

COMPARATIVE STUDY ON EFFECT OF HUMIDITY, WIND AND HARMATTAN DUST ON THE OUTPUT VOLTAGE OF SOLAR PANELS IN THE SAVANNAH AREA

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ABSTRACT

Persistent power outage due to problem occurring on the transmission line, terrain and inadequate power generation in developing countries causes setback in economic activities. Alternative sources are needed to minimise these setback, especially using solar photovoltaic source. The aim of the study is to determine the relationship between wind speed, humidity and harmattan dust and output voltage of the photovoltaic cells. The output voltage of solar array, humidity and wind speed of the area were collected for 9am, 12pm and 4pm and six months (January to June 2021). February and April have the highest wind speed with maximum of 17km/hr and 19km/hr respectively. Maximum humidity occurs in June due to raining while March and May with 80V and 85V at 12pm are the highest output voltage recorded. These results show that output voltage is directly proportional to wind speed and inversely proportional to humidity. This means, increase in wind speed and decrease in humidity increases the output voltage. Wind, humidity and dust deposition have great effect on the output voltage of solar photovoltaic cells. While wind and humidity also influence the rate of dust deposition which consequently affects the power output. This study will serve as a feasibility study to policy makers and other stakeholders and additional knowledge for researchers.

Keywords: Solar panels, humidity, wind speed, output voltage, dust deposition, harmattan

1 INTRODUCTION

Development progress of a country depends on its energy production, usage and storage. This dependence is swelling more and more with advancements in technology and industrial growth [1]. The global and local energy crisis has increased since the beginning of oil crisis (as the highest source of energy) in the seventies of the last century. This is mainly caused by fast economic development, urbanisation worldwide resulting to higher energy needs. Altogether, they spurred the efforts toward harnessing solar power as an alternative source of energy [1, 2]. Developing nations are striving to achieve the various goals, especially the goal of obtaining affordable and clean energy. Renewable energy conversion devices (such as Solar panels and wind turbines) have been encouraged to substitute the conventional non-sustainable energy harvesting systems [2, 3, 4]. This is due to their economic merit (their rapid price decrease due to low production cost) and environmental merit (emission reduction and clean energy production) [5]. The continuous increase in fossil fuel price and its environmental impact is apparent and solar photovoltaic devices appear to be the promising clean energy source among renewable energy technology. Solar photovoltaic panels are being used as a source of electricity generation to complement the instability and consequences of the non-renewable energy sources mostly in developing countries. Solar energy is thus the primary source of energy on our planet and surprisingly it exceeds 8000 times our primary energy needs [6, 7]. Most times when these photons are emitted from the sun, only a small percentage reaches the solar cell. The photons are transmitted, scattered, attenuated, absorbed, or reflected by the airborne particles or material accumulated on the surface covering the PV cell, such as dust [5, 8]. According to Gupta *et al.* [9], the output of the PV module is also significantly influenced by

environmental elements such as solar insolation, ambient temperature, humidity, precipitation, seasonal change, dust, wind speed, and direction. Apart from environmental factors, installation factors such as tilt angle, orientation, altitude, seasonal tilt adjustment and location of installation play the vital role to affect the performance of the PV module [6, 7]. Relative humidity, dust and wind are inter-related. The measure of the effect of the wind on relative humidity in the atmosphere is linked to the deterioration in the productivity of photovoltaic cells. The wind affects the concentration of moisture in the atmosphere. As wind speeds increase, relative humidity decreases in the air, which means that the cell's productivity improves. But the increase in wind speed causes rise in dust resulting in the accumulation of this dust on the surfaces of the cells causing reduction in the productivity of solar panels [3, 5, 10]. Nigeria is characterised by some cool and dusty atmosphere during harmattan in the northern part for a period of about five months from November to March. Extreme heat condition around March to June while June to November excessive rain [6]. Humidity, storm and wind are high during the rainy season around June to November and low during dry season especially around March to June. While wind and dust are high in the dry season especially around November to March [3, 6]. These extreme weather conditions adversely affect the renewable energy collection (especially solar energy). Therefore, there is a need to study the characteristics of the area for proper placement of renewable energy collectors. The study is aimed at studying the relationship between relative humidity, wind speed, harmattan dust deposition and the output voltage of photovoltaic cells in Funakaye Area in Gombe state Nigeria.

2 METHODOLOGY

Study area is located in savannah region of northern part of Nigeria (Funakaye Local Government Area of Gombe state Nigeria). Specifically, the study was conducted at Gombe State Polytechnic Bajoga the major town of Funakaye LGA which lies on latitude 10.85° north and longitude 11.43° east as can be seen from Figure 1.

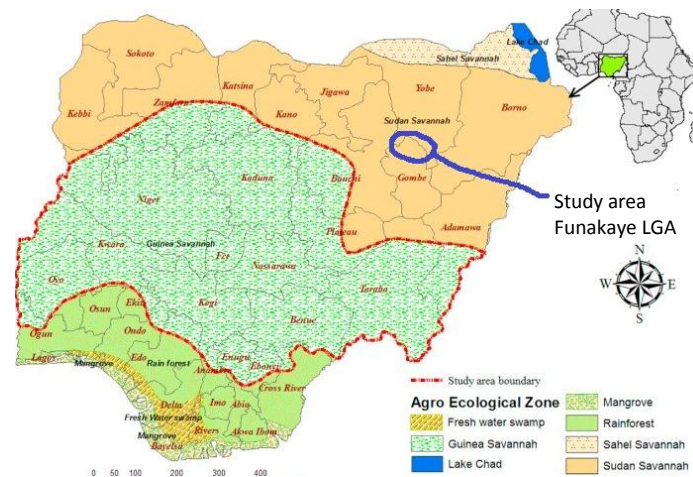


Figure 1. Maps of Nigeria showing the savannah and the study area

Twelve (12) solar panels array (GL300W MONO) installed at the NITDA ICT centre of the Polytechnic were used for the experiment. Each of the six solar panels were connected in series and the two series connections were connected in parallel as shown in Figure 2. This arrangement enables maintaining the required output voltage and power range for the center [11].

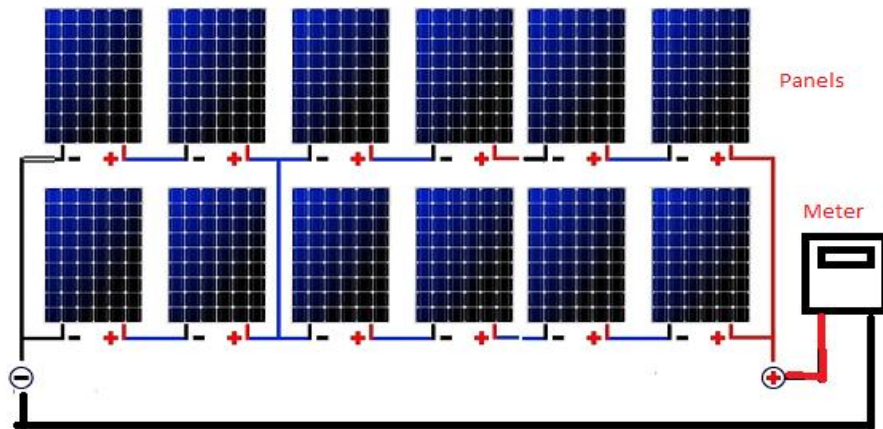


Figure 2. Schematic diagram of the experimental setup

The rating of the panels used were maximum power (P_{max}) is 300W, tolerance (Tol) is $\pm 3\%$, voltage at P_{max} is 35.9V, current at P_{max} is 8.38A, open circuit voltage (V_{oc}) is 43.1V, short circuit current (I_{sc}) 9.2A at operating temperature of -40°C to $+85^{\circ}\text{C}$. The total output voltage was measured using digital multi-meter connected to output of the panels. The data for wind speed and humidity were obtained from weather focus of the study area. The data were collected from January to June 2021 at 9:00am, 12:00pm and 4:00pm daily. The model equations for output voltage for the experimental setup are shown in equations 1 to 3 [11]. If V_{s1} and V_{s2} are the two output voltages of the solar panels in series arrangement then:

$$V_{s1} = \sum_{i=1}^n V_i = V_1 + V_2 + V_3 + V_4 + V_5 + V_6 \quad (1)$$

$$V_{s2} = \sum_{i=1}^n V_i = V_7 + V_8 + V_9 + V_{10} + V_{11} + V_{12} \quad (2)$$

The total voltage for the parallel arrangement (V_{PT}) will be

$$V_{PT} = V_{S1} = V_{S2} \quad (3)$$

Where V_i to V_n are the output voltages of solar panels used in the experiment.

3 RESULTS AND DISCUSSION

Figures 3 to 5 shows the variation of monthly mean wind speed, humidity around the array of the photo voltaic cells in relation to output voltage of the cells for 9am, 12pm and 4pm.

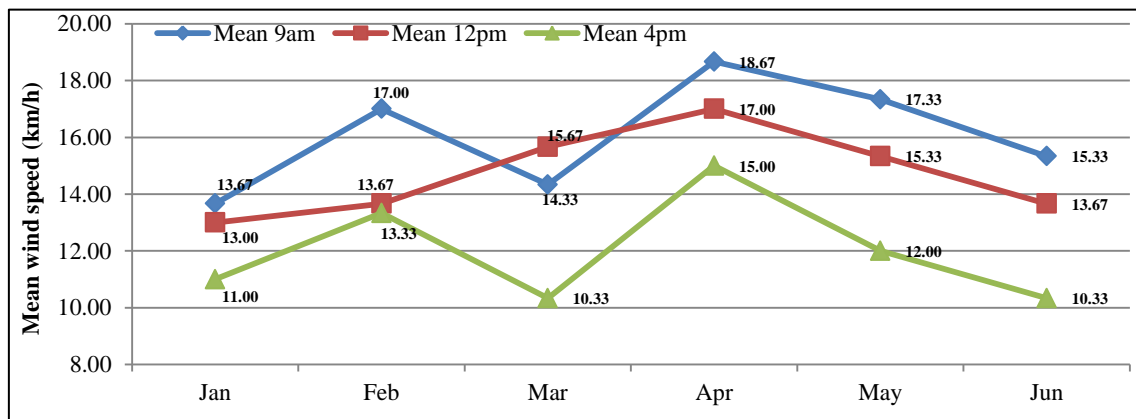


Figure 3. Variation of monthly mean wind speed for 9am, 12pm and 4pm

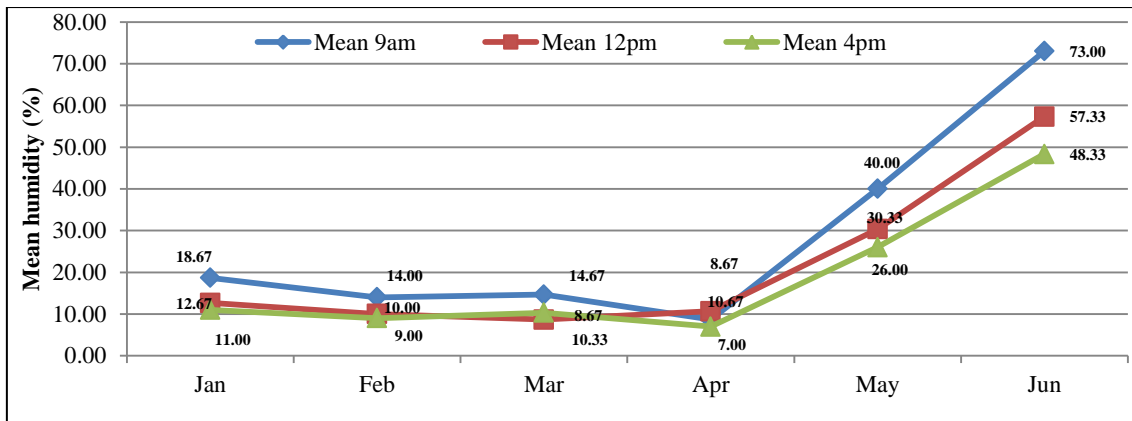


Figure 4. Variation of monthly mean humidity for 9am, 12pm and 4pm

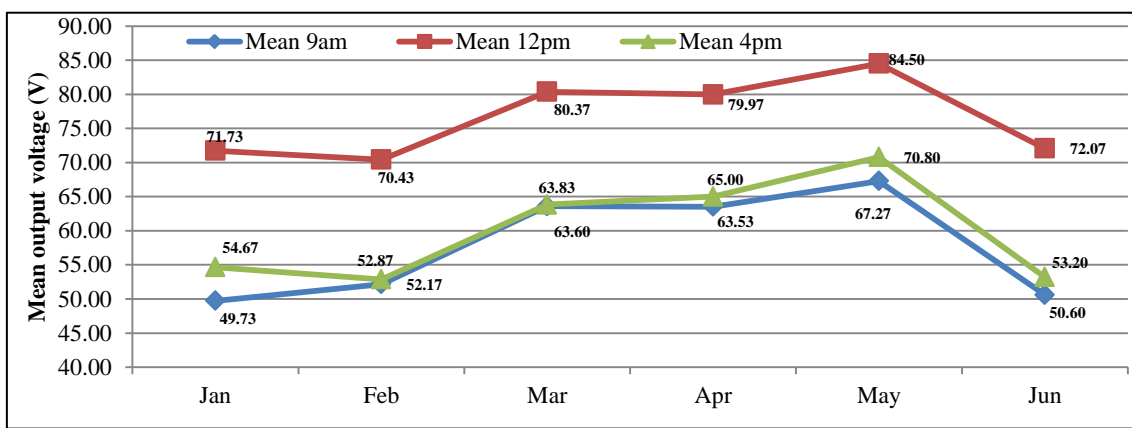


Figure 5. Variation of monthly mean output voltage for 9am, 12pm and 4pm

From Figure 3 for the variation of monthly mean wind speed, it can be seen that the speed decrease from morning to afternoon. In the morning across the months recorded, the highest wind speed is 19 km/h in the month of April while the lowest is 14km/h recorded in the month of January. For morning and afternoon the variation is partially the same with sharp rise in the month of February and April. The highest wind speed is obtained in the month of April. For 12pm there is an increase in wind speed from January up to April and a sharp decrease to the month of June. Generally, the wind speed is high in the morning, medium during the day and very low in the afternoon. Even though weather conditions varies between countries but this variation was supported by [2, 3, 4, 5, 12, 13]. The wind plays an important role in dust deposition and removing from the surface of the solar PV module. The wind behaves like a transporting agent of dust. Slow wind can result in dust deposition while high-speed wind may clean the solar module surface. Dust deposition rate relies upon the attentiveness of airborne dust carried by air and its speed. The dust deposition rate will be more with the high concentration of airborne dust and vise-versa [9]. From Figure 4 the variation of monthly mean humidity, it can be seen that the variation of humidity is partially the same for all the month recorded. From January, there is a slight decrease from range of 11% in the morning to 19% in the afternoon up to the month of April with values of 7% to 10% for afternoon and morning respectively. From April, there is sharp rise in humidity of from 43% to 73% for afternoon and morning respectively. This is due to coming of rainy season of which rain have started in some communities around the state leading to increase in humidity from month of April to June. Generally, the humidity is high in the morning and reduces as afternoon approaches for all the month's daily periods recorded. This variation was supported by the studies of [1, 5, 8, 13]. The result shown in Figure 5 indicate that the output voltage of the photovoltaic cell is high at 12pm which varies from 72V to 85V. These values decrease from 50V to 67V in the morning (9am) and from 53V to 71V in the afternoon (4pm). The lowest values of 50V, 72V and 53V were obtained in the month of January for 9am, 12pm and 4pm respectively. This is due to harmattan cool and dust and high wind speed in January. The highest

values of 67V, 85V and 71V were obtained in the month of May. The reason being raining had started which washed away harmattan dust on the panels thereby improving the output of the panels. April having the highest solar radiation and ambient temperature was not the month with highest output voltage due to remains of harmattan dust from the harmattan season and high wind speed. June is the month to have high output voltage due to absence of dust on the panels, settling of dust due rain and high solar radiation. But it is having low as a result cloud cover of the sky which scattered the sun ray in the atmosphere there by reducing the output voltage of the cells. Generally, the output voltage is very low in the morning and afternoon and very high during the daytime especially (12pm) as can be seen from Figure 4. This is supported by studies of [1, 4, 6, 7]. Figure 6 to 8 show the relationship between the humidity, wind speed and output voltage for 9am, 12pm and 4pm respectively. The values of humidity, wind speed and output voltage were within the same range. Therefore, they were plotted on the same graph as can be seen on the vertical axis of Figures 6 to 8.

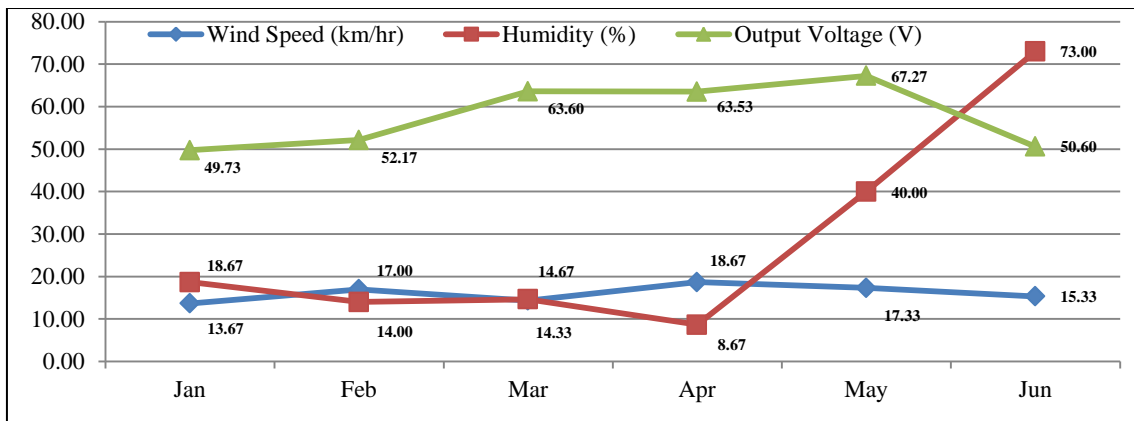


Figure 6. Variation of output voltage due to wind speed and humidity at 9am daily

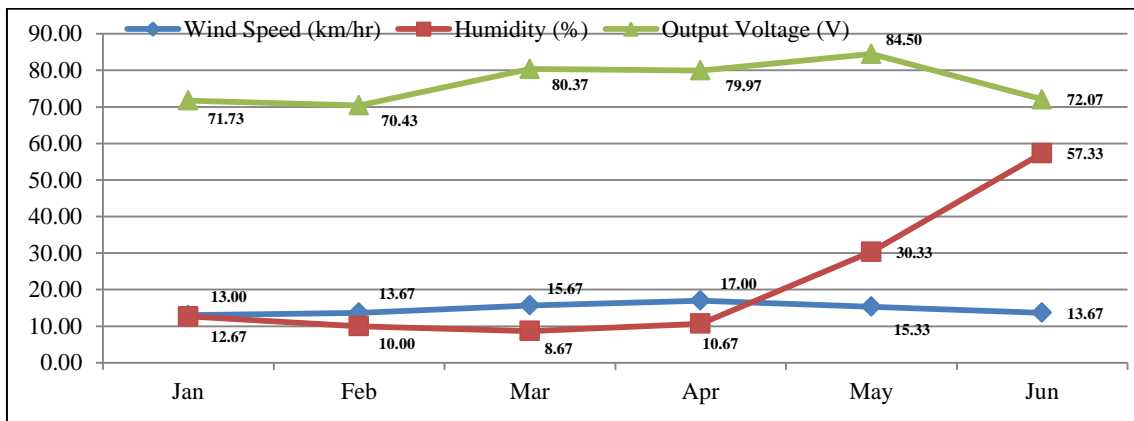


Figure 7. Variation of output voltage due to wind speed and humidity at 12pm daily

From Figures 6 to 8, the output voltage is directly proportional to wind speed and inversely proportional to the relative humidity for all the three period recorded. This means that as the wind speed in the area increases slightly (i.e. from 14km/h to 18km/h) the output voltage increases up to maximum of 64V in April and up to a maximum of 67V in May and vice versa which can be seen from Figure 5. For the humidity, slight decrease in humidity i.e. from 18% to 9% increases the output voltage to a maximum of 64V in April and up to a maximum of 67V in May. While sharp increase in the humidity to 73% reduces the output voltage to 50V.

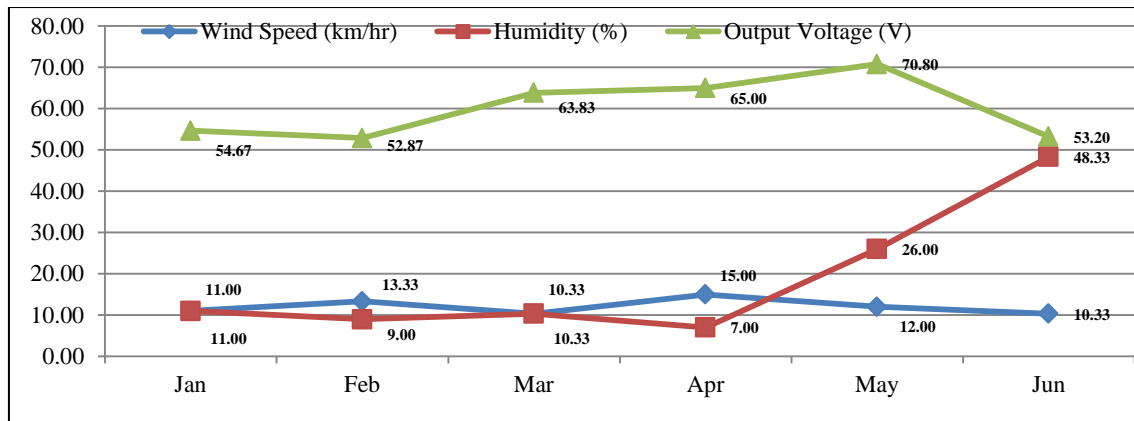


Figure 8. Variation of output voltage due to wind speed and humidity for 4pm

This means that there must be low humidity (i.e. reduction of moisture particles in the atmosphere) and increase in wind speed for high output voltage from the photovoltaic cells which can be seen in Figure 6. Even though wind brings dust to the environment but as the rainy season started in the month of April, May and June, all the dust settles and reduces its quantity in the atmosphere. Figure 7 and 8 for 12pm and 4pm respectively follows similar pattern but the output voltage of the 12pm is reasonably higher than 9am and 4pm. In the current technological era, predicting the power and energy output based on the changing weather factors play an important role in the economic growth of the renewable energy sector. Unlike traditional fossil fuel-based resources, renewable energy sources potentially play a pivotal role in sustaining a country's economy and improving the quality of life [4]. As reported in previous studies of Katoch *et al.* [14], Kennedy *et al.* [15], Zhao *et al.* [16] and Liu *et al.* [17], the rate of dust deposition & properties of dust is varying from site to site throughout the world. Dust deposition is the function of numerous factors, but mainly influence of the ecological factors such as wind speed, wind direction, temperature and moisture. Dust properties, humidity, rainfall and installation factors such as tilt angle, orientation, height, and front surface of PV module and location of the installation site also have great effect on dust deposition. Dust deposition degrades the performance of the PV module by affecting the electrical characteristics, optical characteristics and thermal characteristic of the PV module. The two elements sun oriented irradiance and temperature assume the crucial part in deciding the power yield from the PV module. Dust degrades the performance of the PV module by influencing the strength of solar irradiance, surface temperature and producing partial shading [14, 15, 16, 17]. According to several studies such as Gupta *et al.* [9], Sadat *et al.* [18] and Zhao *et al.* [16], the output of the PV module is also significantly influenced by environmental elements such as solar insulation, ambient temperature, humidity, precipitation, seasonal change, dust, wind speed, and direction. Apart from environmental factors, installation factors such as tilt angle, orientation, altitude, seasonal tilt adjustment and location of installation play the vital role to affect the performance of the PV module.

4 CONCLUSIONS

The study shows that there is solar energy potential in the study area. The results obtained shows that wind, humidity and harmattan dust deposition have substantial effect on the output voltage of solar photovoltaic cells. The implication of the result has clearly shows that there is direct proportionality relationship between wind speed and output voltage on one hand and inverse proportionality relationship between humidity and output voltage. Since high humidity means high moisture particles contents in the atmosphere which scatters the solar radiation from the sun which reduce its absorption by the solar panels. Since low wind speed leads to high deposition of dust on the solar panels, impliedly, high wind speed clears the solar panels surface and increases its output voltage.

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