



## Investigation of Effects of Dust on the Performance Photo- Voltaic Modules in the North Western Nigeria

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### ABSTRACT

This paper investigated the effect of dust accumulation on the efficiency of Photovoltaic (PV) modules experimentally. For this purpose, two identical PV modules were installed and studies were conducted at the testing ground of Sokoto Energy Research Centre, Usmanu Danfodiyo University Sokoto (Nigeria). This study covers measurements done in winter months of January, October, November and December for the period of three years (2016 - 2018). The generated data were pre-processed and utilized to generate I-V and P-V characteristic curves; the curves generated for the PV module were found to compare satisfactorily well with those obtained from existing conventional PV model. The results obtained show the maximum PV efficiency achieved by dusty and clean module are 73.49% and 85.76% respectively, all in the month of October 2016. While the minimum PV efficiency achieved by dusty and clean module are 48.34% and 51.23% respectively, all in the month of January and December respectively. It is therefore evident that the dust deposition on PV module could cause significant losses in PV output power generation.

**Keywords:** Dust (d), Performance efficiency (%), Photovoltaic (PV) module, Solar Irradiance (G)

### INTRODUCTION

Climate change and the scarcity of energy resources are two of the biggest challenges the world is facing today. Two main conventional fuels which play major roles in our energy supply are oil and nuclear energy in developed countries while in developing countries like Nigeria, oil and wood. Probably the central questions regarding these fuels concern their cost and availability in the future. Renewable energy has considerable potentials in Nigeria, and could bridge the major energy gaps in rural areas, particularly northern Nigeria (Tsoho, 2015).

The scale of opportunities is only just becoming apparent as new grid technologies such as solar power is emerging as in competitors with conventional power generation. Changes in technology also mean that solar power, with the correct financing, could bring transformational change to household energy needs. Recent studies credibly put concentrated solar thermal power potential in Nigeria at over 427,000MW. Present levels of power generation of around 5000MW meet only a fraction of demand, and renewable energy could play an escalating role

(Chris, 2012). Large-scale renewable power generation could prove transformational, but small consumer- and household-level systems could offer energy independence for the majority with presently limited or zero access to reliable electricity. Increasing trends in the installation of PV systems needs for more accurate prediction of their operational performance under different condition. Manufacturers rate the output power, and the efficiency of PV module under standard test conditions (STC), with 25 °C Temperature, 1000 W/m<sup>2</sup> solar radiation, 1.5 Air Mass Ratio (Duffie and Beckan, 2013).

Dust accumulation and photovoltaic surface temperature are important factors which must be considered, especially in desert areas. Dust deposition on the surface of PV modules causes a reduction in the amount of incident solar radiation on the panel which leads to decreases in the generated power (Khamooshiet *al.*, 2014).

Received 11 March, 2021

Accepted 18 April, 2021

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In literature, some studies have been carried out to investigate the effect of weather conditions on photovoltaic performance. Many of these papers examined the relationship between PV output and dust deposition density (Al-Dousari and Al-Wadhi, 2012). Others decided to make comparisons between types of dust and their particle sizes and analyses their effects for specific periods (Alnaser and Alnaser 2011). Most of these studies are implemented for fixed tilt angle. According to the authors, Chapin *et al.*, (2005), studied the output power of PV modules for the different tilted angle by using single and dual axes tracker system on the cleaned panel in Kirkuk City. However, the relationship between the dust accumulation and tilt angle in real time study is not cleared yet. This work presents the experimental investigation of the effect of dust on polycrystalline photovoltaic module performance efficiency in north-west, Nigeria.

Sokoto has a hot semi-arid climate. It is located in the dry Sahel surrounded by sandy savannah and isolated hills. With an annual average temperature of 28.3 °C, Sokoto is one of the hottest cities in the world, however the maximum daytime temperatures are generally under 40 °C most of the year, and the dryness makes the heat bearable, (Tsoho, 2015). The warmest months are February to April, where daytime temperatures can exceed 45 °C. The highest recorded temperature is 47.2 °C, which is also the highest recorded temperature in Nigeria. The rainy season is from June to October, during which showers are a

daily occurrence. The showers rarely last long and are a far cry from the regular torrential showers known in many tropical regions. From late October to February, during the 'cold season', the climate is dominated by the harmattan wind blowing Sahara dust over the land. The dust dims the sunlight, thereby lowering temperatures significantly and also leading to the inconvenience of dust everywhere in the house. Sand and dust storms are familiar weather phenomena in North-West Nigeria, and its occurrence at different times of the year, especially during the winter (Mohammed *et al.*, 2019). In the last 14 years, Sokoto, a North-West town of Nigeria has been hit by many waves of dust storms, in some years have exceeded 11 dust storms (Mohammed *et al.*, 2019). Dust and temperature are the main factors affecting the efficiency of the installed photovoltaic modules, and it must be studied with some care.

## METHODOLOGY

In this study, the analysis of four months' (January, October, November and December) outdoor exposure was carried out. Two identical photovoltaic modules were used, the specifications of the modules are presented in Table 1, while, the list of equipment used are listed in Table 2. The experimental setup is shown in figure 1. The photovoltaic modules were fixed at 13° inclination angle facing Southward for maximum solar energy harvest as suggested by Al-Dousari and Al-Wadhi (2012) and at a location devoid of overcasts from nearby trees and buildings.

Table 1: Specification of the Two PV Panels

PV Panels	Types	Power (w)	I <sub>sc</sub> (A)	V <sub>oc</sub> (v)	I <sub>m</sub> (A)	V <sub>m</sub> (v)	Length (m)	Width (m)	Area (m <sup>2</sup> )
Clean	Polycrystalline-Silicon	160	4.677	44.322	4.370	36.663	1.58	0.81	1.28
dusty	Polycrystalline-Silicon	160	4.677	44.322	4.370	36.663	1.58	0.81	1.28

Table 2: List of Equipment and Materials Used

Equipment	Type/Range	Model No.	Purpose
Multi-meter	Digital Megger	DT830	I and V Measurement
Rheostat	1000Ω	Volt craft IR 260-8S	To vary load
Pyranometer	0-20mv	CMP3	Solar irradiance Measurement
Infra-red thermometer	-30 <sup>0</sup> to +260 °C	IR 260 8-S	Temperature Measurement
Anemometer	0.4-30.0m/s	popular	Measuring wind speed

The outdoor measurements for the PV modules were installed and conducted at the testing ground of Sokoto Energy Research Centre, Usmanu Danfodiyo University Sokoto (Nigeria) which is located at  $05^{\circ} 15'$  E longitudes and  $13^{\circ} 05'$  N latitudes. The PV modules was oriented South with tilt angle of  $13^{\circ}$ , which received the maximum solar radiation. To make a correct measurement and minimize differences in irradiation, the two

modules are kept side by side with the same elevation from the ground. The PV modules were connected to the equipment given in figure 2 below. Output voltage and current are continuously measured for dusty and cleaned module with one-hour period from 10:00 am to 05:00 pm. Also, the ambient and the module back surface temperature was measured and stored in the same measurement system.



Figure 1: Relief Photo of the Experimental Set-up of the cleaned and dusty PV modules

### Calculation of the PV Parameters

The characteristic I-V test was conducted on both the PV modules (dusty and cleaned). The Rheostats were connected as a variable resistive load ( $R$ ) with the panels separately and by varying the  $R$  value, the values of voltage and current are noted down. From the test values, the

maximum power points of the voltage and current were calculated from the I-V characteristic curve;

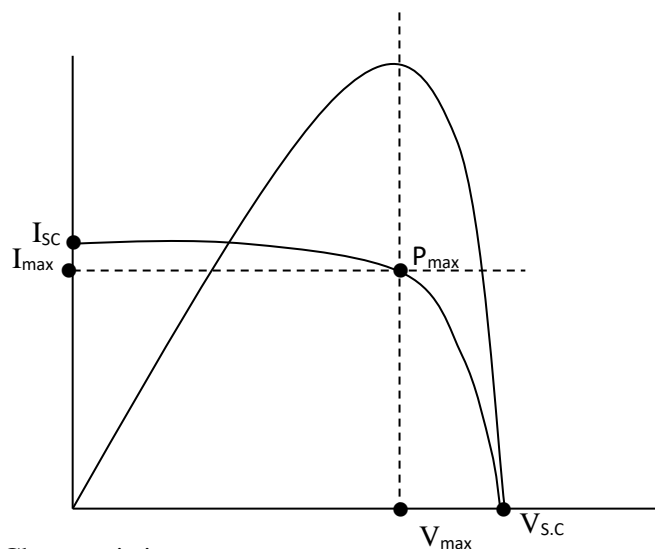


Figure 2 : I - V Characteristic curve

The test was conducted on the two panels 1 hour once from 9:00 am to 5:00 pm daily. The electrical efficiency depends mainly on the incoming solar radiation and the PV module temperature (Chow *et al.*, 2007). It is calculated using equation below:

$$\eta_{el} = \frac{I_m V_m}{G_T A_c}$$

Here,  $I_m$  and  $V_m$  are the current and the voltage of the PV module operating under a maximum power.  $G_T$  is the solar irradiation and  $A_c$  is the area of the solar modules

## RESULTS AND DISCUSSION

The experimental observations of the two PV panel were carried out within the months of October, November, December and January for three years of 2016, 2017 and 2018 in order to study the effect of dust on a poly 44 crystalline module. The experimental results of the modules on solar radiation vs winter months, solar radiation vs wind speed and Monthly average PV module efficiency and winter months for cleaned and dusty modules are shown in figure 2, 3 and 4 respectively.

North – West Nigeria atmosphere is sunny and cloudless most of the year specifically during

summer period in months of April, May, June, July and August, and that increases the amount of solar radiation delivered to PV modules. While, the winter period recorded less amount of solar radiation due to lower clearness index, specifically in months of January and December. Figure 2 shows the average monthly measured solar irradiation for three years. The Month of October have the maximum solar irradiation with about 750 W/m<sup>2</sup> whereas December and January have the minimal solar radiation with around 500 W/m<sup>2</sup>. As a result of dust storms occurrences, the solar radiation dropped during these winter months of December and January.

It was observed from literature that as wind velocity increases, dust storm occurrence

increases (Gossens *et al.*, 1993). An increase in wind speed can lead to the increase of the accumulated dust layers on a PV surface (Mekhilef *et al.*, 2012). An increase in wind speed leads to a low visibility due to suspended dust accumulation as shown in Figure 3. Dust accumulation above 1.2 ms<sup>-1</sup> wind speed in the months of December and January. Also the months of October and November are the calmest month at average wind speed below 0.8 ms<sup>-1</sup>.

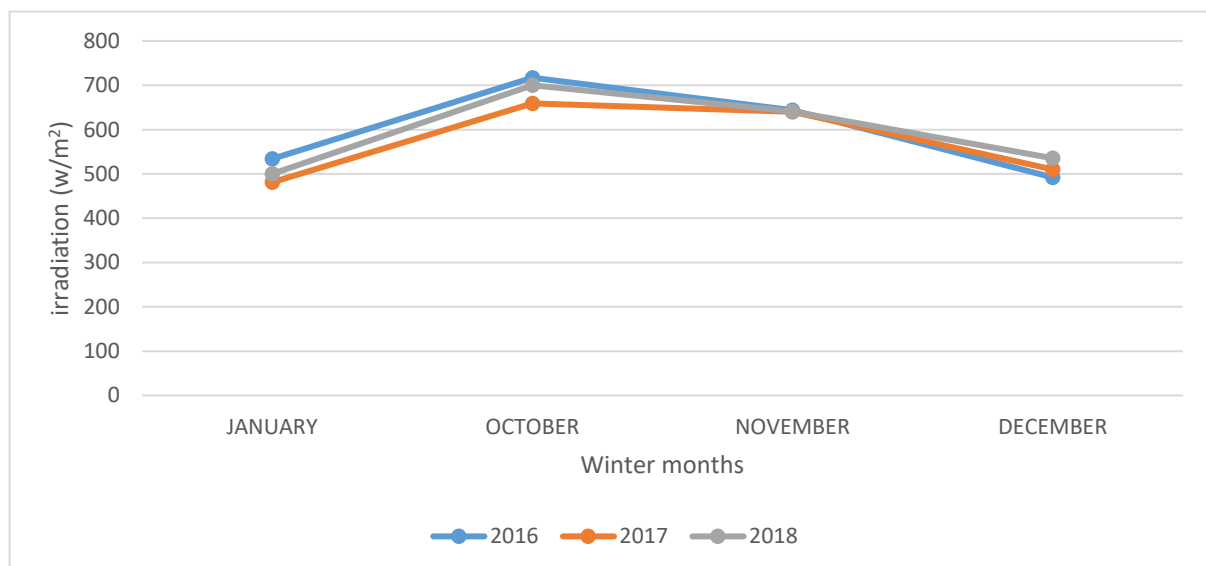


Figure 2: Average solar irradiation vs winter months

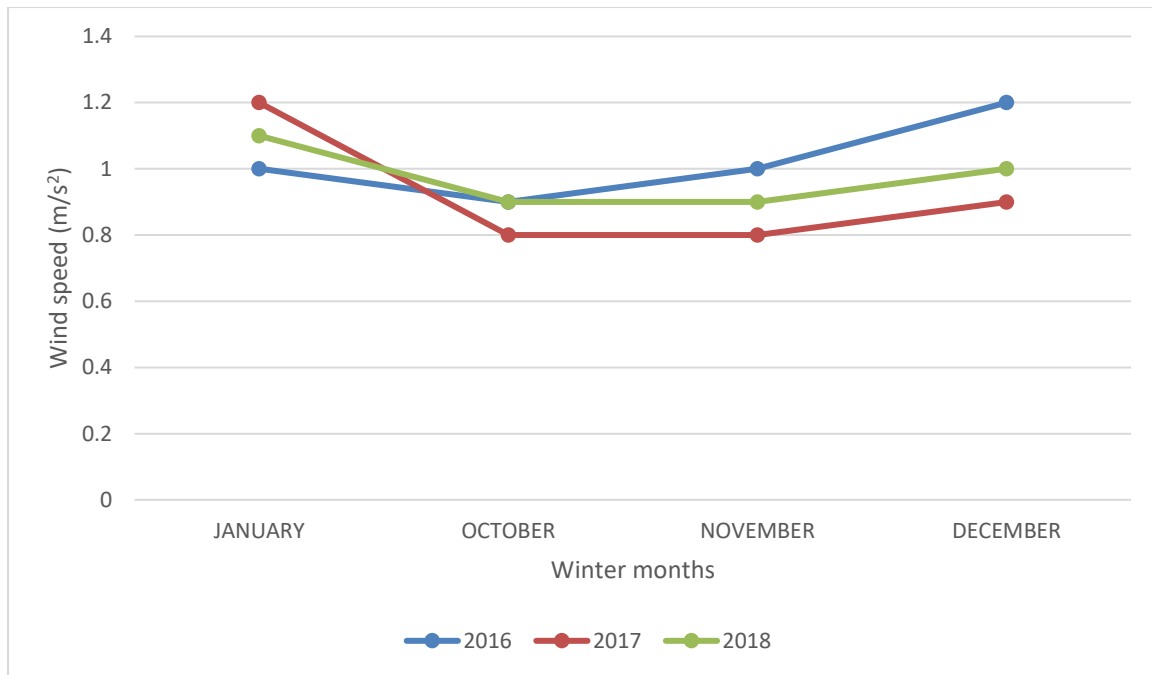


Figure 3: Average wind speed vs Winter months

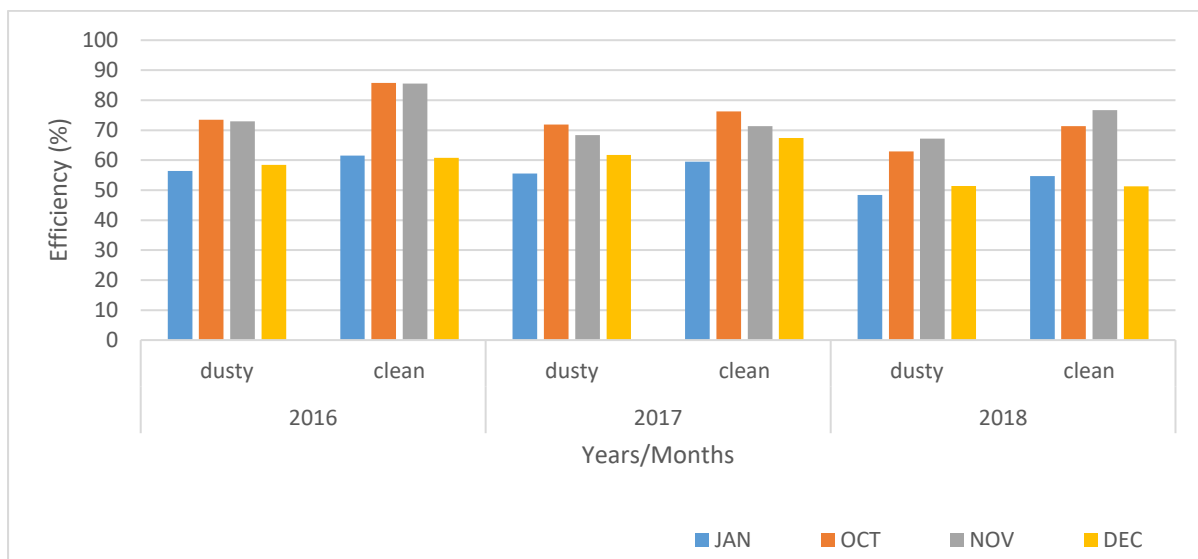


Figure 4: Monthly average PV module efficiency and winter months for cleaned and dusty modules.

The modules monthly efficiencies were determined to study the dust effects on the modules performance as expressed by equation below:

$$\eta_{el} = \frac{I_m V_m}{G_T A_c}$$

The monthly average efficiencies of clean and dusty PV modules are illustrated in

Figure 4. This figure reveals that the efficiency of the dusty modules is lower than clean modules during the whole measurement period. However, the clean PV efficiency is also affected by other conditions which is not in the scope of this work. The maximum efficiency reached for Polycrystalline module in clean and dusty conditions was around 85.76 % in 2016 and 73.49 % in 2016 respectively all in the months of October.

## Conclusion

In this paper, the effects of dust accumulation on polycrystalline Photovoltaic modules performance efficiency have been investigated through outdoor experiments under North – west Nigeria climatic conditions. Two experimental studies were conducted to compare the performance efficiency of polycrystalline PV module technology in clean and dusty condition. The results showed that the polycrystalline module is affected by dust accumulation. Moreover, an increase in wind speed can lead to the increase of the accumulated dust layers on a PV surface thereby reducing the performance efficiency of the polycrystalline module.

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