Adaptable Bladeless Disc Wind Turbine

Raj Oak, Meet Lakhani, Avinash Gupta

Abstract—Disc Wind Turbine is a development of a new design of a wind turbine which does not use traditional air foil sectioned blades. The research involves developing a turbine that uses three discs mounted along the periphery of the central hub in specific geometry and convert the kinetic energy of the wind, much more efficiently into rotational mechanical energy which could further be converted into electrical power. The working principle of this technology along with the experimental findings obtained by directly comparing our design with traditional wind turbine is further elaborated. Finally, various pitfalls of a traditional turbine designs are being discussed which are effectively lessened or eradicated in the Disc Turbine design. The design was developed realizing the fact that there is immense wind energy potential and the existing technology is only able to harness a part of it into a usable form.

Index Terms— Disc Turbine, Drag, Adaptation, Wind, Electricity, Reaction force, Wind speed sensor, Low RPM.

1 Introduction

Wind power is one of the perennial sources of energy along with being available during day time as well as at night time almost throughout the year which could be harnessed from most of the parts of the planet. But modern day wind turbines could convert only upto around 45 percent of the total energy content in the wind. Along with this the space constraints are a major concern in any developing or developed country and this should be considered as one of the major factor when energy generation through wind power is at stake since wind energy generation requires a considerable amount of free space. Considering all these factors, Disc Turbine design is a new form of wind turbine, requiring less amount of space along with being able to convert most of the wind power into usable energy and minimize various difficulties associated with conventional wind turbine design related to on-field application. This design uses three disc shaped rotors along the central hub with adaptability depending on wind conditions by a servo mechanism. This is one of a kind unique design of a wind turbine which uses radically different concepts for wind power trapping and apt for increasing future energy demands.

2 Description

Wind energy is being used since a long time for generating useful work like cruising a ship through ocean to grinding grains in mills powered by wind to modern electrical energy generation by harnessing this immense wind power.

A conventional turbine uses an aerodynamic lift and reaction force generated while wind moves past each blade. These turbines generally have three blades with relatively smaller width compared to the length equally spaced from each other and have a large amount of unoccupied space between these blades. This is explainable since these conventional turbines generate power by the means of flow concept, which means that greater the velocity of wind flowing over these blades the greater will be the power generated, and hence if three blades, with relatively small width are designed then it would create less overall drag force and the wind could easily move with same speed over the blades. If the number of blades is increased to around six or ten then there would be a large drag force offered to the flowing wind and the velocity of the wind flowing past each blade would decrease and hence would develop less power along with increase in cost of additional blades and weight constraint.

Due to this a traditional turbine has small width of blades, in order to prohibit the decrease in the wind speed due to drag effect and letting most of the upcoming stream of wind to be passed over the blades and develop the motive power.

Disc Turbine utilizes the drag force which caused a problem in the traditional turbine design as the main source for generating the motive power. Along with this, our design is capable of utilizing the reactive force generated by the wind while leaving the turbine blades, similar to the force generated by a jet of water leaving a nozzle.

3 Limitiations of current design

The traditional design of the wind turbine is less efficient, consuming great amount of space and providing low output electrical energy. The cost of the entire wind farm project is very high and this could be the main reason for reluctance to most of the wind energy projects.

The manufacturing facilities required for construction of massive blades of turbine are not cost effective to build. The transportation cost involved in carrying huge and heavy machinery is high. Along with this the set up measures required to assemble the traditional wind turbine on site are quite cumbersome and involves a high amount of risk.

The blades of the turbine are made sharp to minimize the wind resistance, but these sharp edges take lives of thousands of migratory birds and bats all over the world [1].

• *Raj Oak, Meet Lakhani, Avinash Gupta are currently pusuing bachelors'degree program in Mechanical Engineering at Thakur College of Engineering, Mumbai, India.*

The allied cost involved with the traditional technologies like the cost involved in raw materials, manufacturing, labour, transportation and on site assembly are substantially high and this makes it less practical for implementation for any governmental or non-governmental organisation and are naturally gravitated towards the fossil fuel based energy source which are cheap but pernicious to our environment.

Limitations of the traditional wind turbines are low torque for the given wind flow. These turbines are effective only when wind speeds are quite high, they are inefficient in low wind conditions. Some of the available designs harnessing low wind speeds are only capable of intercepting surface wind and hence are unable to capture full potential of the wind like the Invelox System [2].

4 History

In 2004 Shawn Frayne invented a bladeless wind energy harvesting technique which is based on the aeroelastic flutter of a polymer film held against the wind. The electrical energy is generated as the magnets attached at the ends of the polymer strip exibit a to and fro motion and electric current is induced in the copper coil held nearby [3].

In 2013 a startup Vortex Bladeless S.L presented a turbine with no blades which used a phenomenon called vortex shedding. This technology uses a fiber glass based column which sways in wind due to the vortices of air caused on either side due to its specific design and converts the linear motion into electrical energy [4].

A Tunisian startup Saphon Energy has developed a similar bladeless single disc designed turbine which converts wind energy into mechanical energy and then into hydraulic energy by pistons inside the hub. The hydraulic energy could be converted into usable electrical energy by a hydraulic motor. As the design uses single disc, it has a tendence to wobble and the structure starts shaking in high winds [5].

5 Design

Our design is inspired from the canopy of the umbrella and the sails of the ship. We realized that immense drag force is produced when the gust of the wind is obstructed by a specific geometry such as the canopy of an open umbrella. An umbrella held in the wrong direction against the wind could generate a huge amount of drag force enough to overturn the entire fragile umbrella structure. The sails of the wind work in a similar manner by trapping large portion of the wind flow and converting into drag force which inturn propels the ship further. By altering the angle of attack of the wind with respect to the sail, a component of the drag force could be utilized for changing the direction of ship. We combined the two concepts of umbrella canopy producing immense drag force and changing the angle of attack could make the drag component work in the required direction. If this force component is made to work in a tangential direction with respect to a shaft attached to the central hub, then a torque could be produced. The turning moment depends upon the diameter of each disc and the length of the shaft. The speed of the turbine will depend on the velocity of wind flow.

Our bladeless design of the turbine consists of three circular discs which are slightly concave or funnel shaped towards the wind facing direction. These three discs are fixed to a central hub by means of a connecting rod. All the three discs are mounted equally on the hub with 120 degrees angle between two consecutive discs. These three discs are given a certain angle so as to produce a tangential thrust effect required to generate rotary motion of the turbine. The preliminary prototype shown below is constructed with above specification as a proof of concept of our innovative turbine. The actual turbine would have an electrical servo motor attachment in the central hub to equally change the angle with which each turbine is attached. Another servo motor will be mounted on the whole generator turbine assembly in order to smartly adjust the front side of the turbine towards the wind direction or upstream direction. These servo motors would be using a small amount of electrical energy generated by turbine itself and smartly controlled by a microcontroller depending on the real time wind condition and the flow direction or directly through a base controller.

6 Working

Our design is inspired from one of the oldest source of wind energy harvesting technique which is the sail of a ship along with the shape of an umbrella. Sail ships are propelled by the huge drag force experienced by the massive sails which are kept at a certain angle with respect to direction of wind flow in order to steer the ship in the desired direction in the downstream of a wind current. Our turbine works in a similar way but allows the sails to rotate in order to obtain power, we are referring this technique as wind capture, and this will be discussed shortly. The another technology that we are using is the reactive force thrust generation, in which the wind when moves past the blades which are moving in relatively lesser speed than that of the wind impart some tangential reaction force while leaving the disc edge thus providing an extra moment towards the center. Yet another technology, which in fact is a controlling technology that we are using, is the adaptable blade technology in which the angle of these blades relative to the central shaft will be automatically changed depending upon the wind conditions. All these three key techniques are further briefed below.

6.1 Wind Capture Technique

As mentioned earlier our design is largely inspired from sail of the ship. A sail of the ship is used to provide a motive power for the ship to move. When the sail is tilted along the direction of wind one side of the sail faces the wind directly on its frontal area than the other sides of the sail, due to this high pressure is created on the windward side than other sail sides and the sail gets a pushing force from high pressure side. In a sail ship due to the angle of the sail, some wind power is utilized in moving the ship forward and some power in moving the ship sidewise since the high pressure side generates almost a perpendicular force to the wind velocity, but a ship utilizes a stabilizers and long fins submerged under water which minimizes this lateral movement and only allows forward thrust. Our disc will perform in almost a similar manner with the change being, our design would utilize the lateral force generated when wind is imparted on the discs.

Due to the disc design, wind will impose a huge drag force in the direction of the wind; again as these discs are angled relative to the central shaft, this drag force now could be resolved into two components one tangential component and other simple pushing force. This tangential component acting at the end of the connecting rod where the disc will be mounted is the most important factor as it would provide a turning moment necessary to rotate the turbine and hence the generator connected to the central shaft and produce electrical energy.

6.2 Reactive Force Technique

When the wind blows over the disc most of the kinetic energy of the wind is used to create the drag force when it is imparted on the discs, but still it contains enough energy to flow past the discs. These discs are angled, due to which one side of the disc is higher than the other side. The wind flows past these discs from the side which is slightly lower than the other side. Here the wind speed is still slightly higher than the tip velocity of the rotating disc and hence while leaving the disc it imparts some reactive force on the tip of the disc in the direction of motion of the disc tip. This force contributes to the total torque generated at the center and this torque can be calculated as the force times the distance between connecting rod disc attachments to the center of the shaft.

6.3 Adaptable Disc Technoloygy-

This is the technique which we have developed and it gives turbine the name adaptable bladeless disc wind turbine. An ideal turbine should provide almost constant power output in variable wind speeds and also offer a control over the turbine speed in case of emergency or high wind conditions. This control over the speed could be effectively achieved by changing the blade angle with respect to central shaft. When the wind flow is having a lower velocity the angle of all the blades could be increased due to which greater tangential forces would develop; when the wind speeds are very high, this angle will be reduced due to which lesser tangential force would be generated and hence the speed of the turbine could be maintained in the given range of wind speeds.

This change of the disc angle could be either made by a servo mechanism or by a mechanical means such as a torsion spring. Here we are initially using a tension spring which will make the entire system less bulky than a servo and a controller unit. The tension spring will be mounted between the connecting rod and the central hub inside the hub itself. Some initial tension would be maintained in the spring and when excess stress would develop due to high wind conditions the torsion spring would slightly twist thus twisting the connecting rod and eventually the disc angle and controlling the turbine speed in most of the variable wind conditions, acting like a mechanical governor system.

7 Proof of Concept

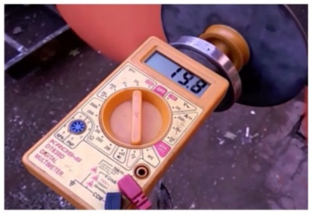
In order to realize the concept in the form of workable model a small scale model of Bladeless Disc Turbine was built and along with this a model of traditional three bladed wind turbine of similar dimensions was tested.

7.1 Experiment

An experiment was designed to compare the electrical output power produced from a traditional and the advanced design. Two turbines having the similar centre to tip distance were constructed and were exposed to the wind draft generated by a horizontal fan, the distance between the fan and the turbine was fixed for both the turbines under test to 7 meters. The fan was set to constant speed to generate approximately same wind speed as experienced by both the turbines.

Same Center to Tip Distance

7.2 Outcome and Conclusion



The experiment carried out under similar wind conditions displayed the higher efficiency of Bladeless Disk Turbine over a Traditional Wind Turbine. Our design was capable of producing a peak voltage of 19.8 volt DC as against the traditional one producing peak of only 7.1 volt DC. The average voltage generated by our design was around 16 volts DC and that for the other was around 5.5 volts. Disc Turbine is capable to produce voltage more than twice that for a traditionally made turbine. The area swept by both the turbines is same indicating that same power could be generated by the advanced design with consuming only half the space as occupied by a regular one.

8 Applications

Adaptable Bladeless Disc Wind Turbine is essentially a design for generating energy by harvesting the wind energy by consusuming minimum space and producing much higher power output and capability to work in low wind conditions. Due to this there is an immense scope in various fields which require energy to function.

The scaled version of such a turbine can be used for offshore wind-farm projects which work away from the coast and can generate adequate power to meet the demands of a small city. It could be effectively used for off grid power requirements where such turbine could suffice the need of small power requirement.

These kinds of turbines are well suited for military outpost and cities of developing and developed countries as it occupies less space and does not produce noise when it is operating. Along with this the huge disc could even capture the lightest breeze which enables it to produce electrical power in low wind conditions in cities.

9 Conclusion

Wind turbines are today primarily used for the purpose of generating electrical power without depending upon the depleting sources of fossil fuel. Wind Power has tremendous environmental benefits over any fossil fuel burning power station, but due to the massive size of these structures, their noise pollution in the locality, requirement of immense free space, constant high windy conditions, difficulty in transport of each fragile blade over long distance and a large amount of capital requirement has restricted the wide scale applications of all traditional wind turbines.

This research of Adaptable Blade Less Disc Wind Turbines aims at curbing various issues which cause the hindrance to the implementation of these power generators. This design requires much less space and can even produce power in very low wind speed conditions.

The material used for their construction would comprise of glass fiber central skeleton covered with a synthetic polymer fiber similar to the construction of an umbrella with a sophisticated design. Due to this the material cost of the turbine is much reduced. This kind of design can be constructed in modular fashion which facilitates the ease of transportation over long distances. Utilizing such kind of design would allow us to increase the energy production from the renewable source and eventually lessen the dependence over fossil fuel.

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