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Research Article

Design and Construction of Vertical Axis Wind Turbine

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Abstract: Increasing demand in energy facilitated the need of clean energy such as wind energy. Residences, buildings and commercial sites needs more power, but also continuous power. Important facilities such as wireless or radio sets requires small amount of energy, but with a continuous supply. This project was done to design and construct a vertical axis wind turbine for small scale use. After an introduction about the historical background of wind turbine, the report deals with a more accurate analysis of the main type of vertical axis wind turbine, showing their characteristics, advantages and disadvantages, differences between vertical axis wind turbine and horizontal axis wind turbine and their operations. The parameter of the wind turbines was discussed and the generators (stator) that can be used to connect the wind mill to the electricity grid are reported as well. Several statistics are also presented, in order to explain how the development of the wind energy in Nigeria. Results from trials shows that as the speed increases, there is increase in voltage and this in turn implies a watt change at different speeds. This also implies that when there is high wind, there is a higher rpm. The turbine fulfilled all specifications such as efficiency above 80%, 33Watt output power and likewise the capacity is adequate for its purpose and was proven to be efficient in generation of current.
Keywords: Turbine, wind, electricity, power, energy, fossil fuel and natural gas.

BACKGROUND OF THE STUDY

In the time of increasing energy consumption and diminishing natural resources, it is necessary to generate energy in a way that is renewable and climate friendly. Energy has a major impact on every aspect of our socio-economic life; it plays a vital role in the economic, social and political development of our nation. Despite the abundance of energy resources in Nigeria, the country is still in short supply of electrical power. Only about 40% of the nation's over 140 million has access to grid electricity. Even the electricity supply to the consumers that are connected to the grid is erratic. There is therefore the need to harness renewable energy potential (such as wind, solar etc.) for reliable power supply in this country. Also the concern about global warming and continued apprehensions about nuclear power around the world should drive us into strong demand for wind generation. The main advantages of electricity generation from renewable energy sources, such as wind, are the absence of harmful emissions, very clean and almost infinite availability of wind that is converted into electricity. Wind generation has been described to be one of the mature and cost effective resources among different renewable energy technologies. Wind is a natural phenomenon related to the movement of air masses caused primarily by the differential solar heating of the earth's surface. Wind is a classical example of a stochastic variable; due to this stochastic nature, wind energy cannot be controlled, but can be managed. This is because wind power is available only when the wind speed is above a certain threshold.

A wind turbine is a rotating machine that converts kinetic energy of wind into mechanical energy which in turn can be converted into electricity Wind. Wind turbines are classified into horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT). The main difference between these two is the orientation of the rotational axis. The advantage of having a vertical axis wind turbine of rotation is that it can absorb wind in all direction without the need for yaw mechanism. The blades do not require to be pitched to compensate for fluctuations in wind speed, these factors makes the VAWT simpler to build and maintain than the HAWT, however, the VAWT are generally less noisy than the HAWT and therefore makes it environmental friendly.

Although the construction of wind turbines are not universally welcome due to the negative visual impact and the effect on wildlife but it remains one of the largest forms of green energy used in the world today.

AIM AND THE OBJECTIVE OF THE STUDY

The aim of this project is to design and construct a micro scale vertical axis wind turbine for generation of electric current. However, the objective of the study is to enhance the design system of a wind turbine in order to create and to easily harness most efficiently wind power energy.

HISTORY OF WIND TURBINE

The wind has been used as an energy source for a very long time for example in sailing boats. The first windmills were used by the Persians approximately 900 AD.

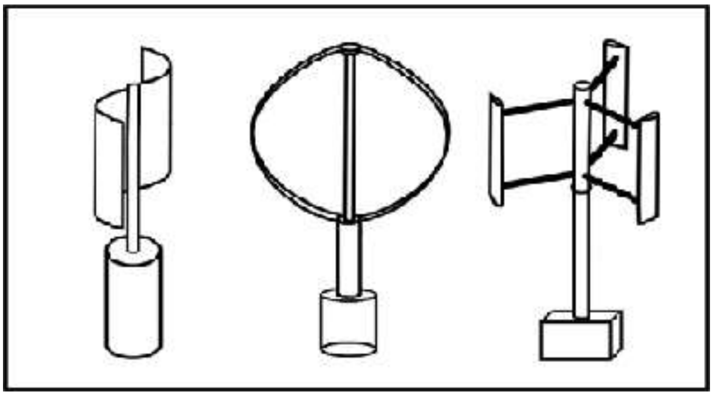

Fig-1: Basic VAWT Configurations

These first windmills were vertical axis wind turbines. During the middle Ages horizontal axis windmills were built in Europe and used for mechanical tasks such as pumping water or grinding grain. These were the classical four bladed windmills that had a yawing system and were mounted on a big structure. These windmills lost popularity after the industrial revolution. At about the same time water pumping windmills became popular in the United States, recognizable for their many blades and typically situated on a farm [1]. Charles Brush, (1888) was one of the people who first attempts to generate electricity by using the wind was made in the United States. Among the most important early turbines was the turbine developed by Marcellus Jacobs. Jacobs' turbine had three airfoil shaped blades, battery storage and a wind wane keeping the turbine facing the wind.

Fig-2: A Sandia turbine with 34 m diameter

During the 20th century the horizontal axis wind turbines continued to evolve, which resulted in bigger and more advanced turbines, leading to the modern horizontal axis wind turbines [1]. Vertical axis wind turbines have been developed in parallel with HAWTs, but with less financial support and less interest. Savonius, (1922) invented the Savonius turbine, (see Fig. 1). Darrieus, [2] patented his idea to have a vertical axis wind turbine with straight or bent lifting blades. During the 70's and 80's vertical axis machines came back into focus when both Canada and the United States built several prototypes of Darrieus turbines, (see Fig. 2), which proved to be quite efficient and reliable [3]. However, according to a report from Sandia National Laboratories (USA), the VAWTs fell victims to the poor wind energy market in the USA. The last of the Sandia VAWTs was dismantled in 1997 after cracks had been found in its foundation. In the 80's the American company Flow wind commercialized the Darrieus turbine and built several wind farms [4], (see Fig. 3). The machines worked efficiently but had problems with fatigue of the blades, which were designed to flex [5]. More than 500 commercial VAWTs were operating in California in the mid 80's.

Fig-3: A Flow wind farm

The Eole, a 96 meters tall Darrieus turbine built in 1986, is the largest VAWT ever constructed with a rated maximum power of 3.8 MW [6]. The North American Darrieus turbines used in the 80's mostly had induction generators with gearboxes. However, the Eole had a direct driven generator with a diameter of 12 meters. It produced 12 GWh of electric energy during the five years it was running and reached power levels of up to 2.7 MW. The machine was shut down in 1993 due to failure of the bottom bearing.

The straight-bladed VAWT was also an invention included in the original Darrieus patent [2]. This turbine is usually referred to as the straight-bladed Darrieus turbine or the H-rotor, but has also been called giromill or cycloturbine (different concepts of the same invention). In the United Kingdom the H-rotor was investigated by a research team led by Peter Musgrove. The biggest H-rotor built in the U.K. was a 500 kW machine, which was designed in 1989 (Mays and Morgan, 1989). This machine had a gearbox and an induction generator inside the top of the tower. One of the machines had blades that could be folded in high wind speeds, (see Fig. 4). In the 90's the German company Heidelberg Motor GmbH worked with development of H-rotors and they built several 300 kW prototypes. These turbines had direct driven generators with large diameters. In some turbines the generator was placed on top of the tower, and in some turbines the generator was situated on the ground. From this short historical review it is clear that the first windmill was a VAWT but that later HAWTs received most attention.

Fig-4: To the left is an H-rotor developed in the U.K. and to the right is one of the Heidelberg rotors

REVIEW OF PROJECT ON VERTICAL AXIS MICRO WIND TURBINE

Murat, 2003 design and construct a project on Vertical Axis Micro Wind Turbine. This study was done to investigate the design and development of the vertical axis micro wind turbines. The contribution of counter rotating impellers with a freely rotating generator to produce energy was investigated. From the analysis, Solid works, Mathcad and Abacus CAE programs were used to design and to analyze the Vertical Axis Micro Wind Turbine. Possible developments were considered. Heuristic method was used to complete the task of design of a vertical axis micro wind turbine. It was imagined that the task has been completed and all the targets were reached. The main consideration of the wind turbine was its counter rotating blades that reduce the inertia and increase the relative speed of the motor shaft. It must have a frame to hold the bearings and two identical counter rotating blade components such as Savonius or Darrieus blade types, etc. these two blade components are to be connected to two different shafts. Then, the torque should be gathered through a generator whose stator is connected to one of the shafts while the rotor is connected to the other shaft. As the two separate shafts are connected to the generator, the power has to be transmitted by a slip ring to a battery tank, the grid or the experimental measurement devices. In the assembly process, there are 7 points of interest to be concerned with; degrees of freedom (movement), material differentiation, product and establishment (replace ability) considerations, differentiation of functions, particular functional conditions and design considerations. All these points are examined during the complete concept design process. The generator used for the project was the Printed DC motors which are a kind of improved axial flux permanent magnet (AFPM) machines. They are also known as Printed Circuit (PCB) or "Pancake" Motors. Printed DC motors have very thin structure because the wires are placed on a thin disk and the magnets are relatively small, the rotation of the motor is directing the current through the printed wires by a magnetic field of permanent magnets. The printed motor has guided magnetic fields so that the power produced is very efficient. Like all DC motors this machine has a commutator to take the current out through two wires.

These motors can produce about the same amount of electricity as motorcycle alternators with similar rotational speeds, while they have far less inertia due to small weight. Because of their small dimensions and small inertias which are less than motorcycle alternators and also their highly efficient power output. The Shafts which are the easiest components to manufacture and design, so that they were required to be designed in connection with other components such as impellers, slip rings, frames etc. However, their basic cross sections need to be chosen. As all the components have inner diameter to fit on a shaft, the outer shape of the shaft was chosen as round. Possible round shapes for shafts can be suggested as; solid shaft and hollow shaft.

However, using a hollow shaft limits the possibilities of connections and fits, so that a solid shaft which will also have higher inertia but also higher strength will be used in the final design. In addition, solid shaft will be machined to create steps as so that the bearings will be fitted easily to the ends.

In this research, it was revealed that using a counter rotating wind turbine with a freely rotating generator can produce higher amounts of power than common wind generators. Even though the power output of counter rotating vertical axis micro wind turbine was 6 times higher than the total of the two separate wheels‟ power outputs it has to be due to the power curve of the generator which indicates that increasing rotation speeds the output increases drastically in the beginning.

However, the machine couldn't reach the design speed of the generator which would have given better information as it was assumed that the speed increase in the motor with counter rotating ability would be only two times less than if we had single ones. Therefore the power output could be estimated proportional to that ratio.

METHODS

In small scale residential or rural applications, the use of small wind turbines for the production of electricity is a common practice, when connection to the grid is not an option or when favorable feed in tariffs exist. Small wind turbines have a wide range of nominal power values reaching up to 88 kW and frequently use permanent magnets to produce the generator's excitation field. The use of permanent magnets in a coreless axial flux generator makes the construction process easier and suitable for locally manufactured open hardware wind power applications. Using these lay down designs as a basic platform, along with some simple theoretical equations, the generator can be designed and manufactured according to the nominal power needed, in any small scale application. In this chapter, a description of these basic theoretical concepts and construction methods is presented.

WIND TURBINE DESIGN PARAMETERS

The wind turbine parameters considered in the design process are:

- Swept area
- Wind Power and power coefficient
- Tip speed ratio
- Number of blades

Table 1: Choice of Components

S/N	Components	Material selected
1	Stator coil	Copper
2	Hub	Galvanized steel
3	Blade	Aluminum
4	Magnetic disk	Mild steel
5	Stator casting	Epoxy
6	Magnet	Neodymium
7	Spindle	Mild steel

RESULT OF THE DESIGNED VERTICAL AXIS WIND TURBINE

The performance of the machine was satisfactory during the preliminary tests. Voltage was generated accordingly. The machine can be applied for small scale use like charging of batteries, lightening of electric bulb etc. The turbine is made up of four parts, namely the stator, hub, magnetic disk and the blade (Figure 5).

Fig-5: vertical axis wind turbine

The assembling of parts and component of this vertical axis wind turbine started with the various sequence of operation and fabrication processes such as winding of the of the coil, casting of the stator, machining the magnetic disk, machining of the hub, fabrication of the blades, machining of the spindle and final assembling and testing. The stator was casted using epoxy resin which is use to glue the copper coils, the stator consist nine copper coil and three terminals. The copper winding of the stator is 75turns per double coils. The stator forms a circular shape of outer diameter of 430mm and Inner diameter of 160mm (center of the stator). The hub of height 240mm which was made from galvanizes steel pipe of diameter 82mm for the outer diameter and 80mm for the inner diameter and welded to the small sheet metal (circular) of thickness 2mm of radius 55mm. The magnetic disks when coupled with the stator forms the generator. It's a two circular metal plate of 322mm diameter and 5mm thickness with magnets on it. The magnetic disks when coupled with the stator forms the generator.. The 25mm x 50mm x 10mm Neodymium magnet (NdFeB) grade N50 is arranged round on the two magnetic disks plate in north and south orientation. The magnetic disks wit0h the 12magnets on each plate are mounted on rotor such that the each magnetic plate is facing each other so that the required magnetic circuit can be created.

The blade being one of the components of the rotor was fabricated using lighter aluminum pan/sheet which allows for easy rotation by the wind. The frame of the blade was made from flat bar and square rod. Each blade consists of three square rod of height 800mm each and three flat bar of 440mm. The flat bar was used to form the curved part of the blade and was welded to the square rod.

OPERATION OF THE VERTICAL AXIS WIND TURBINE

The first step to be taken in the operation of the wind turbine is when wind turns turbine blades, which in turn rotates the two magnetic disks i.e. the magnet. This creates an electrical field that is made into Alternating current (AC). The AC current can be converted to direct current (DC) using uncontrolled diode rectifier with a voltage regulator to stabilize the voltage from the wind turbine. The DC can be used to charge a volt battery, after fully charged the DC can be converted into AC using an inverter. AC is the type of current a typical household outlet uses. Then, the AC current runs to either your home or a power plant for distribution across several neighborhoods.

PERFORMANCE TEST AND EVALUATION

For the test, the following equipment and material were used:

1. Stop watch
2. Multi meter
3. Diode rectifier (D.C converter)
4. Calculator
5. Voltage regulator
6. Led light
7. Bread board
8. Recording materials (paper and pen)

TEST PROCEDURE

The first step involved measurement of the speed of the turbine blade in rev/min. This was achieved by the rotation of the wind blade at different wind speed. A stop watch was also used to determine the time in seconds after each revolution of the wind turbine blade.

The second step was to determine the amount of EMF (volt) and amount of current generated by the turbine. This was achieved by connection of the diode rectifier to the stator terminal which was then connected to the voltage regulator for stable voltage

The multi-meter was used to measure the voltage and the current output.

Table 2: Result of Performance Test

S/N	RPM	Emf (volt)	DC CURRENT (A)
1	0	0	0
2	45	6	3.3
3	55	8	2.5
4	60	9.5	2.1
5	70	11	1.82
6	80	12	1.67
7	90	13	1.54

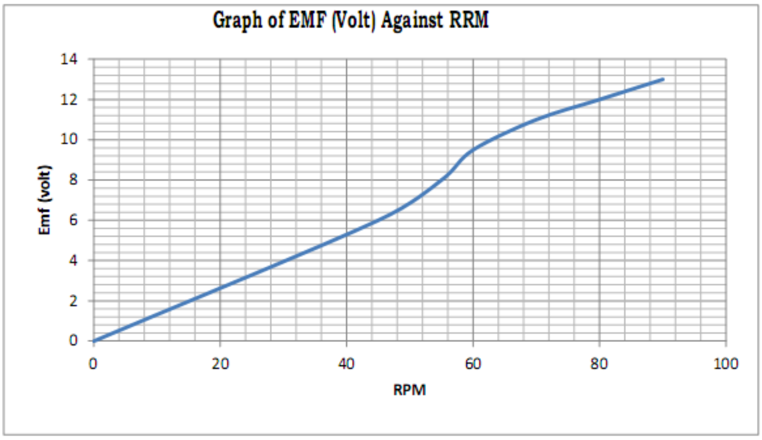

Fig-6: Graph of Electromotive Force against Revolution Per Minute

DISCUSSION ON THE PERFORMANCE TESTS

From the graph above, the speed of the turbine was gotten by running it with an electric motor and the rpm was taken and the voltage output was taken with a multimeter. From the graph also, we find out that as the speed increases, there is increase in voltage and this in turn implies a watt change at different speeds. This also implies that when there is high wind, there is a higher rpm.

Table 3: Bill of Materials

S/N	DESCRIPTION	QUANTITY	UNIT PRICE (₦)	TOTAL PRICE (₦)
1	Neodymium Magnet	30 pcs	2,000	60,000
2	Copper Wire	5kg	1,100	5,500
3	Spindle	1pcs	1,500	1,500
4	Sheet Metal	2pcs	1,500	3,000
5	Aluminium Sheet	2500 X 2500mm	1,800	1,800
6	Rivet	30pcs	10	300
7	Galvanized pipe	1pcs	300	300
8	Epoxy Resin	2Cans	8,000	16,000
9	Flat Bar	2pcs	650	1,300
10	Square Rod	3pcs	400	1,200
11	Pole	3pcs	1,000	3,000
12	Screw, nut, washer			2,200
13	TOTAL			96,100

CONCLUSIONS

In the world today, most machines are designed with the aim of limiting greenhouse gas emissions which is a major cause of climate change. Non-renewable source of energy looks to be slowly losing its dominance. Through innovative ideas in technology, renewable sources of energy have been tapped to provide this clean energy.

By using this clean source of renewable source of energy, not only will it reduce the money spent on electricity bills but also help our planet recover from the effects of pollution and therefore reduce emission of greenhouse gases to the ozone layer.

The vertical axis wind turbine was designed, fabricated and tested to meet the challenge of environmental pollution and low cost of operation since there is no cost for fueling. The turbine is mainly for small scale use, operation and maintenance. Result of the test shows that the turbine has an efficiency of 80%. The turbine capacity is adequate for its purpose and has been proven to be efficient in generation of current.

In recommendation, the federal government should embark on the project of wind turbine which helps to solve the problem of global warming and still produces electric power.

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