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RESEARCH ARTICLE

ASSEMBLY AND PERFORMANCE EVALUATION OF A WIND TURBINE IN SOUTHWESTERN NIGERIA

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Abstract

Wind turbine technology has been growing rapidly in the past decades for varieties of application especially for agriculture and other remote uses. For the purpose of energy research, a 300W wind turbine was assembled and its performance was evaluated.The wind turbine was installed on a fabricated and adjustable tower of maximum height of 150 m. The turbine as characterized at 11m/s, 1.25 meter wind wheel diameter was installed with an instrumentation system for appropriate measurement and control. The wind turbine was tested and found suitable for generation of electricity. An experiment was carried out to determine the effect of the turbine height on the performance of the wind turbine using varying heights of 100m, 110m, 120m, 130m, 140m, and 150m. The output voltage and the current at different wind speeds were recorded by the ammeter and voltmeter respectively. The results revealed that the current and voltage increased with an increase in the turbine height. The turbine is therefore recommended for multiplication for domestic and agricultural uses.

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Introduction:-

Wind energy is the conversion of the kinetic energy in the wind into a useful form of energy such as using wind turbines to make electrical power, wind mills for mechanical power, wind pump for water pumping or drainage, ("Iowa State Profile Overview".2021) Wind is an inexpensive source of electricity and in many ways cheaper than fossil fuel, it is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emission during operation and uses little land, therefore making it a good alternative to fossil fuel plant. The effects on the environment are generally less problematic than those from other power sources (Goudarzi and Weidong, 2012). Human beings have been harvesting the wind energy for hundreds of years by the use of a mechanical device called Wind Turbine which is a device that convert kinetic energy from the wind into electrical power, this started from)Old Holland to farmsin the United States, **(**International Energy Agency, 2014).Wind mills have been used for pumping water or grinding grains. But today windmills that are modern and equivalent to a wind turbine can use the wind energy to generate electricity (Abbasiet al, 2010).

The increase in the demand for fossil fuels over the past few years has resulted in the depletion of our natural resources. Our non- renewable energy sources are being consumed far faster than

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They are being produced due to the facts, that it takes hundreds of millions of years to create fossil fuels. Our need for fossil fuels as source of power has driven up, the cost per barrel of crude oil significantly over the past decades. Other technologies such as wind turbines and photovoltaic panels actually produce power and more efficient equipment of these technologies will reduce energy usage overall and wastage of resources(Sokonaet al,, 2011)

The lack of electricity is a world problem especially affects over 1.6 billion people in the world entirely (Asumadu and Owusu, 2016). This problem especially affects rural areas in developing countries that contribute to aggravating the urban-rural divide.

In Nigeria, an estimated 68% of the population does not have access to electricity (Electrical Commission of Nigeria, 2008) most of these people live in rural areas and the lack of direct access to energy act, like a barrier to overcome poverty in those areas where there is no or little impact of electricity.

According to World Health Organization (2020), an estimated one and half billion people still rely on solid fuels like traditional biomass to fulfill some of their daily needs. The direct situation is in sub-Saharan- Africa, where more than three quarters of its 587 million citizen, in both rural and urban areas live without electricity. Two fifths of south Asia's population mostly rural communities do not have connection to electricity either (Panwar, 2011).

Despite this challenge, measures can be taken to proffer a better and lasting solution in solving this problem. The importance of the role of energy and access to energy to achieve a sustainable development has been recognized worldwide and it is stated as one of the objectives of the millennium development goals (Ajanovic, 2011).

In order to accomplish this aim or objectives, intense research in renewable energy technologies has been done. These technologies have proven to work as a substitution solution to provide energy in isolated or rural areas by taking the advantages of the natural resources (Wind) around us. In order for us to extract power from the wind, we are improving on the existing wind turbines that all work around the same principle of energy production.But it is believed that there is no enough wind in Southwestern Nigeria for generation of electricity. This has been generating argument for a long time. This study was conceived to investigate this argument. Therefore, this study is on the assembly and performance evaluation of a wind turbine.

Materials and Methods:-

Design Consideration for the Tower

Several different factors influence the potential wind resource in an area that can affect a wind turbine performance the three main factors that influence power output are: wind speed, air density, and blade radius. These are fundamental in the design of the wind turbine tower, any Wind turbine that will perform optimallywill need to be in areas with a lot of wind on a regular basis, which is more important than having occasional high winds. Aside these factors, the turbine should be affordable to farmers, simple and cheap to repair and maintain, produce optimum energy for agricultural production and processing and resist the effects of wind and rain storms.

Design Calculation

TipSpeed Ratio (TSR) this is the most important concept in wind turbine design. This is a dimensionless factor and it is defined as TSR = (Rotor tip speed) / (wind speed)

$$= \quad \lambda = {}^{v}/_{V} = \frac{w}{r} = \frac{m/sec}{m/sec}$$ where

w = Rotation angular velocity [rad/sec]

Where W= $2\pi f$

Therefore $\lambda = 2\pi f/v$ and f = rotational frequency (HZ) (sec^{-1}) also we should know that the rotor is tip seep ratio is dependent on the black air profile use which are:

i. Number of blades

ii. Wind turbine type.

In general, a three bladed wind turbine operates with a tip seep ratio between 6 and 8. A high tip seep ratio value is highly desirable and preferred because it allows for a high sharp rotational speed. Which allows for the most efficient operation of the electric generator.

Power (W) = 0.6 x Cp x N x A x V^2

Revolutions (rpm) = V x TSR x 60/ (6.28 x R)
Where Cp is Rotor efficiency; N is Efficiency of the driven machineries; A is swept rotor area (M2).
V is speed of the Wind (m/s). TSR is Tip speed Ratio, R is Radius of rotor, and Rotor Efficiency can go as high as 0.45. Cp.

But for this calculation, we choose 0.5 as its rotor efficiency; Cp
This concept works without transmission. If a considered, then N = 0.95 x 0.7.
Tip speed ratio "TSR£ = 7
Wind speed "V" = 8.6m/s
Rotor efficiency "Cp" = 0.5
Generator efficiency "N" = 0.7
Swept rotor area "A" = 1.227m^2
Power output =300w
The width of the blade is also called chord. To get this, we can use the formula. Blade Chord (m) = 5.6 x R^2/ (I x CL x r x TSR^2) where R is Radius at tip; r is radius at point of computation, I is number of blades, CL is Lift coefficient, TSR is Tip Speed Ratio.

Calculation of Wind Power
There are numerous cumbersome calculations and equations found in some textbooks on understanding and constructing of wind turbine generators.

However, for the case of this research work, we limit ourselves to these simple and vital information listed below.
1. The power output of a wind generator is proportional to the area swept by the rotor.
2. The power output of a wind generator is proportional to the cube of the wind speed.

By formula, Kinetic Energy (KE) = ½ mV^2, where m; the mass measures in kg, V; the velocity is in m/s and energy is given in Joules. Air is known to have a density of 1.2041kg/m^3 at 20^{0}C temperature [Wikipedia]. So the mass of air striking our wind turbine each second is given by the following equation: mass per second (Kg/m^3).

Therefore, power = ½ x swept Area x Air Density x Velocity^3, where Power is in the Watts, swept area in square meters, Air density in kilograms per cubic meter and the velocity in meters per second.

Then wind power (P) is equal; P = ½ x P x A x Cp x V^3 x Ng x Nb where q is Air density in kg/m^3, A is the Rotor Swept Area (m^2), Cp is Coefficient of performance V is wind velocity (m/s), Ng = generator efficiency and Nb is gear box efficiency.

This research work has a turbine rotor blade with diameter of 1.25 meters. Therefore, the rotor sweep area earlier determined equals 1.227m^2.

Wind Power = ½ x 1.2041 x 1.227 x 0.5 x (11^3).

This gives the wind power of 491.62 Watts which is for larger than the rated power of the turbine generator. This is explained by Betz law which says that you can only convert less than 59.3% of the Kinetic energy in the wind to mechanical energy using a wind a turbine. This BetZ factor multiply by 491.62 W gives 291.53 near the rated power of 300 Watts.

Results and Discussion:-

Machine Description and Working Principle

The components of the wind turbine includes (Figure 1) rotors that capture the energy from the wind spin which in turn spin a shaft which is connected to an electrical generator, usually through some gearing arrangement which creates electrical energy through induction. As the wind blows, therefore the blades spin.

The wind turbine tower serves as frame that carries the turbine. The components are made of 4" galvanized pipes for the main supports that have good contact with the ground in erection of the tower and another 4" galvanized pipe that carries the wind turbine. The tower was designed in a way that enables appropriate regulation of the turbine height for evaluationof the performance of the turbine. The turbine also consists of a standing platform for appropriate operation and future maintenance. The standing platform is made up of 100 mm galvanized pipe; 25mm galvanized pipe, 2mm plate; 12mm iron rod as a ladder, rubber roller tire, and 38 mm angle iron to support the rolling tires.

Figure 2:- The pictorial view of the installed wind turbine.

Effects of Height of the Turbine on Power Generation

The effect of the height of the turbine on the power generation is presented in Figure 1. The result shows a linear relationship between the turbine height and the power generated with the coefficient of determination r^2 of 0.9339. The power generated increased with an increase in the turbine height. This is in conformity with Mohamed et al. (2017) in a study on the evaluation of factors affecting wind turbine output power.

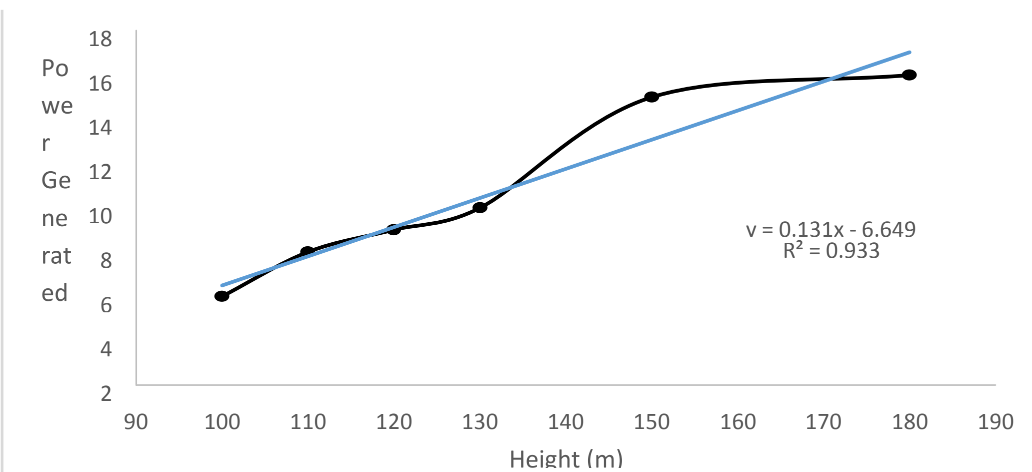

Figure 2: Turbine Height versus Power Generated

Effects of Wind Speed on Power Generation

The effect of the wind speed on the power generation is presented in Figure 2. The linear relationship showed that power generated also increased increase in the wind speed with the coefficient of determination r^2 of 0.9082. The difference was more pronounced at 7.7m/s wind speed and the minimum change in voltage was recorded at 8 and 8.5 m/s wind speed while no significant power change was observed afterword. This is similar to Photong and

Promdee (2016) in a study on the effects of wind angles and wind speeds on voltage generation..

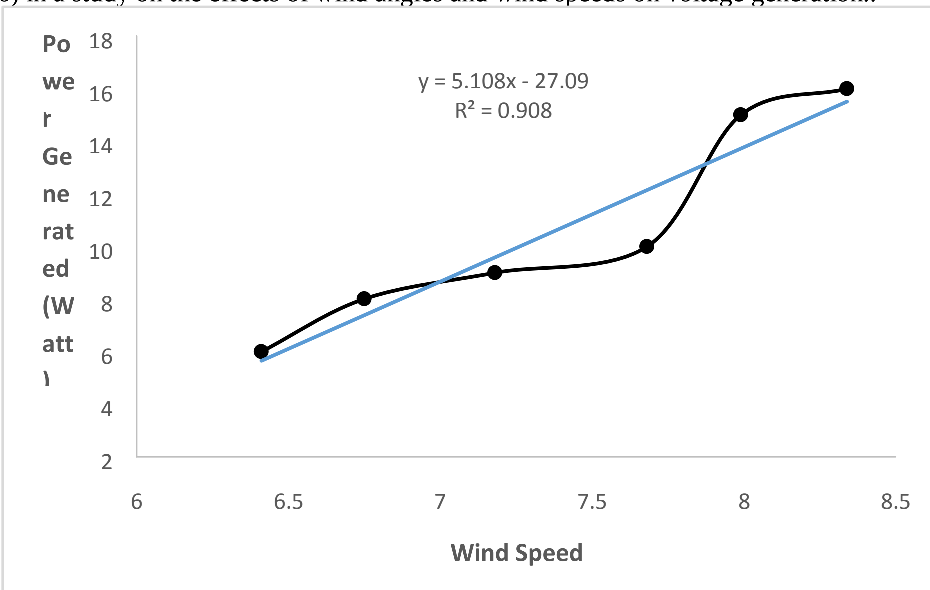

Figure 3:- Wind Speed versus Power Generated.

Effect of the Height of Turbine on the Wind Speed

The effect of height of turbine on wind speed as presented in Figure 3 revealed that wind speed increased with an increase in turbine heightwith the coefficient of determination r^2 of 0.9109. The stable increase in wind speed was observed between the height of 100 and 140m, but a relatively lower change in wind speed was observedbetween the height of 140 and 180m.This is in conformity with Ata and Cetin (2011) in a study on analysis of height effect on average wind speed. .

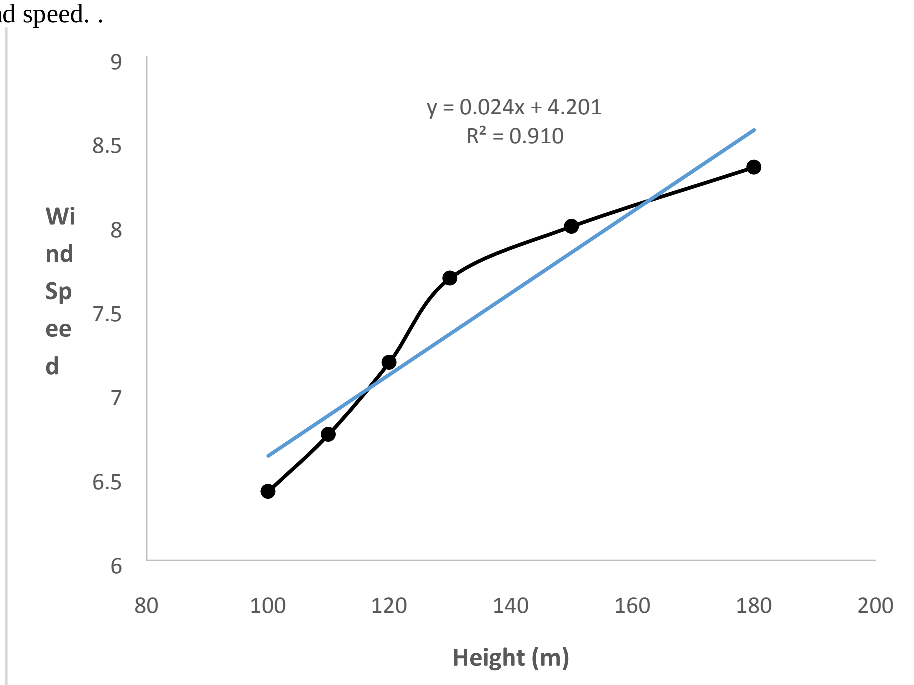

Figure 4:- Wind Speed versus Turbine Height.

Conclusion and Recommendation:-

A 300W wind turbine was assembled and its performance was evaluated. The wind turbine was installed on a fabricated and adjustable tower of maximum height of 150 m. The turbine as characterized at 11m/s, 1.25meter wind wheel diameter was installed with an instrumentation system for appropriate measurement and control. The wind turbine was tested and found suitable for generation of electricity haven been examined. It was observed at the experiment location that the heights of 130m and above have the sufficient wind speed that will power a wind turbine to achieve adequate voltage and power supply required for electricity that can affordable for farmers and rural dwellers

It is recommended that this turbine should be commercially assembled and provided for the use of farmers and rural dwellers for agricultural production and processing.

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