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Wind Energy Systems for Omu Aran, Kwara State, Nigeria.

D. C. Uguru-Okorie*[1], I. Ikpotokin[1], C. O. Osueke[1], O. Olawale[2]

[1]Mechanical Engineering Department, Landmark University, Omu-Aran. Kwara State, Nigeria.
[2]Chemical Engineering Department, Landmark University, Omu-Aran. Kwara State, Nigeria.
*Corresponding Author: uguru-okorie.daniel@lmu.edu.ng

Abstract

The quest for energy from renewable and sustainable sources has led to the investment on exploration and installations of wind energy systems to harness energy from wind for use by mankind. Various wind energy systems exist and they are quite expensive. Selections of appropriate systems for installation are dependent on the wind power available in a location. It is therefore important that proper wind assessment is done before investments on infrastructures for harnessing wind power are put in place. Wind data between 2014 and 2018 were obtained from the Landmark University Weather Station in Omu Aran and the pattern of wind speed distribution in the location over the years in focus were determined by the Weibull function. The power law was used to estimate the wind speeds at heights of 10 and 20 metres respectively. Recommendations on appropriate wind energy systems suitable for Omu Aran region were made based on the wind speed pattern.

Keywords: Energy, wind, sustainable, turbine, height

1. Introduction

Mankind's existence is tied significantly to the availability of energy for his day to day activities. For this reason, man has been exploring several energy sources over the centuries. Some of these sources are renewable while others are non-renewable. Some of these energy sources come with by-products that are harmful to man and this makes them unsustainable. As a result, over the last few decades, attention of man has been channelled to sourcing for energy from renewable and sustainable sources [1-10].

Various renewable energy sources exist such as solar, geothermal, wind, hydropower and tidal. Amongst the various sources of renewable and sustainable energy, wind power ranks among the most explored and invested in by governments and private establishments [11]. Wind being in substantial amount all over the globe, can generate the amount of energy the world needs if properly harnessed but it is disappointing to note that only a few pockets of countries are harnessing the wind power available in their locality [12].

Wind power capacity is known to vary with heights and locations and also the initial cost of installation of wind systems are quite high. It is therefore important, to conduct proper wind assessment before investments on infrastructures for harnessing wind power are put in place.

According to National Renewable Energy Laboratory (NREL) wind power classification, wind power in a location can fall into seven classes [13]. This article assesses the wind speed distribution in Omu Aran and based on the wind power class, makes recommendations on energy systems that can perform efficiently in the Omu Aran region.

1.1 Wind Energy Systems

Wind energy systems are systems used to extract energy from atmospheric air in motion (wind). For centuries wind has be harnessed for use by man in sailing, as windmills for grinding, to pump water and for electricity generation as obtained from turbines [14]. In the past few decades, investments have been channelled to installation of wind turbines for electrical energy generation [15].

Wind turbines come in two (2) broad classifications which are horizontal axis wind turbines (HAWTs) and Vertical axis wind turbines (VAWTs). HAWTs are lift based turbines while VAWTs could either be lift-based or drag-based. These turbines could have a single blade, two blades, three blades or multi-blades [16]. Figures (1) to (3) show some designs of HAWTs and VAWTs.

Horizontal wind axis turbines (HAWTs) are known to have wind speed cut-in speeds higher than that of vertical axis wind turbines (VAWTs). The cut-in speed for HAWTs is estimated to be 5 m/s and for an improved HAWT rotor design 3.24 m/s was reported [18] while VAWTs are estimated to be 2.5 m/s [19] and for large VAWTs 4 m/s [20].

Wind Turbines [17] Wind Turbine [17]

1.2 Wind Speed Distribution

Wind speed in a location varies from time to time; this fluctuation makes it difficult to choose a wind speed value that represents the wind speed pattern of a location. A stochastic tool, probability density function makes the determination and representation of wind speed pattern of a location possible [21].

Weibull function is a probability density function used to estimate wind speed behaviour to a reasonably accurate degree. The distribution function is expressed in equation (1) as:-

$$f(v)=\left(\frac{q}{z}\right)\left(\frac{v}{z}\right)^{q-1}e^{-\left(\frac{v}{z}\right)^{q}} \quad (1)$$

$$q = \left(\frac{\sigma}{v_m} \right)^{-1.086} \tag{2}$$

$$z = \frac{v_m q^{2.6674}}{0.184 + 0.816 q^{2.73855}} \tag{3}$$

Where

q = shape factor, z = scale factor (m/s), v_m = average wind speed, σ = standard deviation

1.3 Estimation of Wind Speeds at Heights

This is the widely used model to determine wind speeds at various elevations and is expressed in equation (4).

$$\frac{v_{H2}}{v_{H1}} = \left(\frac{H_2}{H_1} \right)^{\theta} \tag{4}$$

$$v_{H2} = v_{H1} \left(\frac{H_2}{H_1} \right)^{\theta} \tag{5}$$

Where,

v_{H2} and v_{H1} represent the velocities of wind at elevations of H_2 and H_1 respectively. θ is the wind shear exponential and its value is dependent on the environment. For grassland plains, forests, residential areas with trees and places with high rise buildings, the values of wind shear exponential are taken to be 0.15, 0.25, 0.3 and 0.4 respectively [22, 23].

2.0 Methodology

Wind speed data were obtained from the Landmark University weather station. The wind speed data were recorded hour at the weather station and the wind speed data obtained were from June, 2014 to August, 2018. The obtained wind speed data were processed with the weibull distribution function where the wind speed patterns in Omu Aran on yearly basis were established.

The wind speeds at heights of 10 and 20 metres were determined using the Power law model [22] and using the wind shear exponential for residential areas with trees.

With the established wind speed distribution, appropriate wind turbines that can efficiently harness energy at various heights were recommended.

3.0 Results and Discussion

The results obtained from the weibull distribution for wind speeds on yearly basis are shown in figure 4. The readings were obtained from the height of 3 metres.

At a height of 3 metres, the weibull distribution for the yearly wind speeds between 2014 to 2018, were observed be right-skewed (positive skewness). The mode of this distribution over the years considered except for 2017 was 4 m/s. In 2017, the mode obtained for the distribution was 3m/s.

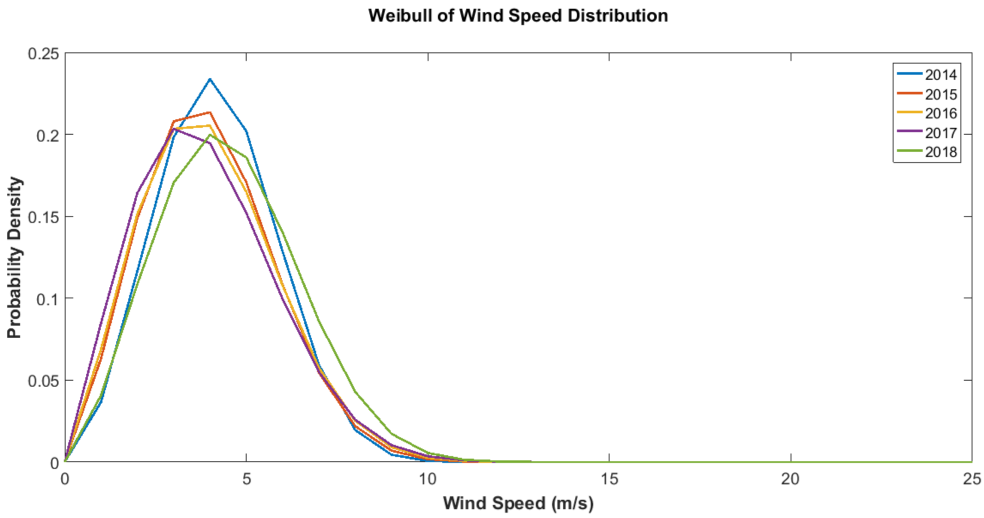

Figure 4: Weibull Wind Speed Distribution from 2014 to 2018.

At the 10 metres height, the minimum wind speed estimated was 3.675 m/s while the maximum speed recorded was 7.925 m/s as shown in figure 5.

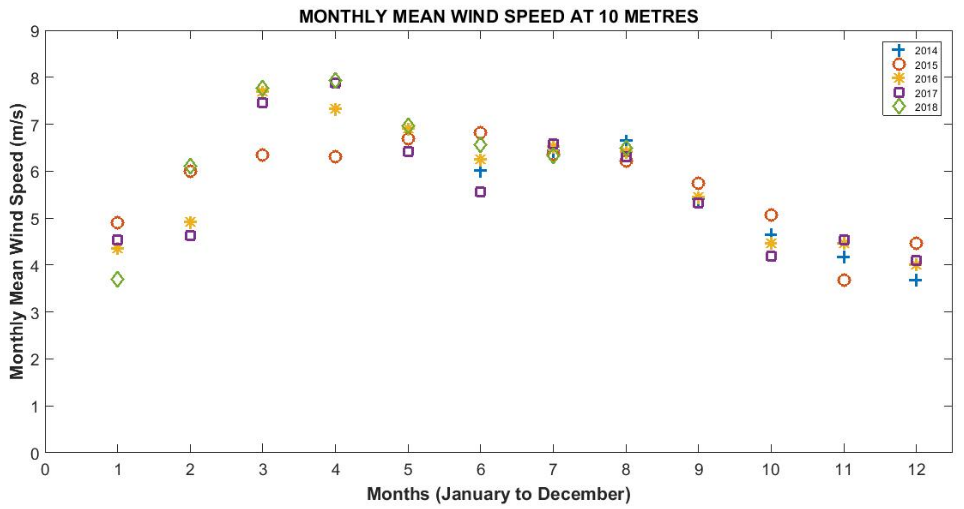

Figure 5: Mean monthly wind speeds from 2014 to 2018 at 10 metres height

At the height of 20 metres, the minimum wind speed estimated was 4.525 m/s while the maximum speed recorded was 9.559 m/s as shown in figure 6.

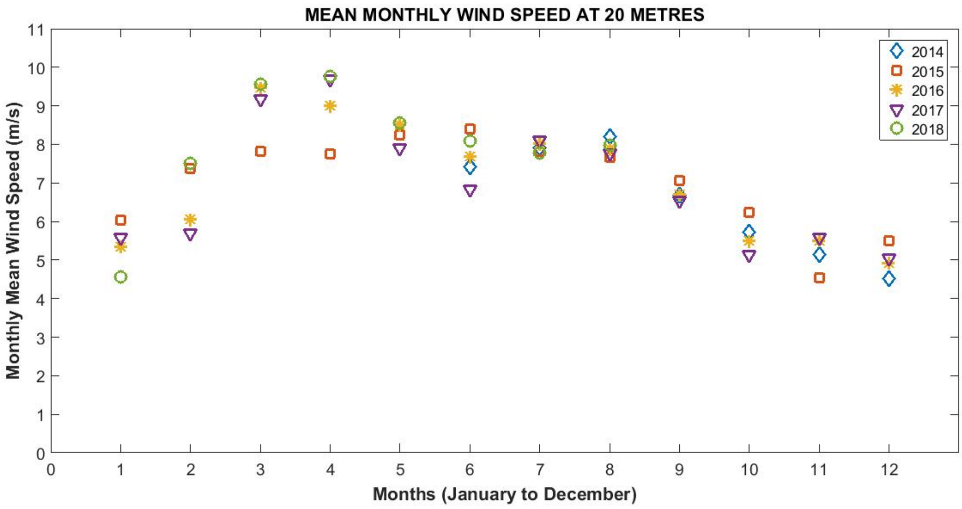

Figure 6: Mean monthly wind speeds from 2014 to 2018 at 20 metres height

4.0 Conclusion

The findings from the results obtained, show that Omu Aran, has satisfactory wind energy potential. At a heights of 3metres, for most of the years (2014 to 2016 and 2018), the most occurring wind speed was 4 m/s. At heights of 10 and 20 metres, the minimum mean wind speed recorded was 3.675 and 4.525 respectively. For the maximum mean monthly wind speeds of 7.925 and 9.559 m/s respectively.

At all heights, records of wind speed data show that vertical axis wind turbine will operate effectively. At heights of 20metres and above the installation of horizontal axis wind turbines (HAWTs) are recommended because they have better efficiency when compared to vertical wind axis turbines (VAWTs).

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