



Effect of Environmental Dust on the Performance of Photovoltaic Panels in Northern Nigeria

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Abstract

Effect of dust from outdoor environment on the performance of solar photovoltaic panels is natural. There were studies that showed that environmental dust reduces the performance of solar panels, but the results were not clearly quantified. The aim of this study is to determine the extent to which environmental dust affects the performance of solar PV panel in North Western region of Nigeria. The study was carried out in Kazaure Town located 12°39N and 8°24E between November 2015 to February 2016. In this work, electrical performances of photo-voltaic panel were studied experimentally for the effect of environmental dust particles. The experimental data are used for the calculation of the energy efficiency and power output of the PV systems. It was found from the study that the environmental dust reduces the efficiency of solar PV panel by up to 48% and output power by up to 30%.

Keywords: Dust, PV Panel, Solar Energy, Performance.

INTRODUCTION

Now are days, energy-related aspects are becoming extremely important. They involve, for instance, a rational use of resources, the environmental impact related to the pollutants emission and the consumption of non-renewable resources. For these reasons there is an increasing worldwide interest in sustainable energy production and energy saving. Among the technologies that could play a role in the generation of sustainable and widespread energy, interesting solutions are represented by photovoltaic (PV) cells, wind generators, biomass plants and fuel cells. In particular, photovoltaic systems can be considered one of the most widespread solutions with significant margins of improvement while ensuring the generation of energy with low environmental impact. The research activity and development in PV field has usually been focused on solar radiation analysis, efficient operating strategies, design and sizing of these systems.



Previous papers analyzed the PV module in terms of panel modeling and I-V characteristics. However, in these works, critical aspects and external conditions that could involve the PV system are not taken into account. In 2002, Castaner & Silvestre stated that solar cell efficiency is an important input parameter in PV-powered product design and become a principle criterion of system feasibility. They also stated that, cell efficiency serves as an input in calculating the optimal system configuration. However, Catelani, Ciani, (2012) stated that dust is the lesser acknowledged factor that significantly influences the performance of the PV installations. Few studies analyzed this effect and the consequent efficiency degradation. Current research on PV system performance and the effects of the deposition of dust is limited due to the fact that powder is a complex phenomenon that is influenced by different environmental and weather conditions (Shaharin, 2011). Therefore, a detailed analysis of the influence of environmental dust on the PV modules performance is proposed in this paper. Based on all this information the effect of environmental dust on the PV panels electrical performances were studied for dusty and dust-free environment.

MATERIALS AND METHOD

In this work, the materials used are silicon solar panel, digital multimeter, pyrometer, digital dust particle meter and a digital computer. The experimental study was carried out in Kazaure Town, in North Western region of Nigeria. The latitude and longitude of the location are 12°39 N and 8°24, while the ambient temperature fluctuates in the range of 10 to 45°C during a year in Kazaure, Wikipedia (2016). Experiment was conducted using a 130W solar photovoltaic panel mounted on a stand. The panel was tested and parameters such as V_{oc} , I_{sc} , solar radiation, dust particles, ambient temperature and relative humidity were measured at exactly 11:30am once a week from November 2015 to February 2016. The net effect of dust on the power reduction was evaluated and analyzed. The effect of dust was quantified by comparing the efficiency of panel exposed to dust and free dust environments. Table 2.1 shows the characteristics of the panel.



Table 2.1: Characteristics of 130W PV module

Model	Silicon
Maximum Power	130W
Open Circuit Voltage	22V
Short Circuit Current	8.04A
Number of Cells	36
Area	0.992m ²
Weight	7.5kg
Fill Factor	0.735

Equation (i) and (ii) were used to calculate the maximum power of the solar PV panel and efficiency. In 2011, Gabriel expressed maximum power as:

$$P_{max} = V_{oc} \times I_{sc} \times FF \dots\dots\dots(2.1)$$

$$\text{and efficiency as, } \eta = \frac{V_{oc} \times I_{sc} \times FF}{A \times I} \times 100 \dots\dots\dots(2.2)$$

Where; I_{sc} is the short-circuit current produced by the solar PV panel, V_{oc} is the open-circuit voltage of the electricity produced, I is the power density of the incident solar radiation (W/m²), A is the exposed area of the solar cell and FF is the fill factor.

$$\text{And fill factor, } FF = \frac{V_{mp} \times I_{mp}}{V_{oc} \times I_{sc}} \dots\dots\dots(2.3)$$

Similarly, equation (iii) and (iv) were used to calculate the percentage reduction in power and percentage reduction in efficiency of the solar PV panel as given by Gabriel (2011).

$$\% \text{ reduction in power} = \frac{P_{without dust} - P_{withdust}}{P_{without dust}} \times 100 \dots\dots\dots(2.4)$$

$$\% \text{ reduction in efficiency} = \frac{\eta_{without dust} - \eta_{withdust}}{\eta_{without dust}} \times 100 \dots\dots\dots(2.5)$$



RESULTS AND DISCUSSION

The graphs for Solar Radiation v/s Time, Environmental Dust Particles v/s Time, Panel Maximum Power v/s Time and Panel Efficiency v/s Time analysis for the 130W silicon solar panel under investigation are shown in Table 3.1 to 3.3 and in Figure 3.1 to 3.7.

Table 3.1: Result Summary in Dusty Environment

PVC VOLTAGE (V)	PVC CURRENT (A)	RADIATION FROM THE SUN (w/m^2)	AMBIENT TEMPERATURE ($^{\circ}C$)	DUST PARTICLES (ug/m^2)	TIME (Hrs)
18.7	5.1	1042	25	393	336
19.8	5.18	1085	25	354	672
19.1	5.15	985	26	181	1008
19.73	5.22	928	23	326	1344
19.12	5.11	958	29	433	1680
19.20	5.1	998	33	128	2016
18.8	5.24	979	41	105	2352
19.15	5.13	973	37	383	2688

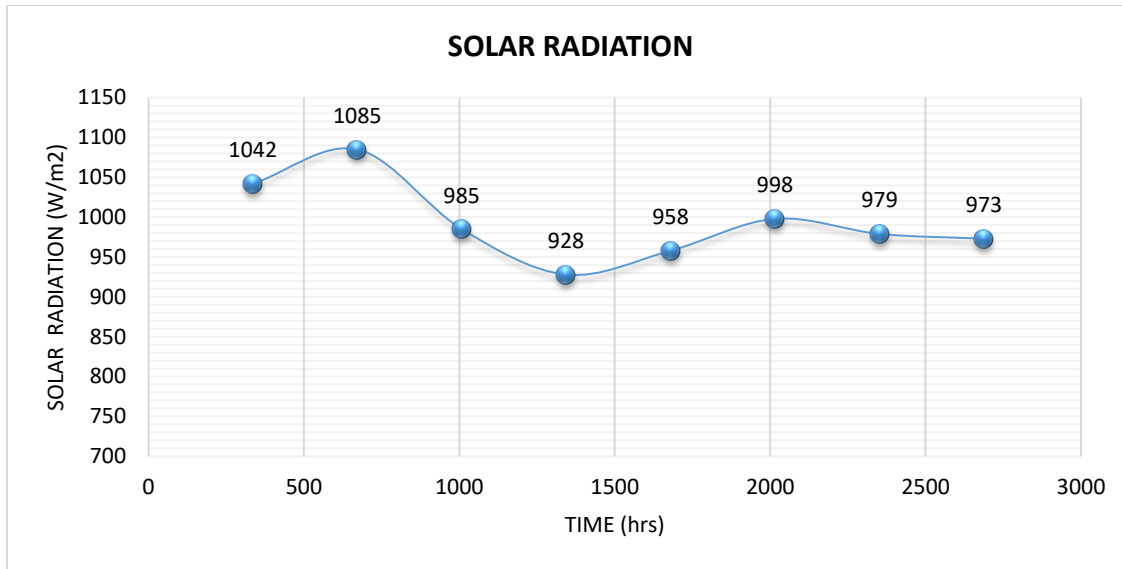


Figure 3.1: Solar Radiation v/s Time characteristics

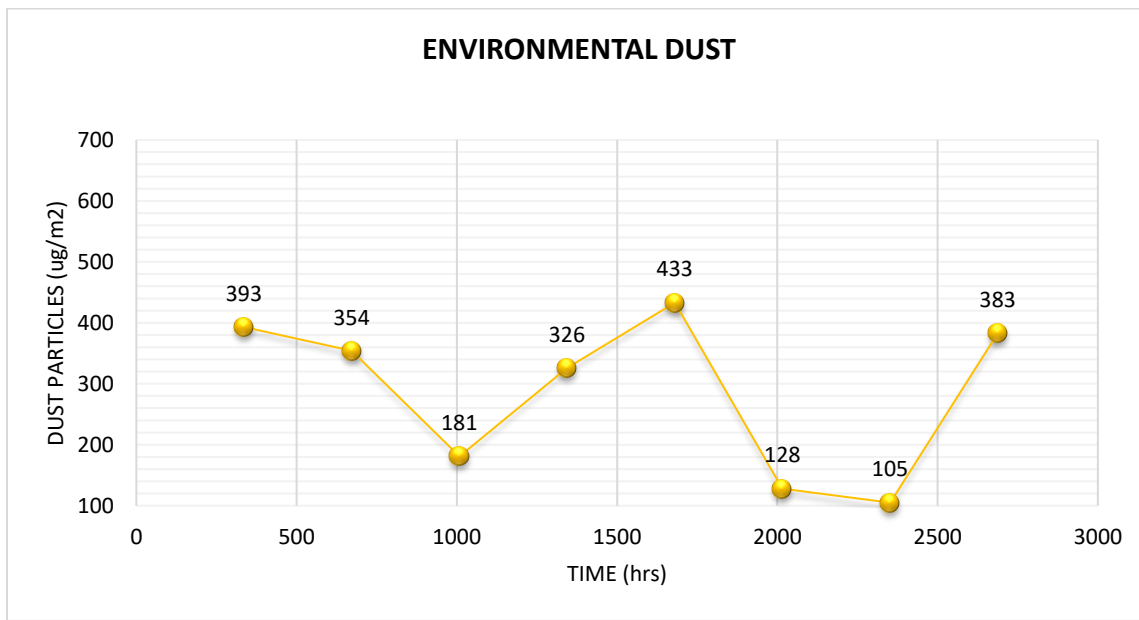


Figure 3.2: Measured Environmental Dust v/s Time characteristics



By substituting the value in to the equation (ii) above. The panel efficiency in dusty environment can be calculated as,

$$\eta = \frac{V_{oc} \times I_{sc} \times FF}{A \times I} \times 100$$

$$\eta = \frac{18.7 \times 5.1 \times 0.735}{0.992 \times 1042} \times 100 = 6.8\% \dots\dots\dots(v)$$

Table 3.2: Panel Efficiency in Dusty Environment (Calculated)

PVC VOLTAGE (V)	PVC CURRENCT (A)	RADIATION FROM THE SUN (w/m ²)	PANEL IN THE ENVIRONMENT (%)	PANEL EFFICIENCY IN DUSTY TIME (Hrs)
18.7	5.1	1042	6.8	336
19.8	5.18	1085	6.9	672
19.1	5.15	985	7.4	1008
19.73	5.22	928	8.2	1344
19.12	5.11	958	7.5	1680
19.20	5.1	998	7.2	2016
18.8	5.24	979	7.45	2352
19.15	5.13	973	7.48	2688

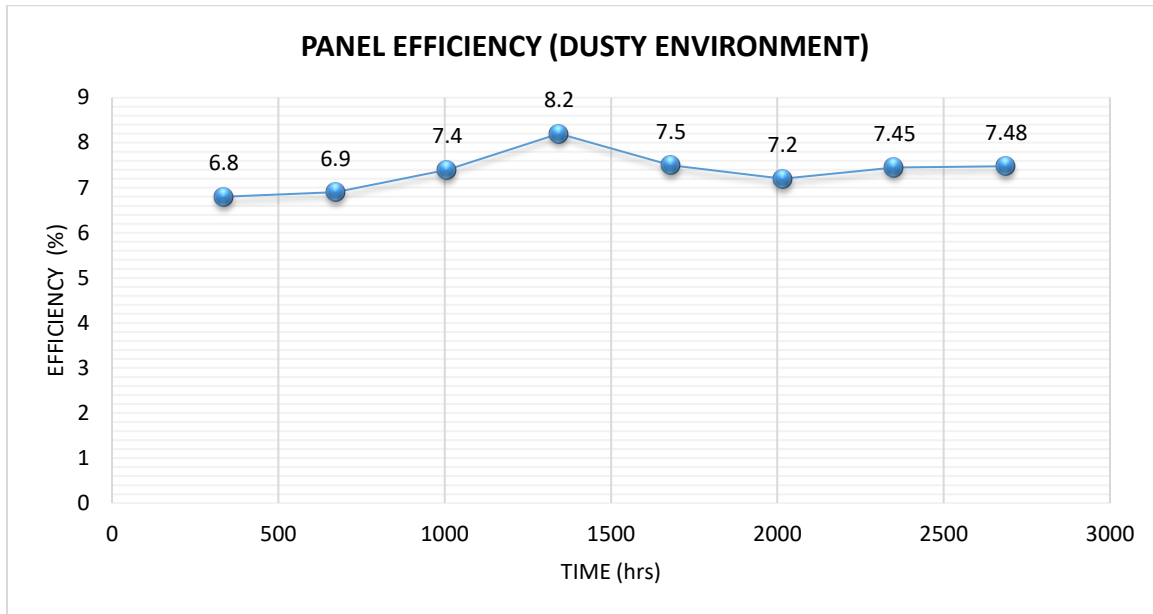


Figure 3.3:Panel Efficiency v/s Time Characteristics (Dust Environment)

By substituting the value in to the equation (ii) above. The panel efficiency in Dust-Free environment can be calculated as,

$$\eta = \frac{V_{oc} \times I_{sc} \times FF}{A \times I} \times 100$$

$$\eta = \frac{21.75 \times 6.19 \times 0.735}{0.992 \times 831} \times 100 = 12\% \dots\dots\dots(v)$$

Table 3.3: Panel Efficiency in Dust-Free Environment (Calculated)

PVC VOLTAGE (V)	PVC CURRENCT (A)	RADIATION FROM THE SUN (w/m ²)	PANEL	
			EFFICIENCY IN DUST-FREE ENVIRONMENT (%)	TIME (Hrs)
21.75	6.19	831	12	336
21.89	6.31	845	12.1	672
21.97	6.35	910	11.35	1008



22.66	6.56	1001	11	1344
22.89	6.69	806	14.1	1680
21.86	6.29	927	10.99	2016
22.75	6.64	709	15.77	2352
21.69	6.11	740	13.3	2688

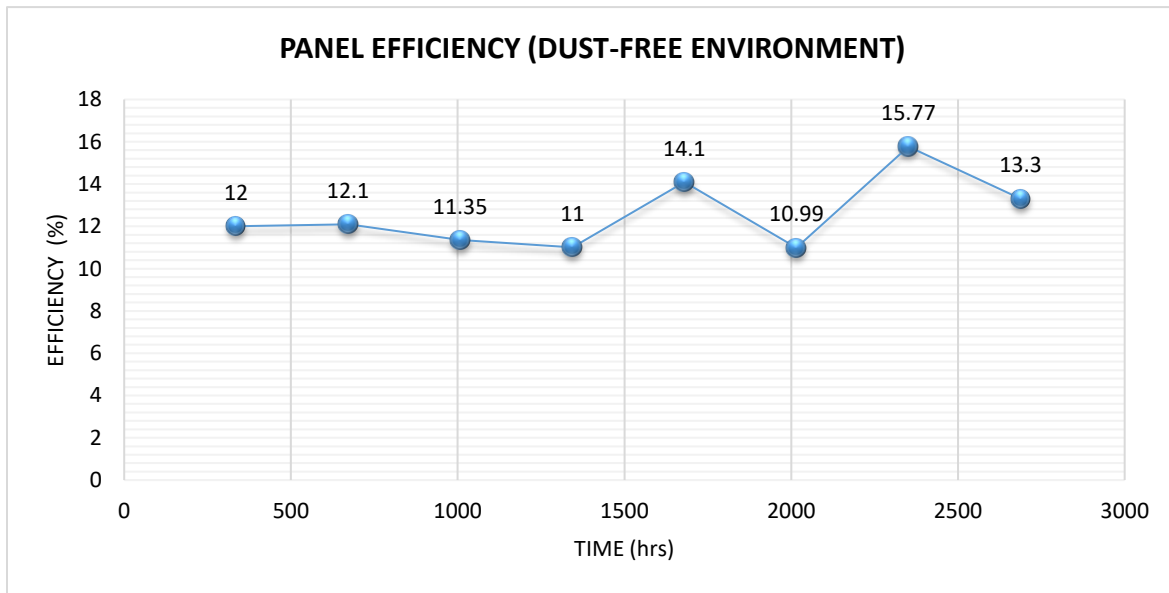


Figure 3.4: Panel Efficiency v/s Time Characteristics (Dust-Free Environment)

Hence, by substituting the values obtained from the dusty environment, in to the equation (i) above.

The panel maximum power in dusty environment can be calculated as,

$$P_{max} = V_{oc} \times I_{sc} \times FF$$

$$P_{max} = 18.7 \times 5.1 \times 0.735 = 75\% \dots\dots\dots(vi)$$

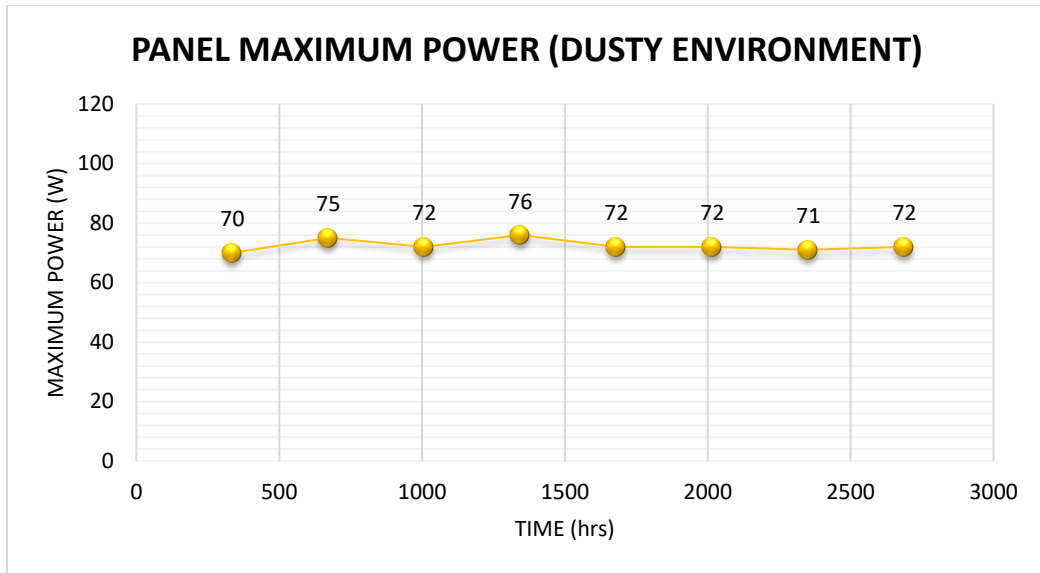


Figure 3.5: Panel Power v/s Time Characteristics (Dusty Environment)

However, by substituting the values obtained from the dust-free environment, in to the equation (i) above. The panel maximum power in dusty environment can be calculated as,

$$P_{max} = 21.75 \times 6.19 \times 0.735 = 98.9\% \dots\dots\dots(vii)$$

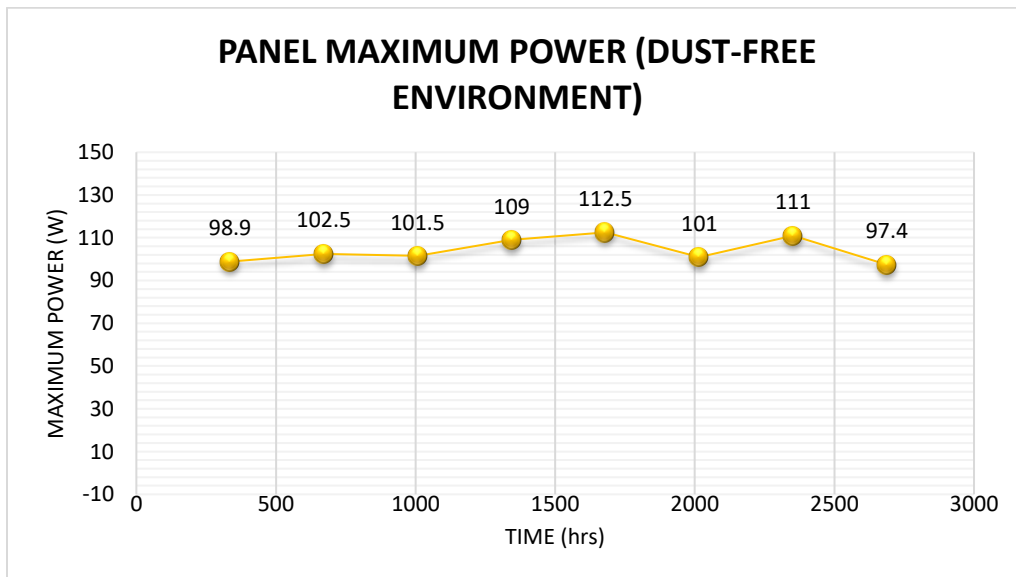


Figure 3.6: Panel Power v/s Time Characteristics (Dust- Free Environment)



From the Figure 3.1 and Figure 3.2, the solar radiation intensity and the environmental dust particles vary between 928 to 1085w/m² and 105 to 433ug/m³ respectively. This shows the minimum and maximum environmental dust fallen in the study geographic location during winter. Also, Figure 3.3 and Figure 3.4, shows the minimum and maximum efficiency of the PV panel subjected to dust environment, which are 6.8% and 8.2%, while that of free dust environment are 10.99% and 15.77%. Similarly, Figure 3.5, shows the minimum and maximum power of PV panel subjected to dust environment are 70 and 76W, while that of free dust environment are 97.4 and 112.5W as shown in Figure 3.6. The result shows that dust considerably reduces the power production and efficiency by about 30% and 48% respectively.

CONCLUSION

In this paper, the performance of solar photovoltaic panel subjected to environmental dust was experimentally studied. The effect of dust on the power reduction and efficiency reduction of PV module was quantified. The result shows that dust considerably reduces the power production and efficiency by about 30% and 48% respectively. The study concluded that electrical parameters of solar panel are sensitive to dust density. It also recommended that solar system designers and engineers should make a provision at design stage reference to the quantified result of this study in order to overcome the losses due to environmental dust for high system performance.



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