Effect of pitch angle in the performance of wind turbine using numerical techniques

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Abstract: The study of performance on the Darrieus turbine is an emerging topic using many techniques to make it improve the performance up to the industrial standard. The angle of air received at the leading edge of the aerodynamic wind blade influencing the performance of the turbine. Every instant of the angle of air varying each blade due to the rotating motion of the turbine. The objective of this paper is to determine the optimum pitch angle using the Computational Fluid Dynamics simulation technique in Ansys 18.1, where the sliding mesh technique is used. The geometry of the blade is taken from the previous literature which is used to verify the results. The various pitch angles are chosen from -6° to +6°. The coefficient of the moment is calculated using K-epsilon SST 2 equation model. The graph is plotted between TSR and the coefficient of performance of various pitch angle for optimization purpose.

Keywords: Pitch angle, Wind turbine, blade, aerodynamic, meshing, airfoil

1. Introduction

Now a days there is a good progress of research towards VAWTs due to their many advantages while comparing from HAWTs as minimum manufacturing cost, uni-direction, minimum maintenance cost, good compact, less noise [1]. There is more focus on these topics now a days on research by including low-fidelity modelling, moderate fidelity and high fidelity (such as viscous CFD) methods [2] which helps in getting out accurate results. It depends on parameters like domain size, number of revolutions of blade, data sampling, grid resolution and etc [3]. The methods like wind tunnel and field experiments have been used to analyse the results by which it helps to increase the performance of VAWTs in blade solidity, pitch angle, tip speed ratio and airfoil shape[4]. Among these entire parameters blade pitch angle is having an impressive output by Appling it. It has less manufacturing, setup cost[5]. Due to less study and concept of aerodynamics there is a inaccuracy in low-fidelity. The moderate-fidelity in effect of pitch angle has been studied on -3°,0° and +3° by which they observed the shift of loads and moments due to change in wind direction [6]. The effect of fixed pitch angles -7°, -4°, -2°, -0.5°, +1° and +3° was studied and in which -2° is the optimum. The effect of fixed pitch angles was also by using viscous CFD simulations for which there output of VAWTs was not satisfied but significant for judging the limit of the angles [7]. An H-type 3-bladed VAWT with pitch angles -9° to +3° was studied, in which they got -3° was found optimum [8–10]. They also have done research
with pitch angles -5.5°, -3.5°, -1.5° and 2.5° in which they found the pitch angle -3.5° was optimum. From these researches we can conclude that the effect of fixed pitch angle have mainly focused on the value of the optimal pitch angle, considering only $C_p$ values [3,11-12]. Dynamic pitching also gained interest in getting a good output for performance [12 - 14]. Pitch angle of each blade varies with azimuthal position. In this study NACA0018 airfoil has been chosen and the study has been done with pitch angles -4°, -2°, 0°, 2°, 4°. The airfoil has designed in Catia and simulated in Ansys. The novelty of the work lies in the usage of various pitch angles and validating the optimum.

2. Effect of Pitch Angle

Angle between the extension of the blade chord length and the circumferential tangent of the blade is known as pitch angle.

![Pitch Angle](image)

Figure 1. a) Zero pitch angle b) Positive pitch angle c) Negative pitch angle

If the extension of the blade chord length and the circumferential tangent of the blade coincide then it will be having a pitch angle of zero as shown in figure 1a. If the angle formed between the extension of the blade chord length and the circumferential tangent of the blade above the circumferential tangent line then it is said to be having of positive pitch angle as shown in figure 1b. If the angle formed between the extension of the blade chord length and the circumferential tangent of the blade below the circumferential tangent line then it is said to be having of negative pitch angle as shown in figure 1c.

3. Methodology

In this study, we have selected an Airfoil NACA0018 by referring research papers. A NACA0018 profile point has been imported to Catia software and modelling of 3 blades, rotor and Domain has been done. After completion of modelling in Catia, the design is imported in to Ansys as simulation and analysis is done in Ansys software. In Ansys all the edges, liquid faces and interfaces are named. Inflation, edge sizing, face sizing is done in Meshing. Following the setup has been created and the points has been exported and simulation is done. The simulation is done for both steady and transient state, using certain boundary conditions and input parameters as mentioned below in the Table 1.
Further the counter graphs has been plotted and the data is collected from the generated design points. Finally validation is done from the result from simulation and existing literature.

4. Domain, Meshing and Boundary Conditions

4.1 Domain

This domain is referred from reference paper [66]. The study showed that distance of the boundaries (length and height) can vary the performance of VAWT. The domain is very much required system as less then preferred distance can block the simulation. In this study ‘D’ is 500mm. It helps to locate the VAWT at particular location maintaining a distance from other VAWT, such that efficiency of working can increase and more VAWT can be located in lesser space with a better working conditions.

4.2 Meshing

The methods used is triangular method. All the edges, liquid faces and interfaces has been named. Input, output and boundaries has mentioned. Inflation layer is created by selecting all the three profile blades, edge sizing is done to three blade profiles, rotor and Domain. Face sizing is done to all the surfaces. Finally, the mesh has generated as shown in the Figure 4.

4.3 Boundary Conditions

| Table 1. Boundary Conditions |
|-----------------------------|
| Inlet velocity             | 6 m/s          |
| Outlet processor           | 0              |
5. Results and Discussion

According to the above values the simulation has been done and the following contour graphs has been generated for pressure and velocity. These contour graphs has been generated for various pitch angles and by varying the no. of elements and nodes.

![Figure 5. Velocity contour for rotor](image)

The following graph represents the contour of the zeroth pitch angle for velocity and pressure, figure 5 and figure 6 depicts velocity contour for rotor and for domain respectively and figure 7 and figure 8 depicts pressure contour for rotor and for domain respectively.

![Figure 6. Velocity contour for domain](image)

As we can see in the figure 5 and figure 6 that variety of colours including red, blue and dark blue appears, the red colour across the edge of the blade represents the maximum velocity required following the yellowish colour at the tip of the every blade represents some decrease in the velocity. In the same way we can see some greenish tint following the yellow and then blue which represents decrease in the velocity respectively. So according to the velocity magnitude present, the maximum
velocity output for this is observed to be 21.7001 m/s which is across the blades and the minimum velocity output observed is 3.459059e-05 m/s according to the contour generated.

And now the figure 7 and figure 8 depicts pressure where red, green, yellow colours are visible. As we can see the Maximum pressure obtained is 295.647 Pascal at the tip of the three blades followed by the yellowish tint and blue and green. The minimum pressure outcome is -359.7886 Pascal.

Figure 7. Pressure contour for rotor

Figure 8. Pressure contour for domain
6. Conclusion

As per observation made from the analysis, we came to know that in the pressure and velocity contour graphs that there are pressure and velocity differences in the respective graphs, due to which the variable pressure differences the pressure is created around the blade and is set to rotate. Hence we can conclude that the contour graphs generated are good and the blade rotates because of the variations created in the pressure and velocity.

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