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Research Article

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Development of Oscillatory Turbine for Harnessing Energy from Wind

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Abstract The wind oscillatory turbine was designed, fabricated and tested. The fabricated turbine generate electricity independently with a rigid chassis structure which converts the linear motion of the wind energy to electricity without using huge moving parts. It consists of oscillatory blade, rack and pinion, springs, chain, shafts, rotor, coil, generator, ladder, casing, etc that assembled together on a rigid frame stand. The wind moves the turbine blade into oscillatory movement and the springs at both sides increases the movement. The to and fro movement will be converted to rotational movement via the rack and pinion through the chain and a shaft. The rotational shaft transfer the force generated to the generator for converting the mechanical force into electricity. Wind is a natural phenomenon that is related to the movement of air masses caused primarily by the differential solar heating of the earth's surface. Seasonal and location variations in the energy received from the sun affect the strength and direction of the wind. Power from the wind depends upon the swept area of the turbine blades and the cube of the wind speed. The developed machine was tested at 10 meter, 20 meter and 30 meter respectively of meteorological height of Enugu town over the studied period, which was 2016. It was discovered that most of the rated power variations happened within the months of December and August whereas January and August for wind speed variations. The only deviation was at 10meter height where variation of speed came on January and July; also variation of power came around November and August. The result was as expected since difference in wind speed distributions may be related to the difference in altitude and season. It was also gathered that the height of the turbine affect the performance of the developed machine.. The developed machine generated the highest annual average power of 500watt at 30 meter height and the lowest annual average power of 325.05watt at 10 meter height. The highest annual average speed of 6.04m/s was extracted by the machine at 30meter height and the lowest annual average speed of 4.4m/s was got at 10meter height. The ANOVA for the effect of height on the rated power from the turbine show that F calculated was greater than the F table at 5% probability level. This means that the treatment or effect means are not statistically equal and one of the treatment means is different from one or more of the remaining treatment.

Keywords Development, Wind, Oscillatory Turbine, Harnessing, Energy

Introduction

As fossil fuels diminish, energy solutions for the future depend on the increase use of renewable energy resources. Many people are becoming interested in alternative sources of power to supplement or replace the expensive electricity offered by the local power companies. A wind turbine is used to convert wind to electricity. Wind spins the turbine blades to operate a generator located inside. Power made by the generator is harnessed and set out for consumption [1].

Wind is a form of renewable energy. Winds are caused by the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain and vegetative cover. This wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity [10].

The terms "wind energy" describe the process by which the wind is used to generate mechanical energy or electricity. Wind turbines convert the kinetic energy in the wind into mechanical energy. This mechanical energy can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical energy into electricity to power homes, businesses, schools, and the like [10].

Harnessing the wind is one of the cleanest, most sustainable ways to generate electricity. Wind energy produces no toxic emissions and one of the heat-trapping emissions that contribute to global warming. This, and the fact that wind energy is one of the most abundant and increasingly cost-competitive energy resources, makes it a viable alternative to the fossil fuels that harm our health and threaten the environment [9].

Wind speeds are divided into seven classes and each class depends on the height above the land, with class one being the lowest and class seven being the highest. A wind resource assessment evaluates the average wind speeds above a section of land (e.g. 50 meters high), and assigns that area a wind class. Wind turbines operate over a limited range of wind speeds. If the wind is too slow, they won't be able to turn, and if too fast, they shut down to avoid being damaged. Wind speeds in classes three (6.7 – 7.4 m/s) and above are typically needed to economically generate power. Ideally, a wind turbine should be matched to the speed and frequency of the resource to maximize power production [8].

Wind energy is one of the fastest growing sources of electricity in the world. In 2012, nearly 45,000 megawatts (MW) of new capacity were installed worldwide. This stands as a 10 percent increase in annual additions compared with 2011 [3].

The United States installed a record 13,351 MW of wind energy in 2012, capable of producing enough electricity to power more than 3 million typical homes. It already generates more than 10 percent of the electricity in nine U.S. states. Thanks to its many benefits and significantly reduced costs and wind energy is poised to play a major role as we move toward a sustainable energy future [2].

Oscillation is the process of swinging or moving to and fro in a steady, uninterrupted manner, and oscillatory motion is the movement created by the process**.** When a body or object moves to and fro it is called oscillation but there shall be a condition that this movement must be around a main point or position. Generally, the oscillatory movement is termed as periodic movement of the object around a point or center. It means the body will come to touch the point of origin or center after short periods of times. In this movement the body moves forward and then backward but both types of movements are repetitive [4].

This wind oscillatory turbine generate electricity independently with a rigid chassis structure which converts wind's kinetic energy into electricity without using huge moving parts. It creates no noise. The operating principle of wind oscillatory turbine differs from wind wheels. Wind turbines use huge rotating parts to converts wind energy to electricity, but the wind oscillatory turbine converts the linear motion of the wind energy to electricity. Wind oscillatory turbine slows down and let out the wind at 15 – 20Hz operation. There are no harmful effects on humans or animals, the equipment emits no annoying sounds, and building them does not require high-technical methods [7].

A tower of between 80-140 feet (2440-4270 cm) is required to get above the disturbances generated by obstacles and trees on the ground. Wind velocity and the turbine performance increases as you get higher off the ground. For most situations an 80 or 100 foot (2440 or 3048 cm) tower is sufficient. The most economical type of tower is the guyed lattice type, but other types that are hinged or have no guy wires are also available. Since the wind oscillatory turbine uses oscillating air foils to produce electrical power, the device can be installed on buildings to extract energy from wind [11].

The potential areas of use of wind oscillatory turbines are residential, industrial, agricultural machinery and lightening. It allows farmers, individual landowners and businesses to take control of their carbon foot prints and preserve their land for the benefit of the whole community.

The expansion of using environmentally friendly energy sources is a relevant component of the sustainable development concept. These inventions should be economical. Current wind turbines are very costly, noisy and harmful for living nature. These turbines cannot turn light wind into power. Henceforth, most of the target consumers are living in urban and suburban settings where trees and buildings could easily block wind. Therefore, wind turbine cannot generate power around the clock, only when the wind is blowing, which makes it a less reliable energy source.

The objectives of this project is to develop a wind oscillatory turbine that can generate power in low wind speed, which will be easy to maintain, economical and can produce no noise to living nature and the performance will be tested.

Materials and Methods

The process of designing a wind oscillatory turbine involves the conceptual implementation of a number of electrical and mechanical subsystems to create a machine capable of converting the energy contained in wind to useful electrical energy. The wind oscillatory machine was developed by using the following materials which include clinch device, hack saw, tape, welding machine and electrodes, an electric filling machine and Lathe machine, wires, bar magnets, and shaft. A wind oscillatory machine, efficient and economically viable was designed and fabricated with readily available and cheap materials (suitable engineering materials that could give optimum performance in service). Materials for fabricating the machine were chosen on the basis of their availability, suitability, economic consideration, viability in service etc.

Determination of Wind Output to be Harness

Wind turbines are machines that sap energy from the wind by leveraging the aerodynamic principles of lift and drag. Lift and drag forces move the turbine blade which convert kinetic wind energy to rotational energy. The rotational energy can then be transformed into electrical energy. The rate of energy extracted from the wind is governed by Equation (1), where P is the power, T is the torque, and ω is the angular velocity of the turbine blades.

$$P = T\omega \qquad (1)$$

Design of Rotating Shaft

The shaft is a cylindrical solid rod for transmitting motion through a set of load carried on it. The shaft uses for the Oscillatory turbine is loaded by a pinion, and bearings, All these forces act on the shaft. The design is based on Fluctuating torque, bending moment and shearing force. These called for knowing the combined shock and fatigue on the shaft. To determine the shaft diameter, we adopt the formula;

$$d^3 = \frac{16}{\pi\delta_{sy}}[(K_b M_b)^2 + (K_t M_t)^2]^{\frac{1}{2}} \quad [5] \qquad (2)$$

Where;

d = diameter of shaft (mm)

K_b = combined shock and fatigue factor for bending moment.

K_t = combined shock and fatigue factor for torsional moment.

M_b = Resultant bending moment (Nm)

M_t = Resultant torsional moment (Nm)

δ_{sy} = Allowable shear stress (MN/m^2)

π = constant, 3.142

Selection of Generator for the oscillatory Turbine

The developed torque in an induction motor/generator depends upon the following equation.

$$T = \frac{\pi}{4} D^2 l_a j_{sm} B_{rm} \sin(\varphi) \quad [6] \qquad (3)$$

D = *stator bore diameter*

la = *stator core length*

T = *output torque*

$\emptyset$ = *rotor power factor*

The following relationship is true given the air gap volume and the stator winding J_{sm} current density in addition to the assumed air gap B_{rm} flux density.

$$\frac{D^2 l_a \varphi}{T} = \text{constant} \qquad (4)$$

Power is the resultant product of torque and speed. The coefficient C_0 can be used for determining the size of electrical AC generators.

$C_o = \frac{\text{kVA}}{\text{D}^2 l_a \omega}$ [6] (5)

Principle of Operation of the Machine

The wind oscillatory turbine generate electricity independently with a rigid chassis structure which converts wind's kinetic energy into electricity without using huge moving parts. It creates no noise. The operating principle of wind oscillatory turbine differs from wind wheels. Wind turbines use huge rotating parts to converts wind energy to electricity, but the wind oscillatory turbine converts the linear motion of the wind energy to electricity. The turbine is mounted on a rigid stand which gives it support for a good performance. The support was designed such that it carries its own weight, the weight of the turbine, and damp variable forces from the turbine actions. Wind moves the turbine blade into oscillatory movement and the springs at both sides increases the movement. The to and fro movement will be converted to rotational movement via the chain and a shaft. The rotational shaft transfer the force generated to the generator for converting the mechanical force into electricity.

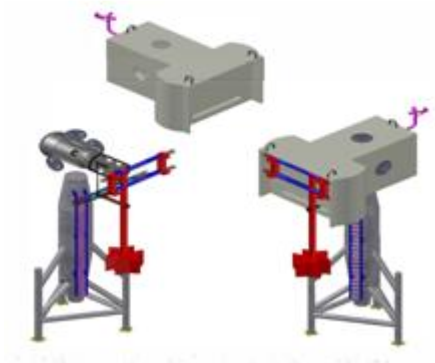

Figure 1: Isometric View of Wind Oscillatory Turbine

Testing the Machine

The machine was first tested to check if it can produce voltage after construction and the actual test was conducted using three different heights, which include 10, 20 and 30meters respectively. On each height, the machine will be tested 10 times in every month and the average will be recorded. The average powers generated on each height by the machine on every month was measured and recorded. The results obtained were analyzed using analysis of variance (ANOVA).

Results and Discussion

The Wind and Solar Resource of Enugu Town is shown on table 1. Enugu town has annual averages of solar clearness index and daily radiation of 0.497 and 4.950kWh/m²/d respectively and its annual average wind is 6.04m/s. The monthly average clearness index of Enugu town was highest on January (0.605) and lowest on September (0.406) 2016. The monthly average radiation of Enugu town was highest on February (5.740kWh/m2/day) and lowest on August (3.910kWh/m2/day) 2016. The amount of clearness index, radiation and wind speed available varies according to the time of day, month and year, the whims of the weather and the region of the country. Turbine is a system that makes use of the wind energy to generate electric power for home and industrial.

The monthly and annual average wind speed distributions at 10meter, 20meter and 30 meter meteorological height of Enugu town over the studied period, which is 2016 was calculated. The power distribution of the monthly average values of the location at 10meter height was shown in table 2 below. However, wind speed is highest in the month of January and lowest in the month of July. Perhaps, the result was as expected since difference in wind speed distributions may be related to the difference in altitude and season. The annual average speed of Enugu metropolis at 10meter height in 2016 was 4.4m/s and the average rated power delivered by the developed turbine was 325.05watt.

The table 3 shows the power distribution of the monthly average values of the location at 20meter height. It was also discovered that the annual average speed of Enugu metropolis at 20meter height in 2016 was 5.26m/s and the average rated power delivered by the developed turbine was 444.17watt. Wind speed is highest (5.9m/s) in the month of January and lowest (4.5m/s) in the month of August, while the rated power is highest (510watt) in December and lowest (390watt) in August the same year.

The averages monthly power distribution and the wind speeds obtained using 30meter height was presented in table 4. The annual average power distribution was 500watt whereas the corresponding annual average speed was 6.04m/s in 2016. The monthly average wind speed was highest (6.8m/s) in the month of January and lowest (5.4m/s) in the month of August, while the monthly average rated power was highest (610watt) in December and lowest (440watt) in August the same year.

Table 5 shows the ANOVA for the effect of height on the rated power from the turbine. The F calculated was 13.854 while the F table was 2.215, *which* means that the computed F was greater than the tabular F at 5% probability level. The conclusion was that one of the treatment means is different from one or more of the remaining treatment. The treatment or effect means are not statistically equal. This was due to variations in wind speed and power generated by the turbine at different height.

Table 1: Average Monthly Wind and Solar Resource of Enugu Town

Month	Clearness Index	Average Radiation (kWh/m^2/day)	Wind Speed (m/s) at 10m
January	0.605	5.680	6.8
February	0.578	5.740	6.7
March	0.537	5.570	6.4
April	0.503	5.250	6.4
May	0.487	4.940	6.2
June	0.458	4.540	5.6
July	0.415	4.140	5.5
August	0.382	3.910	5.4
September	0.406	4.190	5.5
October	0.457	4.570	5.6
November	0.539	5.110	5.8
December	0.595	5.460	6.6
Average		4.950	6.04

Table 2: Monthly average speed and the average rated power from the Turbine at 10m height

Month	Average wind speed (m/s)	Average rated power (watt)
January	4.9	350
February	4.7	330
March	4.5	340
April	4.6	320
May	4.3	310
June	4.4	315
July	3.9	312
August	4.0	300
September	4.1	309
October	4.4	320
November	4.8	360
December	4.7	335
Average	4.4	325.05

Table 3: Monthly average speed and the average rated power from the Turbine at 20m height

Month	Average wind speed (m/s)	Average rated power (watt)
January	5.9	460
February	5.6	440
March	5.5	480
April	5.5	460
May	5.3	420
June	5.0	430
July	4.8	410

August	4.5	390
September	4.9	420
October	5.1	450
November	5.3	460
December	5.7	510
Average	5.26	444.17

Table 4: Monthly average speed and the average rated power from the Turbine at 30m height

Month	**Average wind speed (m/s)**	**Average rated power (watt)**
January	6.8	520
February	6.7	490
March	6.4	540
April	6.4	520
May	6.2	470
June	5.6	480
July	5.5	460
August	5.4	440
September	5.5	470
October	5.6	510
November	5.8	490
December	6.6	610
Average	6.04	500

Table 5: ANOVA for the effect of height on the rated power from the turbine

Source of Variations	**Degree of Freedom**	**Sum of Square**	**Mean Square**	**Computed F**
Between treatment	11	190926	17356.92	13.85
Sources of Error	24	30066.17	1252.76	
Total	35	220992.25		

Conclusions and Recommendation

It was discovered that most of the variations in power generation and wind speed happened within the months of December and August for the power whereas January and August for wind speed in the year 2016 of this experiment. The only deviation was at 10meter height where variation of speed came on January and July; also variation of power came around November and August. The result was as expected since difference in wind speed distributions may be related to the difference in altitude and season. It was also gathered that the height of the turbine affect the performance of the developed machine. This means that the higher the height of turbine, the more power and wind speed generated by the turbine. The developed machine generated the highest annual average power of 500watt at 30 meter height and the lowest annual average power of 325.05watt at 10 meter height. The highest annual average speed of 6.04m/s was extracted by the machine at 30meter height and the lowest annual average speed of 4.4m/s was got at 10meter height.

The ANOVA for the effect of height on the rated power from the turbine show that F calculated was greater than the F table at 5% probability level. This means that the treatment or effect means are not statistically equal and one of the treatment means is different from one or more of the remaining treatment. The cause was the variations in wind speed and power generated by the turbine at different height.

The wind turbine and its conversion equipment are a complex product but are adoptable to mass production, leading to improvements in quality, reliability and cost-effectiveness. The special features of wind energy that makes it attractive are zero cost fuels, low gestation period, quicker benefits and usefulness for sustainable economic development. Wind has strong potential as a fuel-free renewable source of energy, which can contribute to the deployment of off shore datacenters power needs.

The developed machine should be optimized to harness the full rated power of 100 percent desired power output instead of 60 percent harnessed.

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Appendix

Figure 2: Wind oscillatory turbine Parts with labeling

Item No.	Parts detailing Description	Unit	Qty
1	GENERATOR YOKE	mm	1
2	OSCILLATORY BLADE	mm	1
3	SLIDE \NAY \NITH SPRINGS	mm	1
4-	COI L AND ROTOR CHAIVIBER	mm	1
5	LO\N SPEED SHAFT	mm	1

6	PL NION IVIECHANISIVI	mm	2
7	STATOR AND FL ELD \NINDING	mm	1
8	\NIND VANE	mm	1
g	ANEIVIOIVIETER	mm	1
10	ROTOR GEAR BOX	mm	1
11	BLADE HANDLE	mm	1
12	LADDER	mm	1
13	PADEYE	mm	1
14-	TO\NER	mm	1
15	GEAR CHAIN	mm	1
16	DIAGONAL BRACES	mm	1
17	BOLTS	mm	1
18	GRILLAGE	mm	1
19	SPRINGS	mm	1
20	AIR GAP	mm	1
21	CONTROL BELT	mm	1