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GENERATION OF ELECTRICAL ENERGY VIA WIND ENERGY IN ILORIN: AN EXPLORATION OF A LOCALLY CONSTRUCTED WIND TURBINE

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ABSTRACT
Wind energy is a renewable source of energy which has a definite place in the future of the generation of electricity. To harness the energy from the wind, a wind turbine is employed. Wind turbines assist in the production of power to compensate for the moderate intensity of the breeze to drive a generator. With the use of wind turbines, the energy in the wind can be converted into electrical energy. A small scale horizontal wind turbine was constructed with readily available and locally sourced materials. The height of the turbine was varied from 3 to 6 meters and two different locations in Ilorin, a tropical region, was used to observe how the turbine generates electricity via the wind turbine. The dam site, one of the locations, gives very high wind speed which in turn produces high open circuit voltage of around 4000 mV. Electrical energy generation from wind energy is observed to be largely dependent, not only on the electric motor used, but on the wind speed available for the turbine. It was also observed that the height of the turbine has an impact on the electrical energy generated also. An average open circuit voltage obtained was found to be in the range of 2.0 – 4.0 volts, which could power a few of low-powered electrical/electronic appliances. Hence a good prospect awaits large scale generation of electricity via wind energy in Ilorin due to the peculiarities of this location vis-à-vis availability of wind supplied and especially any location where substantial wind current exist, as in the tropical region.

Keywords: *Betz Limit, Electricity, Open-circuit Voltage, Turbine, Wind speed*

INTRODUCTION

With serious concern over climate change as a result of various anthropogenic activities which result in increasing concentrations of greenhouse gases in the earth's atmosphere, international treaties and Carbon dioxide reduction targets have been established (Wills, 2014). Hence, a need has arisen to explore renewable energy which is environmentally friendly. Wind is air in motion, which implies that wind has momentum and because it has momentum, it must possess energy, thus, wind energy.

Garba and Al-Amin (2014), stated that the harnessing of kinetic energy through the wind has been used for centuries, be it in form of powering sail boats, windmills or furnaces. However, it was not until 1979 that the modern wind power industry began in earnest with the production of wind turbines. Wind turbines assist in the production of power to compensate for the moderate intensity of the breeze to drive a generator (Kumar, *et al.,* 2018). With the use of wind turbines, the energy in the wind can be converted into electrical energy. Thus, wind energy can be classified as a source of renewable energy which has no environmental hazard. Examples of renewable energy includes: tidal energy, geothermal energy, wind energy, solar energy, bio-mass energy, hydro-power.

According to Oyedepo *et al.,* (2012), wind energy has also become the fastest growing renewable source of energy in both developed and developing countries because of its many advantages. Small wind turbines are used throughout the developed and developing world and are primarily used in rural or remote settings in the domestic and international markets (Trudy, 1997).

Jaber (2013), stated that generation of electricity by wind energy has the potential to reduce environmental impacts, because unlike generators that use fossil fuel, it does not result in the generation of atmospheric containments or thermal pollution, and it has been attractive to many governments, organizations, and individuals.

Various constraints such as wind farm topology, inter-turbine distance, life span of turbines, noise, cost, to mention but a few have to be taken care of while designing a wind park.

Wind energy is the kinetic energy of the air in motion. The kinetic energy of a packet of air of mass m with velocity v is given by

$$E = \frac{1}{2}mv^2 \quad \text{...(1)}$$

$$but\ \rho = \frac{m}{v}; m = \rho v \quad \text{..........................(2)}$$

where ρ=density

$$E = \frac{1}{2}\rho A t v^3 \quad \text{..............(3)}$$

The total wind power is:

$$P = \frac{dE}{dt} = \frac{1}{2}\rho A v^3 \quad \text{(Kumar, } et\ al. \text{ 2018) ......(4)}$$

Thus, wind power is directly proportional to the third power of the wind velocity. Power density is given by

$$\frac{P}{A} = \frac{1}{2}\rho v^3 \quad \text{..(5)}$$

Betz in 1919 proved that wind turbine is most efficient when the wind speed is retarded by One third just in front of the rotor and another third behind the rotor. It was shown by the German physicist, Albert Betz that the theoretical maximum efficiency for a wind turbine, termed Betz Limit is 59.3%, meaning that at most only 59.3% of the kinetic energy from wind can be used to spin the turbine and generate electricity. Although in reality, turbines don't reach the Betz limit, and common efficiencies are within the range of 35-45% (Donev *et al.,* 2018). Thus according to Carrillo *et al.,* (2014), the maximum efficiency of a wind turbine which is the Betz's coefficient of performance Cp = 0.593 (≈ 59%). Cp = 0.593 (≈59%) is the theoretical limit but in real turbine Cp is lower due to aerodynamic and mechanical losses.

The wind turbine electricity production depends on the following factors, namely wind speed, air density and area swept by the rotor blades. Factors like the geographical location of the wind turbine and the impact of turbine height on the energy generated by the wind system may not have been researched as much. Hence, this work focuses the feasibility of generation of electrical energy via the use of wind energy in Ilorin, a tropical region. The impact of location of the wind turbine, magnitude of wind speed and effect of turbine blade height on the open circuit voltage obtained in the location were also discussed.

MATERIALS AND METHODS

The materials used are: size 13 of a car's tyre rim, round pipes of steel material, iron ball bearing, fan blades of stainless steel, and 12 V DC generator. The base stand for the turbine was made of steel because of the strength it possesses against being blown off easily by wind. The fan blades were made of stainless steel so as to be quickly and easily driven by even little supply of wind.

The car's tyre rim was used to construct the base of the turbine; the round pipes were used for the tower construction, the iron ball was used to construct the yaw system of the turbine, the fan blade was used in harvesting the wind speed, and the electric generator for the conversion of wind energy to electrical energy. Two different locations on the main campus of the University of Ilorin, Ilorin, Nigeria were considered for the generation of electrical energy via the wind turbine used within the region.

The first location was at Physics Department, University of Ilorin, Ilorin, Nigeria with coordinates of 8°28’56.7”N, 4°40’12.3”E. This is referred to as location 1 in this study.

The second location was at the University Dam with coordinates 8°27’59.4”N, 4°38’36.9”E which is referred to as location 2.

At location 1, with obstructions like buildings and trees, the open circuit voltages with respect to different time of the day and at different heights of 5 m, 5.5 m and 6 m were taken. The period of measurements at location 1 were seven hours each; from the periods of 10am-5pm.

At location 2, data were taken at a constant height of 3 m and the period of taking readings was 3 hours; from the periods 11am - 2pm.

The open circuit voltages were obtained from the electric generator by connecting the digital mulltimeter in parallel to the electric generator.

The internal resistance of the electric generator was also obtained by the use of an ohm-meter and it was found to be 50 Ω, while the multimeter used was found to have an internal resistance of 2Ω.

The current was determined from the relationship

$$E=I(R+r) \qquad \text{.............................(6)}$$

where E = electromotive force (open circuit voltage) generated

I = Current

R = Internal resistance of the electric generator

r = Internal resistance of the multimeter.

The wind speed was derived from the power relation,

$$P = \frac{1}{2}\rho A v^3$$

Where ρ=density of air/wind

A = area of the blade

v = wind speed

RESULTS AND DISCUSSION

The wind turbine system set up was tested to observe the generation of electricity using wind energy. The open-circuit voltages generated by the system at the first location of test (location 1) is obtained and represented by figure 1.

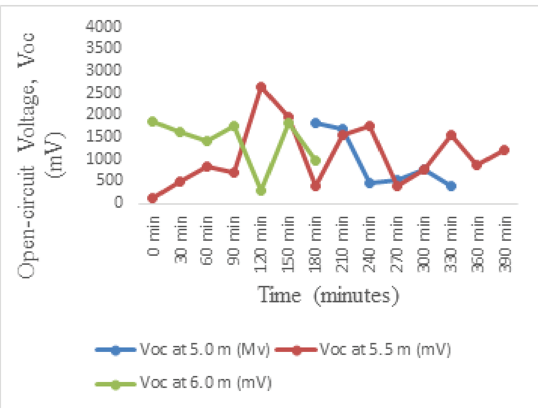

Figure 1: open-circuit voltage against time of the day for different turbine height at Location 1

The height of the turbine was varied between 5 m and 6 m at location 1, at an interval of 0.5 m. It was observed that the turbine at a height of 5 m performed less in terms of having the lowest open-circuit voltage generated (1820 mV) at about an hour after noon of taking the measurement, as compared to others at the different heights. The measurement began at 10 am. The performance could be as a result of less wind still available at this time of the day as compared to the morning when sun intensity was low and wind energy high. This confirms the fact that wind speed is of paramount influence on the energy generated by a wind turbine. Wind energy is generated by uneven heating of the surface of the Earth by the Sun.

The air above the land heats faster than air over water in the day. This warm air over theland expands and rises, and the cooler air, which is heavier takes its place, creating wind. At 5.5 m, the open-circuit voltage peak at noon with a value of about 2652 mV, which is the highest generated at the location as reported in figure 1. The increase in height of the turbine relatively produces increase in the electrical energy generated. However, the sharp drop in the open-circuit voltage generated (300 mV) at a height of 6 m at the same time of the day and location raised a concern. Nevertheless, this could be as a result of the sudden change in the weather condition at this time of the day the measurement was taken.

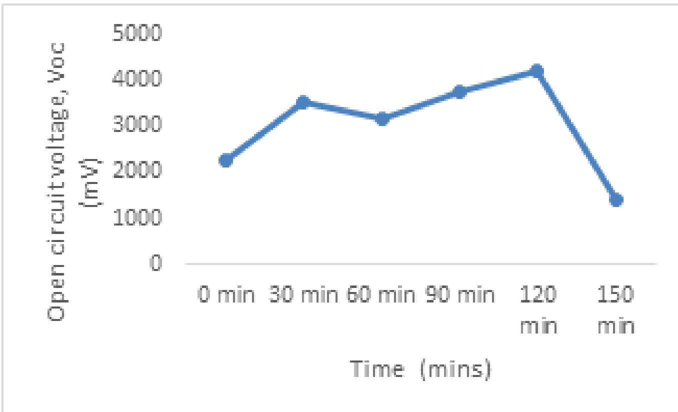

Figure 2: Open-circuit voltage against time between 11am and 2pm at location 2

The dam site, location 2, gives very high wind speed which in turn produces higher open circuit voltage than that obtained at location 2. Apart from changing atmospheric condition which affects production of wind, wind speed can also vary based on geography, topography and season (SolarSchools). As a result, there are some locations better suited for wind energy generation than others. The dam site of the University of Ilorin used as the location 2 for checking the possibility of generating electricity via wind energy was characterized, among others, with no obstructions to wind flow. The height of the turbine used at this location is 3 m, which is lower than all the heights used at the first location. An average open circuit voltage of 2.0 V to 4.0 V was generated which could power a few of low-powered electrical/electronic appliances. From the results obtained at the second location, it could be submitted that despite that the height of turbine influences the electrical energy generated using wind turbine, the magnitude of the wind speed also influences the energy generated which implies that the magnitude of the wind velocity is proportional to the wind power. Table 1 shows the tabular presentation of the average voltages generated at location 2 at different time of the day.

Table 1: Comparison of the open-circuit voltages generated by the wind turbine at locations 1 during different time of the day

Time of the day	Open-circuit voltage (mV) at Location 1
11:00 am	2240
12:00 noon	3160
1:00 pm	4210

Hence a good prospect awaits large scale generation of electricity via wind energy in Ilorin and especially at a location where bodies of water exist. Wind farms can be located both on-shore (n land) and Off-shore (On water body). Offshore wind farms are usually exposed to more wind than onshore farms and this favours efficient operation of a wind turbine.

Moreover, using equation 6 and the values of R and r given under section 2.2, the electric current generated by the open-circuit voltage obtained, for example, at 12 noon at location 2 is obtained as

$$I = \frac{E}{R + r}$$

I = 3.160 / (50+2)

I = 0.061 Amperes. This is an encouraging value to consider a large scale application of wind energy as a renewable energy for electricity generation, especially in a resemblance of location 2 described in this work

CONCLUSION

This research study has been able to establish that the location of the wind system set up favoured the changes in wind speed significantly with significant change in height of turbine. Wind flows at will; it does not always flow when needed. The wind has more speed at location 2 than location 1 probably due to obstructions produced by few structures at location 1, therefore, reducing the wind power getting to the turbine. Locations 2 is closer to a water body than location 1 and hence have an enhanced wind speed which consequently generated better electrical energy via the turbine and generator. Also, the study revealed that variation in height of the wind turbine has effect on the energy generated by harnessing wind energy. It is concluded from this research that Ilorin, a tropical region, favours the use of wind energy as a renewable energy for electrical energy generation.

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