Analysis of Magnetic Levitated Savonius Wind Turbine

Vijayakumar K¹, D.Bubesh Kumar², N Shivakumar³
¹Research Scholar, ²Associate Professor, ³Assistant Professor
Department of Mechanical Engineering, Aarupadai Veedu Institute of Technology,
Vinayaka Mission’s Research Foundation, Deemed to be University, India.
E-mail: vijayakumar@avit.ac.in

Abstract. Vertical axis wind turbine is one of the types of savonius wind turbine; VAWT generates huge twisting moment when running under lower speed by wind. Savonius wind turbine is the self-starting turbine; it uses magnetic levitation principle to get high rotational speed for the Generator. Magnetic Levitation is the phenomenon in which anything can freely suspend in the air without any support with opposed of gravitational energy. This magnetic levitation occurred due to the repulsion between the two symmetrical poles. The strong levitation is occurred with the use of permanent magnets. This type of model is to show its greater efficiency in varying wind conditions as compared to the conventional horizontal axis wind turbine and contribute to steady growing popularity for the purpose of increased utilization in the recent future as a reliable source of power generation.

Keywords: Savonius Wind, Maganetic, Analysis, Computational fluid dynamics

1. Introduction

Renewable energy is a renewable source of energy, available in wind, sunlight, geothermal, rain and tides. In the coming years, solar power is the major energy to the world. It gives more energy and thereby reduces the environmental pollution. Wind energy is a type of energy used to make electricity, like fossil fuels or nuclear power. Vertical axis wind turbines, as shortened to VAWTs, have the main rotor shaft arranged vertically. The main advantage of this arrangement is that the wind turbine does not need to be pointed into the wind [1].

To tackle the tricky concept of converting wind to electricity, first we have to understand energy. Energy is the ability to do work or apply a force over a distance. A force is just a push or a pull. The mechanical energy produced in the turbine which is used to rotate a
generator [2]. Thereby electrical energy produced from generator, that energy is used for
domestic and commercial purposes. Below shows the whole process, from wind, to turbine, to
generator, to transformer to our home. Savonius vertical axis wind turbine can be better
option as it operates in low wind condition also [3]. We observed that the turbine efficiency
mainly dependent on parameters like material selection and design criteria. We have mainly
focused on turbine for low wind speed, which is of savonius wind turbine [4]. The objective
of the work is vertical axis wind turbine is used to produce electricity which is coupled with
generator, in the blade design we modified the blade’s profile and angle to improve torque
and reduce drag force on turbine blade. The objective of the paper is savonius wind turbine of
self-starting turbine, it uses magnetic levitation principle to get high rotational speed for the
Generator. Magnetic Levitation is the phenomenon in which anything can freely suspend in
the air without any support with opposed of gravitational energy

2. Parts of the savonius turbine
There are nearly 5 major elements constituted by any Savonius wind turbine are as follows
with its brief notes, vertical axis wind turbine model shown in figure 1.

![Figure 1 VAWT model](image)

2.1 Turbine Rotor
Turbine Rotor is the most vital part of any type of turbine. It converts the power at the [5]
wind as the shaft work. The design of rotor is most tedious part of the total design
modulation. Here, it is described as two-stage, two-bucket, semi- circular [6] profile rotor
with end plates and staged at 90° angle difference with 15% bucket spacing ratio shows the
typical model of the proposed rotor. To maximize the torque while enforcing typical wind
turbine design constraints such as tip speed ratio, solidity, and blade profile. By fixing the tip
speed ratio of the wind turbine, there exists an airfoil cross section and solidity for which the
torque can be maximized, requiring the development of an iterative design system [7].

2.2 Central Shaft
Central Shaft acts as both Energy Transmitter and Support.

2.3 Stand or Base
Stand or Base acts as the basement to the Turbine set which may vary according to the place
[8] of installation. This base can be in-build with the house or used as the temporary source
of power etc.

2.4 Alternator
An Alternator is a simple device which converts mechanical energy into electrical energy in the form of AC voltage. It uses the properties of electromagnetic induction to produce electrical voltage difference in electrical charge. Voltage is the force that moves the electricity or electric current from one point to another. So generating the voltage is in effect generating current.

3. Magnetic levitation
The project is designed to create frictionless bearings and a magnetic levitation of windmills, because this is the problem in conventional wind turbines. It is usually a major factor in deciding sites for very effective wind turbines especially with the horizontal axis types. Undoubtedly, the project’s ability to function is solely dependent on the power of wind and its availability. With wind turbines, two categories of winds are relevant to their applications, namely local winds and planetary winds.

4. Methodology of the project
The major aim of this methodology is to contrast the analytical and experimental values in order to find out get the cheaper mode of fabrication with higher performance. This process is based on the input and output parameters which are shown in left and right-hand side boxes in the figure 2.

![Figure 2 Methodology of the project](image)

The blades curvature has less drag force when Independence on wind direction, no additional control mechanisms are required electrical equipment can be placed at ground level, low noise emission, high starting torque. Compact size, Simple and cheap construction are the
The parameters collected for the optimized condition are used for the modelling of the proposed system. The solid modelling of the Savonius wind turbine was done in the Software INVENTOR by AUTODESK. Initially, the various parts of the system were identified and specifications were noted. The parts in the proposed system are as follows,

1. Rotor bucket
2. Central hollow shaft
3. Magnets
4. Alternator setup
5. Stand
6. End plate
7. Other Auxiliaries

The above said parts were modelled in the software INVENTOR as separate part work sheet and saved into the author's domain. The parts then assembled in the separate worksheet with suitable constraints to get the overall setup of the proposed system. The model of the proposed system is given below. Vertical axis wind turbine 3d Model, VAWT side view and VAWT top view as shown in figure 3, figure 4 and figure 5 respectively.

- Stand
- Semi-circular blade profile
- End plate

**Figure 3** VAWT 3D model

**Figure 4** Side view of VAWT 3D model
5. Simulation of the turbine
Computational fluid dynamics (CFD) is a useful analysis tool for wind power analysis. A large number of simulations can be performed, analysed and optimized without investing in physical construction of many turbines with different geometrical configurations. Using CFD simulations, the torque and pressure on the rotor can be predicted. ANSYS Fluent flexible general-purpose computational fluid dynamics software package used to model flow, turbulence, heat transfer, and reactions for industrial applications [9-10].

5.1 Geometry Modelling
As the stages of the savonius have similar specification, it is sufficient to analyse the single stage geometry. The 2-D Savonius 35 rotor is initially created using surface from sketch option with the designed specification. Then the rotating domain with the radius of 250mm is created with the same origin. Finally, the fixed domain is drawn as the rectangular sketch with the dimension of 10,000 mm X 5,000 mm where the centre of the origin is slightly misplaced towards the left-hand side and kept symmetrical in the horizontal direction [11].

5.2 Mesh Creation
Meshing is the most important part of the ANSYS simulation. It decides the accuracy of the solution [12]. Meshing is the process of discretizing of the created geometry into finer nodes where the respective equations were solved iteration and gets solved. In meshing, naming of the domains and walls of the geometry is given. Along with this, Interface is also given name to both the rotating and fixed domains. The area of the virtual wind tunnel has been discreted using quadrilateral elements and fine meshing is done all over the surface and edges. Regular mesh with inflation layers on the blade surfaces is used. The mesh interface is situated between the circle zone and the square zone to allow the exchange of data. And the total number of nodes and cells were around 1,15,923 and 1,10,048. Mesh creation as shown in figure 6.
5.3 Solver Setup
The turbulence used are $k$-$\varepsilon$, the standard $k$-$\varepsilon$ model. For a range of tip speed ratios between 0.8 and 2. The pressure-velocity coupling is achieved using the well-known SIMPLE (Semi-Implicit Method for Pressure-Linked Equations) method. Turbulent kinetic energy ($k$) and turbulent dissipation rate ($\varepsilon$) first order upwind scheme was chosen for the momentum equation solution. The left boundary had Velocity Inlet condition of 10 m/s while the right boundary had pressure Outflow condition. The top and bottom boundaries for the wind tunnel 37 sidewalls had Symmetry conditions. Using Mesh Interface option, the interface of both the fixed and rotating domain are connected.

6. Result and Discussion
From the required parameters found out, we came to conclude the various performance of the proposed system. Initially, the turbine is allowed to rotate in various wind speed by varying the distance between the fan and the turbine without alternator connection. This is done to study the turbine performance with respect to various wind speed, direction and endurance of the turbine using CFD simulation. Turbine blade wind simulation analysis as shown in figure 7.
Contours of velocity patterns were extracted from the Post-CFD for 2 different angles, as shown in figures 8 and 9.

6.1 Performance Comparison of Design and Experimental Values

There is huge difference between the designed and experimental value in terms of rotor speed and tip speed ratio due to the wrong selection of material thickness. As the power output the alternator is in voltage, we can’t able to compare the power output of the design and experimental setup. On other hand we can contrast the other additional parameters like rotor speed in RPM, Tip speed ratio. Hence the comparative study of the rotor speed in RPM and tip speed ratio is done. As per the design, the tip speed ratio chosen for the rated speed of 10 m/s is constant, since the study was made up to 5 m/s of wind speed it is assumed as the same TSR for the design value. But in actual practice, it involves mass inertia, friction and various losses have to overcome, so it is varying along with the wind speed. Beyond the wind velocity 4.5 m/s, there is an increase in rotor speed greater than the designed value which is identifies as the instrumental error and there is some constrains at the elevated wind speed. Performance comparison graph as shown in figure 10.
Inference from Ansys Fluent

Moment being force times distance means that a pressure value close to the axis will generate a low moment compared to the same value far from the axis. This is a particularity of the savonius design. Using the same surface area (same amount of material) as Barrel design, savonius is able to generate high-pressure values far from the axis. Our hypothesis for now is that savonius will generate a higher moment compared to barrel. We notice that they show similar maximum and minimum pressure values. However, because of how the savonius rotor is designed, we get the same maximum as barrel but farther from the axis. In order to test this hypothesis, we will generate moment values from the same simulations using ANSYS Fluent. Result of barrel rotor and savonius rotor moment at 30° orientation as shown in figure 11 and figure 12.

**Figure 10** Performance Comparison
We notice that Savonius does indeed generate a higher overall moment. The net moment experienced by the Savonius rotor at this orientation at 30° is 0.035 Nm, whereas the moment experienced by the Barrel rotor is 0.012 Nm only. Our hypothesis is then correct, and fits with the pressure profile we saw previously. Savonius generated 3 times the moment Barrel generated at 5 m/s, and at a 30° orientation. Result of barrel rotor and Savonius rotor moment at 90° orientation as shown in figure 13 and figure 14.
We notice that Savonius still outperforms Barrel design and experiences double the moment values (0.34 Nm vs. 0.15 Nm). We also notice that the worst orientation for pressure distribution (90°) generates a higher moment than that of the best orientation (30°). However, we do not understand what causes these values to differ in this way consistently for both designs (Moment (30°) < Moment (90°)).

From the 3D simulations, we conclude the following:

- Savonius shows high pressure values far from the axis of rotation compared to Barrel design.
- Savonius generates higher moment values than Barrel design.

From these results, it does seem that for the same amount of material (same surface area of the blades) Savonius does show better performance (3x the moment at 30°, and 2x the moment at 90°).
7. Conclusion
It is possible to conclude that the experimental analysis study carried out and developed under expectations. As it knows before, experimental projects are full of unexpected results may come and face to correct in future. The theoretical and geometrical study done at the beginning of this project was essential in order to design the desired model of Savonius wind turbine. From the results, it seems that for the same amount of material savonius does show better performance (3x the moment at 30°, and 2x the moment at 90°). Thereafter, the designing done to build the rotor was very useful because it saved a lot of time for advancing in other issues, like preparing the necessary material and equipment for experimental testing. Recommendations and improvements of this project, more accurate theoretical analysis should be made in static torque study in order to obtain results more similar to the experimental one. Multi stage turbine is the double generation concept with the same size rotor.

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