Design and Fabrication of Savonius Vertical Axis Wind Turbine

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Abstract: *The project deals with the design and fabrication of four blades Savonius Vertical Axis Wind Turbine. It is a type of Vertical Axis Wind Turbine (VAWT) which is used to produce power. The turbine has four blades in airfoil shaped and connected to the rotating main shaft using designed bearing and assembled on sturdy structure. The power calculated with respect to the velocity of wind is included. The components are made from aluminum, steel and wood which are assembled together after manufacturing of blades. Finally, the performance of the turbine was tested at different heights and wind speed.*

Keywords: Savonius vertical axis wind turbine, Wind, Blades, Power, Main shaft, etc.

1. INTRODUCTION

For the purpose of using the available wind resources and to reduce the usage of non-renewable energy resources which has many negative effects on the environment, Wind energy is the easiest and fasted growing source of energy. In particular, the wind energy has been widely used in industrial fields and supported by market rewards besides considering it as a vital policy to construct a sustainable source of energy. This project deals with the design and fabrication of a Savonius VAWT. The Savonius wind turbine is constructed from four blades according to design. In this project the components required for this VAWT design such as blades, main shaft, bearing, DC Generator, and gears are considered in the design process.

2. LITERATURE SURVEY

2.1 Historical Background

The vertical axis wind turbines are different from traditional wind turbines because, their axis of rotation is perpendicular to the flow of wind. Their configuration adapts to rural and urban settings and gives numerous opportunities to eliminate rising electricity and environmental costs. Besides, they do not require sophisticated head routes of standard horizontal axis wind turbines. The Savonius VAWT with straight or H-rotor characters is a type of VAWT's developed by Sigurd Johannes Savonius in 1922. This type of VAWT was studied in the United Kingdom during the 80's by a group of Musgrove researchers.

In this type of turbine, the egg beater shaped blades are replaced by curved blades that face up to a large tower with a horizontal axis. Savonius turbines typically have 3 or 4 straight airplanes. The design of the Savonius blade is easier to build than other VAWT models, but it has a larger structure than the standard order and requires sturdy hardware. Savonius turbines have a generator located at the bottom of the scarf and as a result, they may have a larger and heavier structure than the axis turbines generators with a simpler structure. Although the Savonius machine is simple and cheaper than the standard Darrieus machine, it is less efficient and require a external source to overcome initial torque. However, it can work well in stormy conditions. Also, it shows good selections in areas where horizontal axis wind turbines are not suitable. Table 1 shows comparisons between different types of vertical axis wind turbines.

Table-1: Comparison of Darrieus and Savonius Turbine

Elements	Darrieus	Savonius
Blades	Airfoils	Curved Scoops
Force Component	Lift	Drag
Blade Profile	Complex	Simple
Blade Area	Moderate	Moderate
Generation Site	Ground	Top of a tower
Structure	Simple	Simple
Blade Weight	Large	Moderate
Self-Starting	No	No

3. DESIGN OF SAVONIUS VERTICAL AXIS WIND TURBINE

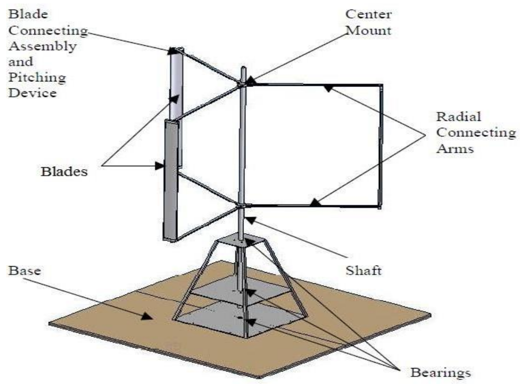

Fig-1: Savonius VAWT

3.1 Turbine Blades

Turbine blades are selected such that most of the air wetting blade surface should create drag so enough torque should be produced to drive the alternator. The design is a triangular sheet rolled in semicircle. Two blades have its length greater than other two blades as shown in Fig 2. The reason for making the blades triangular and rolling them is to make the air wet on one blade in order to give the force to the blade behind it. In this way at low velocities some rpms are gained and efficiency of the turbine can be improved.

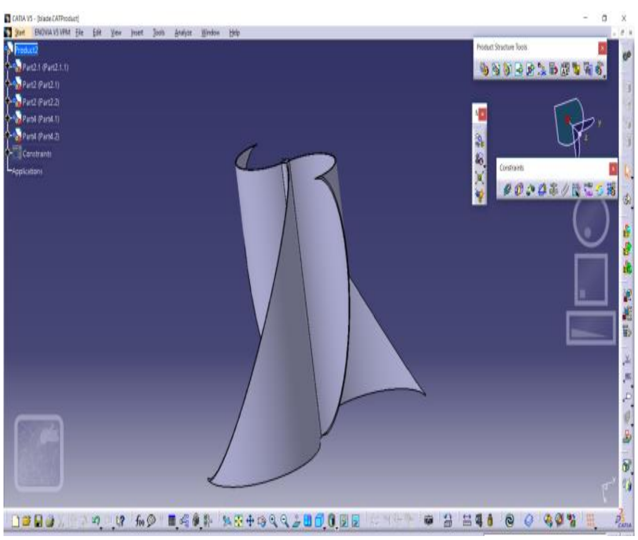

Fig-2: 3D Model of Blade

3.2 Setup Arm

The setup arms are constructed at the columns which serve our alignment requirements of the rotor. Specific systems are needed to be installed for easy assembling and dismantling of blades and shaft. The material used for fabrication of setup arms is aluminum because of its light weight and high strength.

To fasten the shaft with the arms, 15 cm screws are used. There are two setup arms that are designed, one for the top and another for the bottom which goes through 90^0 apart from each other.

In our design we have used length of each arm as 186 cm approximately to the ratio length and size of the rotor and blades weight. After this, we adjusted the assembly to get better wind effect over the blade area and less deformation of the arms. This deformation arises due to arms bending in case of force over the structure of rotor.

Table-2: Dimensions of arm

S.N.	DESCRIPTION	DIMENSION
1	Arm numbers	2
2	Arm length	186 cm
4	Top drill diameter	0.8cm
5	Bottom drill diameter	0.8cm
6	Position from the outer end to the center	32 cm
7	Arm width	40 cm
8	Thickness	4 sq.cm

3.2 Shaft

Shaft is a rotating element of machine which is used to transmit power from one point to another. A 3D Model of shaft is given in Fig 3. Due to the tangential force of the wind, the power is delivered to the shaft and transmitted to the various members that are linked to the shaft. To transfer the power from one shaft to another (Generator Shaft), various members such as pulleys, gears etc. are mounted on it. This member causes the shaft to rotate. In other words the shaft is used for the transmission of torque and bending moment.

Table-3: Dimensions of Shaft

NO.	DESCRIPTION	DIMENSION
1	Diameter of shaft	55mm
2	Length of shaft	243.83cm

Fig-3: Shaft

3.3 Bearing (T5505)

A bearing is a device used to support the shaft and permit constrained relative motion between two parts, typically rotation or linear movement. In our project, we used two types of bearing on the basis of their functions a rolling tapered 55 mm for bottom and a 55mm ball bearing for the top. Because the diameter of the shaft is 55mm, the further turning on shaft for precise 55mm fitting of bearing has been done.

3.4 Gears

We have used two gears for torque transformation. The driver gear [70 teeth] is attached to the rotor shaft while the driven gear [19teeth] is connected to the generator shaft (as shown in Fig.4). In order to achieve 150 rpm, we adopt the gear ratio of 1:3.

Fig-4: Gears

4. MANUFACTURING AND TESTING

4.1 Assembly Procedure:

Firstly, we considered the base should be the starting point of our assembly. Then we installed the shaft of the turbine rotor into the base and made sure that the shaft is stable. To prevent friction between the shaft and the base we installed two steel bearings for the upper and lower structure of the shaft. Also, these bearing aids to improve the efficiency of the rotor rotation. The first step is to construct base using welding machine in a rectangular shape in order to resist the structural load to provide more stability.

Finally, we assembled the ac generator with the wind turbine that is connected to a gear of bigger diameter as shown in figure 4. The aim of this generator is to convert the rotational power of the wind turbine and transfers it to dc source where voltmeter measures the current and the power is generated.

5. TESTING AND RESULT

To analyze the effectiveness of the system that we manufactured, we performed some tests. Moreover, the power output of the blades was measured and is as shown in fig 5. It shows that the values obtained from test are different than the expected result. This error is found due to the use of two heavy gears to transfer energy and the gear ratio is optimized for current design. Secondly, installation of the setup arms by fixing it on the shaft using an appropriate steel supporter to handle the arms and separate it from the upper bearings. With the help of threaded bolts, those supporters are fixed radially to keep each arm from both the sides stable and fixed to the shaft. Finally, in the blade's installation step, we fixed the four blades between the setup arms using small screws and nut bolt washers. The placing of the blades depends on the angle of contact at which the wind attacks the airfoil and gives the maximum wind power over the sectional area of the airfoil structure.

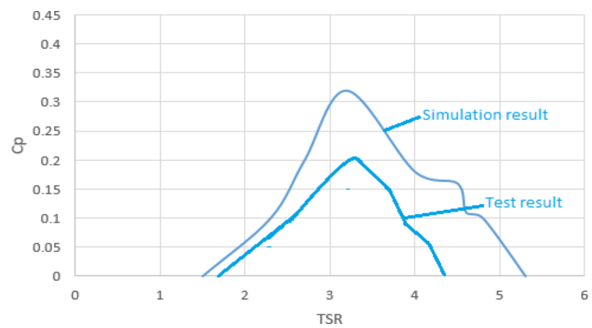

Fig-5: Testing and Result

5.1 Turbine testing

For determining efficiency of the turbine, we used an adjustable angle system for making variation in the blades angle. By changing the angle position of blades using trial and error method to get greater wind effect on the blades. Then we calculated the power output at that angle and the revolutions per minute (RPM). These shows the effect of angle of attack on the rotor speed.

5.2 Turbine Data

As a result of low wind speeds the output of our design has generated maximum power of 87 V. This value of voltage varies according to wind speed. However, the varying results had some systematic error due to inaccurate reading of the measurement devices used in the testing procedure.

5.3 Maximum rotational speed

The rotor speed is calculated at highest wind speed. In order to get an ideal result of our rotor speed we noted the data of 2 hours. The results are in between 2 m/s up to 7 m/s wind speed.

Table -4: Wind Speed VS Rotational Speed

Wind Speed (m/s)	Rotational Speed (rpm)
4.9	32
5.05	36
5.95	39
6.01	46
6.38	52
6.64	52.9
7.51	57
8.872	60
9.30	74
10.34	76

As wind speed increases revolution of the rotor also increases, maximum value is obtained at 76 rpm but it may vary with wind speed.

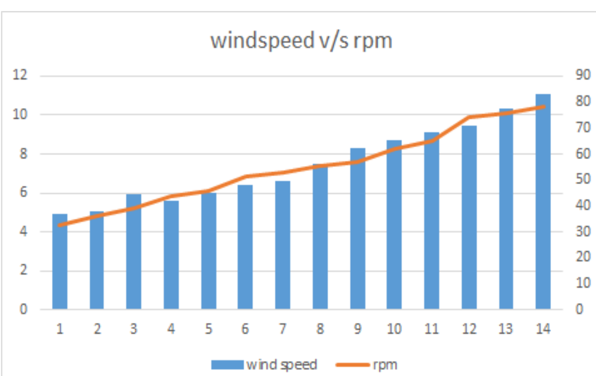

Fig-6: Maximum Rotational Speed

5.4 Voltage with Wind Speed

Table-5: Wind Speed VS Voltage

Wind Speed (m/s)	Voltage (Volt)
2.5	13.1
4.5	14.3
5.26	15.1
6.32	22.5
7.12	25
7.55	35.40
8.24	47.6
11.40	65.3
11.74	85.5
12.10	87

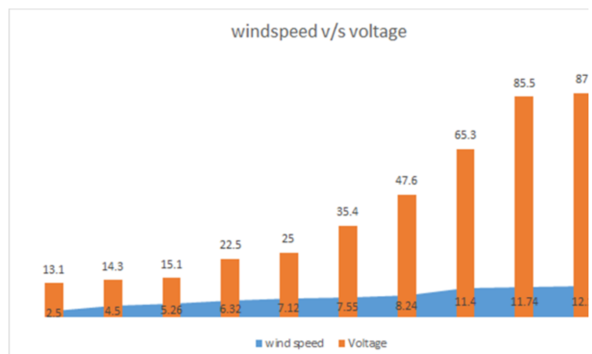

Fig-7: Wind Speed VS Voltage

6. CONCLUSION

It is seen that the power generated by using Savonious Wind Turbine is directly proportional to the wind speed. It also depends on the natural conditions of the site selected for the turbine. Also, the angle of contact between the wind and blades has a profound impact on output generated for which we used an angle that generates maximum power using trial and error method.

7. FUTURE SCOPE

As a summary of our data many improvements can be considered to advance existing system capacity. According to our design the data and test results have shown that having good material selection, better site placement and more accurate flexibility can bring us better results.

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