DESIGN AND ANALYSIS OF HORIZONTAL AXIS WIND TURBINE BLADE

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Abstract- India has a vast source of renewable energy sector, in that wind energy contributes a major role. From the source of wind energy we cannot be able to attain maximum generation of power due to the operation wind turbine under European atmospheric condition. So there should be need to optimization of blade profiles which should be suited for low wind condition (India) that leads to increase in coefficient of performance. In this work varying of blade profiles taken in root, mid and tip section of blades are evaluated. According to properties of blade element momentum theory (BEMT) and computational work are developed for getting power curves for varying parameters such as tip speed ratio, lift and drag coefficient and main parameters like chord and twist distribution.

Keywords- Blade Element Momentum Theory, lift and drag coefficient, twist and chord distribution

I. INTRODUCTION

Presently the demand for electricity in India has been increasing due to the increase in population and economic development in our country this has lead to a major electricity crisis in our country because a major part of electricity produced in India is by burning fossil fuels such as coal. Thermal power plants are the main source of electricity production in India as coal is easily available due to the fact that India has the third largest coal reserves in the world but this leads to a lot of environmental concern as coal is a major source of green house gases which would eventually lead to depletion of the ozone layer. In order to decrease the effect of environmental degradation and for a cheaper source of fuel we are considering renewable energy such as wind energy. Mankind started using wind power centuries ago through the help of wind mills. Wind mills were used for circulating water for irrigation purposes. Wind energy is the most promising renewable source of energy. There has been a constant increase in deployment of wind energy around the world. The efficiency of the wind turbine depends various subsystems such as: blades, gearbox, electric generator and control. The blade is key element of wind turbines which converts the kinetic energy of the wind and in electricity through generators[8]. BEM theory is used for evaluating the forces on the wind turbine in its design and optimization[3]. The main factors that must be considered for blade design. First, power extraction occurs mainly on the outer part of any turbine blade. Second, starting torque is generated mainly near the hub[7]. The maximum energy that can be extracted from the wind can be calculated using Betz limit. The Betz limit was found out by Albert Betz which states that no wind turbine could convert more than 59.3% of kinetic energy of the wind into mechanical energy and finally into electrical energy. Wind turbines can rotate in horizontal or vertical axis. Horizontal axis wind turbines are ones in which the shafts are located parallel to the ground where as vertical axis wind turbines are ones in which the shafts are located perpendicular to the ground[6]. Based on the limited knowledge and information investigations started on the HAWT in early 80’s, but only limited amount of work had been done in this field. There various classes based on number of blades, wind direction and brake system. Our project concentrates on the three bladed Horizontal Axis Wind Turbine. In HAWT the blades are fixed at 120° and rotate about the same direction and the axis of the wind turbine is defined by Z-axis, radially outward from the hub center.
along the blade axis, X-axis, perpendicular to the blade axis, and in the blade and shaft axis in downward direction and Y-axis, perpendicular to the blade and shaft axis to give a right hand co-ordinate system. This type of turbine is aesthetic and they produce less noise. Hence this type of Horizontal Axis Wind Turbines is preferred for economical purpose. The selection of blade profiles for Indian wind condition is done by carrying literature survey, choose a existing multi section airfoil, calculate the performance using analytical tool for selected airfoil, comparisons of the performance data and optimization of the performance. In this project we are mainly going to concentrate on the twist and chord distribution of the rotor blade.

II. ANALYTICAL STUDY

India has low wind conditions ranging from 6-10m/s and the wind turbines used in India are of European which operate at higher wind speed conditions. This results in decrease in efficiency of the wind turbines. Aerodynamic optimization of the rotor blades can be associated with adjustment of twist and chord distribution, blade numbers, shape of airfoil, and tip speed ratio (TSR) [1]. One of the main factors is to change the chord and twist distribution rotor blade. This is done with the help of a software known as PROPID.

2.1 Selection of Twist and Chord distribution

India has low wind speed condition with speed ranging from 6-10m/s but the windmills used in India are of European wind mills which operate at high speed conditions ranging 11-15m/s. So our project mainly deals with suitable modifications of twist and cordon distributions of a wind turbine blade so that it can attain rated power at low wind speed conditions. We are doing this with the help of a software called PROPID. PROPID is a computer program for the design and analysis of horizontal axis wind turbine. It will allow designers to specify peak power for a stall regulated wind turbine. PROPID is a computer program for the design and analysis of horizontal axis wind turbines. Inverse design capability is the unique strength of the current design method[6]. The current method allows the designer to directly specify the peak power for a stall-regulated rotor. The desired peak rotor power is achieved by adjusting the user selected input by using iterative inverse solver. This method permits the designer to specify several performance characteristics as long as an equal number of input parameters are allowed to be automatically adjusted by the iterative inverse method. The approach is based on similar inverse design methodology for airfoils and cascades.

2.2 Blade Design

The ratio between the speed of the blade tips and the speed of the wind is called tip speed ratio[5]. High efficiency 3-blade-turbines have tip to 7, designed speed/wind speed ratios of 6. Modern wind turbines are to spin at varying speeds (a consequence of their generator design, see above). Use of aluminum and composite materials in their blades has contributed to low rotational inertia, which means that newer wind can accelerate quickly if the winds pick up, keeping the tip speed ratio more nearly constant.
Operating closer to their optimal tip speed ratio during energetic gusts of wind allows wind turbines to improve energy capture from sudden gusts that are typical in urban settings. Schematic representation of chord and twist distribution is represented in fig-1.1.

In contrast, older style wind turbines were designed with heavier steel blades, which have higher inertia, and rotated at speeds governed by the AC frequency of the power lines. The high inertia buffered the changes in rotation speed and thus made power output more stable.

It is generally understood that noise increases with higher blade tip speeds. To increase tip speed without increasing noise would allow reduction the torque into the gearbox and generator and reduce overall structural loads, thereby reducing cost. The reduction of noise is linked to the detailed aerodynamics of the blades, especially factors that reduce abrupt stalling. The inability to predict stall restricts the development of aggressive aerodynamic concepts.

A blade can have a lift to drag ratio of 120, compared to 70 for a sailplane and 15 for an airliner. An important goal of larger blade systems is to control blade weight.

III. METHODOLOGY

3.1 Steps Involved In Calculations Using Propid
Step:1 Collect an airfoil data with respect to (alpha, Cl, Cd) for root, mid and tip section.
Step:2 Using Airfoil Prep tool for extract the data.
Step:3 Interpolate the extracted data.
Step:4 Create (.pd) files as input for PROPID with varying Reynolds number.
Step:5 Feed the alpha, Cl, Cd in Wt09b.in.
Step:6 Run the .pd file using PROPID.

3.3 Twist Distribution
We are changing the twist and chord distribution with the help of a software known as PROPID, which was developed by National Renewable Energy Laboratory. We are changing the twist and chord distribution based on the Mat lab genetic toolbox is used as the optimization procedure. We use default values for most of the parameters of the genetic algorithm. To improve the convergency speed the option of multiple populations is used. Four populations with 50 individual in each are used with co-evolution and
migration every ten generations. A fraction of the 5% on best individual migrates to other populations[2]. The below table-1.1 was generated using the above method.

<table>
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<th>15%</th>
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</table>

Table 1.1

3.4 Inputs Needed for Propid
- Number of blades----3
- Radius-----------------30 m
- Hub------------------98 m
- Chord distribution----PROPID
- Twist distribution-----PROPID
- Blade pitch-------------6°
- Tip speed ratio---------6
- Wind speed-------------12 m/s
- Airfoils-----------------s812, s813, s814

3.5 Output Attained
- Power Curve
- Power Coefficient Cp
- Rated Power
- Maximum Power Coefficient
- Maximum Torque
- Lift Coefficient Distribution
- Axial Inflow Distribution
- Blade L/D Distribution
- Annual Energy Production

3.6 Airfoil Prep Tool
Airfoil Prep is a useful spreadsheet that helps users generate the airfoil data files needed by AeroDyn. If you start with data for a limited range of angle of attack, it can use the Viterna method to expand it to the full 360-degree data needed by AeroDyn. If you know the airfoil properties for a limited number of blade stations, it can interpolate the aerodynamic coefficients for other span locations. It can also apply rotational augmentation corrections for 3-D delayed stall[4].
3.7 Steps Involved In Preparation Of Airfoil Prep Tool [4]

1) The "Interpolate" worksheet works from a single table of X-Y values.
2) The "BlendAirfoils" worksheet calculates 2-D airfoil data as a weighted average of two input airfoil tables.
3) The "3DStall" worksheet applies the Selig and Eggars adjustments to CL and CD caused by delayed stall on a rotating blade.
4) The "TableExtrap" worksheet extends an airfoil table from the usual limited angle of attack range to the entire ±180° range required by AeroDyn.
5) The "DynStall" worksheet calculates parameters required by the dynamic stall routines in AeroDyn.

IV. RESULT & DISCUSSION

<table>
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<tr>
<th>S.NO</th>
<th>PERCENTAGE OF TWIST DISTRIBUTION</th>
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<th>RATED WIND SPEED (m/s)</th>
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</table>

Analytical Performance For 10% Increase

![Analytical Performance Graph](image)

*fig 1.2*
is attained at a wind speed of 10.936520672 m/s. We attained this value by modifying the twist and chord distribution for 10% of increase. Hence the rated power was attained for 10% increase.

The main objective is to attain rated power at rated wind speed for low wind condition by changing the twist distribution of wind turbine blade with respect to chord.

Hence twist distribution has been evaluated in PROPID tool on the basis of BEMT. The evaluated results are further made to overall percent of distribution by 5%, 10%, 15%, 20%, 25% and similar way decrease of 5%, 10%, 15%, 20%, 25% of its overall distribution. From the above values as obtained in the table(table 1.1), we need to consider the best value suited for low wind condition. The project deals with aerodynamic design of horizontal axis wind turbine with a specification of rotor diameter of 60m, hub height of 70m and power generation of 1000KW. From the above work(table 1.1) we selected a wind turbine of rated wind speed 10.936520672 m/s of which we are attaining a rated power of 1000 KW.
As shown in the above fig 4.46 three graphs are plotted. These graphs were plotted based on the data from WinWind brochure, default as given in PROPID, value obtained using change in 10% of twist.

V. REFERENCES


