"Design and Fabrication of Magnetically Levitated Wind Turbine for Power Generation"

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Abstract— Magnetic levitation is a method by which an object is suspended above another object with no support other than magnetic fields. The electromagnetic force is used to counteract the effects of the gravitational force. Magnetic levitation is used to reduce the energy loss due to friction. This energy wasted in friction can be saved by maglev method. This thesis proposes a method to implement non-conventional source of energy for the generation of electricity. A vertical axis wind turbine is introduced by magnetic levitation technology to optimize the performance. The system utilize nature of permanent magnet as a replacement for ball bearings to levitate the turbine component and thus minimize energy losses while rotating, which is the major problem that faced by conventional wind turbine. Furthermore, the system can be suited in use for rural and urban areas of low wind speed regions. The selection of magnet materials in the design of wind turbine system will be discussed. A model of wind turbine is built to perform several tests such as starting wind speed, rotational speed at constant wind speed, and time taken to stop rotation completely. The results obtained will be compared with the model of conventional wind turbine. Power will then be generated with an axial flux generator, which incorporates the use of permanent magnets and a set of coils. Magnetic levitation, maglev, or magnetic suspension is a method by which an object is suspended with no support other than magnetic fields. Magnetic pressure is used to counteract the effects of the gravitational and any other accelerations.

Key words: Wind Power Generation, Magnetic Levitation, Magnets

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. This paper 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 work 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. LITERATURE SURVEY

Huachun Wu etal,[1] carried out study on magnetic levitation wind turbine for vertical type and low wind speed and geometric parameters were optimized using FEM analysis. The system dynamic analysis was performed. 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. The modeling and implementation of an axial position controller was presented, the simulation results show stable levitation and good levitated rotation.

Santosh kumar Chaturvedi etal, [2] An experimental investigation of maglev wind generator using savonius rotor. In the design, stator had 10 set of coils in 10 slots with each coil having 300 turns of copper wire measuring resistance of 40Ω; a smaller gage wire would further reduce this resistance. For rotor, two circular plates containing 10 permanent magnets of ferrite type with the powers of 2500 gauss each were used with an angular distance of 36 degree equal to the distance between two coils. The magnets placed on these two plates create the magnetic fields. The output of 8.48V was obtained. To get more output, turbine's own inertia's be reduced by using lighter weight materials for turbine. So that for the same wind speed it will rotate faster, hence it will generate more power.

Minu John etal,[3] carried out an experimental study on vertical axis windmill working on maglev using Nd-Fe-B ring shaped permanent magnets of grade N-42 of outer diameter 40 mm, inner diameter 20 mm and thickness 10 mm placed at the center of the shaft by which the required levitation between the stator and the rotor was obtained. Similar disc type magnets of 30 mm diameter and 4mm thickness were arranged as alternate poles one after the other, along the periphery of the rotor made of acrylic of 40mm diameter. 26 gauge wires of 1000 turns each were used as coils for power generation. 12 sets of such coils were used in the prototype and were arranged in the periphery of the stator exactly in a line to the arranged disc magnets. The output voltage obtained from this prototype was a maximum of 45 volts DC.

Dinesh N Nagarkar etal,[4] carried out study on construction and working of magnetic levitation based power plant which has colossal structure where blades were placed vertically along the outer rim of the cylinder. Since the whole assemblage was levitated by permanent magnets there was no friction which allowed the wind turbine to transform all the wind energy into electrical energy thus increasing output and reducing cost. The benefit of having it floating in midair is that it cuts down on the friction that causes so much inefficiency in the traditional windmill. It would also increase generation capacity by 20% over conventional wind turbines and decrease operational costs by 50%. It reduces maintenance costs and increases the lifespan of the generator. Magnetic levitation is an important development to reduce stress from the mechanical load on the wind turbine.

Amit D. Patil etal,[5] designed a prototype model of a VAWT using magnetic bearing. The rotors that were designed harnessed enough air to rotate at low and high wind speeds while keeping the centre of mass closer to the base yielding stability. The wind turbine rotor levitated properly using permanent magnets, which allowed for a smooth rotation with negligible friction. The no. of blades hub is 4 selected to use in project. (Width= 0.1cm, breath= 10cm, height= 26cm.)Other component which is mounted on the base are emf generator, charging circuit, battery. (Model: Height= 45cm, length= 38cm, width=1.5cm. The output voltage obtained from this prototype is measured using a multi-meter and a maximum of 5volts DC was obtained.

Aravind CV etal.[6] carried design procedure and analysis of vertical axis wind turbine using magnetic levitation where gears were replaced with direct drive technology, thereby reducing the maintenance and power loss. Bearing were replaced with magnetic levitation. From the analysis he concluded that the introduction of maglev to the VAWT increases the efficiency and reduces the vibration with by 30% compared to that of the turbine without mechanical bearing.

Nirav Patel etal,[7] incorporated use of magnetic levitation concept using the rare earth permanent magnets between dual rotors to reduce the losses. A novel design and performance improvement of an axial flux PM generator has been presented in this paper. Friction between rotors and stator has been made minimal using passive magnetic levitation in AFPM generator. Moreover, the design helped to reduce the noise and vibration which has been a big issue by AFPM generators in residential area. Additionally, bearing less design reduces the maintenance cost and enhances the life span of the system. Savonius type model of VAWT has been presented for AFPM generator which is very simple design and can run at low wind speed according. The uniqueness of the proposed work was the dual rotor levitating turbine, which was more efficient than the few existing single rotor levitating turbines.

Kamalinni etal,[8] paper presented the design component aspects of a Magnetically levited Vertical Axis Wind Turbine and reported the result analysis using an modified magnetic circuit. A dual magnetic surface was attached into the structure through an external mechanical structure to reduce the mechanical oscillations. The system was then investigated with and without the maglev structure. It is found that the vibrations are reduced by 37.5%.Computational fluid dynamics based finite element approach is used for the analysis on the blade design and the positioning of the blade on the rotor. The lift and drag characteristic of the airfoil was investigated using the FEA tool. The optimal angle is at 30° with respect to the wind approach was determined.

B. Bittumon etal,[9] carried out research on combined savonius and darrieus rotors which is very scarce. He designed and analyzed a Maglev VAWT using 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. This developed a two bucket savonius rotor and placed it on the central shaft of a traditional darrieus. Using a counter rotating wind turbine with a freely rotating generator can produce higher amounts of power than common wind generators.

Shahrukh Adnan Khan etal,[10] analyzed performance of a three phase Permanent Magnet Synchronous Generator(PMSG) connected to a Vertical Axis Wind Turbine(VAWT). The entire simulation was carried out in Matlab/Simulink environment and then the generator was fabricated and tested in a laboratory and compared with the simulation result for error analysis for power upto 1.5KW under different operating scenario. The range of error was about 5-20% for the same output power value.

III. MAGNETIC LEVITATION PRINCIPLE

Magnetic levitation, maglev or magnetic suspension is a method by which an object is suspended above other with no support other than magnetic field. The electromagnetic force is used to counteract the effect of gravitational force. Magnetic Levitation Magnetic levitation is known as maglev and this phenomenon works on the principle of repulsion characteristics of permanent magnets this technology has been mainly used in the railway industry in the Far East to provide very fast and reliable transportation on magnetic levitation trains and with ongoing research its popularity is increasingly attaining new heights. Neodymium magnet pair is used for magnetic levitation and substantial support can be easily experienced.

By placing these two neodymium magnets on top of each other on the same poles for making repulsion on each other the magnetic levitation or repulsion will be strong enough to keep both magnets at a distance away from the each other. Repulsion force or levitation is also used for suspension purpose and its strong to balance the weight of an object depending on the verge (threshold) of the magnets in this project we expects to implements this technology from the purpose of achieving vertical orientation with our rotor as well as axial flux generator.

IV. OBJECTIVES

1) To design a small scale, cheaper Vertical Axis Wind turbine (VAWT) which can be installed in small areas such as balconies of houses, terrace etc.
2) To design it in such a way that, it can generate enough energy to take part small load of households electricity requirement.
3) RPM measurement of wind turbine.
4) Voltage of out coiling
5) Wind direction.
6) Battery voltage monitoring
7) Data manning for data broadcasting
8) Data monitoring using window base application software

V. METHODOLOGY

The basic working principle of a wind turbine is that when the air moves quickly, in the form of wind, the kinetic energy is captured by the turbine blades. The blades rotate and spin the shaft that leads from the hub of the rotor to a generator and electricity is produced. The high speed shaft then drives the generator to produce electricity.

The low speed shaft of wind turbine is connected to shaft of high speed drives through gears to increase their rotational speed during operation. Using the effects of magnetic repulsion, semicircular shaped wind turbine blades will be fitted on a rod for stability during rotation and suspended on magnets as a replacement for ball bearings which are normally used on conventional wind turbines.

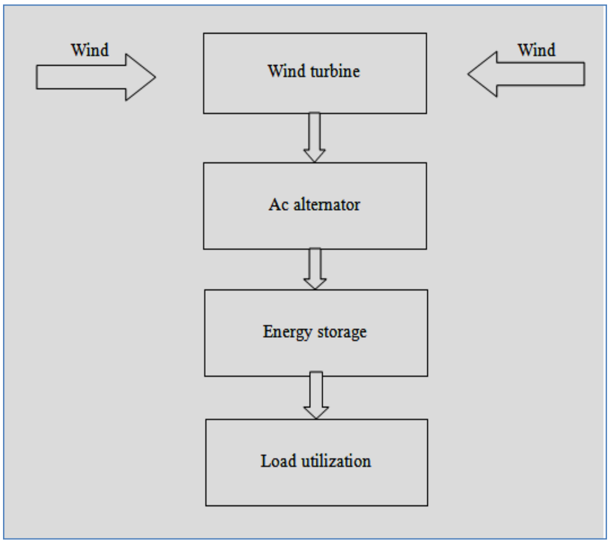

Fig: 1: Block diagram of wind power generation

VI. MODELLING

Figure gives an idea of Magnetic Levitated Wind Turbine. As stated above, it operates on the repulsion property of permanent magnets. 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 certain distance way from each other.

The force then created as a result of this repulsion can be further utilized for suspension purposes and is strong enough to balance the weight of an object depending on the threshold of the magnets. Power will then be generated with an axial flux generator, which incorporates the use of permanent magnets and a set of coils.

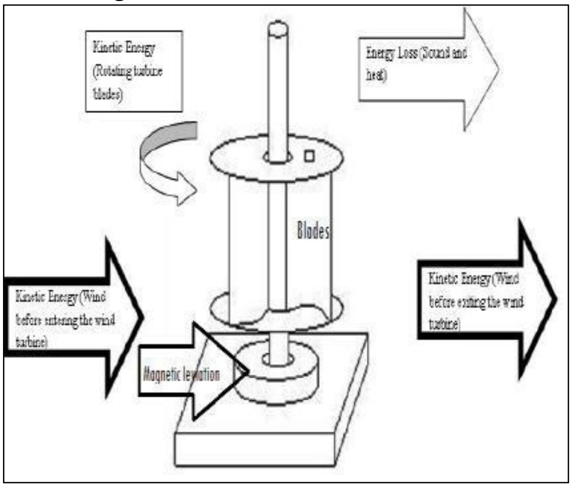

Fig. 2: Working Model of Maglev Wind Turbine

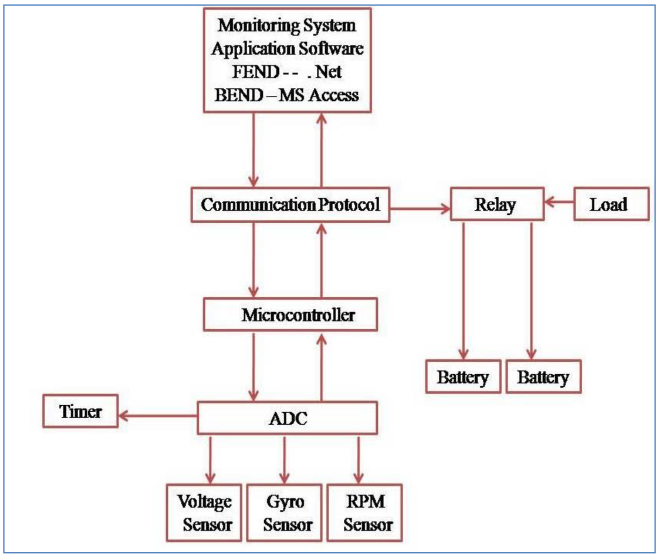

Fig. 3: Block diagram of VAWT interfacing with Monitoring System

VII. DESIGN & CONSTRUCTION

The generated power is in form of DC, stored in battery, this can be used to directly supply the DC loads and can also be converted to AC using inverter to supply AC loads. It can be used as OFF grid and ON grid as shown in above figures. Wind power is a proven and highly effective way to generate electricity. Maglev technology is the most efficient means of transferring kinetic energy to generate electricity.

$$Pw = \frac{1}{2} MAu^3 \quad [1]$$

Where

Pw: power of the wind (W)

M: air density (kg/m^3)

A: area of a segment of the wind being considered (m^2)

u: undisturbed wind speed (m/s)

$$Pm = \frac{1}{2} M (16/27\ A\ u^3) \quad [2]$$

Where

Pm: mechanical power (W)

The constant 16/27 = 0.593 from equation [2] is referred to as the Betz coefficient. The Betz coefficient tells us that 59.3% of the power in the wind can be extracted in the case of an ideal turbine. For a VAWT, this area depends on both the turbine diameter and turbine blade length.

For VAWT the equation for swept area is,

$$As = D_t\ l_b \quad [3]$$

Where

As: swept area (m^2)

D_t: diameter of the turbine (m)

l_b: length of the turbine Blades (m)

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

$$\mathbf{Fw = Cd^2\ A\ \frac{Uw - Ub}{2}}$$

Where,

A - Swept area of the blade

ρ - Air density (about 1.225 kg/m^3 at sea level)

Uw - Wind speed

C_d - The drag coefficient (1.9 for rectangular form)

U_b - The speed on the blade surface.

VIII. CHOICE OF NUMBER OF BLADES

The choice of the number of blades of a wind rotor is critical to its construction as well as operation. Usually the greater number of blades is known to create turbulence in the system, and a lesser number won't be capable enough to capture optimum wind energy. Hence the no of blades to install should be determined by considering both of these constraints. There are several parameters involved in the design of an efficient yet economical wind turbine. Generally and efficient design of the blade is known to maximize the lift and minimize the drag on the blade.

IX. DIAMETER OF ROTOR AND STATOR CASTING

Since the power generated is directly proportional to the square of the diameter of the rotor, it becomes a valuable parameter. It's basically determined by the relation between the optimum power required to be generated and the mean wind speed of the area.

Power generated, $P= \eta_e\ \eta_m\ Cp$

$P =1/2\ \eta_e\ \eta_m\ Cp\ A\rho V^3$

$P = 1/8\ \eta_e\ \eta_m\ Cp\ \pi\ D^2\rho V^3$

Where, η_e= efficiency of electrical generation

η_m= efficiency of mechanical transmission

In the absence of concrete data, the following empirical formulae can be used.

$P = 0.15\ V^3D^2$, for slow rotors

$P = 0.20\ V^3D^2$, for faster rotors.

A rotor is rotating part of a mechanical device, for example in an electric motor, generator, alternator or pump. It operates with a stationary element so called stator.

1) CREO 3D PIC:

The tools we used to design this rotor disks in CREO 2.0 are PART MODELING and ASSEMBLING.

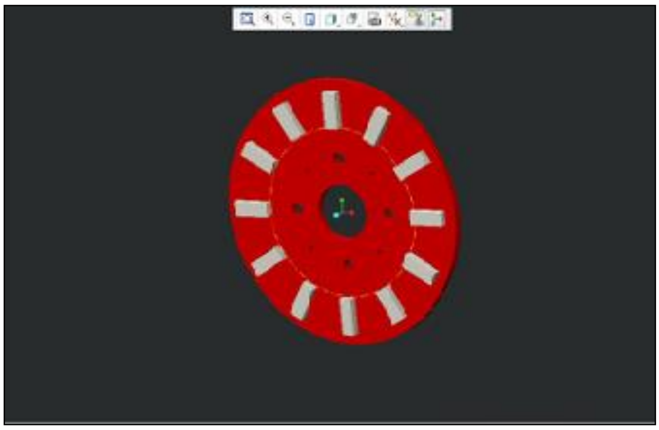

Fig. 4: CREO 3D 2.0 (Rotor 3-D Model)

2) Cast the stator:

Once the coils have been connected they must be cast in a resin mixture with some fiberglass to add strength. This will provide mechanical strength and waterproofing for the stator coils.

Fig. 5: Stator

The stator casting process is as follows. It is best to have a 'dry run' without any resin to ensure that everything will go smoothly.

1) Check the mould and ensure all the pieces (base, outer, centre, lid, nuts and bolts) are ok.
2) Put a ring of silicon sealant around the base to seal the base to the outer section and the base to the centre piece. Ensure these are in the correct position by using the bolts to line them up. The silicon sealant will stop any of the resin from leaking out of the mould.
3) Cover the area where the stator will be produced with scrap newspaper.
4) The mould then requires waxing to ensure that the stator is released easily and will not stick to the mould. 'Wax' is used for this purpose. This must be applied liberally with a soft cloth. Ensure all surfaces that may be exposed to resin are covered. This must then be buff dried using a clean cloth or electric buffer. Repeat this process at least five times so that a thick layer of wax is built up. The mould can then be used.
5) Next cut out two pieces of chopped strand fibre glass mat. These should be cut to the same size as the stator, with a hole in the middle. Use the mould as a template to draw on the fibre glass mat and then cut slightly inside the line to ensure the mat fits comfortably into the mould.

X. TYPES OF MAGNETS

A force-field that either pulls or repels certain materials, such as nickel and iron. Of course, not all magnets are composed of the same elements, and thus can be broken down into categories based on their composition and source of magnetism. Permanent magnets are magnets retain their magnetism once magnetized.

Temporary magnets are Permanent magnets materials magnets that perform like permanent magnets when in the presence of a magnetic field, but lose magnetism when not in a magnetic field. Electromagnets are wound coils of wire that function as magnets when an electrical current is passed through. By adjusting the strength and direction of the current, the strength of the magnet is also altered

Fig. 6: Temporary magnets

1) Permanent Magnets

There are typically four categories of permanent magnets: neodymium iron boron (NdFeB), samarium cobalt (SmCo), alnico, and ceramic or ferrite magnets.

2) Neodymium Iron Boron (NdFeB)

This type of magnet is composed of rare earth magnetic material, and has a high coercive force. They have an extremely high energy product range, up to 50 MGOe. Because of this high product energy level, they can usually be manufactured to be small and compact in size. However, NdFeB magnets have low mechanical strength, tend to be brittle, and low corrosion-resistance if left uncoated. If treated with gold, iron, or nickel plating, they can be used in many applications. They are very strong magnets and are difficult to demagnetize.

Fig. 7: Permanent Magnets

XI. SYSTEM PARAMETERS

Sr. No.	Parameters	Detaeils
1	Blade Material	PVC
2	Supporting Material	Acrylic
3	Blade Quantity	3
4	Diameter	30 cm (base)/ 45 cm (bottom)
5	Height	65 cm
6	Turbine Weight	< 2 Kg
7	No. of Magnet	32
8	Maglev Magnet	Ferranti Magnet
9	ADC 0804	Quantity 1
10	Microcontroller 89C51	Quantity 1
11	MAX232A	Quantity 1
12	Temperature sensor LM35	Quantity 1
13	Design of Blades	45 Degree,30 cm
14	Coil turns	500 turns

Table 1: System Parameter

XII. HARDWARE & SOFTWARE

Following hardware and software are required for complete interfacing of VAWT

1) front end-vb.net
2) Back end ,data base
3) Op-amp
4) ADC
5) Microcontroller
6) Serial communication protocol

XIII. RESULTS

1) The output voltage obtained from this prototype is measured using millimeter and a maximum of 12 V AC was obtained. 16 guage wire of 500 turn each are used as coils for power generation. 5 set of such coils are used in the prototype. On increasing number of turns, output voltage can be increased.

Wind velocity (m/s)	Ac Voltage (rms) in volts
0.7	3
2.3	4
4.4	7
5	8
6.1	10
7	12

Table 2: Wind velocity Vs Voltage

2) As we have designed vertical axis wind turbine for small scale purpose, it is expected for lightening in the rural areas.
3) Stored energy in battery is utilized to light the bulbs ranging from 5 to 40 watt bulbs.
4) Further it can also be used for charging small devices like mobile phone.
5) Temperature of wind is measured with the help of temperature sensor LM35 which is interfaced with monitoring system.

XIV. CONCLUSION

1) A single large Maglev turbine can output more than conventional horizontal wind turbines. The rotor that is designed harness enough air to rotate the stator at low and high wind speeds while keeping the center of mass closer to the base yielding stability due to the effect of magnetic levitation.
2) The efficiency of turbine is increased by replacing the bearings by magnets, the magnetic levitation helps the turbine to spin at much faster rate as it will the stress on the shaft of the turbine.
3) The major components are placed at ground level. We can say the maglev turbine can power more output with high efficiency conversion compared to traditional wind turbine.
4) The system will provide electricity at a rate lower than coal and nuclear. Thus we believe this technology has the capacity to completely displace current technology in use for wind farm.
5) After testing the project as an overall system we found that it functioned properly but there are many things that can be improved upon. The stator and rotor itself had some design flaws which we feel limited the amount of power it could output. These flaws start at the coils which were initially made too thick and limited how close the magnets attached to the stator could be positioned from each other. If the magnets were pulled in closer to one another, the magnetic field density would be much greater allowing for more power to be induced into the coils.

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