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Magnetic Levitated Windmill

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***Abstract*— Magnetic levitation is a method by which an object is levitated with magnetic fields. The principal advantage of a maglev windmill from a conventional one is, as the rotor is floating in the air due to levitation, mechanical friction is totally removed. That makes the rotation possible even at very low wind speeds. Maglev wind turbines have several advantages over conventional wind turbines. For instance, they're able to use winds with starting speeds as low as 1.56 meters per second (m/s). Also, they could operate in winds exceeding 40 m/s.**

***Keywords* — Power Generation, Wind Energy, Magnetic Levitation, Magnets)**

I. INTRODUCTION

Renewable energy is generally electricity supplied from renewable sources, such as solar power, wind power, hydropower, geothermal energy, and various forms of biomass. The popularity of renewable energy has increased 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 supported by research and innovative technology that has been introduced so far to aid in the effective tapping of these natural resources. It is estimated that renewable sources might contribute about 20% – 50% to energy consumption in coming years 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 expected net growth rate of more than 21% per year. The main focus of this project is to improve utilization of wind energy as a renewable source.

The aim of this project is to design and implement a magnetically levitated vertical axis wind turbine system which can operate in both high and low wind speed conditions. Our choice for this model is to showcase its efficiency in deviating wind conditions as compared to the traditional horizontal axis wind turbine and contribute to its growing popularity for the purpose of mass utilization in the near future as a dependable source of power generation. Unlike the traditional horizontal axis wind turbine, this design is levitated by magnetic levitation vertically on a rotor shaft. This magnetic levitation technology, which will be discussed in detail, serves as an efficient replacement for ball bearings used on the conventional wind turbine. 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 helix-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 appropriate 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 try to acquire an effective magnetic field and the copper coils will facilitate voltage capture due to the changing magnetic field. The varying output voltage obtained at this stage will then be passed through a DC-DC converter to achieve a steady output DC voltage.

II. MAGNETIC LEVITATION

Magnetic levitation is also known as maglev, this phenomenon works 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 magnetic levitated trains and with ongoing research its popularity is increasingly attaining new heights. Using a pair of permanent magnets like neodymium magnets and solid support magnetic levitation can easily be observed by placing these two magnets on top of each other with like polarities facing each other, the magnetic repulsion will be sufficiently strong to keep both magnets away from each other. The force created as a result of this repulsion can be used for suspension purposes and is strong enough to stabilize the weight of an object depending on the threshold of the magnets. In this project, we will be implementing this technology for the purpose of achieving vertical orientation with our rotors as well as the axial flux generator.

A. *Magnet Selection:*

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

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magnetic properties. The four different classes are Ceramic, Alnico, Samarium Cobalt and Neodymium Iron Boron also known Nd-Fe-B. Nd-Fe-B is the new addition to this commercial list of materials and at room temperature shows the highest properties of all of the magnetic materials. It can be seen in the B-H graph shown in Figure that Nd-Fe-B has a very strong attractive magnetic characteristic which offers high flux density operation and the ability to resist demagnetization. This attribute will be very important because the load that will be levitated will be heavy and rotating at high speed which will cause a large downward force on the axis.

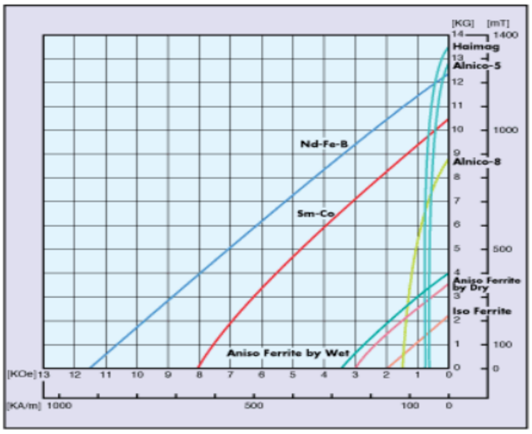

Fig 1. B-H Curve of Various Magnetic Material

Size and shape of magnet is related to the placement of the magnet. It is evident that levitation would be most effective on the central axis line under a distributed load, the wind turbine center of mass will be found as seen in Figure. This figure shows a basic function of how a maglev functions. If the magnets where ring shaped then they could easily be slid tandem down the shaft with the like poles facing toward each other. This would enable the repelling force required to support the force and weight of the wind turbine and minimize the amount of magnets needed to complete the concept.

B. Magnet Placement:

Two ring type neodymium (NdFeB) magnets of grade N-52 of outer diameter 50 mm, inner diameter 30 mm and thickness 20 mm are placed at the center of the shaft by which the required levitation between the rotor and the stator 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. These magnets are responsible for the useful flux that is going to be utilized by the power generation system.

III. TYPES OF WIND TURBINE:

Many types of turbines exist today and their designs are usually falls in one of the two categories: horizontal-axis wind turbines (HAWTs) and vertical-axis wind turbines (VAWTs). As the name suggests, each turbine is distinguished by the orientation of their rotor shafts. The former is the more conventional and common type everyone has come to know, while the latter due to its rarely usage and misuse, is quiet unpopular.

A. Horizontal Axis Wind Turbine:

The HAWTs usually consist of two or three propeller-like blades attached to a horizontal and mounted on bearings the top of a support tower as seen in Figure 2.

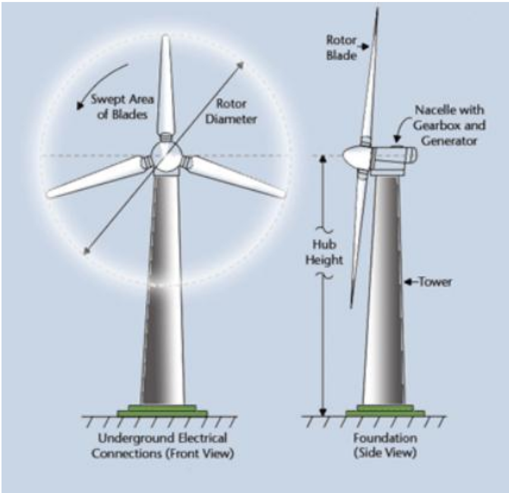

Fig 2. Horizontal Axis Wind Turbine

When the wind blows, the turbine blades are set in motion which drives a generator that produces AC electricity. For maximum efficiency, these horizontal turbines are usually made to point towards the wind with the aid of a sensor and a servo motor or a wind vane for smaller wind turbine applications.

B. Vertical Axis Wind Turbine:

With the vertical axis wind turbines, the concept behind their operation is identical to that of the horizontal designs. The major difference is the orientation of the generators and rotor which are all vertically arranged and generally on a shaft for support and firmness. This also results in a different response of the turbine blades to the wind in relation to that of the horizontal configurations. A normal vertical axis design is shown in Figure 3.

Vertical axis wind turbines are further divided into two major types namely the Darrieus model and the Savonius model. Pictured above in figure is an example of the Darrieus Model. This form of the design is best described as an eggbeater with cup shaped two or three blades on the shaft.

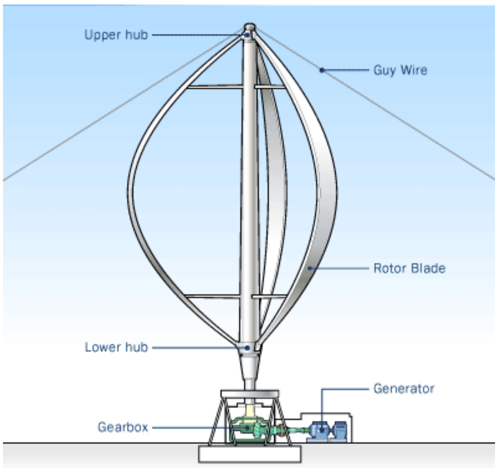

Fig 3. Darrieus Model of Vertical Axis Wind Turbine

The Savonius model was invented by Finnish engineer Sigurd Savonius and an example is shown in Figure 4.

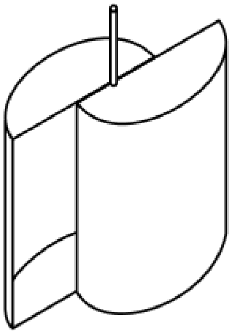
Fig 4. Savonius Model of Vertical Axis Wind Turbine

The functioning of this model is dependent on drag forces from the wind. This force produced is a differential of the wind hitting by the inner part of the scoops and the wind blowing against the back of the scoops. Like the Darrieus model, the Savonius turbines will also work with winds approaching in any direction and also work well with lower wind speeds due to their very low clearance off the ground.

IV. BLADE DESIGN:

The blades used in this prototype are of hybrid design. We took a bit of a different approach in our design compared to the Savonius design. This design was attained with four rectangular shapes cut out from acrylic sheet and due to the light weight of the acrylic sheet, we were able to rotate the rotor at low wind speed. The height of blades were 400mm.

V. POWER GENERATION:

When designing a generator it is important to have a firm understanding 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 depends on the magnitude of the field density and the coil area. The relationship between the area and field density is known as flux (Φ). The way in which this flux fluctuates 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,

$$V= -N(d\Phi/dt)$$

A. Power of wind

When wind is blowing the energy is in kinetic form due to the motion of the wind so the power of the wind is related to the kinetic energy.

We know,

$$KE =1/2\ MV^2$$

The volume of air passing in unit time through an area A, with speed V is AV and its mass M is equal to the Volume V multiplied by its density ρ so:

$$M= \rho AV$$

Substituting the value of M in equation above we get:

$$KE=1/2\ (\rho AV)\ V^2$$

$$KE=1/2\ \rho AV^3$$

To convert the energy to kilowatts, a non-dimensional proportionality constant k is introduced where,

$$K = 2.14\times10^{-3}$$

Therefore,

$$\text{Power in KW (P)} = 2.14\rho AV^3\times10^{-3}$$

Where:

Air Density (ρ) = 1.2 kg/ 3/2.33x 10^{-3} slugs/f 3
Area (A) = Area swept by the blades by the turbine
Velocity (V) = wind speed in m/s

With the above equation, 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 for generation.

The power harnessed from the wind cannot exceed 59% of the overall power in the wind. Only a portion can be used and that usable portion is only assured depending on the wind turbine being used and the aerodynamic characteristics that accompany it.

B. Induced EMF:

In order to explain how a flux generator is designed the elements that produce an electromotive force or voltage must be explained. An induced EMF is produced by a time varying magnetic field. Faraday performed experiments with a simple transformer and steady currents in hopes of producing a voltage from a magnetic field. He discovered that a constant magnetic field would not induce a voltage but a time varying field can. This was very important discovery in EMI, a discovery that is fundamental in the design of a generator. It is this relative motion of a magnetic field producing a voltage that allows us to be creative in the ways we produce electricity.

C. Magnetic Flux:

The magnitude of the magnetic flux is greatest when the field is perpendicular to the coil in a magnetic field. In the design of an axial flux generator it is best to keep the coils perpendicular to the field produced by the permanent magnets. In numerous conventional motors a winding rotates inside a magnetic field. The number of windings is increased so that each winding is positioned close to 90 degrees to the field. In our design the angle between the coils and the field does not change, instead the field itself varies with time. Faraday's law of induction states that the induced EMF is equal to the change in magnetic flux over the change in time.

$V = -d\text{Ø}/dt$

VI. COIL ARRANGEMENT:

26 gauge wires of about 1000 turns each are used as coils for power generation. 8 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.

VII. ENERGY STORAGE:

Energy storage is useful only if available where and where it is wanted. Carrying energy to where it is wanted is called as distribution and keeping it where it is wanted is called as storage. There different types of energy storage. Those can be classified on the basis of the form in which energy is stored. Naming a few of energy storage system, they are as follows: flywheel and pumped storage comes in mechanical form of energy storage where as lead battery comes under the electrical form of energy storage. Hydrogen cell and ammonia cell comes under chemical for of energy storage and other few forms of energy storage cold be electromagnetic energy storage ,thermal energy storage, biological storage. In ML-VAWT we will be probably using the lead acid battery as it is compact in size and secondly we only need to save energy for household type work in our prototype.

A device that has electricity both as input and output is called as storage battery. Battery forms an essential component of almost all a photo voltaic and small electric system. When a battery is charged by connecting it into a source of DC the chemical chances occur I the battery materials. As a result electrical energy is converted into stored chemical energy. When a battery is discharged by connecting a load between the terminals the chemical reactions are reversed and stored chemical energy is re-converted into electrical energy. The energy recovery efficiency of the system lies between 70-75% .

VIII. CONCLUSION

The use of Magnetic Levitated Windmill increases efficiency and reduces vibrations compared to VAWT with mechanical bearings. Due to lower friction the ML-VAWT becomes more efficient. The quality of working at a lower wind speed gives the new scope of wind energy for future fuel generation ie. Even at residential area or on roof tops. This gives the user a free and green energy. The future scope for ML-VAWT could be using it with a hybrid system.

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