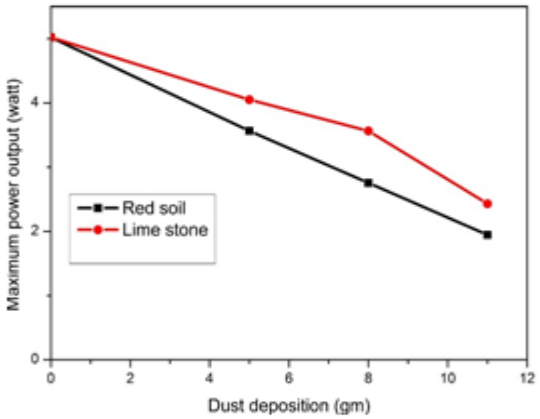

Fig. 5: Reduction in maximum power output with red soil and lime stone dust deposition.

5. Conclusions

The generation of the electric power via solar PV system is becoming more and more attractive in developing country. This is mainly due to the scarcity in fossil fuels, increase in price of fossil fuels and also because of hazardous impact on the environment due to burning of fossil fuels. The performance of solar PV system mainly depends on the sun light falling on the module surface. This incoming sun light reduces gradually due to the deposition of dust pollutants on the module surface. The dust pollutants act as a barrier in the path of sun radiation approaching the cover glass of the PV module. This results in the degradation of electrical responses of the module, such as short circuit current, open circuit voltage and power output. The short circuit current and the power output of PV module are highly influenced by the dust deposition on its surface when compared to the open circuit voltage. The results of this study demonstrated that the 5gm of red soil dust and lime stone dust deposition on the PV module surface reduces the short circuit current by 22.2% and 13.8%, respectively. The increase in dust deposition also increase the reduction in short circuit current. Similarly, the reduction in maximum power output was also increased by 25.8% and 19.3%. Further, the reduction in maximum power output increases with increases in the dust deposition. Compared to short circuit current and maximum power output the reduction in open circuit voltage due to dust deposition is not very significant. The results obtained also indicate that the performance degradation of PV module due to red soil dust is higher compared to the lime stone dust.

References

[1] S. Mekhilef,et al., A review on solar energy use in industries, Renewable and Sustainable, Energy Reviews, 2011, p.1777-1790,15(4).

[2] A. A. Bayod-Rújula, et al., Photovoltaics on flat roofs: energy considerations, Energy, 2011, p.1996-2010, 36, (4).

[3] F. J. Chueco-Fernández, et al., Power supply for pumping systems in northern Chile: photovoltaics as alternative to grid extension and diesel, Energy, 2010, p. 2909-2921, 35(7).

[4] M. Oliver, et al., Energy and economic evaluation of building-integrated photovoltaics, Energy, 2011, p. 431-439, 26(4).

[5] A. Goetzberger, et al., Photovoltaic materials, history, status and outlook, Materials Science and Engineering: R: Reports, 2003, p.1-46, 40(1).

[6] H. Jiang, etal., Experimental investigation of the impact of airborne dust deposition on the performance of solar photovoltaic (PV) modules, Atmospheric Environment, 2011, p.4299-4304, 45(25).

[7] S. Semaoui, et al., Dust effect on optical transmittance of photovoltaic module glazing in a desert region, Energy Procedia, 2015, p.1347-1357.

[8] A.K. Tripathi, et al., Output Power Loss of Photovoltaic Panel Due to Dust and Temperature, International Journal of Renewable Energy Research (IJRER), 2017, p.439-442, 7(1).

[9] M. S. El-Shobokshy, et al., Effects of dust on the performance of concentrator photovoltaic cells, IEE Proceedings I-Solid-State and Electron Devices, 1985, p.5-8, 132(1).

[10] A.Y. Al-Hasan, et al., A new correlation between photovoltaic panel's efficiency and amount of sand dust accumulated on their surface, International Journal of Sustainable Energy, 2005, p.187-197.

[11] M. S. El-Shobokshy, et al., Degradation of photovoltaic cell performance due to dust deposition on to its surface, Renewable Energy, 1993, p.585-590.

[12] R. Appels, et al., The effect of dust deposition on photovoltaic modules, In Photovoltaic Specialists Conference (PVSC), 2012 38th IEEE, p.001886-001889.

[13] D. S. Rajput, et al., Effect of dust on the performance of solar PV panel, International Journal of Chem Tech Research, 2013, p. 1083-1086, 5(2).

[14] J. K. Kaldellis, et al., Systematic experimental study of the pollution deposition impact on the energy yield of photovoltaic installations, Renewable Energy, 2011, 2717-2724, 36(10).

[15] J. K. Kaldellis, et al., Simulating the dust effect on the energy performance of photovoltaic generators based on experimental measurements, Energy, 2011, p.5154-5161, 36(8).

[16] T. Khatib, et al., Effect of dust deposition on the performance of multi-crystalline photovoltaic modules based on experimental measurements, International Journal of Renewable Energy Research (IJRER), 2013, p. 850-853, 3(4).

[17] E. S. Kumar, et al., Soiling and dust impact on the efficiency and the maximum power point in the photovoltaic modules, International Journal of Engineering Research and Technology, ESRSA Publications, 2013, 2(2).

[18] J. Tanesab, et al., The contribution of dust to performance degradation of PV modules in a temperate climate zone, Solar Energy,2015, p. 147-157.