Evaluation Of Wind Energy Potentials In Ota, Ogun State, Nigeria

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Abstract— One of the fastest growing technologies in energy production business this time is wind energy. The unpredictable and epileptic state of power in Nigeria and the concerns on green house gas emission should is a huge concern for all and this has culminated into quest for strong demand for sustainable and renewable source of energy, wind energy generation. The absence of green house gasses emission, clean energy and unquenchable accessibility of wind that can be converted to electricity culminate in the main advantages of electricity generation from. Wind power prospect is estimated to be high or moderate in Nigeria, of which it has not connected this renewable resources to the grid, although, it is not sufficient for one to just bring to a close that wind turbines should be constructed and connected to the grid because there are sufficient wind speeds to drive the wind turbine. More often than not, the stability and reliability studies must be conducted whenever wind power is to be generated. This paper therefore describes the wind energy potential in Ogun, South-west, Nigeria and specifies the conditions to be met before the wind turbines can be made to generate electricity.

Keywords— Wind energy, Green house gas emission, Sustainability, Wind turbine, Wind power

1. Introduction

Going by the historic designs, power has been gotten from the wind over hundreds of years, known as wind energy, constructed from stone and wood for the purpose of pumping water or for grinding. From history, typically large, heavy and inefficient, were replaced in the early centuries by fossil fuel engines. A better perceptive of aerodynamics and advances in materials science, particularly polymers, has led to the comeback of wind energy extraction towards the end of 20th. Electricity are now generated from wind power devices generally called wind turbines. Wind energy is a main sustaining column of tomorrow’s renewable electricity generation. Since wind power was first used to generate electricity, its utilization and growth has been staggering [2]. Because of the concerns of climate change, nations have set aggressive targets to minimize CO2 discharge by establishing renewable energy generation services. Of the obtainable renewable energy technologies, wind power has been the most rampant to date due to its lower maintenance costs, its established technological condition, the wealth of abundance of wind resources. In addition to reducing CO2 emissions, renewable energy does not add to already existing pollution from particulate emissions and toxic emissions. Clean energy sources such as wind, hydro, geothermal and solar power have been the focal point in the transition to a healthy, efficient and less polluted ecosystem.

The wind manufacturing industries have set a new limestone for yearly installations in 2014 with wind power capacity on the rise by 44% according to the Global Wind Energy Council [3]. Figure 1 below indicates that nearly 70% of the world’s 370GW of wind energy are located in China, USA, Germany, Spain and India [4].
Figure 1- Total global capacity in 2014.

Figure 2- Inside view of a wind turbine
Source: [http://www.alternative-energy-tutorials.com/wind-energy/wind-turbine-design.html](http://www.alternative-energy-tutorials.com/wind-energy/wind-turbine-design.html)
The essential components for large scale wind turbines include

I. Rotor: aerodynamic, brake and hub.
II. Drive train: rotor shaft, bearings, brake, gearbox and generator.
III. Supporting structure that is the tower and foundation.
IV. Electrical components which is for control and connection to the grid.

Wind turbines function on a straightforward principle. The energy in the wind turns propeller-like blades around the rotor. While the rotor is connected to the main shaft, which rotates within a stator surrounded by copper wire loops, then Electromagnetic induction is created and electricity is generated [6].

The first classification of the wind turbine is determined by the direction of the shaft and rotational axis. Horizontal Axis Wind Turbine (HAWT) is the turbine whose shaft mounted horizontally parallel to the ground. HAWT sits high atop towers to take advantage of the stronger and less turbulent wind at 100 feet (30 meters)[4]. Vertical axis wind turbine (VAWT) has its shaft at right angle to the ground (Figure 1).

![Vertical Axis Wind Turbine (VAWT)](unusual-configurations-for-shaft-and-rotor-orientation)

Figure 3. unusual configurations for shaft and rotor orientation.

Both HAWT and VAWT have totally differently rotor designs, each having its own unique configurations [1]. The low tip speed ratio and difficulty in controlling rotor speed is ascribed to a the discontinuity in the mainstream development of the VAWT. Difficulties in the starting of a VAWT have also disadvantaged progress [2]. However, the Vertical Axis Wind Turbine requires no extra mechanism to tackle the wind and weighty electromechanical equipment can be placed on the ground, therefore reducing tower loads. Consequently, the VAWT is not ignored completely for future prospects [3]. In addition to the problems associated with alternative designs, the popularity of the HAWT can be attributed to increased rotor control through pitch and yaw control. The Horizontal Axis Wind Turbine has therefore appeared as the leading design configuration, used by all of today’s leading large scale turbine manufacturers.

1.1 Theoretical Efficiency

High theoretical efficiency is advantageous for increased wind energy extraction and should be exploited within the limits of affordable production. Energy (E) carried by moving air is expressed as a sum of its kinetic energy [Equation (1)]:

\[ E = \frac{1}{2} \rho AV^3 \]
Where,

\[ \ell \] – Air density in kg/m²
\[ A \] – Area of blade coverage in m²
\[ v \] – Wind speed in m/sec

There is a limit to the amount of energy that can be gotten, which does not depend on the design. The generation of energy is sustained in a flow process through the decrease of kinetic energy and consequent wind velocity. The enormity of energy exploited depends on the reduction in speed of air over the turbine. Hundred percent extractions simply means zero final velocity which is consequently zero flow. The zero flow situation cannot be accomplished therefore all the wind energy may not be made use of. This principle is extensively established \[4,5\] and specified that turbine efficiency cannot go beyond 59.3%. And this is generally referred to as the power coefficient \( C_p \), where max \( C_p = 0.593 \) is called the Betz limit \[6\]. Losses in wind power efficiency are most of the time reduced by:

i. Not using low tip speed ratios.
ii. Choosing aerofoils which have a lift to drag ratio that is high. And

iii. Dedicated tip geometries

Further explanation are established in the literature \[4,6\].

1.2 Practical Efficiency
Rotor designs suffer from the addition of minor losses practically, resulting from:

- Tip losses
- Wake effects
- Losses in efficiency of drive train
- Simplification losses of blade shapee

1.3 Aerodynamics

There is no perfect and efficient rotor design without aerodynamic performance \[19\]. The force that is responsible for the power yield produced by turbine is aerodynamic lift and it is for that reason vital to make the most of this force using suitable design. A resistant drag force which resists the blade’s motion is also produced by friction which of necessity, be minimized. So therefore, aerofoil section with a high lift to drag ratio, typically greater than 30 \[20\], be chosen for the design of rotor blade \[19\]:

\[
\frac{Lift}{Drag} = \frac{Coefficient of Lift}{Coefficient of Drag} = \frac{C_l}{C_d} \quad 2
\]

The co-efficient for the lift and drag of aerofoils is complex to mathematically predict it, even though there exists software that are freely available, for instance XFOIL \[21\] model results accurately \[22,23\]. Conventionally tables correlating lift and drag at given angles of attack and Reynolds numbers are used for testing aerofoils experimentally \[24\].
Previously aircraft technologies paved way for wind turbine aerofoil designs with similar number of Reynolds coupled with section thicknesses appropriate for conditions at the blade tip. Nevertheless, exceptional considerations must be made for the wind turbine design of specific aerofoil profiles due to the variation in operating conditions and mechanical loads.

2. Background Theoretical Wind Energy Information:
The wind energy turns two, three or more propeller-like blades about a rotor. The rotor is connected to the main shaft, which spins a generator to generate electric current [6].

The blade of the turbines behaves much similar to the wings of an airplane. The moment wind puffs, a low-pressure air coagulates on the downward part of blades. This low-pressure air afterwards drags the blade closer to it, causing the rotation of the rotor. This is termed ‘lift’. The force of the lift is obviously stronger than the force of the wind against the front side of the blade, which is described as ‘drag’. The mixture of drag and lift makes the rotor to revolve like a propeller, then turning shaft spins generator to produce electricity [7].

The 3-phase power produced from a balanced system is gotten by

$$P_{\text{phase}} = 3 * V_{\text{phase}} * I_{\text{phase}}$$

The computation of frequency theoretically rely directly on the Revolution per minute and directly on the number of poles inside the generator

$$f = \frac{R.P.M * P}{120}$$

where RPM is the generator revolutions per minute

P is number of generator poles.

The turbine pitch of the wind control system modifies the incidence of blades rotors in a wind energy production system that is dependent on real-time speed of the wind for the purpose of changing power output, reaching far more utilization efficiency of wind power and serving as shield for blade’s rotor. When the rated speed is lower than the speed of the wind, the blade incidence stays at the highest power point, that is close to angle 0°. Otherwise, the pitch control mechanism changes blade incidence so that the output power of generator is within the allowed range. This serves both as a control feature and an optimisation plus a defense technique stopping runaway conditions of the generator [13].

The rotor shaft of the turbine forces a precision machined alloy planetary gearbox, which increases turbine rotor shaft revolution per minute by 4.

Figure 4: image of a typical wind turbine

![Image of wind turbine](image_url)
3. Methodology

3.1 Data Collection & Importing To Excel From Davis Weather Station

Three months seconds by seconds wind data was imported to excel directly from 2012 Davis weather station, then with the wind speed, theoretical equation 1 was used to get theoretical power. We assumed air density to be 1.22g/m and the radius of blade to be 35.36m. MATLAB was used to get the Weibull Distribution Function while the data analysis of EXCEL was used for plotting the line graphs.

3.2 The Weibull Probability Density Function

This is a function of a continuous random variable whose integral across an interval gives the probability that the variable lies within the same interval. According to Slootweg et al., 2001, it is given as:

\[ f(t) = \frac{\beta}{\theta} \left( \frac{t}{\theta} \right)^{\beta-1} \exp \left[ -\left( \frac{t}{\theta} \right)^{\beta} \right] \]

Where
- \( \beta \) = shape parameter, or slope parameter
- \( \theta \) = scale parameter, or characteristic life parameter
- \( t \) = time

4.0 Results and Discussion

Results are presented for time against the theoretical power for 8 cardinal directions that are: North, North-East, East, South-East, South, South-West, West and North-West directions which are figures 1-figure 8. Figure 9 indicates the wind speed of the station against frequency while figure 10 is the wind rose plot. From the plots, West directions have highest power values with West direction having the highest and relatively high theoretical values while other directions have power values that are not stable.

Figure 5: Wind speed in north direction against time
Figure 6: Wind speed in north-east direction against time

Figure 7: Wind speed in east direction against time
Figure 8: wind speed in south-east direction against time

Figure 9: wind speed in south direction against time

Figure 10: wind speed in south west direction against time
Figure 11: wind speed in west direction against time

Figure 12: wind speed in north-west direction against time
Figure 13: Weibull distribution of the data

5. Conclusions
In conclusion, the wind velocity, direction and characteristics in Ogun State, south-west Nigeria have been studied. The work evaluates wind energy potential in Ogun state and conclusively the wind speed in west direction is the most stable in Covenant University and has highest theoretical power compare to other directions. So therefore, having a wind turbine with above specifications will most likely work perfectly.

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