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Study on Magnetic Levitation for Vertical Axis Wind Turbine and Low Wind Speed

Mr. Sharangdhar Dehadrai
UG Student
Department of Electronics Communication Engineering
Dr. Babasaheb Ambedkar College of Engineering & Research Nagpur, Maharashtra, India

Mr. Anurag Wasnik
UG Student
Department of Electronics Communication Engineering
Dr. Babasaheb Ambedkar College of Engineering & Research Nagpur, Maharashtra, India

Mr. Yogesh Gaidhane
Assistant Professor
Department of Electronics Communication Engineering
Dr. Babasaheb Ambedkar College of Engineering & Research Nagpur, Maharashtra, India

Abstract

This paper presents the design component aspects of a Magnetically levitated Vertical Axis Wind Turbine and to report the result analysis using an modified magnetic circuit. The modified magnetic circuit generator reported in our earlier work is tested with the built-in MAGLEV-VAWT. Initially three different wind profiles and the suitable airfoil for the vertical axis wind turbine is derived. The position of the blades to derive maximum velocity is analysed. The degree of impact at angle of 300 is found to have the highest lift coefficient. The structure is then built under laboratory conditions. A modified magnetic circuit generator is used to test the generating capability of the turbine under low speed and high speed conditions. A dual magnetic surface is attached into the structure through an external mechanical structure to reduce the mechanical oscillations. The system is then investigated with and without the maglev structure.
Keywords: Wind Turbine; Magnetic Levitation; FEM; Rotor Dynamic; Vertical Type

I. Introduction

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. This popularity has been bolstered by cutting edge research and ground breaking technology that has been introduced so far to aid in the effective tapping of these natural resources and it is estimated that renewable sources might contribute about 20% – 50% to energy consumption in the latter part of the 21st century. Facts from the World Wind Energy Association estimates that by 2010, 160GW of wind power capacity is expected to be installed worldwide which implies an anticipated net growth rate of more than 21% per year. The aim of this major qualifying project is to design and implement a magnetically levitated vertical axis wind turbine system that has the ability to operate in both high and low wind speed conditions. Our choice for this model is to showcase its efficiency in varying wind conditions as compared to the traditional horizontal axis wind turbine and contribute to its steady growing popularity for the purpose of mass utilization in the near future as a reliable source of power generation. Unlike the traditional horizontal axis wind turbine, this design is levitated via maglev (magnetic levitation) vertically on a rotor shaft. This maglev technology, which will be looked at in great detail, serves as an efficient replacement for ball bearings used on the conventional wind turbine and is usually implemented with permanent magnets. This levitation will be used between the rotating shaft of the turbine blades and the base of the whole wind turbine system. The conceptual design also entails the usage of spiral shaped blades and with continuing effective research into the functioning of sails in varying wind speeds and other factors, an efficient shape and size will be determined for a suitable turbine blade for the project.

With the appropriate mechanisms in place, we expect to harness enough wind for power generation by way of an axial flux generator built from permanent magnets and copper coils. The arrangement of the magnets will cultivate an effective magnetic field and the copper coils will facilitate voltage capture due to the changing magnetic field.

II. Design aspects

This section introduces and provides a brief description of the major components and factors that will contribute to an efficiently functioning wind turbine. These factors are wind power, the generator, magnet levitation and the DC-DC converter. Later sections will provide an in-depth look into the essence of each factor and its function and importance to the overall operation of the vertical axis wind turbine. The blade shape design and the angle of attack influence heavily the power generating capability as the cut-in speed is proportional to the amount of wind generated. With proper optimized design of the blade, the VAWT to generate more power at low wind speed. This is further enhanced by the appropriation on the angle of attack on the surface of the blade. The design includes blade shape, the positioning of the blade followed by the design for the generator and the maglev bearing structure. Once all the above structures are integrated they are tested under laboratory conditions for performance evaluations.

A. Wind Power

Undoubtedly, the project's 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. 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.

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 for the most part have 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. In further chapters we will take a detailed look into their basic operation and the configuration of our design.

1) Magnet Placement

Two ring type neodymium (NdFeB) magnets of grade N- 42 of outer diameter 40 mm, inner diameter 20 mm and thickness 10 mm are placed at the center of the shaft by which the required levitation between the stator and the rotor is obtained. Similar disc type magnets of 30 mm diameter and 4mm thickness are arranged as alternate poles one after the other, along the periphery of the rotor made of acrylic of 40mm diameter as in Figure 6.1. These magnets are responsible for the useful flux that is going to be utilized by the power generation system.

Fig. 1: Magnet Placement

2) Coil Arrangement

26 gauge wires of 1000 turns each are used as coils for power generation. 12 sets of such coils are used in the prototype. These coils are arranged in the periphery of the stator exactly in a line to the arranged disc magnets.

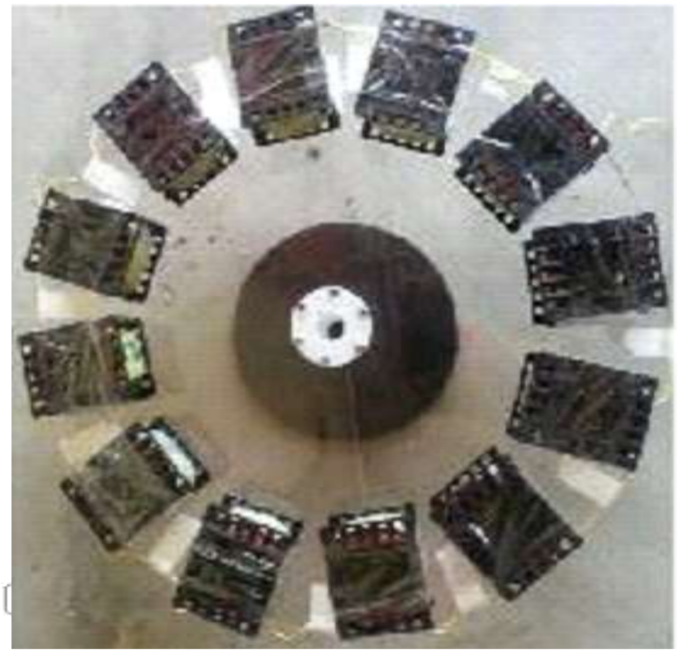

Fig. 2: Coil Arrangement

C. *Magnetic Levitation*

Also known as maglev, this phenomenon operates on the repulsion characteristics of permanent magnets. This technology has been predominantly utilized in the rail industry in the Far East 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. 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. In this project, we expect to implement this technology for the purpose of achieving vertical orientation with our rotors as well as the axial flux generator.

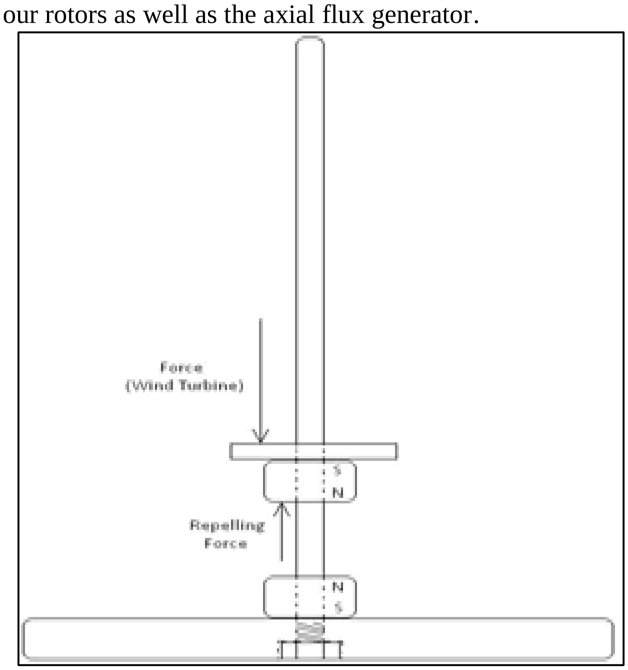

Fig. 3:

D. *DC-DC Conversion*

In order to begin the analysis of DC-DC converters it is important to first understand the concept behind a converter. Over the years, alternating current has been the common choice of power supply. AC is popular because the voltage can be easily stepped up or down using a transformer. Due to the inherent properties of a transformer, DC voltage cannot be altered using this type of equipment. Transformers operate due to a changing magnetic field in which the change in magnetic flux induces a current. Direct current cannot provide a changing magnetic field therefore a transformer with an applied DC input would only produce heat. The concept of DC-DC conversion emerged after the development of fast switching transistors. By varying the duty cycle of the pulse that is applied to the gate of the transistor for switching, these converters can buck or boost the voltage as if it were a DC transformer. When accurate feedback back is applied to this type of circuit, the converter will not only transform a supply voltage to the desired output but also maintain it given a varying input. These qualities of DC-DC converters are the foundation of the circuit that will be chosen for this project

1) E-Phase Connections

A 3-phase connection implies that a generator produces three voltages each with their own phase angle. A major advantage of the 1-phase connection is that the output allows the current to peak a different times allowing for smaller more frequent peaks as opposed to one large peak produced in a single phase connection. These smaller current peaks produce less vibration as the generator spins. Less vibration leads to less wear on the parts of the generator such as the bearings.

2) Types of Connections

There are two basic 3-phase connections known as wye and delta. During analysis we may assume a balanced condition, which refers to all three voltages having equal magnitude and being displaced by 120 degrees. We made use of six coils in our generator allowing for two coils per phase. Coils opposite each other in the physical design are connected in series in turn summing the voltages from each coil to produce a phase voltage. The circuit diagrams for the wye and delta connections to the rectifier are shown below.

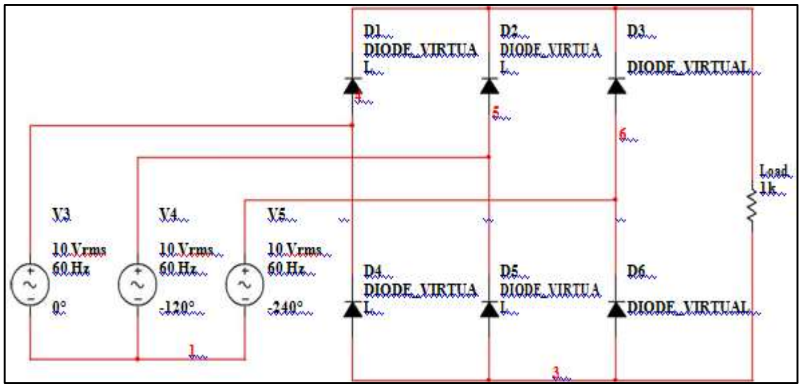

Fig. 4: Wve Connection

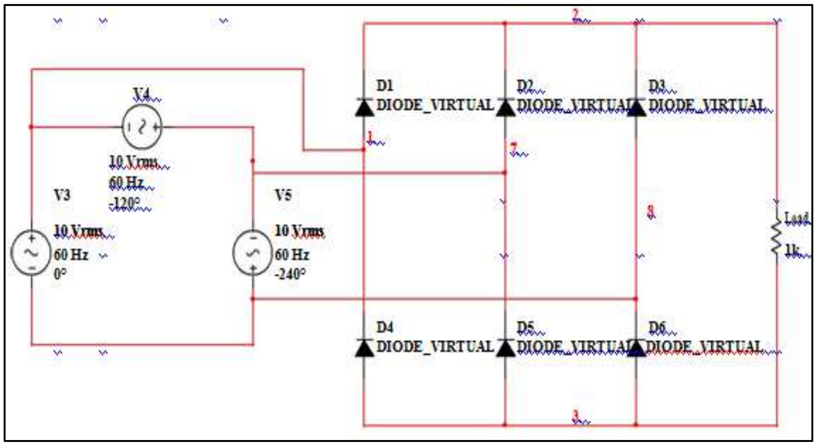

Fig. 5: Delta Connation

Three voltages, equal in magnitude, following a sequence a-b-c. Using this convention ‘a’ leads ‘b’ by 120 degrees and ‘b’ in turn leads ‘c’ by 120 degrees]. Each phase voltage is superimposed upon the other in the figure below, illustrating the phase shift.
The phases are displaced both in the time and the phasor domain. The phasor domain is shown below.

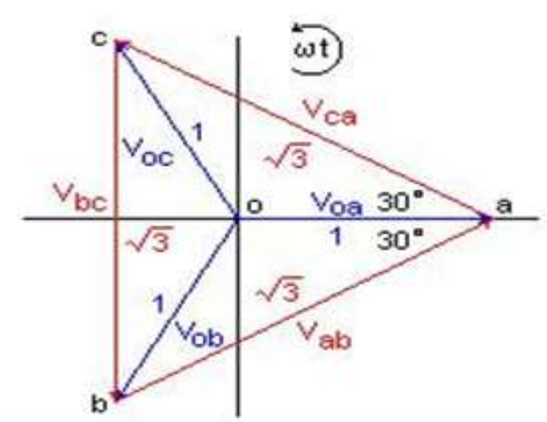

Fig. 6: Three Phase Voltage in Phasor Domain

The voltage equations can be written in phasor form. Each voltage phase with respect to the neutral is the phase voltage amplitude shifted 120 degrees.

III. DESIGN AND FORMULATION

Power Coefficient Analysis*:* This hypothesis is reproduced to show the relationship between the power coefficient (Cp) and the wind speed, Which expresses the basic theory of the Savonius wind machine. Principally the power that the rotor can extract from the wind (Pw) is less than the actual available from the wind power (Pa). In order to calculate the performance of this wind machine, its configuration is essentially important.

A. According to the Kinetic Energy,

KE = ½ mv2

B. The available power, Pa from the wind is:

Pa = ½ mv2 When m= Pav
Pa= ½ pAv3

C. The power coefficient Cp is given by:

Cp = *Pw/ Pa*

Therefore: Power extracted from the wind,

Pw=Cp x Pa

= Cp x ½ pAv3
Power by air impact = cp x 1/2 x density x area x v3
This is the standard wind equation that is used in this documentation.

D. To Calculate Area (A) =?

A= (power x 2)/(Cp x density x v3)
Where, Cp= Pw/ Pa= 3
e) To Calculate Shaft Rotation (ὼ) =?
The equation below is used whereby the radius value R (D/2) is manipulated to obtain w. It is assumed that the value of X (tip speed ratio) is equal to 1, to eliminate X in the equation below.
X = R ω /V
ω = rotational speed (rad/s);
R = radius of rotor (m);
V = average wind speed, assume 10 m/s.
ω = V/R, R is varied between 0.2 and 0.55 meters, a reasonable range baring in mind the speed of rotation.
To calculate the height (h) =?
The equation below is used to calculate h:
Area (A) = height (h) x diameter (D)

IV. CONCLUSION

By using no mechanical contact for magnetic bearing, substitution of traditional bearing in general wind turbine, reducing the damping of the wind turbine, which solved wind turbine start up with low speed wind and work with breeze. Then detailed structure of vertical type wind turbine by magnetic bearing suspended has been introduced. By using FEM analysis, the optimized geometric parameters be given. The simulation results show stable levitation and good levitated rotation. In the future, the prototype will be manufactured; some comparison experiments will be done. This design method can be used other type wind turbine.

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