

Design and Development of Vertical Axis Wind Turbine Using Maglev System

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Abstract: A combined savonius and darrieus vertical axis wind turbine would have many advantages over an individual savonius or darrieus rotor. A savonius produces high torque which would be useful in self-starting and darrieus rotor having a high tip speed ratio useful for electrical generation. Therefore the combined effect is more. This developed a two bucket savonius rotor and placed it on the central shaft of a traditional darrieus. Though the tip speed ratio is a still a little low for use as an electrical generator, the research demonstrated a simple way to enable a darrieus VAWT to be self-starting and achieve higher efficiencies. Historically VAWTs cost more to operate and maintain than HAWTs. Finally, traditional Darrieus rotors are not self-starting under most of wind conditions and manufacture of their blades is a challenge because of the complex shape which adds expense to the turbine. However, evidence shows that a Darrieus turbine using fixed geometry symmetrical airfoils can self-start in the field during atmospheric gusting it was suggested that using a Darrieus blade together with a Savonius blade has better performance than using them individually according to self-start ability and efficiency of the turbine. Using a counter rotating wind turbine with a freely rotating generator can produce higher amounts of electric power than common wind generators.

Keywords: VAWTs, HAWTs, Savonius, Darrieus, Maglev system.

1. 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.

This project focuses on the utilization of wind energy as a renewable source. In the United States alone, wind capacity has grown about 45% to 16.7GW and it continues to grow with the facilitation of new wind projects. 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.

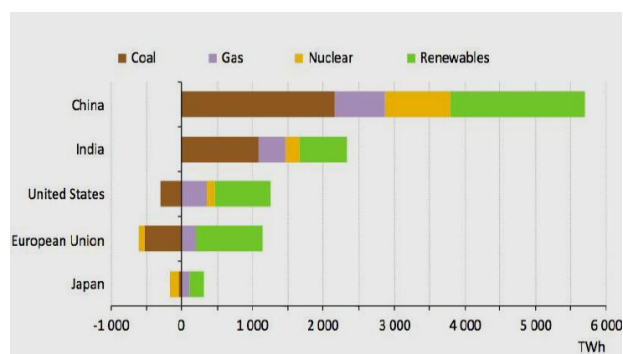


Figure 1: Power Generation 2010-2013

The Maglev wind turbine, which was first unveiled at the Wind Power Asia exhibition in Beijing, is expected take wind power technology to the next level with magnetic levitation. Magnetic Levitation (Maglev) into turbine system in order to increase the efficiency. If the efficiency of a wind turbine is increased, then more power can be generated thus decreasing the need for expensive power generators that cause pollution.

2. Basic Design

The effective functioning of a wind turbine is dictated by the wind availability in an area and if the amount of power it has is sufficient enough to keep the blades in constant rotation. The wind power increases as a function of the cube of the velocity of the wind and this power is calculable with respect to the area in which the wind is present as well as the wind velocity.

Kinetic energy [11](K.E)= $0.5 \rho v^3$

Amount of Air passing is given by

$$m = \rho AV \dots\dots\dots (1)$$

Substituting this value of the mass in expression of K.E.

$$K.E = 0.5 \rho A v^3 \text{ watts} \dots\dots\dots (2)$$

To convert power to kilo watt a non-dimensional proportionality constant k is introduced where, $k = 2.14 \times 10^{-3}$

Therefore

$$\text{Power in KW (P)} = 2.14 \rho A v^3 \times 10^{-3} \dots \dots (3)$$

Where

m = mass of air traversing

Air Density (ρ) = 1.2 kg/m³

Area (A) = area swept by the blades of the turbine

Velocity (V) = wind speed

With equation above, the power being generated can be calculated, however one should note that it is not possible to convert all the power of the wind into power. The turbine absorbs the wind energy with their individual blade will move slower than the wind velocity. The different speed generates a drag force to drive the blades. The drag force acting on one blade is calculated as

$$F_w = C_d 2A(U_w - U_b)^2$$

Where

A is swept area of the blade

ρ is air density (about 1.225 kg/m³ at sea level)

U_w is wind speed

C_d is the drag coefficient (1.9 for rectangular form)

U_b is the speed on the blade surface.

3. Materials for Wind Turbine

A wide range of materials are used in wind turbines. There are substantial differences between smaller and larger machines and there are projected changes in designs that will accommodate the introduction of new material technologies and manufacturing solutions.

Physically, chemically and mechanically aluminium is a metal like steel, brass, copper, zinc, lead or titanium. Aluminium is a very light metal with a specific weight of 2.7 g/cm², about a third that of steel. Its strength can be adapted to the application required by modifying the composition of its alloys. Aluminium naturally generates a protective oxide coating and is highly corrosion resistant. Aluminium is a good reflector of visible light as well as heat, and that together with its low weight makes it an ideal material for reflectors in, for example, light fittings or rescue blankets. Aluminium is strong with a tensile strength of 70 to 700 MP depending on the alloy and manufacturing process [3]. Extrusions of the right alloy and design are as strong as structural steel. This means that the moment of inertia has to be three times as more for an aluminium extrusion to achieve the same deflection as a steel profile.

4. Magnet Selection

Some factors need to be assessed in choosing the permanent magnet selection that would be best to implement the maglev portion of the design. Understanding the characteristics of magnet materials and the different assortment of sizes, shapes and materials is critical. There are four classes of commercialized magnets used today which are based on their material composition each having their own magnetic properties.

The four different classes are Alnico, Ceramic, Samarium Cobalt and Boron neodymium Iron [8] also known Nd-Fe-B. Nd-Fe-B is the most recent addition to this commercial list of materials and at room temperature exhibits the highest properties of all of the magnetic materials. All of the following information is supported by reference and explains the importance of the B-H curve [4] corresponding to magnet design. The hysteresis loops also known as the B-H curve, where B is the flux density and H the magnetizing force, is the foundation to magnet design and can be seen in Figure 3. Each type of material has its own B-H characteristic which describes the cycling of the magnet in a closed circuit as it is brought to saturation, demagnetized, saturated in the opposite direction, and then demagnetized again under the influence of an external magnetic field. Of the four quadrants that the hysteresis loop passes through on the B-H graph, the most important is the second. This quadrant commonly known as the demagnetization curve, will give the operating point of a permanent magnet at a given air gap. In the case of maglev for the wind turbine, the air gap corresponds to the space in between the two opposing magnets and should stay moderately constant as long as the wind [5] is not too violent. If the air gaps were to change, the operating point of the magnets on the B-H curve will change respectively.

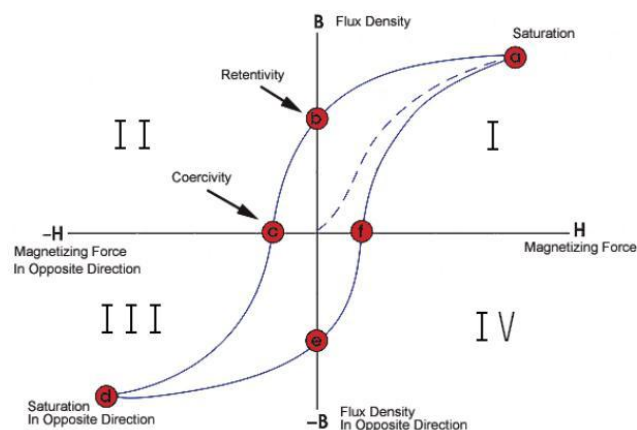


Figure 2: General Hysteresis Loop

The most important points of the hysteresis loop are when it intersects with the B-H. The point where the curve intersects the B axis in the second quadrant is known as the magnets retentively, which is the point where a material will stay magnetized after an external magnetizing field is removed.

It seems that levitation would be most effective directly on the central axis line where, under an evenly distributed load, the wind turbine center of mass will be found as seen in Figure 4. This figure shows a basic rendition of how the maglev will be integrated into the design. If the magnets were ring shaped then they could easily be slid tandem down the shaft with the like poles [9] facing toward each other. This would enable the repelling force required to support the weight and force of the wind turbine and minimize the amount of magnets needed to complete the concept.

The permanent magnets that were chosen for this application were the Big Ferrite Magnets and small Neodymium Magnet. These are Nd-Fe-B ring shaped permanent magnets that are nickel plated to strengthen and

protect the magnet itself. The dimensions for the magnets are reasonable with outside diameter of 70mm, inside diameter of 24 mm and height of 25mm for Big Ferrite Magnet. And for small Neodymium Magnets the dimensions are reasonable with outside diameter of 25mm and height of 10mm.

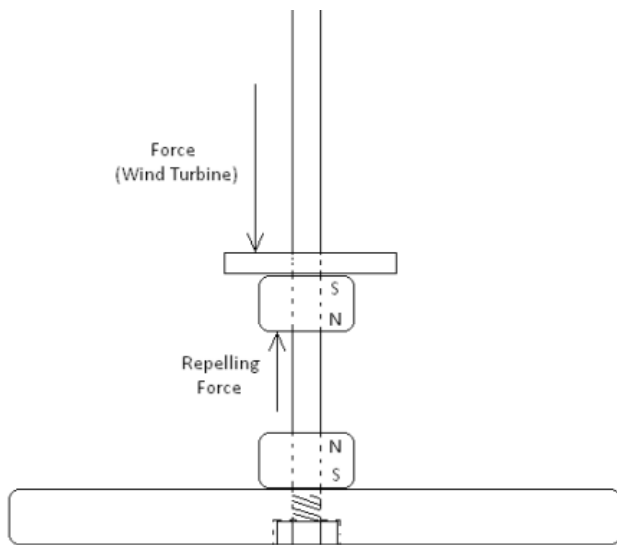
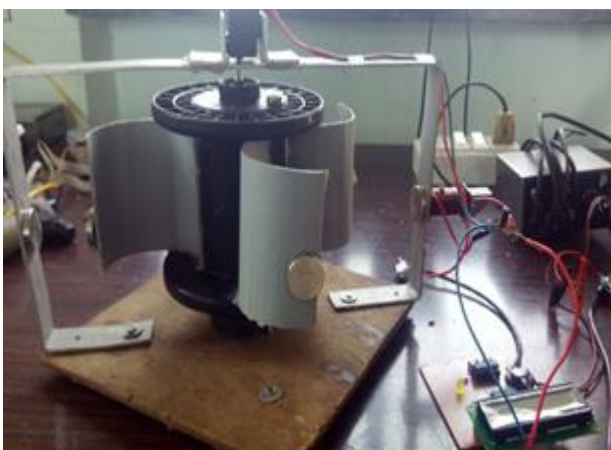


Figure 3: Basic Magnet Placement

5. Modelling



6. Analysis

Solid Edge is a computer-aided design (CAD) system for mechanical assembly, part modelling, and drawing production. Developed by STREAM Technology [6] with an interface that ensures maximized user productivity and return on investment. Solid Edge has separate environments for creating parts, constructing assemblies, and producing drawings. Each environment is self contained.

The Darrieus wind turbine is a type of vertical axis wind turbine (VAWT) used to generate electricity from the energy carried in the wind. The turbine consists of a number of curved aerofoil blades mounted on a vertical rotating shaft or framework. The curvature of the blades allows the blade to be stressed only in tension at high rotating speeds. There are several closely related wind turbines that use straight blades. This design of wind turbine was patented by Georges Jean Marie Darrieus, a French aeronautical

engineer in 1931. There are major difficulties in protecting the Darrieus turbine from extreme wind conditions and in making it self-starting.



Parameters	Values
Number of blades(N)	3
Rotor radius (r)	1.25m
Height of rotor (h)	3
Chord (c)	0.4m
Aerofile profile	NACA0015
Free stream wind speed	6,8,10m/s

Savonius wind turbines are a type of vertical-axis wind turbine (VAWT), used for converting the force of the wind into torque on a rotating shaft. The turbine consists of a number of aerofoils, usually—but not always—vertically mounted on a rotating shaft or framework, either ground stationed or tethered in airborne systems.



Savonius Wind Turbine

Parameter	Value
Power generated	41.4W
Swept area	0.72m ²
Rated wind speed	12 m/s
Aspect ratio	2
Tip speed ratio	1.0
Number of blades	2
Diameter –Height	60cm -120cm
End plate diameter	120cm
Blade thickness	2mm
End plate thickness	20mm

7. Result and Discussion

This section describes the results of our testing and shows how we compared our split Savonius design with the previous 4 flat bladed design and aerofoil designs. The results also address the use of having funnels attached to shrouds, in hope of increasing power output. Lastly, the results will show the analysis of the vibration testing performed on the model house.



Result of vertical axis wind turbine

8. Conclusion

Over the entire magnetically levitated vertical axis wind turbine was a success. The rotors that were designed harnessed enough air to rotate the stator at low and high wind speeds. The wind turbine rotors and stator levitated properly using permanent magnets which allowed for a smooth conduction. At moderate wind speeds the power output of the generator satisfied the specifications needed to supply the LED load. Lastly the circuit operated efficiently and to the specifications that were slated at the beginning of the circuit design. After testing the project as an overall system we found that it functioned properly but there feel limited the amount of power it could output.

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