# IMPACT OF DUST ON ELECTRICAL POWER OUTPUT OF SOLAR PVMODULES IN NORTH-EAST, NIGERIA

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**Abstract**

The impact of dust on the solar PV modules deserves more attention. North-eastern Nigeria hashigh potential of solar irradiance but it is proned to dust accumulation. This paper therefore, investigated the impact of dust on the performance of solar Photovoltaic modules in North- Eastern Nigeria. The investigation entailed field experiment carried out in Maiduguri to assessthe performance of the module based on continuous dust deposition for 14 days during dust accumulation period. The results show that more than 50% loss in power output was recordedunder 14 days of continuous deposition. The efficiency of the module reduced from 17.1% onthe first day to 7.2% on the fourteenth day of the experimentation. The investigation also shows that at high humidity the PV performance drops. Solar irradiance increases the performance. Thedeployment of solar PV energy supply system is recommended in spite of dust accumulation challenges. To maintain adequate performance of the system, a once-a-week cleaning is recommended during intense dust accumulation period.

**Keywords—Dust, efficiency, modules performance, photovoltaic, solar.**

## 1.0 Introduction

The performance of solar PV module is greatly affected by dust which is an emerging area ofresearch in photovoltaic energy conversion system. The studies conducted by (Menoufi, 2017), stated that only 72 studies were conducted on the impact of dust on the performance of solar PVpanels globally. The study presented Africa to have contributed only 12% which amounts to about 8.64 approximately 9 studies in 26 years. This is grossly inadequate considering that Africa is one of the worst dust accumulation zones in the world, in addition to the fact that thereare many initiatives that support renewable energy cooperation between Europe and Africa (Menoufi, 2017; Mann, 2012; Menoufi et al., 2017). This further confirms that there are scantyliteratures on the effect of dust on the performance of PV panels and therefore, buttresses the need for the study on the effect of dust in Maiduguri, Nigeria. This is a region endowed with solarenergy potential, good enough for solar photovoltaic energy supply deployment but unfortunately characterized by intense dust accumulation events compared to other part of thecountry. Solar energy is a renewable energy of choice but the intermittent nature of the solar resource at any location makes solar data analysis imperative and an important prerequisite to accurate sizing of solar PV system components. Nigeria, a country endowed with solar energyand has grossly insufficient energy supply to its citizens for both domestic and industrial purposes, requires a low-cost solar energy conversion system for the development of local communities.

Solar energy has the capacity, if efficiently harnessed, to supply sufficient energy to rural areas inNigeria, which are far from the National grid. Also, the development of solar PV technology is amodern energy system which unlocks access to improved healthcare, improved education, improved economic opportunities and, even, longer life, for those who go solar. Nigeria has thehighest population in Africa (Kamer, 2022). Unfortunately, Nigeria is among the countries withthe lowest electricity consumption per capita in the continent (74 kWh/year) (Ibitoye and Adenikinju, 2007). The residential electricity use per capital of Nigeria is very low and this hascontributed tremendously to the poverty level of the citizenry (Ibitoye and Adenikinju, 2007).Also, because the region under study is a region where dust is prevalent and apart from the factthat there is scanty literature on effect of dust, the researches have varying results from region toregion combine also with the fact that no such study has been carried out in this region. All thesenecessitated the study of the effect of dust on PV panels in North-eastern, Nigeria.

Maiduguri in the North-eastern Nigeria is the most dust accumulation region in the country andthe most suitable region for the development of solar energy conversion system and with largerural communities without access to electricity. This makes the development of solar energy conversion system in this region very important and the study of the impact of dust imperative to guide the maintenance and cleaning of the modules for optimum power supply. The experimentto investigate the impact of dust on the performance of PV modules was conducted in Maiduguri,North-eastern Nigeria during the most dust event period. This occurs annually between the month November and March.

## 2.0 Materials And Methods

The material used in the research include electrical measuring instrument such as Mooshimeterwith the capability to measure current and voltage concurrently and log the results, solar radiation meter, anemometer, hygrometer, and a 50 W solar photovoltaic module. The 50 W monocrystalline solar PV module (TDG-PV Model T050M365), the data of which is presentedin Table I was used for the experiment. The experimental was set-up as shown in Figure 1. Thecurrent and voltage were measured at an interval of 10 minutes using Mooshimeter, an instrument that can measure current and voltage concurrently and data logged. TheMooshimeter was set to log the readings every 10 minutes for 14 days during the day.

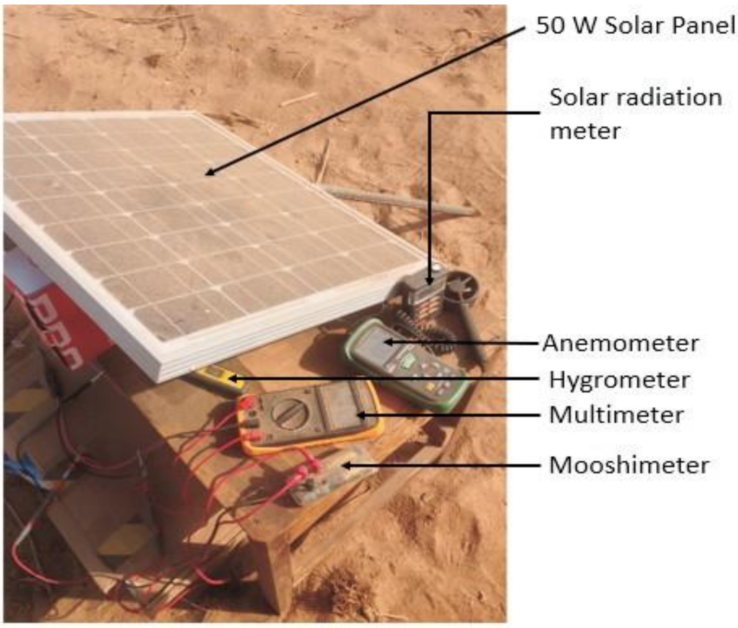


**Figure 1: Experimental Set-up for effect of dust on PV performance**

The ambient temperature, humidity, solar irradiance, and wind speed were recorded every hour.The experiment was conducted from 06:00 to 18:00 hours daily for 14 days. Figure 1 shows theexperimental set-up for the study of impact of dust on the performance of PV module.

**TABLE 1: KEY SPECIFICATIONS OF TDG-PV T050M365**

| S/N | PARAMETERS | SYMBOL | VALUE |
|---|---|---|---|
| 1 | Rated maximum power | Pmax | 50W |
| 2 | Voltage at maximum power | Vmp | 18.75V |
| 3 | Current at maximum power | Imp | 2.690A |
| 4 | Open-circuit voltage | Voc | 22.83V |
| 5 | Short-circuit current | Isc | 2.940A |
| 6 | Operating temperature | Tc | -40oC to +85oC |
| 7 | Cell Technology | Mono-Si | |
| 8 | Weight | Wc | 4.0 kg |

**Data from the Name Plate of the 50 W solar panel used for the experiments**

## 2.1 Dust Collection and Analysis

The accurate quantification of power decline over time that the solar panels experience isreferred to as degradation, which must be known in order to predict power delivery. And the ability to accurately predict power delivery over the course of time is of vital importance to thegrowth of PV industry. In order to assess the potential deterioration of the Photovoltaic modules which could eventually leads to panel degradation, it is important to have full knowledge of howthe deterioration by sand occurs. It is from high wind speed to high windstorm to high sand/dusttransportation that leads to potential deterioration.

In this study, we intend to determine the properties of the sand/dust that could reach the modulesurfaces. Therefore, during the Maiduguri field experiments on the impact of dust, the dusts werecollected at different heights. Four wooden poles with fixed collector plates were individuallyplanted at different positions and at the heights of 0.5 m, 1.0 m, 1.5 m and 2.0 m for dust collection for a period of 14 days. This collection was done outside Maiduguri town. The collected dust samples were placed in different containers properly labelled. The analysis of these samples was carried out in Cranfield University, United Kingdom. Figure 2 shows the wooden poles and the plastic plates for dust collection at different heights.

Dust naturally falls into the plastic plates, the dust from each plastic plate was put in a polythenebag and taken to Cranfield for analysis. Dust does not require any preservation in this regard.

In addition, and for comparison, sand was collected from the ground level as well as from the module surface. Dust collected at different heights in order to compare and note the possible kindof particles that could reach the panels' surfaces since collection at different heights will havedifferent results of the characterization. The characterization of the particles will have effect because dust particle sizes varies with height of collection. At higher height, particle sizes arefiner and have less damaging impact on the glass of the solar panel. At lower heights, the particlesizes are bigger and can cause cracks either visible or invisible cracks on the panel, which obviously affects the output of the solar panel.

**Figure 2: Wooden poles and plastic plates for dust collection**

## 2.2 Characterisation Technique

After collecting the sand from the site, a set of analyses were carried out at Cranfield Universitylaboratories in order to determine the main characteristics of the sand/dust particles present in the site. Three phases of analysis were conducted as enumerated below:

- High precision digital weight balance was used to determine the initial mass of sand collected from each height; the objective is to see how much particles are collected according to the height.

- Another analysis that was carried out before the phase separation is particle sizedistribution.

- The mass of the samples was weighted by high precision digital weigh balance.The particle size distribution of the aggregate collected were analysed using Mastersizer3000. Wet separation of fraction of sand/soil was carried out. The chemical compositions of the samples were determined using X-ray diffraction.

**The analysis conducted are particle size distribution, soil sand fraction, sand particle shape and nature and chemical analysis of the sample. Details are presented in the next section.**

### 2.2.1 Particle size distribution

Sample of sand was properly mixed with the aid of spatula and small quantity was taken and poured into the wet sample dispersion unit (i.e a unique dip-in centrifugal pump and stirrer thatachieves full and rapid dispersion in a standard laboratory beaker) of the Mastersizer 3000 foranalysis. The distribution was made into seven groups viz; 0 - 50 ìm, 50 - 100 ìm, 100 - 150 ìm,150 - 250 ìm, 250 - 500 ìm, 500 – 1000 ìm and >1000 ìm.

### 2.2.2 Sand and soil separation

After weighing each of the samples from the four different heights of collection, sand and soil separation was carried out using phase separation method. This entails putting samples in a cleanbottle and pouring distilled water to allow dirt to float and was removed. This was done a coupleof time until it became clean of dirt. A fresh distilled water was then poured into the bottle containing the sample and shaken lightly to allow smooth soil particle to float in the water.

Thesuspension mixture was poured out of the bottle leaving sand particles settled below the bottle.The bottles were then labelled with their contents as either sand or soil. This procedure was repeated for all the individual samples collected from the four different heights. The bottles wereplaced in an oven set to 150oC to dry the sand and soil. The dried samples were then taken toanalyze the characteristics of the collected particles (i.e. size, morphology and minerology) using scanning electron microscope and Energy Dispersive X-Ray Spectroscopy (SEM-EDX).

## 3. 0 Results and Discussion

Figure 3 shows the time series plot of peak power output of the 50 W module for the 14 days ofthe experiment. Because the output power depends on the irradiance at any time, the time seriesplot shows rise in power from morning hours and reaching maximum during the afternoon of each day. The effect of dust accumulation over the 14 days of the field work can be seen in thereduction in power output by the day as shown in Figure 3. Day 1 recorded the maximum poweroutput of about 50 W at 2:00 pm and day 14 recorded the lowest power output of about 20.5 W.This is an indication that the mximum irradiance occurred at 2:00 pm. There was over 50% dropin power output during the period of the field work. This agrees with over 50% reduction in power as a result of dust accumulation on PV modules in Egypt presented by (Menoufi, 2017).

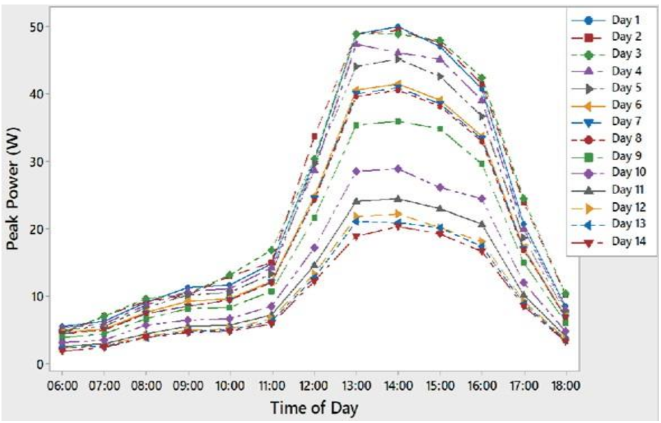


**Figure 3: Time series plot of Peak Power for 14 Days**

The reduction in the efficiency as a result of drop in performance owing to dust accumulationwas studied over the 14 days of the field work. Figure 4 shows the time series plot of peak powerand efficiency during the 14 days. The highest efficiency of 17.1% was obtain on the first dayand the least efficiency of 7.2% was obtained on the last day amounting to a 57.6% drop in efficiency.

This drop in performance was because of continuous deposition of dust on the solar module without cleaning for 14 days which is the basis for the study. This implies that during peak dustperiod in Maiduguri, there is high loss in performance in just two weeks, it is therefore necessaryto clean solar modules at least once in every week to be able to maintain reasonable reduction inefficiency.

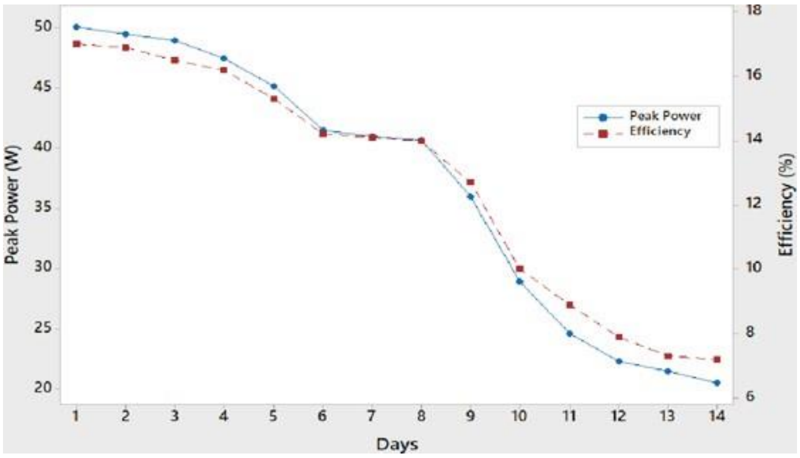


**Figure 4: Peak Power and Panel Efficiency against Days**

Figure 5 to Figure 7 shows the fitted regression line plots of the relationship between peak poweroutput of the 50 W solar PV module and solar irradiance. The regression line shows a positivecorrelation with coefficient of determination, R2 being 97.5% 96.8% and 99.4% for days 1, 5 and 8 respectively. This indicates that increase in solar irradiance directly translates to increase in power output of solar photovoltaic modules. This is supported by a number of literatures (Nasiriet al., 2019; Karafil et al., 2016; Chanchangi et al., 2020).

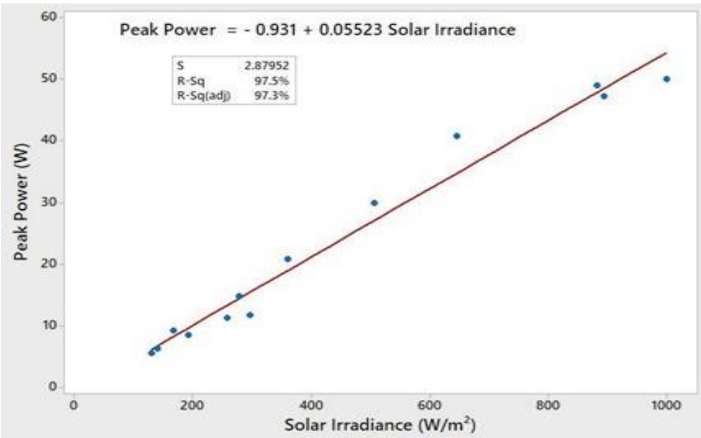


**Figure 5: Fitted regression line plot for Peak power versus Solar Irradiance (Day 1)**

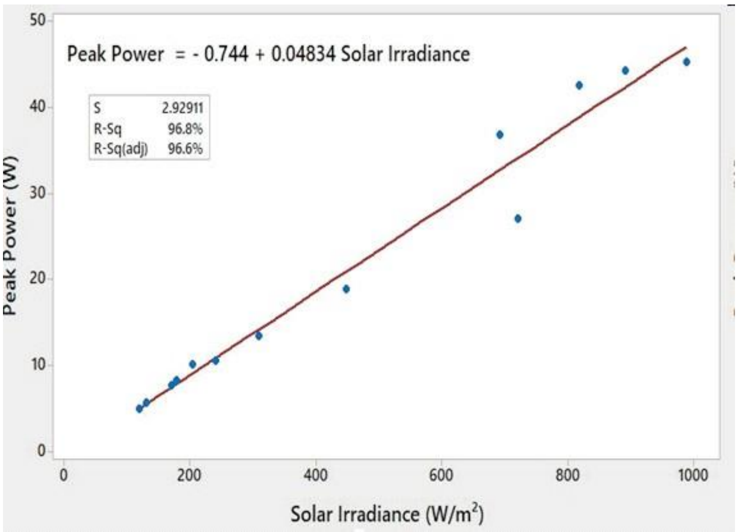


**Figure 6: Fitted regression line plot for Peak power versus Solar Irradiance (Day 5)**

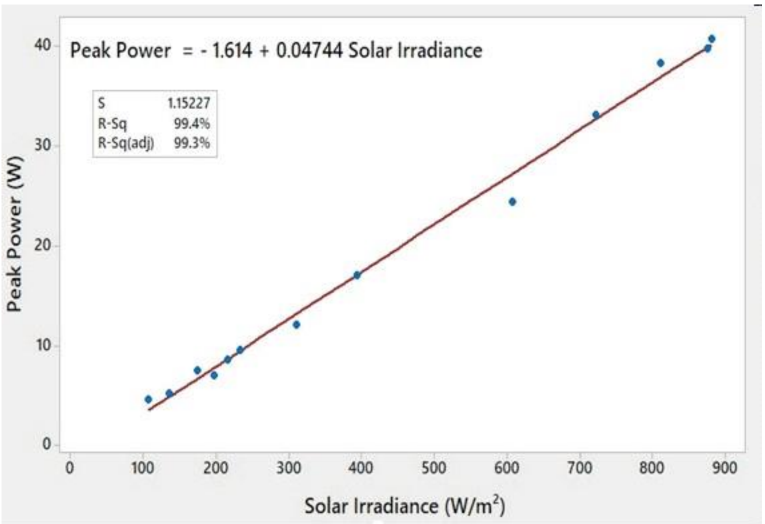


**Figure 7: Fitted regression line plot for Peak power versus Solar Irradiance (Day 8)**

Figure 8 to Figure 10 shows the fitted regression line plots of peak power vs relative humidity fordays 1, 5 and 8 of the field experiments. The fitted regression line indicates that a negative correlation exists between the two quantities. The coefficient of determination, R2 shows thatthe regression line fits the relationship to about 71.2%, 78.3% and 79.1% for days 1, 5 and 8 respectively. This can be attributed to the fact that high humidity causes reflection of solar irradiance in air thereby reducing the amount of irradiance reaching the panel and consequentlyreducing the performance. This agrees with the findings of (Amajama and Oku, 2016) who concluded that relative humidity has negative correlation with voltage, current and consequently on power output of solar panel.

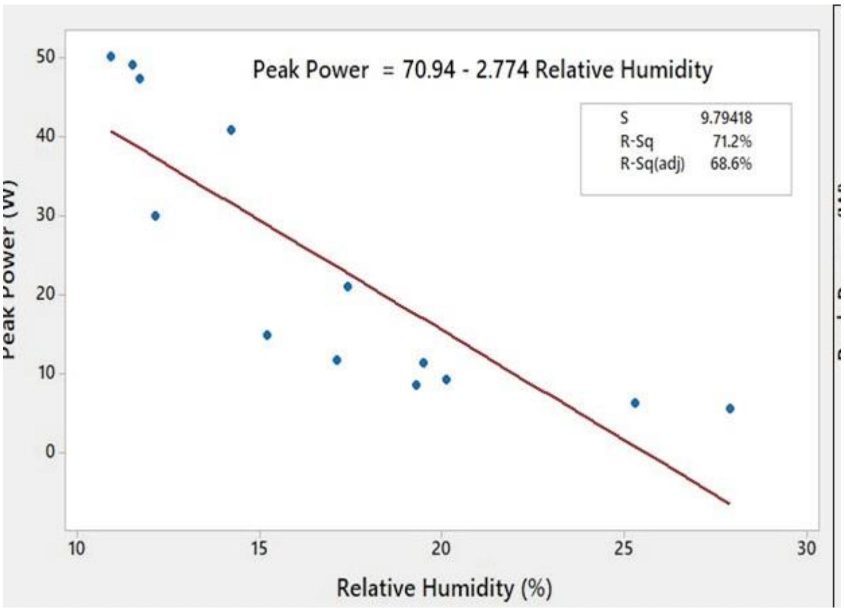


**Figure 8: Fitted regression line plot for Peak power versus Relative Humidity (Day 1)**

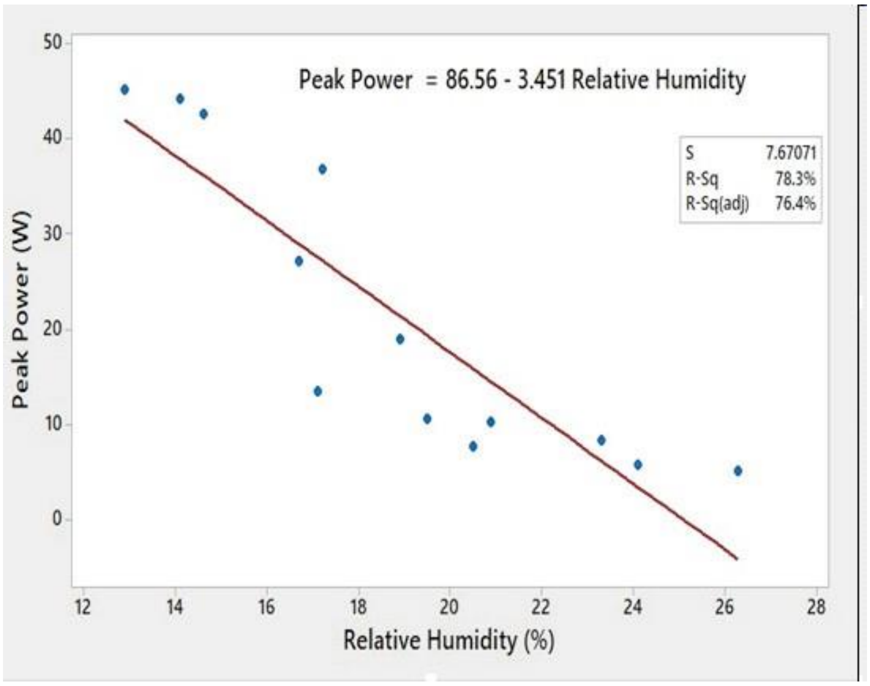


**Figure 9: Fitted regression line plot for Peak power versus Relative Humidity (Day 5)**

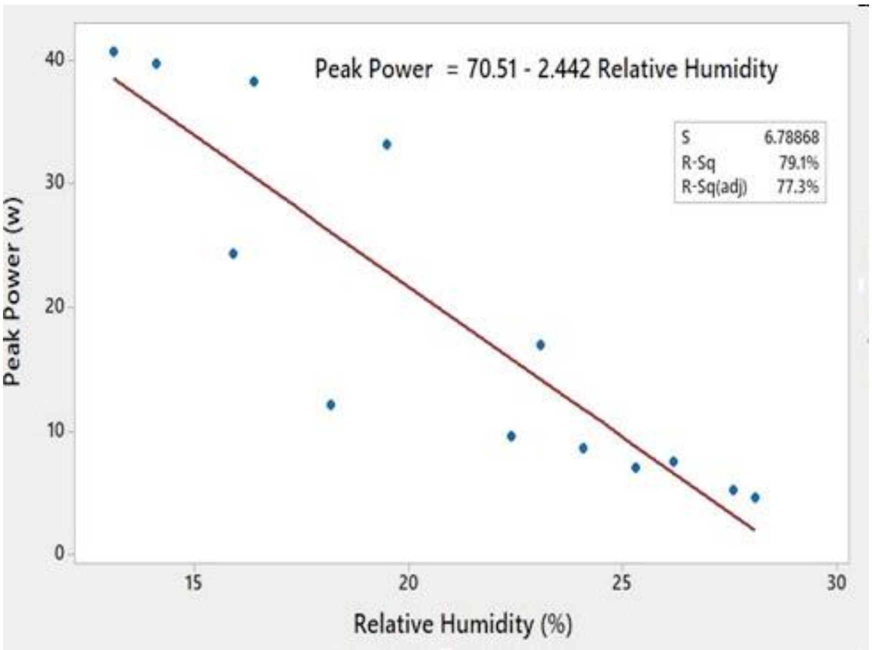


**Figure : Fitted regression line plot for Peak power versus Relative Humidity (Day 8)**

The coefficient of determination, R2 shows that the regression line fits the relationship to about71.2%, 78.3%, 79.1% and 72.4% for days 1, 5, 8 and 13 respectively. This can be attributed to thefact that high humidity causes reflection of solar irradiance in air thereby reducing the amount ofirradiance reaching the panel and consequently reducing the performance. This agrees with thefindings of (Amajama and Oku, 2016) who concluded that relative humidity has negative correlation with voltage, current and consequently on power output of solar panel.

**Figure 11** shows the particle sizes from each height of collection, panel and ground. The 0.5 mheight contains larger particle size up to 1600 ìm range. This is expected at lower heights. Thehighest height of 2.0 m contains the tiniest particle sizes and no larger particle beyond 516 ìm.This is because finer particles tend to be blown higher than heavier ones.

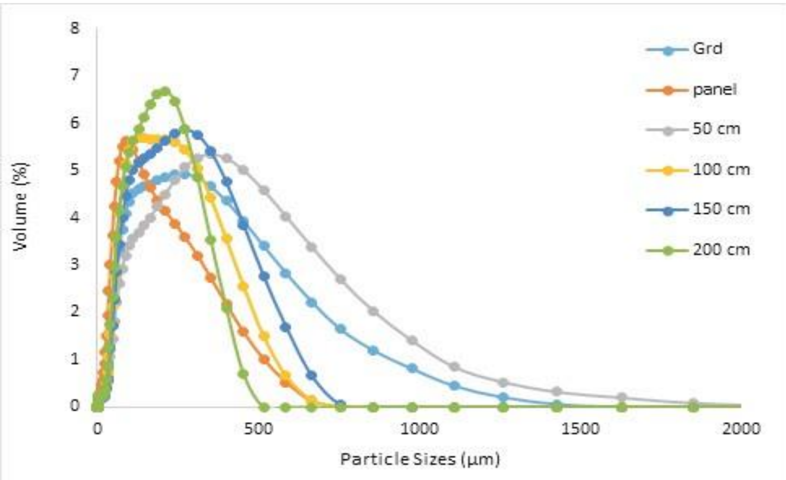


**Figure 11: Percentage Volume vs Particle size**

## 4. 0 Conclusion

The impact of duct on the performance of solar PV system has not received the required globalattention it deserves and only about 12% of global research reports is from Africa. This necessitated experimental investigation of impact of dust on solar PV modules in Maiduguri, North-Eastern Nigeria. The investigation which focused on the impact of continuous dust deposition on the modules revealed that the power output of a 50 W module which was used for the experimentation dropped by more than 50% and consequently the efficiency. Thisexperiment was performed at the peak of dust event in Maiduguri and it can be concluded that dust deposition on solar PV module has tremendous impact on the overall performance of the system and cleaning of the modules at least once a week during this period will sustain the performance of the system. Sands were collected from the site of the field experiment in Maiduguri and subjected to chemical composition analysis, morphology, and size analysis. From the chemical composition and morphology of the sand collected from different heights duringthe field experiments, it can be concluded that the sand in the location of field experiments is quartz since the chemical analysis shows high percentage of oxygen and silicon. Its large particles which were found in the lower platform has higher roundness than those found at higherheights, therefore, deterioration or degradation rate of the PV module is expected to be low sincerounder particles causes lower deterioration than particles with sharp edge.

## 5.0 Recommendation

The following recommendations were made based on the findings of this research:

- The development of solar PV system for energy supply to rural areas of the region understudy is recommended as a result of huge availability of solar resource
- Cleaning of solar PV panel at least once a week is recommended for efficient performance of the system
- Further studies of dust impact is recommended to be carried out in other regions of Nigeria. This is because the result of dust impact from one region cannot be implied forother regions quantitatively.

## 6.0 Acknowledgement

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