MEASUREMENT AND ANALYSIS OF THE VOLTAGE CURRENT CHARACTERISTIC OF A MODEL WIND POWER SYSTEM

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Abstract– Environmental pollution with the attendant global warming is raising concern for friendly, communal/crisis free and renewable energy resources like wind. In this paper, an analysis of the effect of wind speed and direction on the generated voltage and current from an experimental wind power system is carried out in the laboratory as a controlled environment with a variable fan speed at varying angles. The generated voltage and current were measured with the embedded volt - ampere meter while the fan's speed, air flow volume and the swept area were measured using the digital anemometer with proper adjustment. The results showed that the output voltages and consequential currents as well as the volume flow of air are directly proportional to the fan's intensity or speed. The peak voltage is obtained at an angle of zero degree where the wind from the fan moved perpendicularly to the wind electric generator. The peak voltages of 6.64V and 6.40V at positions 0° and 15° of the source wind to the wind generator respectively are obtained.

Keywords: Wind speed, wind angle, voltage, current, anemometer

1. INTRODUCTION

Global warming arising from environmental pollution has been raising concern for alternative energy resources like wind, solar, hydrogen etc.

Wind is a friendly and attractive renewable energy resource for electricity generation similar to solar, hydropower, hydrogen and biomass as a potential replacement for fossil fuels – a big source of the emissions of CO_2, SO_2, NO_X amongst other wastes and characterized with price and supply instability.

Wind energy is adduced to be one of the most importable ingredients of renewable and sustainable energy resource [1].
Wind is an effect from the uneven heating of the earth's surface by the sun and its resultant pressure differentials is available at annual mean speeds of approximately 2.0m/s at the coastal region and 4.0m/s at the extreme northern region of Nigeria [2]

Wind energy conversion systems like wind turbines, wind generators, wind plants, wind machines and wind dynamos are devices which convert the kinetic energy of the moving air to rotary motion of a shaft, that is ,mechanical energy. A report was given [2] that the technologies for harnessing wind energy have been used for water pumping from open wells and wind electrification in the far northern part of Nigeria.

Generation of electricity from wind requires no fuels, less installation space, independent of time (day or night) [3] and has no corruption syndrome in the harnessing and delivery processes unlike fossil fuels as sources of cooking gas, petroleum motor spirit, gasoline oil and other associated products with an inherent problem of corruption along the chain of exploration, transportation, refining processes and sales.

Another problem of fossil fuel is communal or state clashes arising from ownership of land, oil wells or blocks which of course is not peculiar to wind energy exploration.

Sources of wind can be natural or generated from moving parts such as vehicles on the streets or train on rails, rotating fans or moving aircrafts.

This paper is intended to measure and evaluate the electric energy potential of wind energy and the effect of wind speed, wind mass and relative position of the wind source or direction to the wind electric generator on the electric output parameters using an experiment wind power machine available in the Department of Physics, Kogi State University, Anyigba, Nigeria.

2. THEORY

Wind energy is a converted form of solar energy which is produced by the nuclear fusion of hydrogen (H) into helium (He) in its core according to the equation:

$$H \longrightarrow He \qquad 1$$

Wind results from the movement of air due to atmospheric pressure gradient and it flows from regions of higher pressure to region of lower pressure and as such has an associated energy called kinetic (mechanical) energy defined by:

$$E_k = \frac{1}{2} m\bar{u}^2 \qquad 2$$

The wind power, P_w , can be obtained from equation (2) as

$$P_w = \frac{dE_k}{dt} = \frac{1}{2}\dot{m}\bar{u}^2 \qquad 3$$

Where m = mass of air, $\bar{u}$ = mean wind speed, $\dot{m}$ = wind mass flow rate.

The wind mass flow rate, $\dot{m}$, can be defined as:

$$\dot{m} = \rho A\bar{u} \qquad 4$$

Hence, equation (3) becomes

$$P_w = \frac{1}{2}\rho A\bar{u}^3 \qquad 5$$

Where ρ = density of air, A = swept area

Equation (5) reveals that for a higher wind power, a higher wind speed, longer length of blades for attaining a larger swept area and higher air density are required [4].

3. MATERIALS AND METHOD

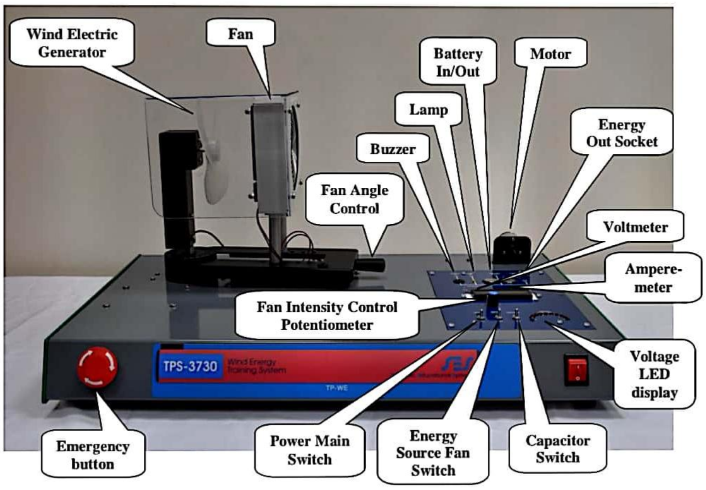

FIGURE 1: SET UP OF THE MODEL AND EXPERIMENTAL WIND ENERGY CONVERSION SYSTEM USED

SOURCE [5]

The functions of the various components of the experimental set up of the wind energy conversion system are:

3.1 FAN – It is used as a wind generator and located on a track in such a manner to provide the mechanical energy required by the wind electric generator as well changing the its directional angle.

3.2 WIND ELECTRIC GENERATOR – It is a motor with a propeller that converts the wind directly to electric energy. It acts as a voltage source and the generated voltage is outputted to the **energy out socket**.

3.3 VOLTAGE AND AMPEREMETER– It is an LCD display with a probe socket for voltage measurement and two probe sockets (A+ and A-) for current measurement in mA.

3.4 CAPACITOR SWITCH–It is used as temporary energy storage for output voltage stabilization and connected in parallel to the energy source.

3.5 FAN INTENSITY CONTROL POTENTIOMETER – It is used to control the speed of the fan from intensity levels 1 – 5 and change its position or angle.

3.6 EMERGENCY BUTTON – It is used to stop all electrical power to the system in case of an emergency.

FIGURE 2: THE DIGITAL ANEMOMETER

Figure 2 is the digital anemometer used in this piece of work to measure the wind speed, area of air flow and air volume by placing the meter between the fan and the wind electric generator such that the fan surface is perpendicular to the wind direction in order to get the maximum reading and avoid measurement error.

4. RESULTS AND DISCUSSION

The table of values of peaks of all the measurements taken occurred at angles 0° as per the position of the fan relative to the wind electric generator is as shown below 1.

Table1: Output Parameters of the Wind Power Device at Angle 0°

Level of Fan's Intensity	Voltage (V)	Current (mA)	Air Speed (m/s)	Air volume (m^3/s)	Swept Area (m^2)
1	2.24	4.30	3.94	4.03	1.00
2	2.86	6.20	4.30	4.21	1.00
3	3.56	9.20	4.65	4.74	1.00
4	3.94	11.50	5.00	4.91	1.00
5	6.46	27.20	6.56	6.65	1.00

Table2: Output Parameters of the Wind Power Device at Angle 15°

Level of Fan's Intensity	Voltage (V)	Current (mA)	Air Speed (m/s)	Air Volume (m^3/s)	Swept Area (m^2)
1	2.22	3.40	3.77	3.89	1.00
2	2.72	4.70	4.12	4.12	1.00
3	3.34	7.00	4.30	4.56	1.00
4	4.10	9.30	4.82	4.74	1.00
5	6.40	23.10	6.49	6.48	1.00

Tables (1) and (2) show the measured values of the generated voltage, consequential current using the volt – ampere meter, air speed, air volume and swept using the digital anemometer placed between the rotating fan and the wind electric generator. The as obtained values of the voltage increases with wind speed but decreases with increasing angle.

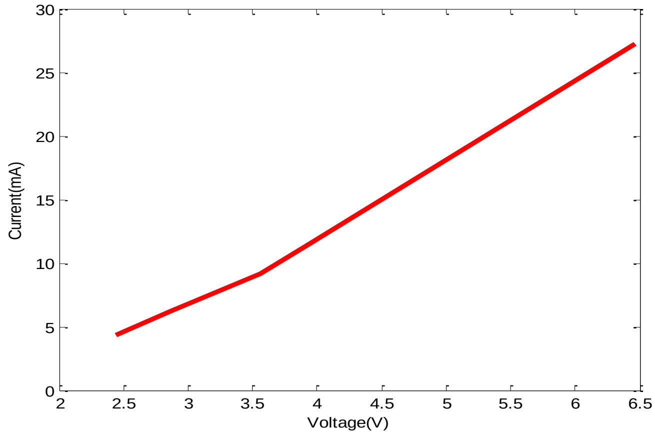

FIGURE 3: GRAPH OF CURRENT AGAINST VOLTAGE AT ANGLE 0°

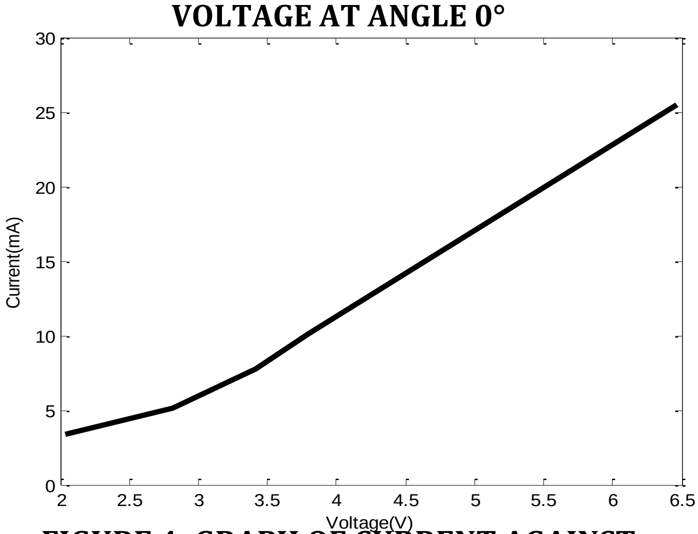

FIGURE 4: GRAPH OF CURRENT AGAINST VOLTAGE AT ANGLE 10°

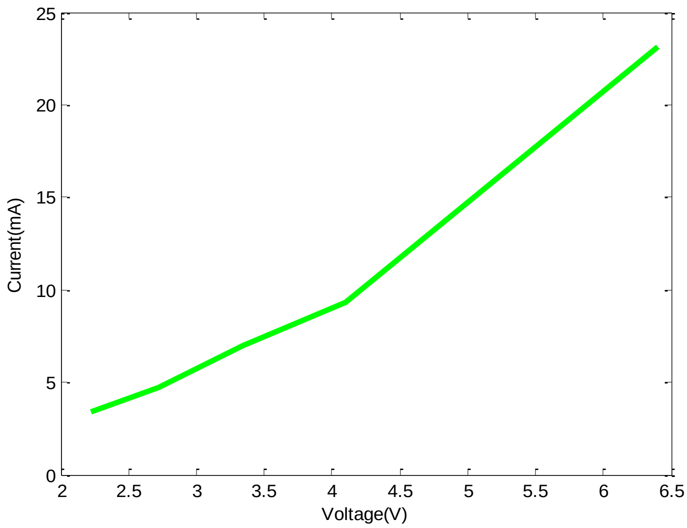

FIGURE 5: GRAPH OF CURRENT AGAINST VOLTAGE AT ANGLE 15°

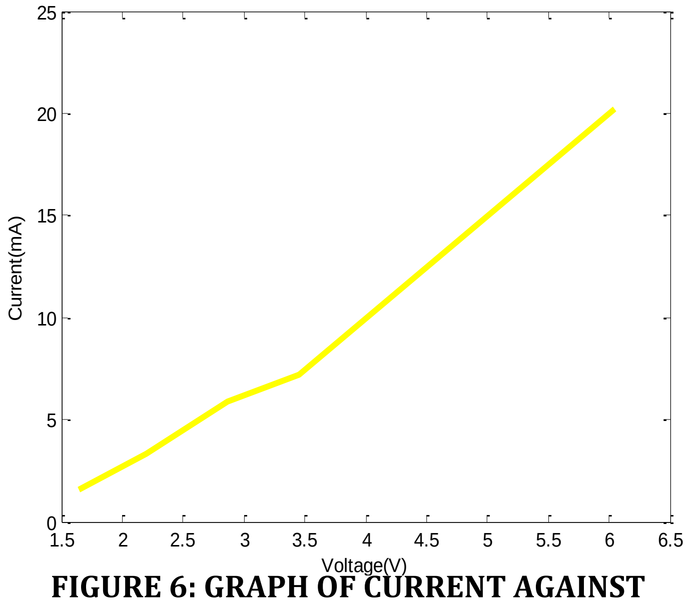

FIGURE 6: GRAPH OF CURRENT AGAINST VOLTAGE AT ANGLE 20°

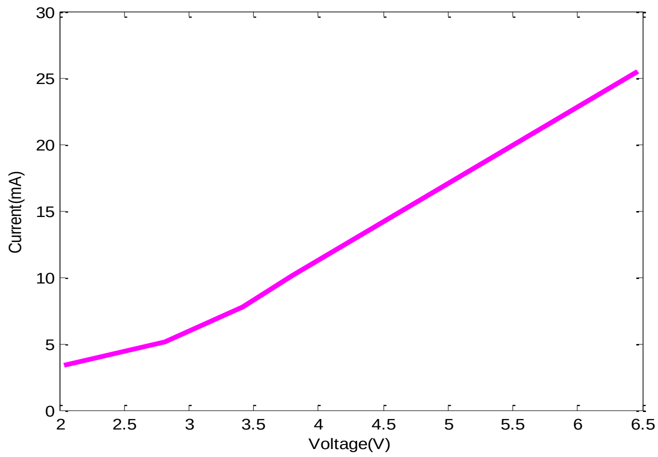

FIGURE 7: GRAPH OF CURRENT AGAINST VOLTAGE AT ANGLE 25°

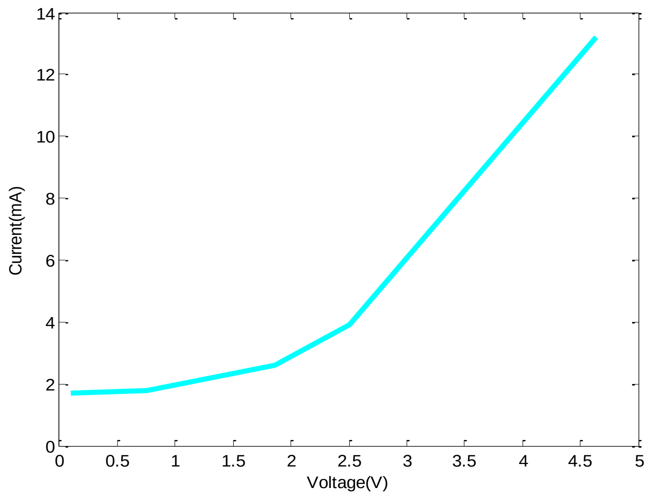

FIGURE 8: GRAPH OF CURRENT AGAINST VOLTAGE AT ANGLE 30°

Figures (3) – (8) are the plots of as obtained current and voltage using MATLAB R2007b version software for different angles or positions of the fan relative to the wind electric generator. The graphs are perfectly non – linear from the origin but showed a higher linearity of the voltage and associated current as the intensity of the fan (speed) increases. The voltage and corresponding current decrease as the fan's position is altered away from its original position to the wind electric generator because the wind direction is no longer perpendicular to the wind electric generator which has significantly reduced the speed and torque (force) on the wind electric generator that usually decide the output of a wind electric generator. The maximum or optimum voltage and current are obtained when the fan is at angle zero to the wind electric generator. Thus, this is crucial in the designing and installation of a wind power system as the energy production from the wind power system depends solely on wind speed, its availability and design arrangement [1].

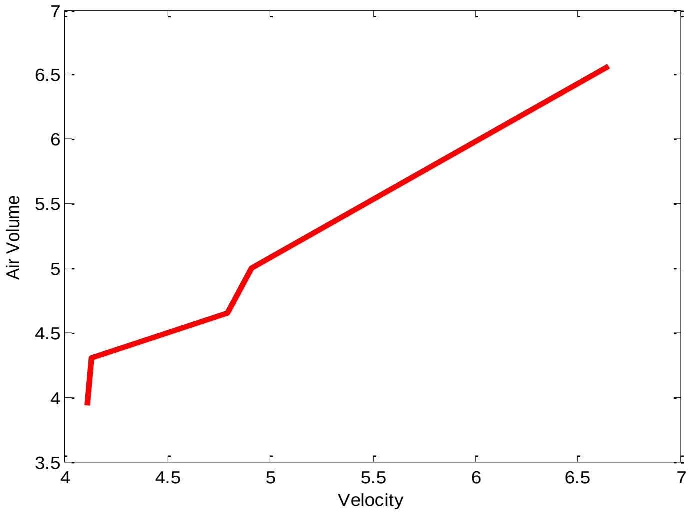

FIGURE 9: GRAPH OF AIR VOLUME AGAINST VELOCITY AT ANGLE O°

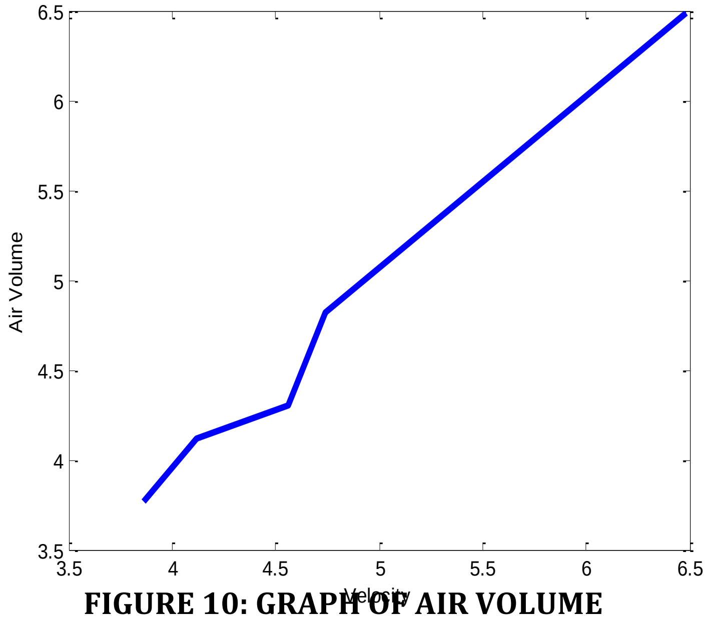

FIGURE 10: GRAPH OF AIR VOLUME AGAINST VELOCITY AT ANGLE 15°

Figures (9) and (10) illustrate the variation of the air flow volume with fan's speed. A directly linear relationship exists between the two variables, with the air flow volume as the dependent variable and wind speed as the independent variable. Peak air flow volume and velocity are attained at the zero position of the fan where the air flow direction is perpendicular to the wind electric generator. The principle exhibited here is that of moment which says that turning effect of a force is most effective at angle 90° and work is efficiently done under this condition.

5. CONCLUSION

The experimental report of the measurement carried out to analyze the voltage current characteristic of a model wind power system showed that the output voltage as the most critical parameter varies directly with the fan speed and volume rate of flow of air. The result also revealed that peak voltage is achieved when the generated wind by the fan flows perpendicularly to the wind electric generator; an indication of the effectiveness of the work done by the force of the wind on the generator to produce the maximum voltage, as obtained, is at an angle of 90°. So, for effective conversion of rotational kinetic (mechanical) energy to electrical energy by a wind energy system, the direction of the wind should be perpendicular to the wind electric generator with the full assurances that the wind speed is at its peak at the same time.

6. REFERENCES

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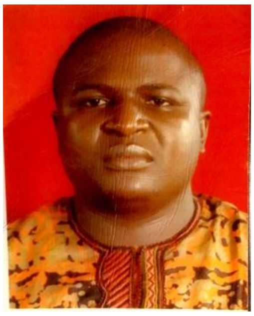

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