Design and Manufacture of Vertical Axis Wind Turbine

Pushkar Bhutada#1, Pratik Chopada#2, Prashant Bhansali#3, Rushikesh Chandak#4,Sameer Agrawal#5

Mechanical Deparment, Savitribai Phule Pune University

***Abstract*-Most of the power generated nowadays is produced using fossil fuels, which emit tons of carbon dioxide and other pollution every second. More importantly, fossil fuel will eventually run out. In order to make the development of our civilization sustainable and cause less harm to our environment, people are looking for new source of substitute clean energy.We studied Horizontal axis wind turbine and its advantages as well as disadvantages .so we got to know the efficiency of HAWT is less and in some areas VAWT is preferred and there is lot of scope for improvement in VAWT. We studied history of development VAWT, Darrieus and Savonius turbine their advantages and why there is need to develop new blades for VAWT. We studied experiments performed by different students on VAWT and factors affecting the blade design of wind turbine.**

I. INTRODUCTION

The most available form of renewable energy is wind thus, the fastest-growing renewable energy source is wind energy. Wind energy is promising in areas where power supply is difficult such as isolated islands or challenging geographical altitudes. Compared to the day time limitation of solar energy harvesting, wind energy harvesting has a clear advantage over it considering coastal areas throughout India. Components of an ideal wind power system are wind turbine and generator. The wind turbine can be categorized in two classes on the basis of orientation of rotation, namely, vertical axis wind turbines (VAWT) and horizontal axis wind turbines (HAWT).

The VAWT offers some distinct advantages relative to HAWT, including easy installation and maintenance, low noise, and potentially simple blade design Also, the forces of the wind on the turbine blades allow for a further classification into lift-force type and the drag-force type. Through further and well-targeted research, increased attention has been paid to the known VAWT. H-type lift type Darrieus turbine is chosen to optimize based on the approaches mentioned in this paper as it was found that performance of a wind turbine is dependent upon the blade pitch angle amplitude, the size of the turbine, the number of blades and the aerofoil profile. The project consist of mechanical system which comprises of the blade profile design, selection of material for the blades, hubs, linkages and the vertical axis shaft and their respective dimensions as per the information.

II. LITERATURE REVIEW

Firstly, we studied about the HAWT and VAWT. We then discovered that HAWT has various disadvantages such as efficiency, enviormental effects. This led us to study the various types of VAWT which were used to counter the disadvantages of HAWT .We studies Darrieus and Savonious VAWT also studies their disadvantages and how there is need to develop new type of blades for VAWT.We studies the characterstics of blade design and started our itteraton for blade design. We have designed flat blade for VAWT and calculated its power. This is our first iteration on blade and we should try to make it more effective by using airfoil design and currently studying blade design for aerfoil shape.

A. *Wind Turbine Blade Design*

Wind turbine blade design, a research paper published by Peter Schubel and Richard Crossely who are faculties at University of Nottingham states current state-of-art for wind turbine blade design is presented, including theoretical maximum efficiency, propulsion, practical efficiency, VAWT blade design, and blade loads. The review provides a complete picture of wind turbine blade design and shows the dominance of modern turbines almost exclusive use of horizontal axis rotors. The aerodynamic design principles for a modern wind turbine blade are detailed, including blade plan shape/quantity, aerofoil selection and optimal attack angles.

1) *Tip Speed Ratio:-* The tip speed ratio defined as the relationship between rotor blade velocity and relative wind velocity is the foremost design parameter around which all other optimum rotor dimensions are calculated

$$TSR = \frac{\text{Tangential Speed at Blade Tip}}{\text{Actual Wind Speed}} = \frac{R\omega}{Vo}$$

Aspects such as efficiency, torque, mechanical stress, aerodynamics and noise should be considered in selecting the appropriate tip speed. The efficiency of a turbine can be increased with higher tip speeds, although the increase is not significant when considering some penalties such as increased noise, aerodynamic and centrifugal stress.

2) *Blade Design:-* The ideal plan form of a VAWT rotor blade is defined using the BEM method by calculating the chord length according to Betz limit, local air velocities and aerofoil lift. Several theories exist for calculating the optimum chord length which range in complexity, with the simplest theory based on the Betz optimisation. For blades with tip speed ratios of six to nine utilising aerofoil sections with negligible drag and tip losses, Betz's momentum theory gives a good approximation. In instances of low tip speeds, high drag aerofoil sections and blade sections around the hub, this method could be considered inaccurate. In such cases, wake and drag losses should be account. The Betz method gives the basic shape of the modern wind turbine blade. However, in practice more advanced methods of optimization are often used. Assuming that a reasonable lift coefficient is maintained, utilising a blade optimisation method produces blade plans principally dependant on design tip speed ratio and number of blades. Low tip speed ratios produce a rotor with a high ratio of solidity, which is the ratio of blade area to the area of the swept rotor. It is useful to reduce the area of solidity as it leads to a decrease in material usage and therefore production costs. However, problems are associated with high tip speeds.

III. CALCULATION

First we decide to design our blade flat and calculate the power generated by the flat blade.

So we assumed dimensions of blade as follows,

L= length of blade =1.5m

R= Radius of rotor = 0.375m

Therefore, power generated by the wind turbine is given by

Power= $0.5*\rho*A*V^3$

Velocity of wind =4.16m/s

Swept Area= 1.5*0.375

=$0.5625m^2$

Density of wind=ρ= $1.22kg/m^3$

Power=$0.5*1.22*0.5625*(4.16)^3$

=24.7 Watt

But for actual power generated we have to multiply above power equation with coefficient of performance,

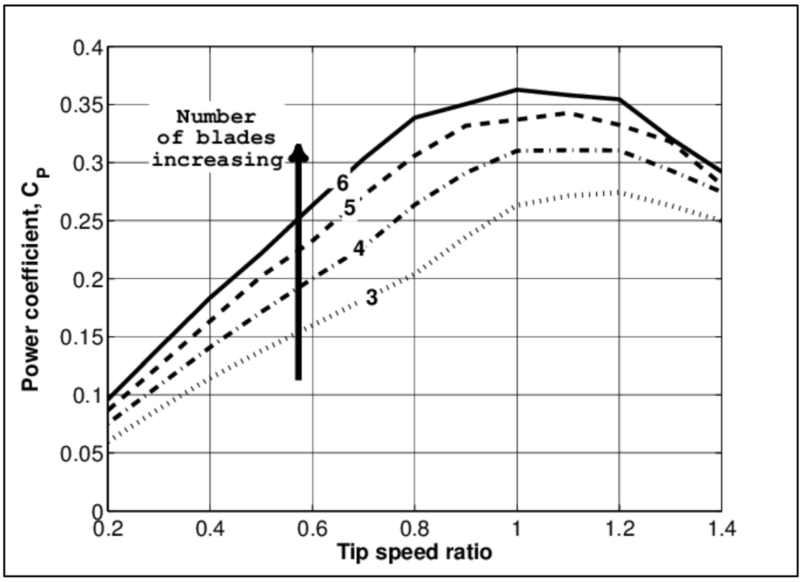

Fig1Graph of Cp Vs TSR

Assuming TSR to be 1.2 we get the value of C_p for 3 number of blades as 0.27

$P_1 = C_p*P$

=0.27*247

=6.669Watts

After the flat blade design we decide to see how much power is generated by using a airfoil.

So we decided to select a airfoil which would generate maximum lift force

Therefore we selected S1223 airfoil

Lift Force $(L_f)=0.5*\rho*A*V^2*C_L$

$=0.5*1.22*0.5675*(4.16)^{2}*1.5$

=4 N

Now, Let the velocity of wind before it strikes the wind blade be V_1 and let the velocity of wind after the striking blade that is area behind the wind turbine be V_2

Energy $=[M*(V_1)^2-M*(V_2)^2]$

$=1.22*\pi*R^2*H$

$=1.22*3.14*(0.375)^{2}*$

=0.5387Kg

Now V_1=4.16m/s and V_2=2m/s

Energy $=[M*(V_1)^2-M*(V_2)^2]$

$=[0.5387*(4.16)^2-0.5387*(2)^2]$

=12Watts

This power generated is the maximum power generated

Mass= Density * Volume

Now for the actual power generated we have to multiply above power with coefficient of performance

Therefore C_p=0.3 because the number of blades are 4

$P_1 = C_p*P$

=0.3*12

=4 Watts

Torque= Lift force * Radius

=4*0.375

=1.5N-m

Power =Torque* Rotational speed

$12 = 1.5*\omega$

Rotational Speed=8 rad/s

Rotational speed=$2\pi n/60$

$8=2\pi n/60$

N=70rpm

This RPM would be maximum RPM as we have consider the maximum power

Actual rotational speed.

Actual power= Torque* Rotational speed

$4=1.5*\omega$

Rotational speed=2.667 rad/s

$2.667=2\pi n/60$

N=25.4 rpm

IV. CONSTRUCTION

Wind turbine blades have on aerofoil—Type cross section and a variable pitch. While designing the size of blade it is must to know the weight and cost of blades. In the project four blades with vertical shaft are used. To construct actual blade, two structures of the above dimensions are made using a stiff material. The two structures are known as ribs. The ribs are placed at a particular distance from each other along the same vertical axis and are connected by rigid pillars known as stringers. The outer edge of the blade is covered with thin and lightweight sheet made of Aluminium. The main aim of the ribs is to maintain the shape of the blade and to hold it to the central shaft. Stringers are supposed to be the main load bearing components in this structure. Due to this reason, four blades each of which is a pillar of 1000mm x 375 mm structures made of plywood. The material used for covering the outer edge experiences maximum shear forces caused due to the wind. Hence these materials should be sufficiently stiff, pliable so as to be bent into the required shape, and most importantly, lightweight. For this purpose aluminum sheet metal of 2 mm thick was used. Aluminium was used as it had the right combination of ductility and strength for this application. It is also very easily available in the market and relatively economic to buy.

V. GENERATOR

The generator used for the prototype is the Low RPM permanent magnet DC generator created by Wind Stream Power and is a 12 volt step generator. The generator has an internal resistance of 21ohms, yet it requires an additional load in order to produce power. Without an additional load no power can be generated. The additional load is a Wheatstone bridge called a wave bridge. This can be created with regular resistors. However, if the objective is to store energy rather than record it, the Wheatstone bridge must be made of single direction resistors to prevent the voltage from the battery from reversing direction back into the generator.

VI. CONCLUSION

This vertical axis windmill gives an idea about the new way of power generation and also about the new windmill technology. The power generation using VAWT is an ecofriendly method and power produced here is almost a continuous one. Design of the frame is also a very important factor, as light frame may lead to instability in high wind condition. Also there is a problem of vibration which may lead to excessive lateral loading. Number of blades can be reduced to two and the experimentation can be carried out. By using the dimensionless numbers various calculations can be carried out. Validation may be carried out with not only the classical equations but also with the analysis software like ANSYS. Shaft material is also an important factor, composite materials could be used and the analysis can be carried out. Shape of the blades can be changed to helical shape and the speed of rotation of the shaft can be noted with the current method. The obtained energy can be stored in batteries and can be used when required. Vertical axis windmill is extremely simple design and it is cost effective.

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