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DEVELOPMENT AND IMPLEMENTATION OF A LEVITATED VERTICAL AXIS WIND TURBINE

[1]Emmanuel Ighodalo Okhueleigbe* & [2]Aaron Okiemute Onyan
[1,2]Department of Electrical and Electronics Engineering
Federal University of Petroleum Resources, Effurun, Delta State, Nigeria
Email: okhueleigbe.emmanuel@fupre.edu.ng

ABSTRACT

The paper presents the development and implementation of a levitated vertical axis wind turbine (LVAWT) whose aim is for power generation. With the utilization of the repulsive forces present in permanent magnetic, the vertically placed vanes of the wind turbine would be levitated resulting in less frictional losses due to contact of shaft with surface of frictionless bearings therefore reducing losses and increasing efficiency. After the blades are set in perfect rotating condition, a shaft which is connected through its normal axes would be geared for increased speed and then connected to an alternator. The main important of gearing is that though the turbine may be constructed to run at certain maximum speed so as to increase the life span of the turbine, the gear in an increased ratio would help to increase the rotating speed of the alternator therefore increasing output. With the implementation of the turbine system, power would be generated at the cost of wind in motion which could be used in homes and even commercial regions.

Keywords: *Wind power; Wind turbine; Magnetic Levitation; Generator; Power*

INTRODUCTION

An important factor in the development of human resource is the Energy. Presently, conventional energy sources are exhausting rigorously leading to the development of inexhaustible and renewable energy resources. Renewable energy is generally electricity supplied from sources, such as wind power, solar power, geothermal energy, hydropower and various forms of biomass. These sources have been coined renewable due to their continuous replenishment and availability for use over and over again. The popularity of renewable energy has experienced a significant upsurge in recent times due to the exhaustion of conventional power generation methods and increasing realization of its adverse effects on the environment [1]. Wind is a source of energy which is created from the atmosphere of the sun causing areas of uneven heating. In conjunction with the uneven heating of the sun, rotation of the earth and the rockiness of the earth's surface winds are formed. The terms wind energy or wind power describes the process by which wind is used to generate mechanical power or electricity. The wind turbine is used for conversion of kinetic energy of wind into electrical energy. The wind turns the blades, which spin a shaft, which connects the generator and generates electricity [1]. The levitated vertical axis wind turbine (LVAWT) design is a vast departure from conventional propeller designs [1]. The merits for levitated vertical-axis wind turbine can be noted such as requirement of minimum cost, reduced losses to friction, easy installation, easy maintenance, and the capability to accept wind from all directions. The unique operating principle behind this design is through magnetic levitation. Compared with the traditional horizontal axis wind turbine, its levitated or suspended using magnetic levitation directing vertically on a rotor shaft. This technology is utilized as an efficient replacement for ball bearings having its application on the traditional wind turbine. sThe levitated vertical axis wind turbine has the features of no mechanical contact, no friction etc. thereby minimizing damping, which enables the wind turbine start up at low speed wind.

OVERVIEW OF THE SYSTEM

This section presents an overview of the system. It introduces and provides a brief description of the major components and factors that contributes to an efficiently functioning levitated vertical axis wind turbine. These factors include wind power, generator, and magnet levitation

A. Wind Power

Undoubtedly, the research ability to function is solely dependent on the power of wind and its availability. Wind is known to be another form of solar energy because it comes about as a result of uneven heating of the atmosphere by the sun coupled with the abstract topography of the earth's surface [2]. With wind turbines, two categories of winds are relevant to their applications, namely local winds and planetary winds. The latter is the most dominant and it is usually a major factor in deciding sites for very effective wind turbines especially with the horizontal axis types. These winds are usually found along shore lines, mountain tops, valleys and open plains. The former is the type you will find in regular environments like the city or rural areas, basically where settlements are present. This type of wind is not conducive for effective power generation; it only has a lot of worth when it accompanies moving planetary winds [2][3] [4].

B. Generator

The basic understanding of a generator is that it converts mechanical energy to electrical energy. Generators are utilized extensively in various applications and most part has similarities that exist between these applications. However, the few differences present is what really distinguishes a system operating on an AC motor from another on the same principle of operation and likewise with DC motors. With the axial flux generator design, its operability is based on permanent magnet alternators where the concept of magnets and magnetic fields are the dominant factors in this form of generator functioning. These generators have air gap surface perpendicular to the rotating axis and the air gap generates magnetic fluxes parallel to the axis.

C. Magnetic Levitation:

Magnetic levitation is a method by which an object is suspended in air so effect of gravity on that object reduces significantly with no support other than magnetic fields. Here magnetic pressure is used to mainly counteract the effects of the gravitational forces [5]. Magnetic levitation is an extremely efficient system for wind energy. This phenomenon operates on the repulsion characteristics of permanent magnets. This technology has been predominantly utilized in the rail industry to provide very fast and reliable transportation on maglev trains and with ongoing research its popularity is increasingly attaining new heights. Using a pair of permanent magnets like neodymium magnets and substantial support magnetic levitation can easily be experienced. By placing these two magnets on top of each other with like polarities facing each other, the magnetic repulsion will be strong enough to keep both magnets at a distance away from each other.

D. The force created as a result of this repulsion can be used for suspension purposes and is strong enough to balance the weight of an object depending on the threshold of the magnets [2].

E. Wind Power and Wind Turbines

Wind power technology is the various infrastructure and process that promote the harnessing of wind generation for mechanical power to generate electricity. This basically entails the wind and characteristics related to its strength and direction, as well as the functioning of both internal and external components of a wind turbine with respect to wind behavior. The figure 1, show the block diagram of the wind power generation system.

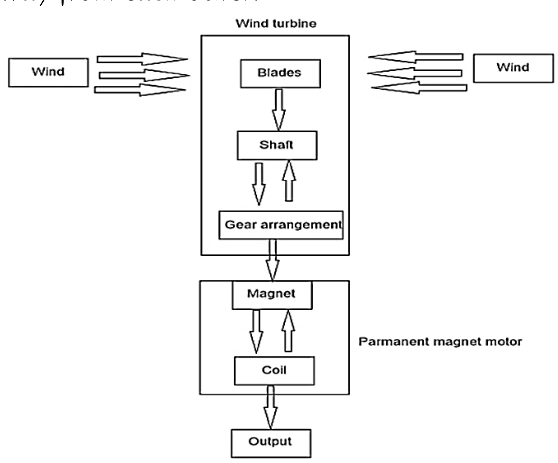


Figure 1: Block Diagram of Wind Power Generation

DESIGN AND CONSTRUCTION

A. ***Blade Design***

B. The turbine used in this prototype is a turbine ventilator. A different approach was employed in the blade design. The turbine is made up of 8 blades with the base and top diameter of 300mm. The height of the blade hub is 648mm with a diameter of 360mm.Total height of the shaft is 637mm. Figure2 (a) and (b) shows the 3D design of the wind turbine. The turbine blades used for this design has the following specifications:

Bade and hub specification

Blade type:	J-type (drag)
Blade number:	8
Blade material:	Pvc materials with wooden plate
Hub material:	iron rod with iron plate
Blade height (bh):	569 mm
Blade diameter (bd):	300 mm
Blade thickness (bt):	2 mm
Hub height (h):	648 mm
Hub diameter (d):	360 mm

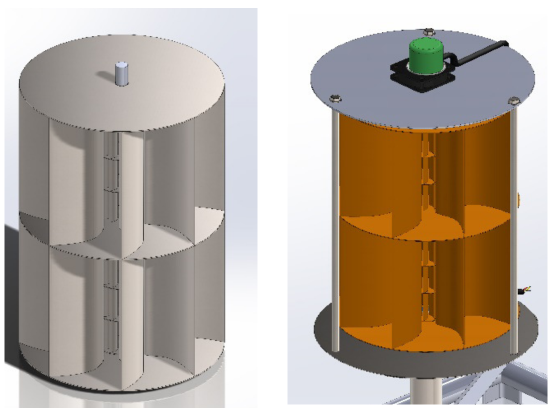


Figure 2 (a): 3D View of the Wind Turbine

C. Magnetic Levitation

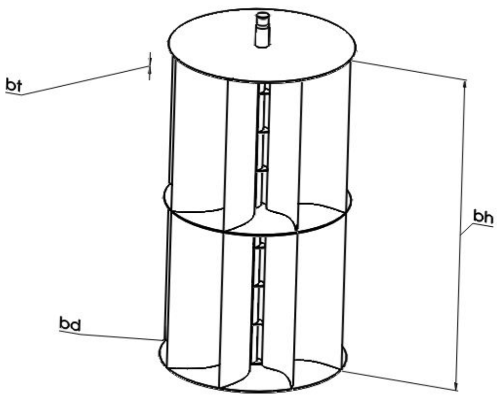
i. Mode of operation

At the base of the blade hub, a magnet is placed. The magnet repels the other magnet which is welded to the shaft of generator. The shaft contains the vertically oriented blades of the wind turbine. Now due to this repulsion power between the magnets the upper magnet attached to shaft is suspends is air suspended, replacing the need for ball bearings. For this levitation, a full permanent rare earth magnets made from neodymium are used. Due to this, there are no energy losses through friction. This also helps in reducing the maintenance cost and increases the lifespan of the wind generator [5].

ii. Levitation of Rotor

For this design, the base and rotor are separated in the air using the principle of magnetic levitation. The rotor is lifted up the base into the air by the magnetic pull forces created by the ring type Neodymium magnets. This is the principal advantage of a maglev windmill from a conventional one. That is, as the rotor is floating in the air due to levitation, mechanical friction is totally eliminated. That makes the rotation possible in very low wind speeds.

Magnet Placement: Two ring type rare earth magnets of grade N52 of outer diameter 85 mm, inner diameter 20 mm and thickness 12 mm are placed at the shaft, by which the required levitation between the rotor and the base is obtained. Figure 3, shows the concept of magnetic levitation.



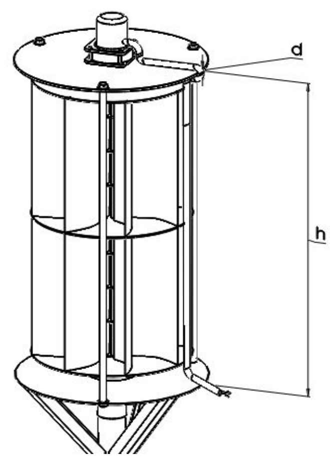


Figure 3: Concept of Magnetic Levitation

D. Generator Design

For the generator, it is important to have a firm grasp of the basic laws that govern its performance. In order to induce a voltage in a wire a nearby changing magnetic field must exist. The voltage induced not only depends on the magnitude of the field density but also on the coil area. The relationship between the area and field density is known as flux (Φ) [6]. The way in which this flux varies in time depends on the generator design. The axial flux generator uses the changing magnetic flux to produce a voltage. The voltage produced by each coil can be calculated using Faraday's law of induction: $V = N\, d\phi / dt$ [4] [6] [7].

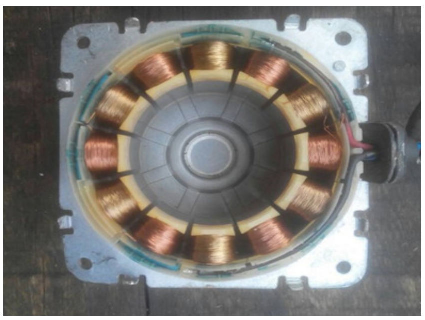


Figure 4: Stator

The stator design consists of a stator frame, slots and coils. The stator frame is compartment made up of 12 slots and 12 set of coils with each slot consisting of 245 turns of copper wire. The copper wire used is of 32 SWG (standard wire gauge) each having measured resistance of 40Ω

For the rotor design, the rotor consists of 5 permanent magnets. The angular distance between to magnets is 36 degrees equal to the distance between two coils. The magnets placed on the rotor frame creates the magnetic fields. These magnets are of ferrite type with the powers of 0.5 gauss each.

Figure 5: Synchronous generator

Result

In this paper, a levitated vertical axis wind turbine has been developed, modelled and implemented for outdoor utility. Test analysis was carried out on the wind turbine to determine its expected electricity generating capacity to wind speed. A wind blower is used to vary the wind speed and a multimeter to measure the output voltage and current. Figure 6, shows the 3D wind turbine model and figure 7, shows the test environment and result for voltage and current output at the maximum wind speed.

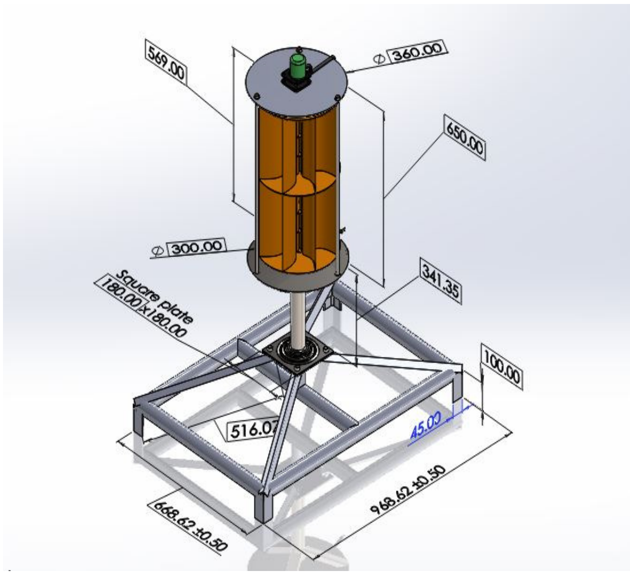


Figure 6:3D Wind turbine model

Figure 7: Voltage and current output at the maximum wind speed

Table 1, shows the voltage and current output of the wind turbine at different wind speed. A comparative analysis on velocity to current and velocity to voltage is presented using a graphical representation in figure 8 and 9 respectively.

Table 1: Wind velocity, Voltage output and Current output

Velocity (m/s)	Voltage (V)	Current (I)
75	32.23	3.24
60	30.27	3.18
55	27.35	3.05
40	23.24	2.97
25	19.83	2.84

Figure 8, shows a graphical representation on the comparative analysis of the current output to wind velocity.

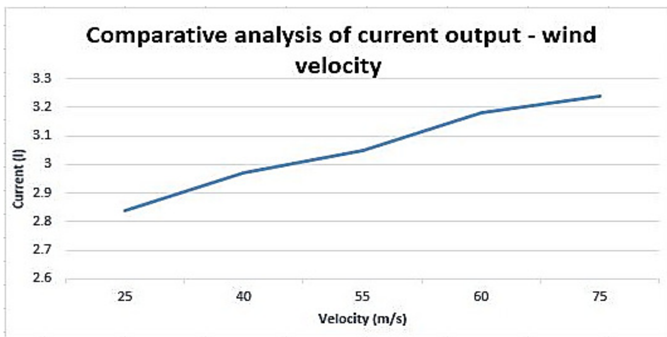


Figure 8: Comparative analysis of current output to wind velocity

Figure 9, shows a graphical representation on the comparative analysis of the current output to wind velocity.

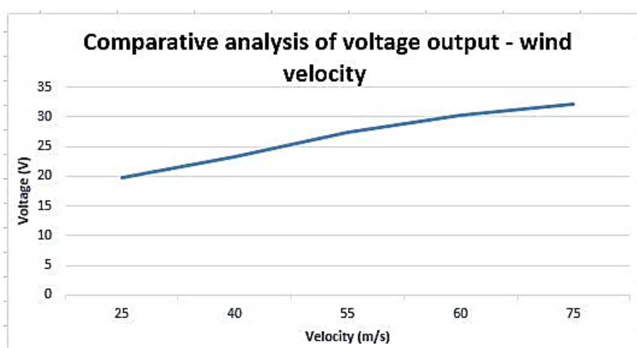


Figure 9: Comparative analysis of voltage output to wind velocity

Conclusion

Small-scale wind turbines are attractive option for a host of remote applications, such as rural electrification, water pumping or telecommunication, and also provide an option for saving energy and mitigating greenhouse gases in grid-tied situations. In this paper, a levitated vertical axis wind turbine has been developed, modelled and implemented. Test analysis carried out on the wind turbine to determine its expected electricity generating capacity to wind speed shows at 75 m/s (maximum wind velocity) the wind turbine produces a voltage of 32.23V and a current output of 3.2A. The power output of the prototype poses suitable for battery charging applications. Applying this technology of power generation on a large scale in the power sector of Nigeria presents a long-term sustainable approach to energy self-sufficiency and economic development.

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