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Design and Development of Micro Vertical Axis Wind Turbine for Rural Application

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Abstract: In this paper we describes what is micro vertical axis wind turbine and its importance in energy production. This paper describes briefly the design consideration of vertical axis wind turbine with the aim to start or work in very low speed of wind. The model has been develop and fabricated in this project. The aim is to make micro axis wind turbine which can be installed at rural areas where electricity crises is the main problem. The effort has been taken to design the VAWT which can work at very low wind speed of 2 m/s.

Keywords: Design and fabrication of Micro VAWT

1. Introduction

Regular wind turbines are designed for large electricity production hence occupy large areas of land. These cannot operate in places where the wind speed is below 10m/s. Regular wind turbines can only operate given wind-speeds between 10m/s and 25m/s.

On the other hand, Micro wind turbines have been designed to operate with low wind speeds (above 2 m/s). Further, these do not require large land areas. These are installable in smaller places due to their small size and modular construction. Smaller places like apartment-balconies, building-terraces and of course the small farm houses.

The size of Micro wind turbines can be adapted to the available space and the power output required. The design simplicity and components used make the installation and maintenance very easy for anyone. The simplicity allows very low manufacturing cost, in turn low retail price. By using different shapes and configurations, Micro wind turbines can adapt to the immediate surroundings.

Only Micro wind turbines can work in wind speeds as low as 1m/s. Their light weight, small size, and flexible configuration allows them to be installed in both urban and rural environments, for individual or corporate use. Micro wind turbines give Green warriors and Eco-conscious users a new option in their environmental resurgence crusade for efficient renewable energy.

2. DESIGN PARAMETERS OF MICRO VERTICAL AXIS WIND TURBINE

2.1 Swept area

The swept area is the section of air that encloses the turbine in its movement, the shape of the swept area depends on the rotor configuration, this way the swept area of an HAWT is circular shaped while for a straight-bladed vertical axis wind turbine the swept area has a rectangular shape and is calculated using:
$S = 2\,RL$
Considering R as 310mm and length of blade as 300mm we get
$S = 2x0.155x0.300$
$S = 0.093m^2$
where S is the swept area [m^2], R is the rotor radius [m], and L is the blade length [m]. The swept area limits the volume of air passing by the turbine. The rotor converts the energy contained in the wind in rotational movement so as bigger the area, bigger power output in the same wind conditions.

2.2 Power and power coefficient

The power available from wind for a vertical axis wind turbine can be found from the following formula:

$$Pw = \frac{1}{2} \rho S Vo^3$$

Where, Vo is the velocity of the wind [m/s] and ρ is the air density [kg/m3], the reference density used its standard sea level value (1.225 kg/m^3 at 15ºC), for other values the source (Aerospaceweb.org, 2005) can be consulted. Note that available power is dependent on the cube of the airspeed. The power the turbine takes from wind is calculated using the power coefficient:

$$Cp = \frac{\text{Captured mechanical power by blade}}{\text{Available power in wind}}$$

Cp value represents the part of the total available power that is actually taken from wind, which can be understood as its efficiency. This project has been carried out to produce the output of 15watt power maximum

The theoretical calculation for 6m/s wind is as follows

$$Pw = \frac{1}{2} \rho S Vo^3$$
$$= 1/2 x 1.225 x 0.093 x 6^3$$
$$Pw = 12.25 \text{ watt}$$

Hence from above Power available (Pw) at 6m/s we get the output of 12.25 watt. Considering the efficiency of 20% we get power captured as 2.70 watt.

20m/s

$$Pw = \frac{1}{2} \rho S Vo^3$$
$$= 1/2 x\ 1.225 X 0.093 x\ 12^3$$
$$Pw = 98.43$$

Again considering efficiency of 15-20% we get power captured as 15 watt appx.

2.3 Tip Speed Ratio

The power coefficient is strongly dependent on tip speed ratio, defined as the ratio between the tangential speed at blade tip and the actual wind speed.

$$TSR = \frac{\text{Tangential speed at blade speed}}{\text{Actual wind speed}} = \frac{Rw}{Vo}$$

where ω is the angular speed [rad/s], R the rotor radius [m] and Vo the ambient wind speed [m/s]. Each rotor design has an optimal tip speed ratio at which the maximum power extraction is achieved.

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2.4 Blade chord

The chord is the length between leading edge and trailing edge of the blade profile. The blade thickness and shape is determined by the airfoil used, in this case it will be a NACA airfoil, where the blade curvature and maximum thickness are defined as percentage of the chord.

Chord length 4.5 cm

2.5 Number of blades

The number of blades has a direct effect in the smoothness of rotor operation as they can compensate cycled aerodynamic loads. For easiness of building, five blades have been contemplated. The solidity σ is defined as the ratio between the total blade area and the projected turbine area. It is an important nondimensional parameter which affects self-starting capabilities and for straight bladed VAWTs is calculated

$$\sigma = \frac{N c}{R}$$
$$= \frac{5x45}{155}$$
$$\sigma = 1.45$$

Where, N is the number of blades, c is the blade chord, L is the blade length and S is the swept area, it is considered that each blade sweeps the area twice. Solidity determines when the assumptions of the momentum models are applicable, and only when using high $\sigma \geq 0.4$ a self starting turbine is achieved. In this project with contemplating five blades solidity of 1.45 has been considered for self starting property of the project.

3. MATERIAL SELECTION

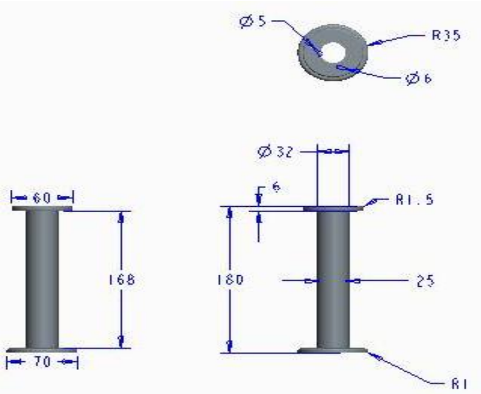
Sr No	Component	Material
1.	Blade	Aluminum Alloy
2.	Flange	Mild Steel
3.	Stand	Mild Steel
4.	Rotor	Mild Steel

Also, the material selection of very light material has been worked out for self starting consideration in turbine.

4. CAD CONCEPTUAL DESIGN BASED ON DESIGN PARAMETERS

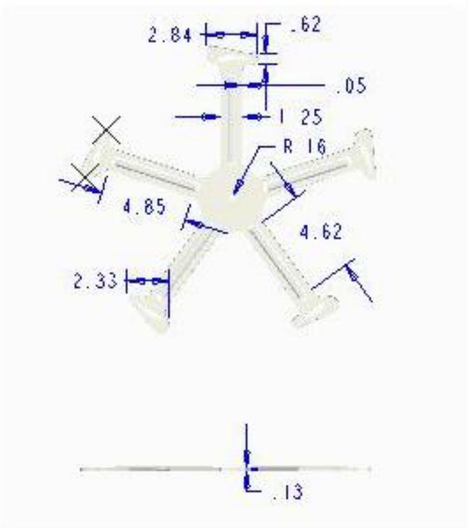
4.1 Stand

Considering the aim of the project the stand has been designed to install it at any area like building, terrace, rural roof etc. stand has been provided Ø6 threaded hole for mounting on ground and Ø5 hole for fixing the rotor assy on it. The simplicity of installation is considered for easy mounted and demounting of the project. Modeling work is done in ProE.



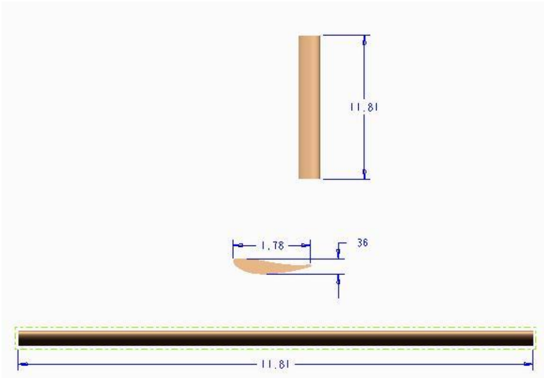
4.2 Flange

Flange is another important component in the project which holds 5 blades in vertical position. Stabilizing of blade while rotating has been considered while designing the flange. As seen from CAD design flange is provided with hole of profile like blade which mount the blades. Two nos flange is used in this project for stabilizing of blades even at high speed of wind.



4.3 Blade

Blade designed to give aerodynamic rotation and generate aerodynamic airfoil. In blade design we have given the details of blade design. Total five blades are considered for the project.

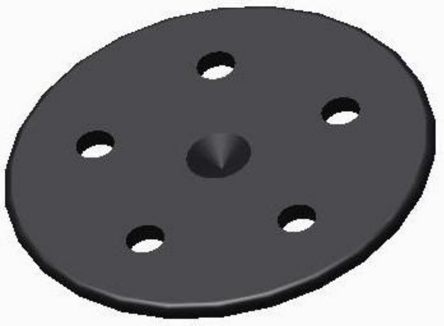


4.4 Rotor

Rotor is the main component in the project which houses 5 blades, 2 flanges, stand on the base and rotor flange. After assy this rotates and gives output. As seen from CAD design model rotor houses generator which constitute of two magnates and coil between it. The generation of electricity takes place on the bases of faradays law.

4.5 Rotor Flange

The rotor flange assembles with the stand.



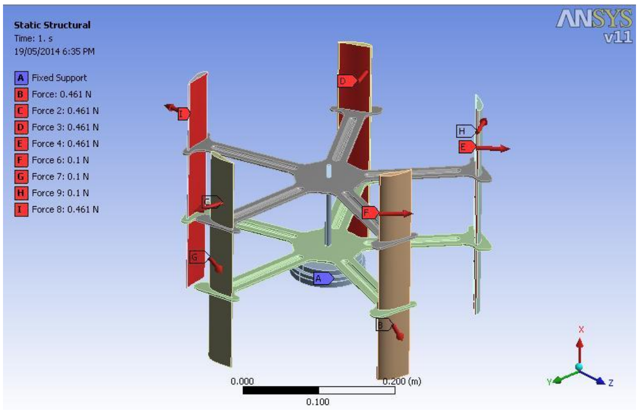
4.6 Assembly model

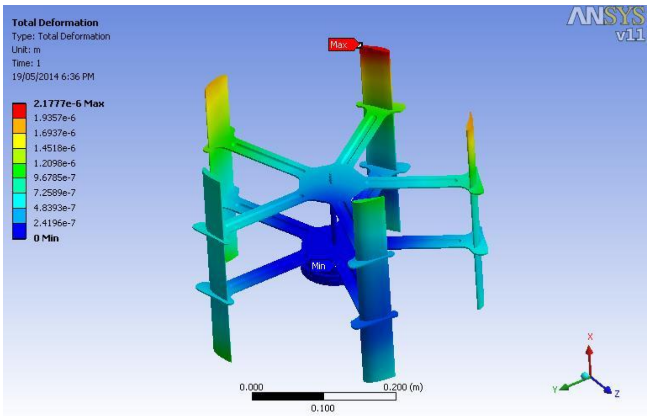
5. Performance and Basic Design Parameter of Vertical Axis Wind Turbine.

Performance	
Rated power	10W @10m/s
Peak power	15W
Start-up wind speed	2m/s
Working wind speed	2-20m/s
Survival wind speed	35m/s
Rotor	
Rotor diameter	310mm
Swept area	$0.1m^2$
Blade	5pcs alumimium alloy
Blade length	300mm
Shell material	Erosion resistant aluminum
Rated RPM	400
Weight	2.3KG
Others	
Generator type	3-phase PM, gearless
Speed regulation & protection	overvoltage charge controlling
Controller rated voltage	DC 12V
Suggested battery capacity	1pcs 7AH/12VDC
Suggested tower	3-4m guyed cable tower
Working temperature	-30-50^{o}C

6. Structural Analysis

In Structural analysis of the VAWT the static analysis has been carried out. The forces at particular condition were calculated and applied in ANSYS software. The result and the applied forces are shown below:-

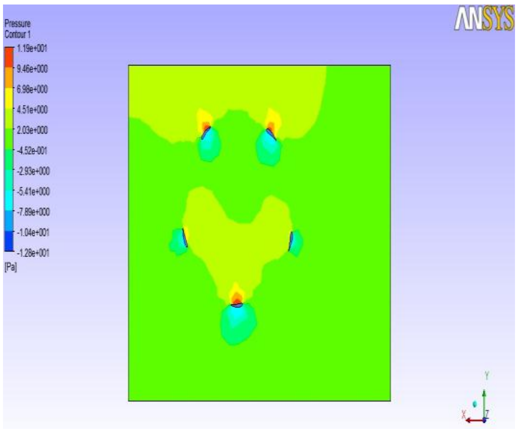




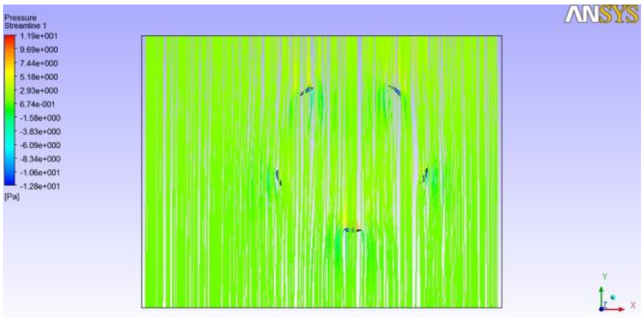
7. CFD Analysis

Computational fluid dynamic (CFD) is a useful design tool for wind power analysis. Using CFD simulation, the pressure on the rotor can be predicted. These can be used to predict the turbine’s power coefficient.

Pressure distribution contour and pressure coefficient calculated around turbine



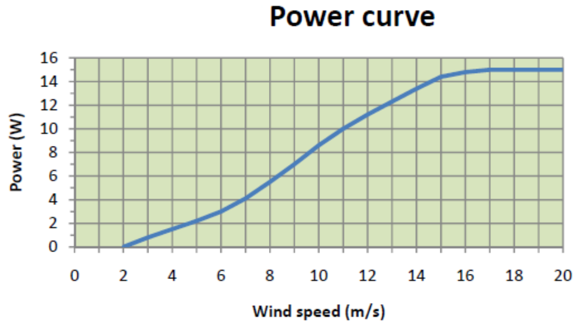
Stream line flow of wind in VAWT using CFD



8. Testing Result

The designed model has been tested at different speed of wind. During the testing model was loaded to output of 12V. Power generated at different wind speed has been noted during the testing of the model and following results has been achieved.

In testing of the model rotation at different speed of wind was also noted.



9. Conclusion

The design and development of micro vertical axis wind turbine has been carried by considering basic design consideration like solidity, number of blade, chord length of blade etc. After the input design parameters decided

conceptual model has been designed based on design parameters and CAD model were developed. The all emphasis during the development was to develop the model which can generate the output even at low wind speed. Towards this aim parts were developed and fabricated with very light material.

Testing of the model was the main area towards the success of project and outcome of the progress of input decided while designing and development of the product.

In this project we succeed to achieve the best result of 12V and 14 watt power output at 15 m/s speed of wind. Also, the product start rotating at speed of 2 m/s and produced 2 watt power at speed of 4 m/s. output was given low energy LED panel light and given satisfactory output. References

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