Efficiency Improvement of Wind Turbine Generator by Introducing Vortex Generator

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Abstract - *Wind is regarded as the renewable energy source that are produced due to the pressure variations on earth surface. At the present scenario, increasing use of fossil fuels for mass energy production leads to increased CO_2 emissions and can lead to climatic changes in global level. In order to reduce the emissions, a gradual shift towards renewable sources is going on. Wind energy is a free source of energy with which very few extract it. Usually wind turbines are placed at place having continuous wind throughout the year. In India, 1.6% of total energy is produced by using WTG's. The extraction of electricity from the turbines is acquired by blades. The design of the blades must be so as to extract maximum energy from wind. A vortex generator is a device used to extract more power or lift from the wind. This will help to delay the boundary layer separation over the blade. The dimensions, placement, position, shape, type of airfoil etc. are also other factors that determines the blade efficiency. In this, aim is to compare the lift forces of two similar wind blades equipped with and without vortex generator thereby finding out the change in lift and the pressure variation throughout each blade profiles. The wind blade is modelled in CATIA and lift forces, pressure variation are found out by simulating wind blades in ANSYS 14.5.*

Key Words: Wind Energy, Vortex Generator, Blade profile, S818 Aerofoil, Blade efficiency

1. INTRODUCTION

India is a country which locates near the equator and also have extensive coastline has large potential for wind energy. Currently Indian energy sector dominated with coal based thermal plants cause large CO_2 emissions which results in environmental pollution in global level. The development of wind power in India began in the 1990s, and has significantly increased in the last few years. At present the Indian wind energy sector has an installed capacity of 21,141.36 MW. Any improvement in efficiency will lead to more energy which may be used to lit homes. The study on the dynamics of the wind blade may help to implement some changes that leads to advancement of the blade structure and thereby extract more power.

2. AERODYNAMICS OF BLADE

The design, shape and dimensions of the wind turbine is a great factor that is designed according to the wind effects on the surface of blades through Wind Tunnel experiments. The dimensions and shape changes for each turbine according to the location, wind velocity, climatic conditions etc. Each blade produces different torques to rotate which depend upon the airfoil or the cross section of blade. The air flow at the blades is not the same as the airflow far away from the turbine. The very nature of the blade in which energy is extracted from the wind causes air to be deflected by the turbine. In addition the aerodynamics of a wind turbine at the rotor surface exhibit phenomena that are rarely seen in other aerodynamic fields.

In wind turbines, aerodynamics provides method to explain the relative motion between aerofoil and air. The wind passing through the upper and lower surface of the aerofoil produces differential pressure which causes lift.

2.1 Boundary Layer Separation

Pressure gradient is one of the factors that influences a flow immensely. It is easy to see that the shear stress caused by viscosity has a retarding effect upon the flow. This effect can however be overcome if there is a negative pressure gradient offered to the flow. A negative pressure gradient is termed a Favourable pressure gradient. Such a gradient enables the flow. A positive pressure gradient has the opposite effect and is termed the Adverse Pressure Gradient. Fluid might find it difficult to negotiate an adverse pressure gradient. Sometimes, we say the fluid has to climb the pressure hill.

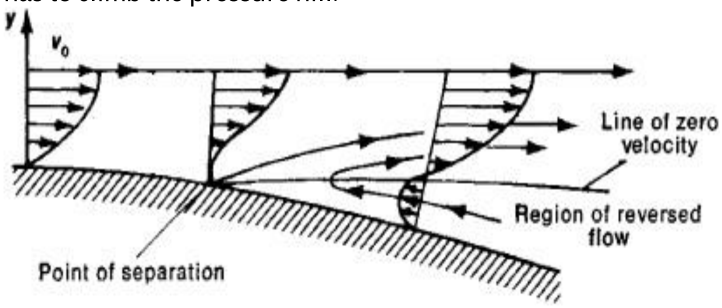

Fig. 1 Separation of Flow over a Curved Surface

Now the adverse pressure gradient begins to retard. This effect is felt more strongly in the regions close to the wall where the momentum is lower than in the regions near the free stream. As indicated in the figure, the velocity near the wall reduces and the boundary layer thickens. A continuous retardation of flow brings the wall shear stress to zero. We see that the flow no longer follows the surface of the body. At that point, the flow has separated. That point where the shear stress is zero is called the Point of Separation

2.2 Vortex Generator

A VG is an aerodynamic device, consisting of a small vane usually attached on blade of a wind turbine. When the wind is in motion relative to the blade, frictional forces acts between airfoil surface and air. When this happens, the air velocity just above the surface of the blade become zero at the point of separation. To solve this problem, they are often placed on the external surfaces of wind turbine blades. The VG creates a vortex by removing some part of the slow-moving boundary layer in contact with the airfoil surface and thereby delays local flow separation.

VGs are typically rectangular or triangular, about as tall as the local boundary layer, and run in span wise lines usually near the thickest part of the airfoil. When the wind flow reaches the vane, the kinetic energy is suppressed. On the other side of vane velocity is almost zero, so low pressure is produced there. When that wind exits the vane, there will be formation of vortex which has a low pressure and turbulent in nature. A turbulent boundary layer is more attached to surface than a laminar one.

3. DIMENSIONS OF THE BLADES

Dimensions of the blade is so important that, on the basis of the dimensions the air effects of wind varies. The dimension should be accurate during the drawing and calculations. So the various parameters that should be taken care of during drawing the wind blade are mainly the shape of the airfoil, length of blade, diameter of the root, length of each section, chord length etc. all these vary with the change in wind velocity

3.1 Airfoil of Blade

An airfoil is not only a shape, it has engineered to increase the lift forces on blade and to lower the drag. The upper side has more length and the wind has to travel more on upper side. So in order to get along with the free stream of air, it gradually increases the velocity of air over the surface leading to lower pressure zone at the upper side. This difference in pressure will lead to lift forces to act perpendicular to the blade profile. According to NREL, there are wide variety of airfoil structures used for wind blades. The standard airfoil used in this is S 818 series airfoils. Coordinates are obtained from the NREL site for standard airfoils

Due to limitations in modelling the only single airfoil structure is utilized instead of three airfoils used in standard blades. As the aim of the experiment is to find the efficiency analysis, it is not affected by this limitation.

3.2 Length of Blade

The length of blade determines the swept area. The wind speed at a particular area is highly influenced by the length. The power extraction depend upon the swept area of the blade. As swept area is dependent upon the diameter of the blade. So length of the blades is also highly dependent on power extraction. The length of blade taken as 23m and the rated wind speed selected as 12m/s.

3.3 Vortex Generator

The dimensions of VG is selected according to chord length, angle of attack. The height is 1 to 2 % of the chord length, length is 2 to 3 % of chord length, angle of attack between 15 and 20 degrees and spacing between the as 10 times height. The VG used here is rectangular type. It is placed at the higher camber length of the airfoil section. Usually placed at the point before the point of separation
Dimensions taken at highest chord calculated as
h= 35mm
l= 60mm
Spacing s= 350mm

3.4 Placement of VG

The VG is placed at the point of seperation. The height of the vortex should be the height of the boundary layer. In the blade 1 the seperation has been found to be at the centre of the chord so that it is placed at the centre line of the chord extending towards the tip.

4. SIMULATION

The wind blade is designed according to the required dimension using Catia v2.5 by Dassalt systems. Catia is a modelling software used in various fields. The atmospheric conditions are simulated in the computer using Ansys Fluent v12.0. The drawing of the wind turbine needed and the dimensions have been taken and is drawn through Catia v2.5.

A fluid volume should be created and defined as fluid around the wind blade designed. Inside this volume, the atmospheric conditions are to be simulated. In order to analysis the boundary is applied as Fluid. Boolean is a tool used to create a thin wall layer over the wind blade. In Boolean, subtract wind blade from the boundary layer so as to give a thin wall over the blade. This structure is sent for meshing.

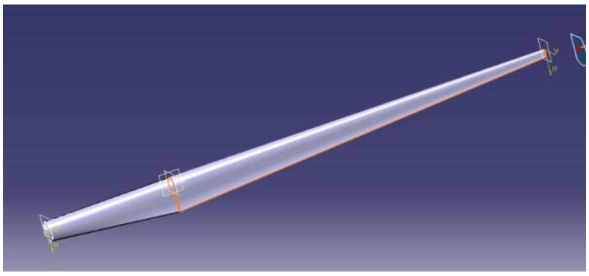

Fig 2 Wind blade drawn in Catia v2.5 without vortex generator

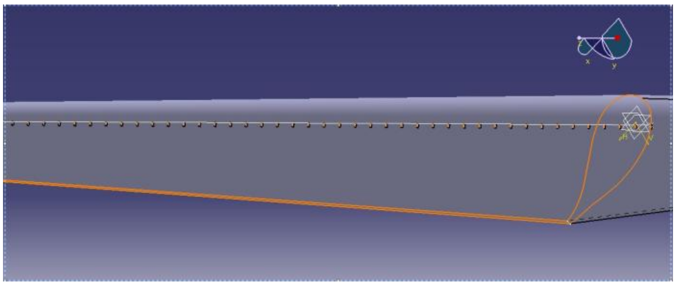

Fig 3 Wind Blade Equipped with Vortex Generator

The most important part of the structure building is the Meshing. Meshing is the phenomenon in which the CAD drawing is converted in a structure build with small geometric structures. These meshes acts as the smallest area at which the simulation concentrates. As the number of meshes increases, the calculation time also increases. Mesh generation is one of the critical aspects of engineering solution.

Table-1: Properties of Air

Property	Value
Density	1.225 kg/m³
Specific Heat Cp	1006.43 J/Kg-K
Viscosity	1.794 e-05 Kg/m-s
Temperature	288.16 K
Reference Zone	Solid
Air Velocity	12 m/s
Pressure	1.013 bar

Too many cells can leads to increased solving time and chances of error. The mesh can be of different types namely tetrahedrons, polygons, triangular etc. Each element of mesh is analyzed using FEA in the CFD. Each mesh denotes the smallest area used for analysis.

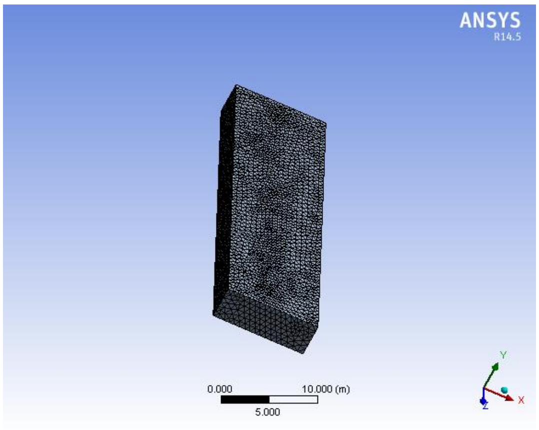

Fig 4 Meshing of the Blade and Fluid Volume

5. RESULTS

Mesh is analyzed in Fluent using k-ε iteration method with all default set values. Current work focused on obtaining smooth flow on the upper surface of the HAWT blade to reduce the turbulence effect. Maximum lift and power generation is obtained by introducing vortex generators over the blades. The results is the increase in efficiency of the wind turbine blade for extracting more power from the wind and better performance at low speeds. This helps to produce more energy from every functioning wind turbine. The result is the change in coefficient of lift between both the wind blades.

Table-2: Coefficient Of Lift obtained for both the Blades

	Blade without Vortex Generator	Blade with Vortex Generator
Coefficient of Lift	0.3269	0.4539

The lift can be increased by placing VG on the separation point and hence the blade efficiency can be increased to a smaller extend. Modifying the shape and angle of attack of the VG further improvement can be obtained.

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