Design and Analysis of Wind Blade For 500w Wind Mill

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Abstract- *Wind energy is the environmental free and one of the best renewable energy for generation of electric power. The main aim of the paper is "to evaluate the aerodynamic performances of variable-speed fixed-pitch horizontal-axis wind turbine blades through two and three dimensional computational fluid dynamics (CFD)analysis. A wind turbine is a device that convert kinetic energy from the wind into electrical power. Primary objective in wind turbine design is to maximize the aerodynamic efficiency ,or power extracted from the wind. The different type of blade are design.They are oriented at different angle of attacks and the blade design is responsible for the efficiency for the wind turbine. The design of blade are done using Q-BLADE software, The power output is also determined using this software which use Blade Elemental Theory.The 3-D model generated in SOLIDEDGE software . The comparatively study is done considering the power output of the designed wind blades and CFD analysis are to be done with ANSYS software for evaluation of lift and drag forces,calculate blade efficiency.*

Keywords- Wind turbine, CFD,ANSYS, Lift force, Drag force, Solid edge.

I. INTRODUCTION

Wind turbines have become an economically competitive form of clean and renewable power generation. The wind turbine blades continuing to be the target of technological improvements by the use of highly effective and productive design, materials, analysis, manufacturing and testing. Wind energy is a low density source of power. To make wind power economically feasible, it is important to maximize the efficiency of converting wind energy into mechanical energy. Among the different aspects involved, rotor aerodynamics is a key determinant for achieving this goal. There is a tradeoff between aerodynamic efficiency (thin airfoil) and structural efficiency (thick efficiency) both of which have a strong effect on the cost of electricity generated. The design process for optimum design therefore requires determining the optimum thickness distribution by finding the effect of blade shape and varying thickness on both the power output and the structural weight.

Aerodynamics performance of wind turbine blades can be analyzed using computational fluid dynamics (CFD).The finite element method (FEM) can be used for the blade 2 structural analysis. To find optimal design of wind turbine blades,numerical methods have become very practical and widely used.

At present, wind turbines are more powerful than early versions and employ sophisticated materials, electronics and aerodynamics. Costs have declined, making wind more competitive clean energy source with other power generation options. Designers apply optimization tools for improving performance and operational efficiency of wind turbines, especially in early stages of product development. In this paper we present some fundamental issues concerning design optimization of the main wind turbine structures, practical realistic optimization models using different strategies for enhancing blade aerodynamics, structural dynamics, robustness, and aero elastic performance.

The objective behind this research work was to evaluate multidisciplinary optimization process for the wind turbine.. The Qblade/XFOIL was used to calculate 2D performance of airfoils and new angle of attack (AOA) defined to modify NACA7620 blade. A 3D modelling software SOLID EDGE was employed to design blade geometry and imported into the ANSYS workbench which provides interconnectivity between different structural, aerodynamic analysis modules and design optimization tools.

II. LITERARURE SURVEY

Mohammad Moshfeghi: From their ExperimentPresented numerically investigates effects of a passive flow control method on aerodynamic performance of a HAWT by splitting its blades along the span. First, 2-D simulations are conducted on S809 airfoil in order to study effects of split width and Reynolds.. The results reveal that for an attached flow, torque value are sensitively dependent upon split location and injected flow angle. This is because injected flow triggers an early separation and reduces aerodynamic performance;Presented numerically investigates effects of a passive flow control method on aerodynamic performance of a

HAWT by splitting its blades along the span. First, 2-D simulations are conducted on S809 airfoil in order to study effects of split width and Reynolds. Later, original blade (without split) and two split blades are simulated, and effects of split location on power coefficient, low speed shaft torque and flow patterns are investigated at different tip speed ratios. The results reveal that for an attached flow, torque value are sensitively dependent upon split location and injected flow angle. This is because injected flow triggers an early separation and reduces aerodynamic performance

R.H. Barnes:A comparative structural analysis of generic high and low wind speed wind turbine blades has shown that the traditional design method results in less efficient low wind speed structures. It wasfound that the conventionally-designed LWS spar was more strongly constrained by deflection than the HWS spar, with stresses far below allowable levels. A more stiffness-driven design process is therefore required to obtain structurally efficient LWS blades. A modified design was developed with a layer of CFRP added to the spar cap. The resulting hybrid spar design was more structurally efficient under extreme loading conditions: deflections and stresses were both close to allowable limits with improvements in materials costs and reductions of up to 28% of spar mass. Increased stresses and deflections in the LWS spar during operational

KalyanDagamoori: It evaluated the aerodynamic performance of variable-speed fixed-pitch horizontal-axis wind turbine blades through two and three dimensional computational fluid dynamics(CFD) analysis. We Proved that wind turbine is a device that converts kinetic energy from the wind into electrical power. This project describes about the principle and working of wind turbine as they are becoming popular in the renewable energy world. In this the Primary objective in wind turbine design is to maximize the aerodynamic efficiency, or power extracted from the wind. The blade is designed using different types of airfoils which are oriented at different angle of attack and the blade design is responsible for the efficiency for the wind turbine. The designs of blades are done using Q-BLADE software, the power output is also determined using this software which uses Blade Elemental Theory. The comparative study is done considering the power output of the designed wind turbine blades and the existing wind turbine blade. We did Structural analysis by using ANSYS software

Mr. Manoj Kumar Chaudhary: The design and optimization of the rotor blade performance for a 400W small wind turbine at the lower values of operating wind speed based on blade element momentum theory (BEM).The main focus is on the relationship between solidity, pitch angle, tip speed ratio, and maximum power coefficient. In this study, airfoil SG 6043 was selected and studies were conducted for variable chord and twisted blade, with solidities in the range of 2% to 30% and blade numbers 3, 5, 7, 12, and 15 and rotor diameter are taken 2m.The pitch angle varied from -50 to 50.These values of blades geometry parameters generated in MATLAB are exported to Q-Blade software this gives results in terms of power coefficient curve (Cp- λ). Hence maximum power coefficient was obtained for the solidity in the range of 3% to 12% for number of blade is equal to be 3, 5 and 7. Also, it may be noted that, Optimum power coefficient depends upon the tip speed ratio and pitch angle. The Rotor performance is optimum if the pitch angle is in between 0o to 30 and tip speed ratio ranges From 4 to 7.Hence optimum number of blade is equal to be 5. The maximum value of electrical power is obtained 388 W, 422 W and 405 W for blade number equal to 3, 5 and 7 respectively. On increasing the blade number more than 5, electrical power decreases. It is also observed that the cut wind speed of optimum rotor is approximate to 2.3 m/s and rated wind speed is equal to be 8m/s while cut-off wind speed is equal to be 15 m/s.

K.SureshBabu: The efficiency of the wind turbine depends on the material of the blade, shape of the blade and angle of the blade. So, the material of the turbine blade plays a vital role in the wind turbines. The material of the blade should possess the high stiffness, low density and long fatigue life. The main objective of our topic is to discuss the different materials as candidates for turbine blades and to select the best material for turbine blades by using one of the MADM (Multiple Attribute Decision Making) approach with fuzzy linguistic variables. After the material selection, the turbine blades are created by using modeling packages (CATIA V5R9) and Analysis can be done by using FEM for different configurations, different operating conditions.

III. THEORETICAL BACKGROUND

This section will consider important theoretical aspects of wind turbine rotor design such as aerodynamics and factors affecting performance of wind turbines. Wind is established as a renewable resource which is sustainable and reliable for power generation. The factors governing the performance of small scale wind turbines are explained in detail

A.Wind:

Wind is movement of air current over the earth surface. Uneven heating of atmosphere by solar radiation results in differential pressure regions causing wind flow from high pressure region to low pressure region. Uneven heating is due to irregular earth surfaces and rotation of earth [4]. Density of air reduces when it is heated which lowers the pressure. Due to this, warm air rises above relatively cool air and results in pressure differences. The rotation of earth causes further turbulence and causes varying wind patterns with different wind speeds across the earth's surface. This flow of wind (kinetic energy) is captured by wind turbines to produce electricity. The kinetic energy of wind flow is converted to mechanical energy and then to electrical power by a generator. Kinetic energy carried by wind in its unperturbed state is given by,

$$P=1/2\rho AV^3$$

Where,

ρ=Air density
A = Rotor swept area
V = Wind velocity

There exists a physical limit to amount of energy that can be extracted from wind which is not dependent on the wind turbine design. The magnitude of energy extracted is dependent on the differential wind speed over the wind turbine. Higher the wind speed differential, higher is the quantity of energy harnessed. Ideally, zero final velocity would imply maximum conversion efficiency. The zero flow criteria cannot be achieved in dynamic conditions, therefore total kinetic energy may not be utilised.This is mathematically explained by Betz theory and indicates that maximum turbine efficiency is 59.3% (coefficient of power,Cp= 0.593 referred to as Betz limit).

Betz theory is developed by assuming constant linear velocity over the turbine. Therefore, dynamic rotational forces such as turbulence, vortex shedding and wake rotation will further limit the maximum efficiency.These losses can be minimized by:

- Selection of aerofoil of rotor blades with high lift to drag ratio.
- Avoiding low tip speed ratios (which result in wake rotation).
- Designing specific tip geometries.

B. Aerodynamics:

Aerodynamic performance of rotor is a fundamental factor that governs the conversion efficiency . As shown in the Figure 3, when rotor blades rotate, two forces acting on the blades are lift and drag force.

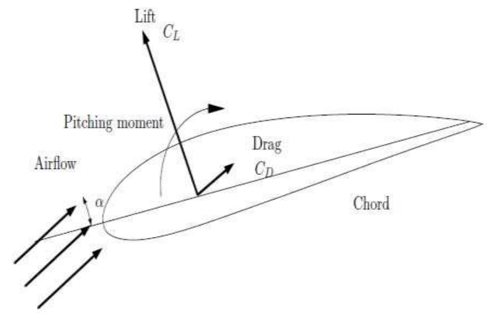

Figure 1: Aerodynamic properties of rotor blade

Force acting perpendicular to direction of the wind as a consequence of differential pressure between upper and lower airfoil sections is defined as lift force (represented in Figure 3 by non-dimensional force coefficient). The drag force acts along the direction of wind flow as the result of viscous friction force at the airfoil surfaces (represented in Figure 3 by non-dimensional force coefficient). Angle of attack of incident wind on the rotor blade increases with the drag force until the point of stall.

Turbine blades are shaped similar to airplane wing as same principles are utilized to convert wind flow to mechanical energy. Lift force is created as the wind takes longer to travel on the upper side of the rotor blade (due to the blade design) and hence travels faster to reach the end of the blade. As a result, a low pressure zone on the upper side of the blade is formed and blade is pulled in the downward direction creating movement which is known as lift. Airfoils of rotor blades are designed to utilize the advantages of this phenomenon.

Angle of attack, as shown in Figure 3, is the incident angle of the wind on the rotor blade or angle made by vector representing wind flow direction and chord line of the blade. When the angle of attack increases (beyond critical angle of attack around 15),there is momentary reduction in the lift, which is defined as stall. Critical angle depends upon design of airfoil and Reynolds number. Due to stalling, air rotates around the turbine blades in an irregular vortex causing turbulence as shown in Figure 4. This regime is Characterized by constant and chaotic changes in the wind flow pattern. To avoid losses due to stalling, this phenomenon should be studied and taken into consideration while designing the wind turbine blades.

Major factors to be considered for development of aerofoil profiles are sensitivity of blades to soiling, thickness of cross sections and dynamic conditions such as stall. Modern materials can be used to design airfoils with thin cross sections and higher lift to drag ratios at the tip, thus increasing the efficiency. Further, higher lift coefficients in thin airfoil sections will reduce the chord lengths which in turn reduce the material usage.

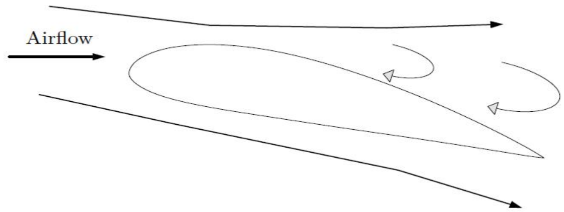

Figure 2: Concept of stall in aerodynamics

C. Airfoil Selection

With technological advancement, numerous types of airfoil shapes are available for development of blades for both conventionalaviation and wind turbine technology. For wind energy systems, dedicated airfoils are designed. Shape of airfoils in small wind turbines is not as critical as in large wind turbines. However, airfoils used in small wind turbines should be operable even at low angle of attack where drag coefficient should be much lower than lift coefficient.

NACA series airfoils are used to design the blade geometry. NACA airfoil selected for designing the rotor blades of miniwhirl wind turbine should have the following characteristics:

- High lift coefficient and low profile drag coefficient;
- Controlled stall characteristics;
- Optimum airfoil thickness;
- Negligible pitching moment coefficient;
- Ability to function at low Reynolds number wind condition;
- Stiffness at blade root section.

By considering the parameters required for design of blade geometry, NACA series 0016- 64 can be utilised for optimum aerodynamic performance . This series of airfoils are practically tested within the required range of Reynolds numbers and surface conditions.

D. Angle of Twist

The lift generated by an airfoil is a function of the angle of attack to the inflowing wind. The incoming angle of the air stream is dependent on the rotational speed and wind velocity at a specified rotor radius. The angle of twist required is dependent upon tip speed ratio and desired airfoil angle of attack. Generally the airfoil section at the hub is angled into the wind due to the high ratio of wind speed to blade radial velocity. The total angle of twist in a blade maybe reduced simplifying the blade shape to cut manufacturing costs. However, this may force airfoils to operate at less than optimum angles of attack where lift to drag ratio is reduced.

IV. ROTOR BLADE DESIGN IN Q-BLADE

A. Q-Blade Software

Q-Blade is open source wind turbine rotor blade calculation and design software. Q-Blade software allows us to define an air foil, compute its polar performance and directly integrates with the wind turbine rotor design and simulation [9].

Q-Blade also gives deep insights into all the relevant rotor and blade variables with its post processing functionality. Software is very flexible and has user friendly interface for wind turbine rotor blade design.

Basic Functionality:

- Airfoil generator;
- Blade design and optimization;
- Defining BEM(Blade Element Momentum);
- Multi parameter rotor simulation;
- Visualization of rotor blades;
- Blade geometry export functionality;
- Testing of aero elastic code.

B. Airfoil Design in Q-Blade

- For the design, NACA 0018 airfoil is selected due to its surface pressure distribution characteristics [10].
- Airfoils are created using splines.
- Desired NACA airfoil can be imported using import function in Q-Blade.
- NACA airfoils geometries are inbuilt in the Q-blade software and additional airfoil data can be integrated by importing airfoil data file in '.dat' format.
- The scale and chamber of the airfoils can also be adjusted.
- NACA 0018 with less thickness is selected for the tip selection of the blade. Circular foils are also used at the tip of
- the blade so that the blade can be fixed in the hub.

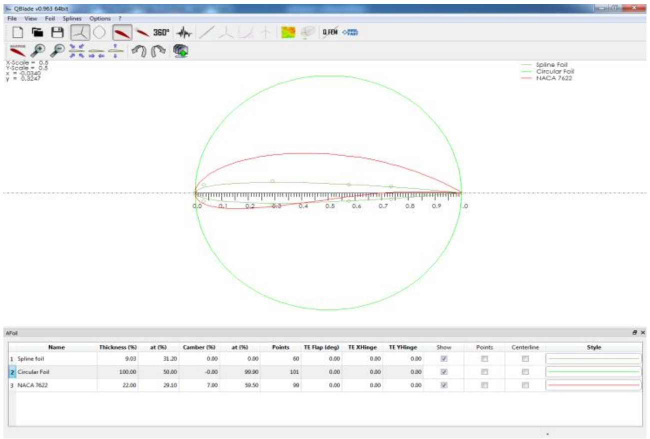

Figure 3: NACA 7622 Aerfoil

Solid Works:

Solid Works is solid modeling CAD (computer-aided design) software. It is a solid modeler, and utilizes a parametric feature-based approach to create models and assemblies. This software makes it possible for designers to quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings. The Solid Works software enables to design models quickly and precisely**.**

Solid works software can import files in STL,STEP,DXF,DXG and many other formats. The modeling in the solid work software is assigned with the designing and the modeling tools. The modeled files are exported in IGES,STEP and other formats.

This software is used to change the format of the file so that it can be imported in CATIA. The exported modelling the mesh lab which is in(.DXF) format is imported into solid work and then the model is exported in to .IGES format. This helps in creating the entities to the body and thus an .IGES modelled file is made.

Calculation of rotor diameter

Power, P = PO ηEηM CP
In the absence of above data we use fast or slow rotor formula as shown below
For slow rotor, P = 0.15 D^2 V^3
For fast rotor, P = 0.2 D^2V^3

We use the fast rotor formula to calculate diameter
D = __ m; R = __m

Calculation of hub radius, Length of blade, thickness*of blade, width of blade*

H.R = 0.14 x R = __m;
L = 0.86 x R = __m;
t = 0.2 x L = __m;
f = 0.1 x t = __m.
Area and Volume of blade
A = Lf =__m2
V = Lft=__m3

From aerofoil data sheet National Advisory Committee of Aeronautics NACA MPXX,
(L/D) = __; CL = __; CD = __; Cmc/a = __; CDO = __; i = __.
Lift force = ½*ρ*Ab*w*C_L

Drag force=½*ρ*Ab*w*C_D

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